Crash on a paritally closed runway during takeoff, Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, CKS Airport, Taoyuan, Taiwan, October 31, 2000

Micro-summary: **A Boeing 747-400 ploughs through construction equipment.**

Event Date: **2000-10-31 at 1517 UTC**

Investigative Body: **Aviation Safety Council (ASC), Taiwan**

Investigative Body's Web Site: **http://www.asc.gov.tw/**

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AIRCRAFT ACCIDENT REPORT
ASC-AAR-02-04-001

CRASHED ON A PARTIALLY CLOSED RUNWAY DURING TAKEOFF SINGAPORE AIRLINES FLIGHT 006 BOEING 747-400, 9V-SPK CKS AIRPORT, TAOYUAN, TAIWAN OCTOBER 31, 2000

AVIATION SAFETY

AVIATION SAFETY COUNCIL
TAIWAN, REPUBLIC OF CHINA

According to the International Civil Aviation Organization (ICAO) Annex 13, Chapter 3, Section 3.1;

The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

Further, according to the Civil Aviation Law of The Republic of China, Article 84;

ASC shall focus on the identification, investigation and cause assessment of aircraft accident or serious incident on preventing the recurrence of similar accident or serious incident, rather than on dispensing penalty or pursuing responsibility.

Thus, based on Both the ICAO Annex 13, as well as the Civil Aviation Law of the Republic of China, this accident investigation report, as the result of the investigation effort of SQ006, shall not be used for any other purpose than to improve safety of the aviation community.

AIRCRAFT ACCIDENT REPORT

CRASHED ON A PARTIALLY CLOSED RUNWAY DURING TAKEOFF

SINGAPORE AIRLINES FLIGHT 006

BOEING 747-400, 9V-SPK

CKS AIRPORT, TAOYUAN, TAIWAN

OCTOBER 31, 2000

AVIATION SAFETY COUNCIL

TAIWAN, REPUBLIC OF CHINA

AIRCRAFT ACCIDENT REPORT

Crashed on a Partially Closed Runway during Takeoff, Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, CKS Airport, Taoyuan, Taiwan, October 31, 2000

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Executive Summary

On October 31, 2000, at 1517 Coordinated Universal Time (UTC), 2317 Taipei local time, Singapore Airlines (SIA) Flight SQ006, a Boeing 747-400 aircraft, bearing Singapore registration No. 9V-SPK, crashed on a partially closed runway at Chiang Kai-Shek (CKS) International Airport during takeoff. Heavy rain and strong winds from typhoon "Xangsane" prevailed at the time of the accident. SQ006 was on a scheduled passenger flight from CKS Airport, Taoyuan, Taiwan, Republic of China (ROC) to Los Angeles International Airport, Los Angeles, California, USA. The flight departed with 3 flight crewmembers, 17 cabin crewmembers, and 159 passengers aboard.

The aircraft was destroyed by its collision with construction equipment and runway construction pits on Runway 05R, and by post crash fire. There were 83 fatalities, including 4 cabin crewmembers and 79 passengers, 39 seriously injured, including 4 cabin crewmembers and 35 passengers, and 32 minor injuries, including 1 flight crewmember, 9 cabin crewmembers and 22 passengers.

According to Article 84 of ROC's Civil Aviation Law, and Annex 13 to the Convention on International Civil Aviation (Chicago Convention), which is administered by the International Civil Aviation Organization (ICAO), the Aviation Safety Council (ASC), an independent government agency of ROC, which is responsible for civil aircraft accident investigation in the territory of ROC, immediately launched an investigation of this accident. The State of Operator, represented by the Ministry of Communications and Information Technology (MCIT)[1] of Singapore, and the State of Manufacture, represented by the National Transportation Safety Board (NTSB) of USA, were invited

1 Since November 23, 2001, MCIT has been changed to Ministry of Transportation (MOT) due to Singapore Government's re-organization. Since MCIT was the name of the investigation authority at the time of the accident, this report still retains the use of MCIT throughout.

as the Accredited Representatives to participate in the investigation. The Australian Transport Safety Bureau (ATSB) of Australia was later on added as an Accredited Representative in accordance with Chapter 5.23 of ICAO Annex 13. The Civil Aeronautics Administration (CAA) of ROC was also invited to participate in the investigation.

The on-scene portion of the investigation was completed on November 13, 2000, and two days later, the ASC officially returned the crash site to the CAA. On the same day, each investigation group, led by ASC investigators, completed the on-scene investigation factual report. The fact-gathering phase of the investigation continued, including a trip by ASC investigators to Singapore to understand the operation of SIA and to conduct interviews of SIA and Civil Aviation Authority of Singapore (CAAS) personnel. All the factual data from each group was assembled into factual reports prepared by the ASC group chairmen.

On February 20, 2001, ASC held a two-day "Factual Data Verification Meeting" in Taipei to verify the factual information collected up to that point. All members of the investigation team including NTSB, MCIT, ATSB and CAA of ROC were invited to attend that meeting. On February 23, 2001, ASC released a "Factual Data Report of SQ006 Accident" to the public and posted on the ASC website.

The analysis phase of the investigation was officially commenced on March 1, 2001. Chapter 5, paragraph 5.25, of Annex 13 specifies that:

"Participation in the investigation shall confer entitlement to participate in all aspects of the investigation, under the control of the Investigator-in-Charge, in particular to:

a) Visit the scene of the accident;
b) examine the wreckage;
c) obtain witness information and suggest areas of questioning;
d) have full access to all relevant evidence as soon as possible;
e) receive copies of all pertinent documents;
f) participate in read-outs of recorded media;
g) participate in off-scene investigative activities such as component examinations, technical briefings, tests, and simulations;
h) participate in investigation process meetings including deliberations related to analysis, findings, causes and safety recommendations; and
i) make submissions in respect of the various elements of the investigation.

Note 1 - It is recognized that the form of participation would be subject to the procedures of the State in which the investigation, or part thereof, is being conducted."

Therefore, ICAO Annex 13 makes it clear that the State conducting the investigation (the State of Occurrence) has the full right to decide the extent of participation of the Accredited Representatives, based on the investigating State's procedures. According to the investigation procedures of the Aviation Safety Council, and following a deliberation and decision made in the 27th ASC Council Meeting, ASC allows Accredited Representatives' teams to participate in all aspects of the investigation, as stated in items mentioned in Annex 13, paragraph 5.25 with the exception of item (h). It was deliberated in the 27th ASC Council Meeting that, in order to maintain its independence, ASC shall independently conduct the analysis, causal factors determination, and safety recommendation portion of the investigation, based on the factual data collected, and it shall not be influenced by anyone else, as long as proper feedback processes are available to the participants.

Based on this fundamental guiding principle, the investigation team initiated the analysis phase independently. On July 4, and 5, 2001, ASC held a "Technical Review Meeting" in Taipei to go over ASC's analysis to date. All members of the investigation team were invited to attend the meeting, and officials from ATSB, CAA OF ROC, MCIT, and NTSB attended.

The first day of the meeting consisted of an ASC briefing to all members about its analysis to that point. The second day was spent receiving feedback from all participants to ASC's analysis presented on the first day and reviewing additional factual evidence collected after February 23, 2001.

After the ASC had evaluated the feedback provided by all participants at the July 4 and 5, 2001, Technical Review Meeting, on September 30, 2001, the ASC issued a "Preliminary Draft Report" to all the participants for their comments. The ASC gave the participants 30 days to provide comments.

On November 1, 2001, ASC received comments from all the participants and subsequently spent three months reviewing the comments received and modifying the Preliminary Draft Report. On January 31, 2002, ASC issued the "Final Draft Report" of the SQ006 investigation to all participants and granted 60 days for comment, in accordance with Annex 13, paragraph 6.3.

ASC also invited all participants to interact directly with the ASC Council Members at the Council's 42nd Meeting held on March 26, 2002. The Singapore MCIT and CAA of ROC accepted the opportunity to present their opinions about the report to the Council Members on that day.

Written comments on the Final Draft Report were received from all participants by March 30, 2002. Based on a review of those comments and verification of factual evidence, the ASC completed its investigation report, which was approved by the ASC Council Members on April 23, 2002, at the 43rd Council Meeting.

Chapter 6, paragraph 6.3, of Annex 13 specifies, in part, that:

"The State conducting the investigation shall send a copy of the draft Final Report to…all States that participated in the investigation, inviting their significant and substantial comments on the report as soon as possible….

If the State conducting the investigation receives comments within sixty days of the date of the transmittal letter, it shall either amend the draft Final Report to include the substance of the comments received or, if desired by the State that provided the comments, append the comments to the final report…."

In summary, the ASC offered multiple opportunities for the participants to comment on the factual and analysis phases of the investigation and that exceeded the requirements of Annex 13, paragraph 6.3. This report was completed after a thorough review and consideration of all of the factual record of the investigation and the comments submitted by all organizations involved in the investigation. Although a significant number of the comments were accepted, wholly or in part, by the ASC, in accordance with Annex 13, paragraph 6.3, the comments submitted by NTSB of US, ATSB of Australia, MCIT of Singapore, as well as CAA of ROC are attached as submitted as an Appendix to this report (Appendix 7). A table indicating the acceptance status of the comments from each organization is also attached.

This investigation report follows the format of ICAO Annex 13 with few minor modifications. First, in Chapter 3, Conclusions, the Safety Council decided in their 39th Council Meeting that in order to further emphasize the importance that the purpose of the investigation report is to enhance aviation safety, and not to apportion blame and liability, this report presents the findings in three categories: findings related to the probable causes, findings related to risks, and other findings. Second, in Chapter 4, Safety Recommendations, other than the safety recommendations suggested to the relevant organizations, the Safety Council also lists the safety actions already taken or being undertaken by both MCIT of Singapore and CAA of ROC. The Safety Council believes this modification would better serve the purpose of improving aviation safety. It should also be noted that the Safety Council encourages the participants to take initiatives in safety improvements before the release of this report.

Therefore, based upon the analysis by the Safety Council, the following are the key findings of this accident investigation.

Findings as the result of this Investigation

There are three different categories of findings as the result of this investigation, findings related to probable causes, findings related to risks, and other findings:

The **findings related to probable causes** identify elements that have been shown to have operated in the accident, or almost certainly operated in the accident. These findings are associated with unsafe acts, unsafe conditions, or safety deficiencies associated with safety significant events that played a major role in the circumstances leading to the accident.

The **findings related to risk** identify elements of risk that have the potential to degrade aviation safety. Some of the findings in this category identify unsafe acts, unsafe conditions, and safety deficiencies, including organizational and systemic risks, that made this accident more likely; however, they cannot be clearly shown to have operated in the accident alone. Further, some of the findings in this category identify risks that are unrelated to this accident, but nonetheless were safety deficiencies that may warrant future safety actions.

Other findings identify elements that have the potential to enhance aviation safety, resolve an issue of controversy, or clarify an issue of unresolved ambiguity. Some of these findings are of general interests that are often included in the ICAO format accident reports for informational, safety awareness, education, and improvement purposes.

Findings Related to Probable Causes

1. At the time of the accident, heavy rain and strong winds from typhoon "Xangsane" prevailed. At 2312:02 Taipei local time, the flight crewmembers of SQ006 received Runway Visual Range (RVR) 450 meters on Runway 05L from Automatic Terminal Information Service (ATIS) "*Uniform*". At 2315:22 Taipei local time, they received wind direction 020 degrees with a magnitude of 28 knots, gusting to 50 knots, together with the takeoff clearance issued by the local controller. (1.1; 1.7)
2. On August 31, 2000, CAA of ROC issued a Notice to Airmen (NOTAM) A0606 indicating that a portion of the Runway 05R between Taxiway N4 and N5 was closed due to work in progress from September 13 to November 22, 2000. The flight crew of SQ006 was aware of the fact that a portion of Runway 05R was closed, and that Runway 05R was only available for taxi. (1.18.2.6; 2.5.2.1; 2.5.3)
3. The aircraft did not completely pass the Runway 05R threshold marking area and continue to taxi towards Runway 05L for the scheduled takeoff. Instead, it entered Runway 05R and CM-1 commenced the takeoff roll. CM-2 and CM-3 did not question CM-1's decision to take off. (1.1; 1.18.1.1)
4. The flight crew did not review the taxi route in a manner sufficient to ensure they all understood that the route to Runway 05L included the need for the aircraft to pass Runway 05R, before taxiing onto Runway 05L. (1.18.1.1; 2.5.3)
5. The flight crew had CKS Airport charts available when taxing from the parking bay to the departure runway; however, when the aircraft was turning from Taxiway NP to Taxiway N1 and continued turning onto Runway 05R, none of the flight crewmembers verified the taxi route. As shown on the Jeppesen "20-9" CKS Airport chart, the taxi route to Runway 05L required that

the aircraft make a 90-degree right turn from Taxiway NP and then taxi straight ahead on Taxiway N1, rather than making a continuous 180-degree turn onto Runway 05R. Further, none of the flight crewmembers confirmed orally which runway they had entered. (1.18.1.1; 2.5.2.2; 2.5.4.3)

6. CM-1's expectation that he was approaching the departure runway coupled with the saliency of the lights leading onto Runway 05R resulted in CM-1 allocating most of his attention to these centerline lights. He followed the green taxiway centerline lights and taxied onto Runway 05R. (1.18.1.1; 2.5.7)
7. The moderate time pressure to take off before the inbound typhoon closed in around CKS Airport, and the condition of taking off in a strong crosswind, low visibility, and slippery runway subtly influenced the flight crew's decision-making ability and the ability to maintain situational awareness. (1.18.1.1; 2.5.6; 2.5.7)
8. On the night of the accident, the information available to the flight crew regarding the orientation of the aircraft on the airport was:

   - CKS Airport navigation chart
   - Aircraft heading references
   - Runway and Taxiway signage and marking
   - Taxiway N1 centerline lights leading to Runway 05L
   - Color of the centerline lights (green) on Runway 05R
   - Runway 05R edge lights most likely not on
   - Width difference between Runway 05L and Runway 05R
   - Lighting configuration differences between Runway 05L and Runway 05R
   - Para-Visual Display (PVD) showing aircraft not properly aligned with the Runway 05L localizer
   - Primary Flight Display (PFD) information

   The flight crew lost situational awareness and commenced takeoff from the wrong runway. (1.1; 1.18.1; 2.5)

Findings Related to Risk

1. Based on the current ICAO Annex 14 Standards and Recommended Practices (SARPs), the CKS Airport should have placed runway closure markings adjacent to the construction area on Runway 05R; however, there was no requirement to place runway closure markings near the threshold of Runway 05R. (1.10.4.2; 2.3.3)
2. There is ambiguity in ICAO Annex 14 SARPs regarding a temporarily closed runway because the term "short term" is not defined. (1.10.4.2; 2.3.3)

3. ICAO Annex 14 SARPs, regarding a temporarily closed runway that is still used as a taxiway, do not provide adequate information with respect to warning flight crews that the runway is closed for other than taxi operations. (1.10.4.2; 2.3.3)
4. Although there are no clear ICAO regulations for placement of warnings on temporarily closed runways that are also used for taxi operations, the lack of adequate warnings at the entrance to Runway 05R did not provide a potential last defense, from an airport infrastructure perspective, to prevent the flight crew of SQ006 from mistakenly entering Runway 05R. (1.10.4.2; 2.3.3)
5. Based on ICAO SARPs, the barriers placed around the construction area on Runway 05R should have been frangible. However, the concrete barriers were used around the construction area on Runway 05R. (1.10.4.2; 2.3.3)
6. At the time of the accident, there were a number of items of CKS Airport infrastructure that did not meet the level of internationally accepted standards and recommended practices. Appropriate attention given to these items could have enhanced the situational awareness of the flight crew while taxiing to Runway 05L; however, the absence of these enhancements was not deemed sufficient to have caused the loss of situational awareness of the flight crew. Among these items were:

   - Four days after the accident, the investigation team found that a green centerline light immediately after the Runway 05R entry point along Taxiway N1 leading to Runway 05L was un-serviceable and the following light was dim. It could not be determined what the status of those lights was on the night of the accident. (1.10.3.2.4; 2.3.1.2.3)
   - The green centerline lights leading from Taxiway NP onto Runway 05R were more visible than the Taxiway N1 centerline lights leading toward Runway 05L because they were more densely spaced. There should have been 16 centerline lights spaced 7.5 meters apart along the straight segment of Taxiway N1 where the curved Taxiway centerline marking from Taxiway NP meets Taxiway N1 up to the Runway 05L holding position, rather than 4 centerline lights spaced at 30 meters, 55 meters, 116 meters, and 138 meters. (1.10.3.2.4; 2.3.1.2.2)
   - Segments of the straight portion of the taxiway centerline marking on Taxiway N1 did not extend all the way down to the Runway 05L threshold marking with interruption stops beginning 12 meters before the Runway 05R threshold marking and ending 12 meters after the Runway 05R threshold marking. (1.10.3.1.2; 2.3.1.1)
   - Runway guard lights and stop bars were not provided at CKS Airport. (1.10.3.2.2; 1.10.3.2.3; 2.3.2)
   - Alternate green/yellow taxiway centerline lights to demarcate the limits of the ILS sensitive area were not installed. (1.10.3.2.4)
   - The mandatory guidance signs installed on the left and right sides of Taxiway N1 were located after the holding position for Runway 05L and not collocated with the runway holding position marking. (1.10.3.1)

- There was no interlocking system installed at CKS Airport to preclude the possibility of simultaneous operation of the runway lighting and the taxiway centerline lighting. (1.10.5.1.1; 2.3.1.2.1)
- The serviceability monitoring mechanism of the CKS airfield lighting system was accomplished both electronically and manually. However, there was a lack of a continuous monitoring feature of individual lights, or percentage of unserviceable lamps, for any circuit of CKS Airport lighting. (1.10.5.1.2)

7. Airport Surface Detection Equipment (ASDE) is designed to reduce the risk of airport ground operations in low visibility, but there is no ICAO SARPs requiring the installation of ASDE at airports. The Safety Council was not able to determine whether ASDE would have provided information to the Air Traffic Controllers (ATC) about SQ006 taxiing onto the incorrect runway, because signal attenuation from heavy precipitation diminishes the effectiveness of the radar presentation. (1.18.2.4; 2.4.2)
8. There was a lack of a safety oversight mechanism within CAA that could have provided an independent audit/assessment of CKS Airport to ensure that its facilities met internationally accepted safety standards and practices. (1.17.9; 2.3.5.2.1; 2.3.5.3.2; 2.3.6)
9. There was a lack of a specified safety regulation monitoring organization and mechanism within the CAA that resulted in the absence of a mechanism to highlight conditions at CKS Airport for taxiways and runways lighting, marking, and signage that did not meet internationally accepted safety standards and practices. (1.17.9; 2.3.6)
10. The CAA had not formed a working group for the derivation of a complete Surface Movement Guidance and Control System (SMGCS) plan according to guidance provided by ICAO Annex 14. (1.10.5.2)
11. Being a non-contracting State, the CAA of ROC does not have the opportunity to participate in ICAO activities in developing its airport safety enhancement programs to correspond with international safety standards and recommended practices. (1.17.10; 2.3.5.2.2)
12. The local controller did not issue progressive taxi/ground movement instructions and did not use the low visibility taxi phraseology to inform the flight crew to slow down during taxi. (1.18.2.3; 2.4.1)
13. The flight crew did not request progressive taxi instructions from Air Traffic Controller (ATC). (1.1; Appendix 3)
14. Reduced visibility in darkness and heavy rain diminished, but did not preclude, the flight crew's ability to see the taxiway and runway lighting, marking, and signage. (1.18.1.1; 2.5.7.1)
15. The SIA crosswind limitation for a "wet" runway was 30 knots and for a "contaminated" runway was 15 knots. CM-1 assessed that the runway condition was "wet" at the time he prepared for takeoff and determined that the crosswind was within company limitations. The lack of SIA and ATC procedures for quantitatively determining a "wet" versus "contaminated"

runway creates ambiguity for flight crews when evaluating takeoff crosswind limitations. (1.18.4; 2.5.8)

16. There was no procedure described in the SIA B747-400 Operations Manual for low visibility taxi operations. (1.17.4.5; 2.5.4)
17. There was no formal training provided to SIA B747-400 pilots for low visibility taxi techniques. (1.18.1.1.1)
18. SIA did not have a procedure for the pilots to use the PVD as a tool for confirming whether the aircraft is in a position for takeoff in low visibility conditions such as existed for the operation of SQ006 on the night of the accident. (1.18.5.1; 2.5.6.3.3)
19. SIA procedures and training documentation did not reflect the CAAS approved B-747-400 AFM supplement regarding use of the PVD for confirming the correct aircraft takeoff position. (1.18.5.3; 2.5.6.3.3)
20. CAAS oversight of SIA operations and training did not ensure that the approved B747-400 AFM supplement regarding use of the PVD for determining whether the aircraft is in a correct position for takeoff was incorporated into the SIA documentation and operational practices. (1.18.5.3; 2.5.10)
21. At the time of the accident, SIA's Aircraft Operations Manual did not include "confirm active runway check" as a before takeoff procedure. (1.18.1.1; 2.5.5)
22. The SIA training and procedures for low visibility taxi operations did not ensure that the flight crew possessed the appropriate level of knowledge and skills to accurately navigate the aircraft on the ground. (1.17.4.5; 2.5.4.5)
23. CAAS had not performed sufficient safety oversight of SIA's procedures and training and the deficiencies in SIA procedures and training were not discovered during routine CAAS safety oversight. (1.17.1; 2.5.10)
24. The SIA typhoon procedure was not well defined and the personnel who were obliged to use the procedure did not fully understand the procedure and their responsibilities. (1.17.7; 2.7.4)
25. The severe impact forces and rapidly spreading fire and smoke rendered much of the existing emergency evacuation training, hardware, and procedures ineffective. (1.15.1.2, 1.15.1.3; 1.15.1.4, 2.6.1)
26. CM-1 did not order cabin crewmembers and passengers to initiate the emergency evacuation when the Passenger Address (PA) system was found inoperative. (1.15.1.2; 2.6.1)
27. During the annual recurrent emergency evacuation training, which was integrated with the cabin crew, the flight crew played the role of passengers. The SIA procedures did not require the flight crew to give the evacuation command. (1.15.1.1)
28. A majority of the cabin crewmembers' performance was affected because of the unexpected dynamics of the accident. (1.15.1; 2.6.1)
29. The dense smoke made breathing difficult and the emergency lights less visible for the survivors during the evacuation. (1.15.1; 2.6.3.1; 2.6.3.2)

30. During the evacuation in dark conditions, only CM-3, CM-2, and 5L crewmembers carried flashlights. The 5L cabin crewmember used the flashlight to assist during the passenger evacuation. (1.15.1.6)
31. CKS Airport did not prescribe in detail the emergency medical treatment procedures and the responsibilities of a medical coordinator or the interim coordinator in accordance with the ICAO recommendations. (1.15.3.6; 2.6.4.1)
32. CKS Airport did not provide contingency procedures for medical treatment and rescue in adverse weather conditions in accordance with the ICAO recommendations. (1.15.3.6; 2.6.4.1)
33. The "CKS Airport Civil Aircraft Accident Handling Procedures and Regulations" contained incomplete features of the surrounding hospitals (such as neurosurgical ability) as suggested in the ICAO recommendations. (1.15.3.5; 2.6.4.2)
34. The manufacturer of the emergency evacuation slides did not provide information on the effects of high wind in the operator's manual. (1.15.1.3; 1.12.2.3.2; 2.6.2.1)
35. The high lateral G forces associated with the accident produced an unexpected self-inflation of the 4R and 5R slides in the cabin. (1.15.1.5; 2.6.2.2)
36. The CKS Airport fire-fighting department was understaffed in handling a major accident. (1.14.1.2; 1.15.3.2; 2.6.4.3)

Other Findings

1. The flight crew was properly certificated and qualified in accordance with the applicable CAAS regulations and SIA Company requirements, and ICAO SARPs. (1.5; 2.1)
2. The flight crew was provided with appropriate and complete dispatch documents, including weather, weight and balance information, NOTAMs and SIA INTAMs, in accordance with the established procedures. (1.18.1.1; 2.1)
3. The cabin crew was qualified in accordance with the SIA training program. (1.5; 2.1)
4. Crew duty time, flight time, rest time, and off duty activity patterns did not indicate influence of pre-existing medical, behavioral, or physiological factors of the flight crew's performance on the day of the accident. (1.5; 2.1)
5. The air traffic controllers involved with the control of SQ006 were properly certificated, and qualified to perform their duties. Their duty time, rest time and off duty time activities were not considered to have influenced their performance on the day of the accident. (1.5.5; 1.5.6; 1.5.7; 1.5.8; 2.1)
6. The aircraft was certificated, equipped, and maintained in accordance with CAAS regulations and approved procedures, and ICAO SARPs. There was no evidence of pre-existing mechanical malfunctions or other failures of the aircraft structure, flight control systems, or power plants that could have contributed to the accident. The accident aircraft was considered airworthy before the accident. (1.6; 2.1)

7. There was no evidence to indicate that there was any undue organizational pressure from SIA placed upon the flight crew to take off on the evening of the accident. (1.17.8; 1.18.1.1; 2.1)
8. The Jeppesen charts used by the flight crew were current at the time of the accident. (1.18.3; 2.5.2.2)
9. The taxi check and procedures used by the flight crew were in accordance with the SIA B747-400 Operations Manual. (1.18.1.1; 2.5.4.4)
10. It was appropriate for the flight crew to consider Runway 05L for takeoff on the evening of the accident. (1.18.1.1; 2.5.3)
11. The SIA SOP did not assign specific duties for the third flight crewmember, although CM-1 requested CM-3 to verify crosswind limitations during taxi. (1.17.4.2; 1.18.1.1; 2.5.9.3)
12. ATC taxi instructions and the takeoff clearance did not mislead the flight crew to take off from the partially closed Runway 05R. SQ006 was cleared for takeoff on Runway 05L and the flight crew confirmed the clearance before takeoff. (1.1; 2.1; Appendix 2,3)
13. The preponderance of evidence indicates that the Runway 05R edge lights were most likely not illuminated during the attempted takeoff of SQ006. (1.12.5; 1.16.5; 2.3.4)
14. The fatality rate of this accident was 46 percent. The serious injury rate was 22 percent. The minor injury rate was 18 percent. The no-injury rate was 14 percent. (1.2)
15. The main deck mid cabin from rows 31 to 48 was not survivable in this accident because of the fuel-fed fire. Sixty four out of seventy six passengers died in this area. All passengers in the tail section survived where there was less fire. (1.2)
16. No slides were fully functional for survivors' evacuation in this accident because of impact forces, fire, and strong wind. (1.12.2.2; 1.16.3; 2.6.2)
17. The Department of Forensic Pathology conducted a total of 7 autopsies. Of the 7 autopsies conducted, 6 died from severe burns and one died from impact injuries. (1.13.2; 2.6.5)
18. Airport Rescue and Fire Fighting (ARFF) personnel arrived at the accident site in approximately 3 minutes and began fire fighting and rescue efforts. A small fire at the tail section was put out immediately. In conditions of severe weather, the fire at the forward and mid-sections of the fuselage were suppressed in 15 minutes and positively controlled in 40 minutes. (1.14.1.1; 1.14.1.2)
19. All fire and medical personnel used the same frequency to communicate in this accident. (1.15.3.1)
20. The majority of the CKS Airport medical and rescue operations were not able to function in accordance with CKS Airport procedures because of strong wind and heavy rain emanating from approaching typhoon "Xangsane." (1.15.3.2; 2.6.4)
21. The first 10 survivors were transported to the hospital in airport ambulances without proper triage procedures. (1.15.3.2; 2.6.4)

22. There was no alcohol and drug testing of the three flight crewmembers of SQ006 and four tower controllers on duty after the accident and there was no evidence to suggest that alcohol or drugs were factors in the accident. (1.13.3)
23. The Ministry of Transportation and Communications (MOTC) staff was not proactive in supporting CAA's requests for the installation of ASDE at CKS Airport. (1.18.2.4; 2.4.2)
24. All new CAA regulations are subject to lengthy formalities in the approval process by the MOTC. (1.17.10; 2.4.2)
25. Although the SQ006 CVR power-on and power-off times were in compliance with ICAO SARPs and CAAS regulations, the Federal Aviation Regulations (FARs) and Joint Aviation Requirements (JARs) require an earlier power-on and later power-off times. An earlier power-on time and later power-off time would be desirable for the examination of operational and human factors safety issues following accidents and incidents. (1.11.1.1; 2.7.1)
26. Only six incident reports collected by ASC were related to air traffic services, the number of reports involving airport facilities at CKS Airport, which has been in service over 22 years, should be more than six. (1.18.2.5; 2.4.3)
27. An airport surface guidance and navigation cockpit display could reduce the risk of incidents and accidents during taxi, take-off and landing operations. (1.18.8; 2.7.6)
28. Singapore does not have an independent aviation accident investigation authority charged with making objective investigations, conclusions, and recommendations. International experience has shown that an independent investigation authority is a benefit to aviation safety, and many States have taken actions to ensure that investigations are conducted by a government agency that is functionally independent from the authority responsible for regulation and oversight of the aviation system. (1.17.2; 2.7.7)

Recommendations

To Singapore Airlines (SIA)

The Safety Council recommends that SIA:

1. Develop and implement a comprehensive surface-movement training program that reflects the current practice in this area, such as the recommendations contained in the FAA's National Blueprint for Runway Safety and FAA Advisory Circular No. 120-74. (3.1-[3~8]; 3.2-[16, 17, 22])
2. Ensure that procedures for low visibility taxi operations include the need for requesting progressive taxi instructions to aid in correct airport surface movement. (3.2-[13])
3. Review the adequacy of current SIA PVD training and procedures and ensure that SIA documentation and operational practices reflect the CAAS approved B747-400 AFM PVD

supplement, which included the use of the PVD to indicate whether the aircraft is in a correct position for takeoff. (3.2-[18, 19])

4. Develop and implement a clear policy that ensures that flight crews consider the implications of the relevant instrument indications, such as the PFD and PVD, whenever the instruments are activated, particularly before commencing takeoff in reduced visibility conditions. (3.1-[8])
5. Include in all company pre-takeoff checklists an item formally requiring positive visual identification and confirmation of the correct takeoff runway. (3.1-[8], 3.2-[21])
6. Implement an Advanced Crew Resource Management (CRM) program to reflect current practices in this area, and ensure that such programs are regularly revised to reflect new developments in CRM. (3.1-[3, 4])
7. Review the adequacy of current runway condition determination procedures and practices for determining a water-affected runway to "wet" or "contaminated" in heavy rain situations, by providing objective criteria for such determinations. (3.2-[15])
8. Conduct a procedural audit to eliminate existing conflicts in the guidance and procedures between the company manuals, the managers' expectations, and the actual practices, such as those contained in the Typhoon Procedures and dispatch briefing policy. (3.2-[24])
9. Modify the emergency procedures to establish an alternate method for initiating the emergency evacuation command in the event of a PA system malfunction. (3.2-[26])
10. Review its procedures and training for the flight and cabin crewmembers to effectively handle diversified emergency situations. (3.2-[25, 26, 27, 28])

To Civil Aviation Authority of Singapore (CAAS)

The Safety Council recommends that the CAAS:

1. Require SIA to develop and implement a comprehensive surface-movement training program, to include a procedure to request progressive taxi instructions during low visibility ground operations. (3.1-[3~8]; 3.2-[13, 16, 17, 22])
2. Review the adequacy of current SIA PVD training and practices and require that SIA revise, if necessary, procedural and training documentation and operational practices to reflect the CAAS approved B747-400 AFM PVD supplement. (3.2-[18, 19, 20])
3. Review the current system of managing AFM supplement document approval, control, distribution, and enactment policies and procedures for operators and make appropriate changes as necessary to ensure that revisions to airline AFMs are adequately managed. (3.2-[20])
4. Ensure that all Singaporean commercial airline operators under its regulatory responsibility implement Advanced Crew Resource Management programs to reflect current practices and ensure that such programs are regularly monitored and revised to reflect new developments in CRM. (3.1-[3, 4])

5. Evaluate and support appropriate research to develop technologies and methods for enhancing flight crews' abilities for objectively determining a water-affected runway condition in heavy rain situations. (3.2-[15])
6. Amend the CAAS Air Navigation Order paragraph 37 (3) to require an earlier power-on and later power-off times for CVRs. (3.3-[25])

To Singapore Government

The Safety Council recommends that the Singapore Government establish an independent aviation accident/incident investigation organization consistent with many other countries in the world. (3.3-[28])

To Civil Aeronautics Administration, ROC (CAA)

The Safety Council recommends that the CAA:

1. Require that the control tower chiefs re-emphasize the concept, training and the use of progressive taxi/ground movement instructions during low visibility ground operations. (3.2-[12])
2. Place priority on budgetary processes and expedite the procurement and installation of ASDE at airports with high traffic volume. (3.2-[7])
3. Clearly redefine its Divisions' job functions to stipulate each individual unit and personnel responsibilities. (3.2-[8, 9])
4. Specifically appoint an organization within the CAA for the development, modification, and issuance of civil aviation regulations. (3.2-[8])
5. Organize a program to continuously monitor ICAO SARPs and industry best practices for safety improvement and distribute them to the relevant organizations for applicable review and necessary action and oversight of their progress. (3.2-[6])
6. Establish an integrated risk assessment and management program, and oversight mechanism to supervise all plans and implementations. (3.2-[6, 7, 8, 9, 10])
7. Evaluate and support appropriate research to develop technologies and methods in providing objective information to pilots regarding water-affected runway conditions (wet versus contaminated) in heavy rain situations. (3.2-[15])
8. Immediately implement all items, or acceptable alternative standards, at CKS and other ROC airports, that are not in compliance with ICAO SARPs and applicable documents, such as the SMGCS plan, the emergency medical procedure, etc. (3.2-[6, 10, 31, 32, 33])
9. Ensure that the ARFF have the necessary manpower to perform their assigned tasks, as compared to similar level 9 international airports. (3.2-[36])

10. Review the communication system at Taiwan airports to develop an integrated plan for improved communications between all agencies involved during emergency fire and rescue operations. (3.3-[19])
11. Establish a reliable incident reporting system, promote the system to the users' groups, and place higher priority to the use of such system. (3.3-[26])
12. Review FAA National Blueprint for Runway Safety and relevant Advisory Circulars with a view toward implementation. (3.2-[4, 5, 6, 7, 8, 9, 10])
13. Ensure that appropriate surface movement technology enabling infrastructure, such as airport and terrain databases, is developed for ROC airports. (3.3-[27])
14. Issue the necessary regulations to support the installation of cockpit-based surface guidance and navigation technologies, such as electronic moving map display, in ROC-registered aircraft engaged in regular public transport for use during airport surface movements. (3.3-[27])

To Ministry of Transportation and Communications, ROC (MOTC)

The Safety Council recommends that the MOTC:

1. Establish professional oversight capabilities for CAA's safety improvement actions and programs for promoting flight safety. (3.3-[23, 24])
2. Proactively provide support to the CAA's safety action plans, such as the ASDE procurement process. (3.2-[10]; 3.3-[23])
3. Grant full authorization to the CAA to avoid lengthy waiting periods for improving and implementing technical safety regulations. (3.3-[24])

To the Boeing Company

The Safety Council recommends that the Boeing Company:

1. Provide airline operators with appropriate guidance information, including cautions to be observed, when required to operate emergency evacuation slides in wind gusts that exceed the certified limit. (3.2-[34])
2. Review the effectiveness of cabin emergency lights to ensure that maximum conspicuity is achieved in dense smoke following survivable accidents. (3.2-[29])
3. Consider incorporating cockpit surface guidance and navigation technologies, such as electronic moving map display, into all proposed and newly certified aircraft. (3.3-[27])
4. Develop and issue the necessary technical support to airline customers to aid in the installation of cockpit surface guidance and navigation system, such as electronic moving map display, for use during airport surface movements. (3.3-[27])
5. Develop a mean to reduce failure of PA systems during survivable accidents and provide modified systems to operators. (3.2-[26])

To International Civil Aviation Organization (ICAO)

The Safety Council recommends that ICAO:

1. Develop Standards that would require ASDE or comparable equipment as standard equipment at civil airports with high traffic volume. (3.2-[7])
2. Amend Annex 14 to include clear Standards for defining and protecting a partially closed runway that may be used for taxi purposes. (3.2-[3])
3. Consider accepting ROC to participate in various ICAO activities as an observer, for the purpose of safety improvement, even though ROC is not a contracting State. (3.2-[11])
4. Support the establishment of a government/industry program involving Flight Safety Foundation, IFALPA, Airport Operations Association, and IATA to develop objective methods to assist pilots in assessing whether a runway is "wet" or "contaminated" due to the presence of water. (3.2-[15])
5. Encourage and support the establishment of research by governments and industry to improve passenger smoke protection and improve emergency evacuation slide performance in heavy winds and post-accident fire. (3.2-[29, 35])
6. Develop and issue the necessary SARPs to ICAO Member States' regulatory authorities to encourage them to adopt the necessary regulations to support the installation and use of cockpit-based surface guidance and navigation technologies, such as electronic moving map display. (3.3-[27])
7. Encourage all ICAO Member States to consider the installation of cockpit surface guidance and navigation system, such as electronic moving map display, in commercial airliners for use during airport surface movements. (3.3-[27])
8. Encourage all ICAO Member States' regulatory authorities to ensure that appropriate surface movement technology enabling infrastructure, such as airport and terrain databases, is developed. (3.3-[27])

To International Air Transport Association (IATA)

The Safety Council recommends that IATA:

1. Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death following an aircraft accident. (3.2-[25])

2. Provide member airlines with appropriate guidance information, including cautions to be observed, when required to operate emergency evacuation slides in wind gusts that exceed the certified limits. (3.2-[34])
3. For safety assurance and risk management purposes, urge its member airlines to work with their prospective regulatory agencies to ensure that airports into which they operate meet the Standards and Recommended Practices of ICAO Annex 14; and urge its member airlines to work with their prospective regulatory agencies to develop procedures for evaluating the airport infrastructure as part of their out-station audits. (3.2-[6])
4. Encourage member airlines to consider equipping their aircraft with cockpit surface guidance and navigation system, such as electronic moving map display, for use during airport surface movements. (3.3-[27])

To the Federal Aviation Administration (FAA) of the U.S.

The Safety Council recommends that FAA:

1. Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death following an aircraft accident. (3.2-[25])
2. Review emergency slide design to reduce the potential for uncommanded inflation resulting from lateral impact forces. (3.2-[35])
3. Review the effectiveness of cabin emergency lights to ensure that maximum conspicuity is achieved in dense smoke following survivable accidents. (3.2-[29])
4. Initiate rulemaking actions to require the installation, on Boeing aircraft, of public address systems that continue to function following survivable accidents[2]. (3.2-[26])

To the Joint Airworthiness Authorities (JAA)

The Safety Council recommends that JAA:

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[2] In April 2001 the Australian Transport Safety Bureau issued Recommendation R20000231, which stated:
The ATSB recommends that the FAA and JAA review the design requirements for high capacity aircraft to ensure the integrity of the cabin interphone and passenger address systems, particularly with respect to cabin/flight deck communications, in the event of runway overruns and other relatively common types of events, which result in landing gear and lower fuselage damage.

1. Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death following an aircraft accident. (3.2-[25])
2. Review emergency slide design to reduce the potential for uncommanded inflation resulting from lateral impact forces. (3.2-[35])
3. Review the effectiveness of cabin emergency lights to ensure that maximum conspicuity is achieved in dense smoke following survivable accidents. (3.2-[29])
4. Initiate rulemaking actions to require the installation, on Boeing aircraft, of public address systems that continue to function following survivable accidents[2]. (3.2-[26])

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Abbreviations

ADRAS	Aircraft Data Recovery and Analysis System
AD	Aerodrome Division
AEP	Airport Emergency Planning
AFFF	Aqueous Film-Forming Foam
AFM	Airplane Flight Manual
AIP	Aeronautical Information Publication
ANWS	Air Navigation and Weather Services
AOC	Air Operator Certificate
AOCR	Air Operator Certificate Requirements
APU	Auxiliary Power Unit
ARFF	Airport Rescue and Fire Fighting
ARM	Aircrew Resource Management
ASDE	Airport Surface Detection Equipment
ASEP	Aircrew Safety Equipment and Procedures
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATPL	Air Transport Pilot License
ATSB	Australian Transport Safety Bureau
AWA	Airport Weather Advisor
BA	Breathing Apparatus
CAA	Civil Aeronautics Administration
CAAS	Civil Aviation Authority of Singapore
CB	Cumulonimbus
CCS	Casualty Clearance Station
CFO	Chief of Flight Operations

CFP	Computer Flight Plan
CIC	Crew-in-Charge
CIQ	Custom, Immigration and Quarantine
CKS	Chiang Kai-Shek International Airport
CRM	Crew Resource Management
CSIST	Chung Shan Institute of Science and Technology
CVR	Cockpit Voice Recorder
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
ETOPS	Extended-Range Two-Engine Operations
EU	European Union
FAA	Federal Aviation Administration
FAM	Flight Administration Manual
FCC	Flight Control Center
FCD	Flight Control Department
FCTM	Flight Crew Training Manual
FDAP	Flight Data Analysis Program
FDR	Flight Data Recorder
FMC	Flight Management Computer
FOD	Foreign Object Damage
FOS	Flight Operations Section
HF	Human Factors
HHDLU	Hand-Held Download Unit
ICAO	International Civil Aviation Organization
IIC	Investigator-in-Charge
ILS	Instrument Landing System
INTAM	Internal Notice to Airmen
LLZ	Localizer
LOFT	Line Oriented Flight Training
LPC	Low-Pressure Compressor
LPT	Low-Pressure Turbine
LT	Local Time
MAC	Mean Aerodynamic Chord
MCIT	Ministry of Communications and Information Technology
MEC	Main Equipment Center
MOTC	Ministry of Transportation and Communications
ND	Navigation Display
NOTAM	Notice to Airmen

NTSB	National Transportation Safety Board
OCS	Operations Control Section
OQAR	Optical Quick Access Recorder
PA	Passenger Address
PAPI	Precision Approach Path Indicator
PEEPLS	Passenger Emergency Evacuation Path Lighting System
PFD	Primary Flight Display
PIC	Pilot-in-Command
PLIAD	Planning, Legal and International Affairs Division
PVD	Para-Visual Display
QAR	Quick Access Recorder
QNH	The barometric pressure as reported by a particular station
RAPS	Recovery, Analysis and Presentation System
RGL	Runway Guard Lights
ROC	Republic of China
RVR	Runway Visual Range
SARPs	Standards and Recommended Practices
SEM	Scanning Electron Microscope
SEP	Safety Equipment and Procedures
SFOO	Senior Flight Operation Officer
SIA	Singapore Airlines
SIGMET	Significant Meteorological Information
SIP	Senior Instructor Pilot
SMFCC	Senior Manager, FCC
SMGCS	Surface Movement Guidance and Control System
SSE	Safety, Security and Environment Department
SSFDR	Solid State Flight Data Recorder
SVP	Senior Vice President
TOGA	Takeoff / Go-Around
UDL	Left Upper Deck Door
UDR	Right Upper Deck Door
UTC	Coordinated Universal Time
VMC	Visual Meteorological Conditions
VPSSE	Vice President of Safety, Security, and Environment

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1 Factual Information

1.1 History of Flight

On October 31, 2000, at 2317 Taipei local time[3] (1517 UTC), Singapore Airlines (SIA) Flight SQ006, a Boeing 747-400 aircraft, bearing Singapore registration 9V-SPK, struck barriers and construction equipment during takeoff on Runway 05R, a portion of which had been closed for maintenance, at CKS Airport. Heavy rain, reduced visibility, and strong winds associated with typhoon "Xangsane" prevailed at the time of the accident. SQ006 was a scheduled international passenger flight from Chiang Kai-Shek International Airport (TPE), in Taoyuan, Taiwan, ROC, to Los Angeles International Airport (LAX), in Los Angeles, California, USA. SQ006 departed with 3 pilots, 17 cabin crewmembers, and 159 passengers aboard.

The captain (Crew Member 1, CM-1), relief pilot (Crew Member 3, CM-3) and 23 passengers were not injured; the first officer (Crew Member 2, CM-2), 9 cabin crewmembers and 22 passengers received minor injuries; 4 cabin crewmembers and 35 passengers received serious injuries; 4 cabin crewmembers and 79 passengers perished. Impact forces and post-accident fire destroyed the aircraft. There were approximately 124,800 kilograms of takeoff fuel in fuel tanks for this flight.

The pilots commenced duty on October 30, 2000, in Singapore and had flown the first sector (Flight SQ006) of the scheduled trip sequence (Singapore to Taipei, Taipei to Los Angeles, Los Angeles to Taipei and return to Singapore). All three pilots arrived at the hotel in Taipei around midnight local

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[3] All times herein are in Taipei local time based on the 24-hour clock.

time of October 30, 2000 and stayed at the hotel until departure for the airport at 2035, the evening of October 31, 2000.

The pilots reported for duty at 2153 and completed preflight departure duties, including receiving dispatch documents[4], and boarded the aircraft, which was parked at Bay B5. The dispatch documents, including the NOTAM[5] pertaining to partial closure of Runway 05R, were reviewed by the pilots. CM-1 was the "pilot flying" and conducted the taxi and takeoff.

According to the transcript of the air traffic control (ATC) Clearance Delivery[6], at 2257:16, the flight crew received the ATC clearance. The Automatic Terminal Information Service (ATIS) "Tango" broadcast, in part, that, "…Runway zero five left is in use, Runway zero six for departure only. Expect ILS Runway zero five left, category-two approach, wind zero two zero at three six, gust five two, visibility five hundred meters, Runway zero five left RVR four hundred fifty meters, Runway zero six, five hundred meters with heavy rain, cloud broken two hundred feet, overcast five hundred feet…Caution Taxiway November Sierra has been re-marked, aircraft using November Sierra advise taxi slowly with caution. Taxiway November Papa behind Alpha one and Alpha three closed, Runway zero five right between November four and November five closed, due to work in progress, Taxiway November four and November five still available…."

At 2305:57, after pushback from Bay B5, SQ006 requested and received clearance from the controller to commence taxiing, "Singapore six, taxi to Runway zero six, via Taxiway, correction, Runway zero five left, via Taxiway Sierra Sierra, West Cross, and November Papa." According to the cockpit voice recorder (CVR) transcript[7], at 2306:08, CM-2 stated, "I missed that man, what is it," after the controller issued the taxi clearance. CM-1 repeated the taxi clearance and for the next few seconds the flight crew discussed the route to Runway 05L. At 2306:15, CM-2 acknowledged the clearance, "And, November Papa for Runway zero five left, Singapore six." At 2307:05, CM-1 stated, "taxi slowly," followed by, "Ok turn left, skidding right passing heading about zero two four zero now." Shortly after, the flight crew engaged in conversation about the designated alternate airport because both Kaohsiung and Hong Kong had closed.

At 2309:58, CM-1 stated "a lot of rudder work man here…," CM-3 responded "cross wind." At 2310:21, CM-3 stated, "…it is coming in ah, the longer they delay the worse it is lah." CM-1

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4 Singapore Airlines contracted with EVA Airways in Taiwan to provide flight dispatch services to SIA flight crews at CKS Airport. See Section 1.17.4.3 for additional information pertaining to pre-flight document preparation for flight crew.
5 See appendix 1 for the Notice to Airmen (NOTAM), A0606.
6 See Appendix 2 for the ATC transcript of Taipei Clearance Delivery.
7 See Appendix 3 for the complete CVR transcript.

responded, “Yah, worse if we are going to get out, if don’t takeoff…I am going to go very slow here because you going get skid.”

At 23:11:49, according to the CVR transcript, CM-1 stated, “The five left also imp..imp..improve already the visibility to five hundred fifty meters.” At 2312:58, shortly after the aircraft turned onto Taxiway NP, the flight crew was instructed to change to tower frequency. CM-2 contacted the tower and the controller acknowledged the transmission saying, “Singapore six good evening, Taipei tower hold short Runway five left.” CM-2 acknowledged the transmission.

At 23:14:41, as SQ006 was proceeding along Taxiway NP, CM-2 stated, “Next one is November one,” followed by CM-1 stating, “Ok, second right.” CM-2 replied, “Second right, that’s right.” At 2314:58, CM-1 instructed CM-2 to, “Tell them we are ready….” The controller responded, “Singapore six roger, Runway zero five left, taxi into position and hold.” Shortly thereafter, the controller transmitted, “Singapore six, Runway zero five left, wind zero two zero at two eight gust to five zero, cleared for takeoff.” CM-2 acknowledged the transmission. According to the Flight Data Recorder (FDR) readout, the aircraft was approaching the southwestern end of Taxiway NP at the time the controller issued the takeoff clearance.

At 2315:48, the flight crew completed the before takeoff checklist. This was followed 2 seconds later by CM-2 saying, “OK green lights are here.” CM-1 responded, “It going to be very slippery, I am going to slow down a bit, slow turn here.” According to data from the FDR, the aircraft turned right from Taxiway NP onto Taxiway N1, and made a continuous right turn onto Runway 05R.

At 2316:07, the CVR recorded CM-2 saying, “and the PVD[8] hasn’t lined up ah.” CM-1 responded, “Yeah we gotta line up first,” followed by CM-3 saying, “we need forty five degrees.” At 2316:23, CM-1 stated, “not on yet er PVD huh never mind we can see the runway, not so bad. OK, I am going to put it to high first. OK ready er, so zero one zero is from the left lah OK.” According to the CVR transcript, CM-2 responded, “OK,” followed by the sound of the windshield wipers going to high speed.

At 2316:44, the CVR recorded the sound of engine noise increasing, followed 11 seconds later by both CM-2 and CM-3 calling “eighty knots.” At 2317:16, CM-1 stated, “(explicative) something there,” followed one second later by the first sound of impact.

Approximately 33 seconds after the takeoff roll commenced, the aircraft collided with several concrete “jersey” barriers, 2 excavators, 2 vibrating rollers, a bulldozer, an air compressor cart, and a

[8] See Section 1.18.5 for description and operational use of the Para-Visual Display (PVD)

pile of metal reinforcement bars on Runway 05R, between Taxiways N4 and N5. The FDR recorded airspeed about 158 knots and ground speed about 131 knots at the end of the recording.

At 2317:36, the CKS tower controller signaled the emergency bell to the fire station after seeing explosions and fire along the takeoff path of the aircraft.

1.2 Injuries to Persons

The Boeing 747-400 was configured with 12 first class seats, 28 business class seats, and 316 economy class seats on the main deck and 30 business class seats on the aircraft's upper deck. There were two pilot seats and two observer seats in the cockpit; sixteen cabin crew seats in the forward, mid and aft sections of the main deck cabin and three cabin crew seats in the upper deck.

The injury distribution is summarized in Table 1.2-1:

Table 1.2-1 Injury table

Injuries	Flight crew	Cabin Crew	Passengers	Other	Total
Fatal	0	4	79	0	83
Serious	0	4	35	0	39
Minor	1	9	22	0	32
None	2	0	23	0	25
Total	3	17	159	0	179

The fatality rate of this accident was 46 percent as defined by the ratio of aircraft occupant fatalities to total aircraft occupant manifest (83/179). The serious injury rate was 22 percent (39/179). The minor injury rate was 18 percent (32/179). The no injury rate was 14 percent (25/179). The passengers' fatality rate was about 50 percent (79/159).

Twelve of the 19 passengers seated in the upper deck did not survive. The fatality rate of the upper deck was 63 percent (12/19). Most of those on the main deck who sustained fatal injuries were seated between Row 31 and Row 48 of economy class. Sixty four out of 76 passengers died in this area, resulting in a fatality rate of 84 percent (64/76). The remaining 12 passengers in this area were seriously injured.

The following diagram (Figure 1.2-1) shows the passenger seat positions and the severity of injuries that they sustained. The information on the passenger seat position was from the airline-seating plan and from interviews with passengers. Some passengers changed seats; therefore, Figure 1.2-1 might not accurately reflect the actual seating positions at the time of the accident.

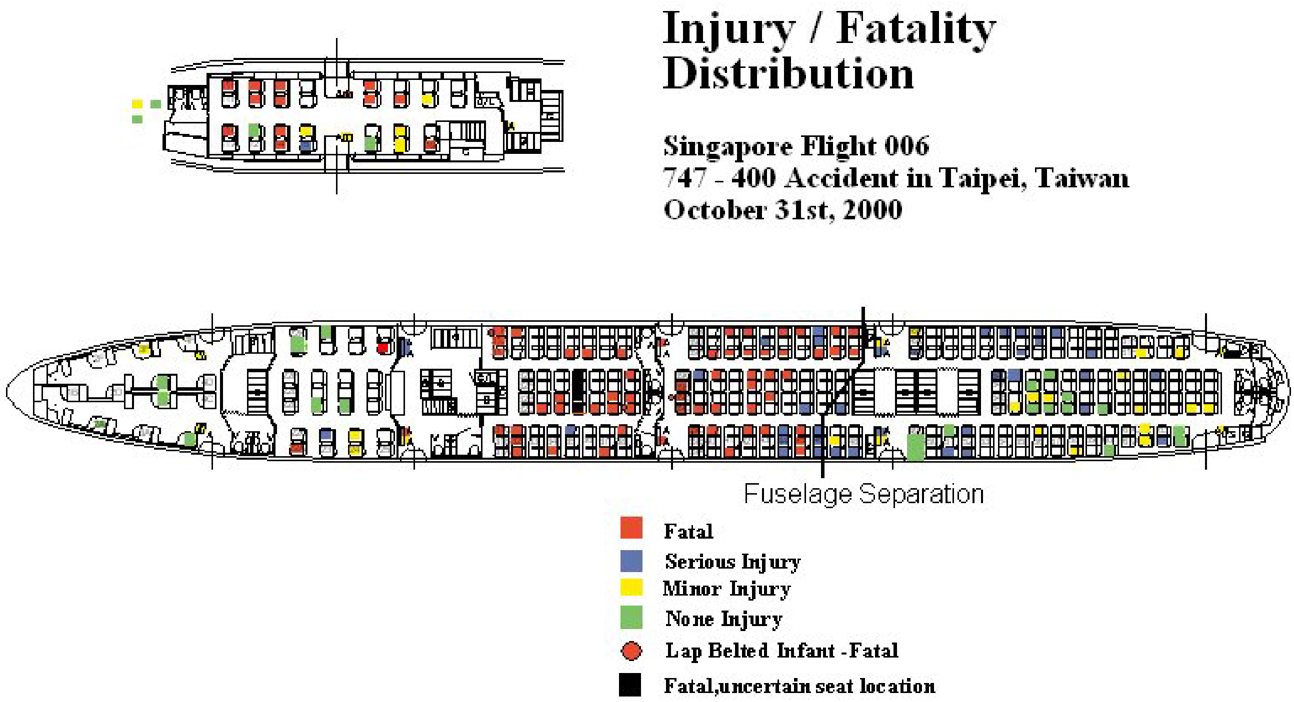

Figure 1.2-1 Injury/fatality distribution

1.3 Damage to Aircraft

Airframe structure components were scattered along the runway over the crash site. The aft fuselage containing passenger seat Rows 49 through 64 had separated from the remainder of the fuselage and was generally intact. The mid and forward portion of the fuselage from passenger seat row 48 forward sustained extreme fire damage. The cockpit instruments and panels were consumed by fire, although the control quadrant with all four-thrust levers was recovered. The left wing, right wing, and forward fuselage were found intact, but heavily damaged by fire. Molten aluminum present in the forward fuselage showed vertical drip patterns.

1.4 Other Damage

The construction crew had left six units of ground equipment on Runway 05R, specifically two excavators (Figures 1.4-1), two vibrating rollers (Figures 1.4-2), one small bulldozer (Figure 1.4-3) and one air compressor. All six units suffered serious impact damage. There were 11 pits at the construction site. With the exception of one excavator and the bulldozer, the rest of the units were scattered during the impact from their original positions in the various pits.

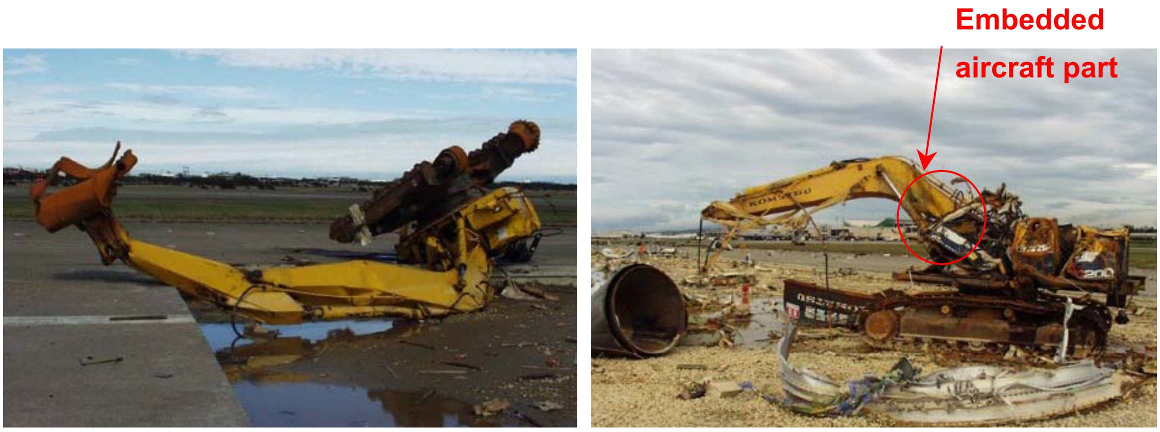

Figure 1.4-1　The excavator in No.5 pit (left) and the excavator in No.11 pit (right)

Figure 1.4-2　The vibrating roller No. 1 (left) and No.2 (right)

Figure 1.4-3　The bulldozer in No.11 pit

1.5 Personnel Information

1.5.1 The Captain (CM-1)

CM-1, a Malaysian national, was born in 1959. He resided in Johor Bahru, West Malaysia, but was based in Singapore.

CM-1 joined SIA as a cadet pilot on March 12, 1979. His flying training and progression was interrupted when he was re-deployed as a flight steward on two occasions between August 1980 through April 1981 and again between February 1983 and May 1984. On resumption of his flying career, CM-1 progressed to the rank of First Officer on the Boeing 747-300 on April 11, 1986. He transitioned to the Boeing 747-400 fleet as a First Officer in July 1991. He was promoted to Captain on the A310-200/300 fleet on November 16, 1995 and later appointed as a Supervisory Captain in April 1997. He transitioned to Captain on the Boeing 747-400 fleet on April 13, 1998.

CM-1 was issued an Air Transport Pilot License (ATPL) on January 2, 1993, and holds ratings on the Boeing 747-200/300, the Airbus A310-200/300 and the Boeing 747-400 aircraft types. His latest competency check that included CAT III operations was conducted on August 19, 2000. His last route check was on April 21, 2000. His latest Safety Equipment and Procedures (SEP) check was done on June 20, 2000. CM-1's latest PVD recurrent training was conducted on June 14, 2000.

CM-1's first Aircrew Resource Management training (ARM 1) was conducted on July 7, 1985. His ARM 2 training was conducted on July 14, 1988 and ARM 3 was completed on June 28, 1999.

At the date of the accident, he had accrued a total flying time of 11,235 hours, of which 2,017 hours were on the Boeing 747-400. His flying time over the last 12 months was 806 hours 53 minutes, last 90 days was 164 hours 11 minutes, last 60 days was 148 hours 35 minutes, and last 30 days was 78 hours 56 minutes. The rest period before the accident flight was 23 hours 39 minutes.

1.5.1.1 Personal Factors

CM-1 had not been subject to any recent disciplinary incidents or warnings. His personnel records indicated that the company had sent him a note to be more mindful of his operational duties regarding a noise abatement departure out of Zurich 13 years prior to the accident.

According to company records, CM-1's performance exceeded the minimum requirements during his initial training, recurrent (simulator) checks, line checks, and base checks on the B747-400. A summary review based on training records of his technical performance indicated that he was assessed to be an above average pilot.

During an interview with the Senior Instructor Pilot (SIP) who had conducted CM-1's most recent base check, the SIP stated that CM-1 received an average rating for the check. The Instructor Pilot who had conducted CM-1's most recent line check and a pilot who had been on a recent flight with CM-1 prior to the accident flight reported nothing unusual or significant regarding CM-1's performance.

CM-1 declared no financial or personal problems.

1.5.1.2 Medical Factors

CM-1 held a valid Singapore ATPL Medical Examination dated September 5, 2000. There were no restrictions. His height was 1.7 meters and his weight was 65.7 kg. Distant vision was 6/6 (equal to 20/20) for both eyes without correction and his near vision was N5 (normal) for both eyes without correction. He had normal color perception as tested by Ishihara plates.

1.5.1.3 72 Hour History

On October 27, 2000, CM-1 operated a flight from Singapore to Melbourne, Australia, departing at 2100 Singapore time (UTC+8). On October 28, 2000, he arrived Melbourne at 0600 Melbourne time (UTC+10). After checking into the hotel about an hour later, he slept until 1700. He met the co-pilot for dinner. He then returned to his hotel room about 2 hours later. On October 29, 2000, he did not sleep until about 0300 Melbourne time. He then slept until mid-day and joined the co-pilot for lunch at 1400. On returning to his room after lunch, he rested until call time. He departed Melbourne at 1730 Melbourne time and arrived Singapore about 2230 Singapore time.

On October 30, 2000, he went to sleep about 0100 and woke about 1100. After lunch at home, he left for the airport for the flight to Taipei about 1730. The flight arrived in Taipei at around 2145 Taipei time (Same as Singapore time) and he checked into the hotel around midnight.

On October 31, 2000, he went to sleep at 0100 Taipei time and slept until 1100 Taipei time. During interviews, he commented that he had "good quality uninterrupted sleep.". He joined his flight crew for lunch at 1130. Lunch lasted about 2 hours. He rested for a while and slept again from 1600 to 1900. He left the hotel at 2035 and reported for duty at 2155.

In the 3 days prior to the accident, CM-1 described that his eating, sleeping, and working patterns were as routine.

1.5.2 The First Officer (CM-2)

CM-2, a Singapore citizen, was born in 1964. He resided and was based in Singapore.

CM-2 joined SIA on June 6, 1994, as a cadet pilot. Previously, he was an officer in the Singapore Army. After successfully completing the cadet pilot phase of his training, he was appointed First Officer on the Airbus A310-200/300 fleet in January 1997. He transitioned to the Boeing 777-200/300 in June 1998 and to the Boeing 747-400 in February 2000.

CM-2 was issued an ATPL on August 6, 1999, and holds ratings on Airbus A310-200/300, Boeing 777-200/300 and Boeing 747-400 aircraft types. His latest competency check that included CAT III operations was conducted on October 19, 2000. His last route check was on February 16, 2000. His latest SEP check was completed on July 20, 2000. CM-2's latest PVD recurrent training was completed on September 24, 2000.

CM-2's ARM 1 training was conducted on June 12, 1997. His ARM 2 training was conducted on October 18, 1999.

At the date of the accident, he had accrued a total flight time of 2,442 hours, of which 552 hours were on the Boeing 747-400. His flying time over the last 12 months was 682 hours 02 minutes, last 90 days was 201 hours 11 minutes, last 60 days was 133 hours 46 minutes, and last 30 days was 42 hours 14 minutes. The rest period before the accident flight was 23 hours 39 minutes.

1.5.2.1 Personal Factors

A review of CM-2's records revealed no disciplinary events.

CM-2's performance exceeded the minimum requirements during his initial training, recurrent (simulator) checks, line checks, and base checks on the B747-400. A summary review based on training records of his technical performance showed that he was assessed to be an average to above average pilot.

During an interview with the SIP who had conducted CM-2's most recent base check, the SIP rated CM-2 as average. The Instructor Pilot who had conducted the most recent line check stated that CM-2 performed average during the check. A pilot on a recent flight with CM-2 prior to the accident flight reported that CM-2 was an average to above average pilot.

CM-2 declared no financial or personal problems.

1.5.2.2 Medical Factors

CM-2 held a valid Singapore ATPL Medical Examination dated July 26, 2000. There were no restrictions. His height was 1.74 meters and his weight was 76.3 kg. Distant vision was 6/6 (equal to 20/20) for both eyes without correction, and his near vision was N4.5 (normal) for both eyes without correction. He had normal color perception as tested by Ishihara plates.

1.5.2.3 72 Hour History

CM-2 had operated a flight from San Francisco to Singapore on October 26. He was off duty between October 27 and October 29, 2000. During this period, he spent most of his time at home with his family.

On October 30, 2000, he woke up at 0615 Singapore local time (LT). Later in the morning, he drove to SIA to resolve a financial matter. In the afternoon, he reported that he took a short nap until 1600. He was driven to the airport and arrived between 1630-1645 for the SQ006 flight (Singapore-Taipei, departing from Singapore at 1730 and arriving in Taipei at 2125 LT). He checked into the hotel at Taipei about midnight but he reported that he could not fall asleep immediately.

On October 31, 2000, he fell asleep towards the end of a television show. He woke up at 0800 and went to the gym for a couple of hours. He jogged on the treadmill for about 30 minutes and did some stretching and weights for about an hour. He met the other flight crewmembers for lunch at 1130. Lunch lasted about 2 hours after which he returned to the hotel and went to sleep. He left the hotel at 2035 for the airport and reported for duty at 2155.

CM-2 reported that in the 3 days prior to the accident, his eating and working patterns were as routine.

1.5.3 The Relief Pilot (CM-3)

CM-3, a Singapore citizen, was born in 1962. He resided and was based in Singapore.

He joined SIA on March 9,1992 as a cadet pilot. After successfully completing the cadet pilot phase of his training, he was appointed a First Officer on the Airbus A310-200/300 fleet in November 9, 1993. He transitioned onto the Boeing 747-400 in June 1995.

He was issued an ATPL on January 7, 1997 and holds ratings on the Airbus A310-200/300 and Boeing 747-400 aircraft types. His latest competency check that included CAT III operations was on August 31, 2000. His last route check was on February 20, 2000. His latest SEP check was on February 22, 2000. He underwent “recency” training in the flight simulator on October 29, 2000 after returning from 28 days of leave. CM-3's latest PVD recurrent training was completed on July 18, 2000.

CM-3's ARM 1 training was conducted on July 30, 1993. His ARM 2 training was conducted on August 10, 1994.

At the date of the accident, he had accrued a total flight time of 5,508 hours, of which 4,518 hours were on the Boeing 747-400. His flying time over the last 12 months was 823 hours 57 minutes, last 90 days was 139 hours 30 minutes, last 60 days was 92 hours 19 minutes, and last 30 days was 4 hours in the simulator for recency. The rest period before the accident flight was 23 hours 39 minutes.

1.5.3.1 Personal Factors

CM-3 had no record of disciplinary problems in the 8 years he has been with the company.

CM-3's performance exceeded the minimum requirements during his initial training, recurrent (simulator) checks, line checks, and base checks on the B747-400. A summary review based on training records of his technical performance showed that he was assessed to be an above average pilot.

CM-3 declared no financial or personal problems.

1.5.3.2 Medical Factors

CM-3 held a valid Singapore ATPL Medical Examination dated September 7, 2000. His height was 1.77 meters and his weight was 72 kg. Distant vision was 6/18 (equal to 20/60) for both eyes without correction and correctable to 6/6 with corrective lenses. His near vision was N5 (normal) for both eyes without correction. He was required to wear spectacles for distant vision and carry a spare pair whilst exercising the privileges of the license. There were no other restrictions on his license. He had normal color perception as tested by Ishihara plates.

1.5.3.3 72 Hour History

CM-3 was on leave for 28 days until October 28. He had spent a few days in Hong Kong. He indicated that he returned to Singapore for the last 3 days of his leave period. During interviews, he commented that he had rested well, sleeping for about 10 hours every day. He flew the flight simulator on October 29 to regain his currency on the B747-400 after his leave break. On October 30, 2000, CM-3 was a passenger on SQ006 from Singapore to Taipei. He was positioning to Taipei to be part of a three-pilot-crew for the next day's flight from TPE to LAX. He arrived at the hotel about midnight and went to sleep shortly after that.

On October 31, he woke up about 1030 for the lunch appointment at 1130 with the rest of the flight crewmembers. The lunch lasted about 2 hours. He returned to his hotel room, reviewed some charts and rested for another 2-3 hours. He reported for duty at the airport with the other crewmembers about 2155.

CM-3 described that his eating and sleeping patterns were as routine in the last 3 days prior to the accident.

1.5.4 The Cabin Crew

The cabin crewmembers onboard SQ006, received their initial and recurrent training at SIA on the dates listed in Table 1.5-1.

Table 1.5-1 Cabin crewmembers' training record

Crew Seat Position	Initial Training Date	Recurrent Training Date	Crew-In-Charge (CIC) Recurrent Training Date
UDL	29 Oct 97	10 Oct 00	Not Applicable
UDR	30 Jun 78	19 Sep 00	28 Apr 00
Upper Deck Galley	11 Nov 97	10 Oct 00	Not Applicable
Door 1L	25 Sep 90	30 Mar 00	Not Applicable
Door 1R	3 May 89	23 Aug 00	Not Applicable
Door 2L, Inboard	3 Aug 73	25 Nov 99	23 May 00
Door 2L, Outboard	21 Oct 98	11 Oct 00	Not Applicable
Door 2R, Inboard	23 Dec 87	13 Sep 00	Not Applicable
Door 2R, Outboard	7 Nov 79	20 Jul 00	13 Jan 00
Door 3L, Inboard	Not occupied	Not Applicable	Not Applicable
Door 3L, Outboard	13 Jul 92	31 Aug 00	Not Applicable
Door 3R, Inboard	Not occupied	Not Applicable	Not Applicable
Door 3R, Outboard	30 Apr 96	27 Apr 00	Not Applicable
Door 4L, Inboard	16 Oct 95	22 Aug 00	Not Applicable
Door 4L, Outboard	11 May 92	6 Apr 00	Not Applicable
Door 4R, Inboard	10 Aug 00	Not due	Not Applicable
Door 4R, Outboard	13 Jan 95	23 Dec 99	Not Applicable
Door 5L	24 Feb 00	Not due	Not Applicable
Door 5R	23Feb 00	Not due	Not Applicable

1.5.5 Local Controller (LC)

The local controller had served three years in the CKS Tower. He was qualified in accordance with CAA's current regulations and met all CAA training requirements.

1.5.5.1 72 Hour History

On October 29, 2000, the LC was off duty.

During interviews with the LC, he reported that he awoke on October 30, 2000, at 0700 and read for a while. He had lunch at noon before taking a nap at 1230 until 1600. He arrived at the Tower at 1840 and started his shift at 1845. The Tower duty records indicated that the LC commenced his shift at 1845. The LC reported that after he had finished work at 0900 on October 31, 2000, he went home and arrived at about 1030. He reported that he slept until 1200, woke up for lunch and then slept again until about 1500 or 1600. He arrived for work at the Tower at 1840. He declared that he had no problems with sleeping, personal difficulties or family difficulties in the 72 hours before coming to work on the October 31, 2000.

The duty time in the last 72 hours prior to the accident was 18.5 hours, including shift breaks on duty. The LC reported that he had been eating, working and sleeping as routine in the last 72 hours prior to the accident.

1.5.6 Ground Controller (GC)

The ground controller had served four years in CKS Approach and Tower. He was qualified in accordance with CAA's current regulations and met all CAA training requirements.

1.5.6.1 72 hour History

The GC was on duty on October 29, 2000. He reported that he left home for CKS Airport at about 0720. He arrived for work at about 0845 and commenced his shift at 0900. He finished work at 1900 and arrived home at about 2020 then went to bed. On October 30, 2000, he left home for CKS Airport at about 0720. He arrived for work at about 0845 and commenced his shift at 0900. He finished work at 1900 and arrived home at about 2020 and then went to bed. On October 31, the GC reported that he rested at home during the day. He left home for CKS Tower at about 1720 and arrived about 1840. He commenced the shift at 1900 and finished work at 0900 on November 1, 2000.

The duty time in the last 72 hours prior to the accident was 24.5 hours, including shift breaks on duty. The GC reported that he had been eating, working and sleeping as routine in the last 72 hours prior to the accident.

1.5.7 Clearance Delivery Controller (CD)

The CD had served three years in the CKS Tower. He was qualified in accordance with CAA's current regulations and met all CAA training requirements.

1.5.7.1 72 hour History

The CD was off duty on the day of October 29, 2000. About 1720 he drove to CKS Tower and arrived about 1840. He commenced his shift at 1900 and finished work at 0900 next morning and arrived home at 1020. He took the whole day rest at home.

On October 30, 2000, he was off duty on the day. At about 1720 he drove to CKS Tower and arrived at about 1840. He commenced his shift at 1900 and finished work at 0900 next morning and arrived home at 1020. He took the whole day rest at home.

On October 31, 2000, he was off duty on the day. At about 1720 he left home for CKS Tower and arrived at about 1840. He commenced his shift at 1900 and finished work at 0900 next morning and arrived home at 1020. He rested at home for the remainder of the day.

The duty time in the last 72 hours prior to the accident was 31.5 hours, including shift breaks on duty. The CD reported that he had been eating, working and sleeping as routine in the last 72 hours prior to the accident.

1.5.8 Flight Data Controller (FD)

The FD had worked with CAA for five years; she held both Approach and Tower ratings. She was also a tower instructor.

1.5.8.1 72 Hour History

On October 29, 2000 at about 0640, the FD drove to CKS Tower and arrived at about 0800. She commenced her shift at 0840. At 1900, she finished work and left Tower, and arrived home at about 2010.

On October30, 2000 at about 0640, the FD drove to CKS Tower and arrived at about 0800. She commenced her shift at 0840. At 1900, she finished work and left Tower, and arrived home at about 2010.

The FD was off duty on October31, 2000. She drove to CKS Tower at about 1600, which is earlier than usual because of the approaching typhoon, and arrived Approach at about 1700 and commenced work at 1840. She finished work at 0900 the next morning and arrived home at about 1010. She rested at home for the remainder of the day.

The duty time in the last 72 hours prior to the accident was 31.5 hours, including shift breaks on duty. The FD reported that he had been eating, working and sleeping as routine in the last 72 hours prior to the accident.

1.6 Aircraft Information

1.6.1 Basic Information

Basic information of the accident aircraft is shown in Table 1.6-1.

Table 1.6-1 Basic information of the accident aircraft

1	Aircraft Registration Mark	Singapore-registered 9V-SPK
2	Type of Aircraft	Boeing 747-412B
3	Manufacturer	Boeing Commercial Aircraft Group
4	Manufacturer's Serial Number	28023
5	Delivery Date	January 21, 1997
6	Operator	Singapore Airlines Limited, Airline House, 25 Airline Road, Singapore 819829
7	Owner	Singapore Airlines Limited, Airline House, 25 Airline Road, Singapore 819829
8	Certificate of Registration Number	S151
9	Certificate of Airworthiness Number (Validity Period)	AWC431 (January 21, 2000 ~ January 20, 2001)
10	Total Flight Hours	18459 hours (as at October 29, 2000)
11	Total Cycles	2274 cycles (as at October 29, 2000)
12	Last Maintenance Check	A Check
13	Last Maintenance Check Date	16 Sep 2000, 17838 flight hours / 2187 cycles
14	Hours / Cycles Elapsed Since Last Maintenance Check	621 flight hours / 87 cycles (as at October 29, 2000)

1.6.2 Weight and Balance

The China Airlines loadmaster at CKS Airport prepared the load sheet for SQ006. The Safety Council reviewed the load sheet for the accident flight and found that the Weight and Balance were within operational limits.

1.6.3 Maintenance Records

The Safety Council reviewed the Flight Technical Logbook records covering a 3-month period from August 1, 2000 to October 31, 2000. Review of the maintenance logbooks revealed no deferred or open items for the flight. No related defects were found in the 30 days of Tech Log Entries. The review also showed no evidence indicating that the aircraft was not airworthy.

1.7 Meteorological Information

1.7.1 General Weather Information

Taiwan was affected by north-east monsoon flow and Typhoon "Xangsane," centered about 360 kilometers south of CKS Airport around the time of the accident. The maximum wind speed of the storm was 75 knots gusting to 90 knots; the pressure of the storm center was 965 hPa.

The Taipei Aeronautical Meteorological Center in Taipei City issued a Significant Meteorological Information (SIGMET) for cumulonimbus (CB), which was applicable for CKS Airport at the time of the accident. Additionally, the Taipei Aeronautical Meteorological Center issued several gale warnings and typhoon warnings, which were applicable for CKS Airport about the time of the accident.

1.7.2 Surface Weather Observations

CKS Weather Station took the following surface weather observations before and after the accident[9]:

> 2240: Type—special; Wind—020 degrees at 38 knots gusting 58 knots; Visibility—800 meters; Runway Visual Range (RVR)—RWY05/800 meters, RWY06/800 meters; Present Weather-heavy rain; Clouds—broken 200 feet overcast 500 feet; Temperature—21 degrees

9 The wind and RVR data of the surface weather observations were based on 10 minutes average.

Celsius; Dew Point—20 degrees Celsius; Altimeter Setting—1002 hPa (A29.60 inches Hg); Wind shear RWY05[10]; Trend Forecast—no significant change

2254: Type—special; Wind—020 degrees at 36 knots gusting 52 knots; Visibility—500 meters; RVR—RWY05/450 meters, RWY06/500 meters; Present Weather-heavy rain; Clouds—broken 200 feet overcast 500 feet; Temperature—21 degrees Celsius; Dew Point—20 degrees Celsius; Altimeter Setting—1001 hPa (A29.58 inches Hg); Wind shear RWY05; Trend Forecast—no significant change

2300: Type—routine; Wind—020 degrees at 36 knots gusting 56 knots; Visibility—600 meters; RVR—RWY05/450 meters, RWY06/550 meters; Present Weather-heavy rain; Clouds—broken 200 feet overcast 500 feet; Temperature—21 degrees Celsius; Dew Point—20 degrees Celsius; Altimeter Setting—1001 hPa (A29.58 inches Hg); Wind shear RWY05; Trend Forecast—no significant change; Remark rain amount 22.50 millimeters

2320: Type—additional; Wind—020 degrees at 30 knots gusting 61 knots; Visibility—600 meters; RVR—RWY05/550 meters, RWY06/800 meters; Present Weather-heavy rain; Clouds—broken 200 feet overcast 500 feet; Temperature—21 degrees Celsius; Dew Point—21 degrees Celsius; Altimeter Setting—1002 hPa (A29.59 inches Hg); Wind shear RWY05

1.7.3 Weather information obtained from ATC communication

According to the CVR transcript, the flight crew received the following weather information for Runway 05L before takeoff[11]:

2307:16: Wind—020 degrees at 25 knots, gusting to 41 knots; RVR—450 meters

2313:38: Wind—020 degrees at 24 knots, gusting to 43 knots

2315:22: Wind—020 degrees at 28 knots, gusting to 50 knots

1.8 Aids to Navigation

There were no reported difficulties with navigational aids at CKS Airport.

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[10] The wind shear remark was obtained from a pilot report at 2127. The aircraft encountered wind shear at altitude 500 feet on final approach.

[11] The wind and RVR data displayed on CKS Tower console were based on 2 minutes average.

1.9 Communications

There were no communications problems between SQ006 and CKS Airport Control Tower.

1.10 Airport Information

1.10.1 General

The Ralph Parsons Company of the United States commenced the planning and design of the CKS Airport in 1970. At that time, the ROC was still a participating member of ICAO and the airport design conformed to the ICAO Standards and Recommended Practices (SARPs). The construction started from 1974 and completed in 1979 and the ROC was no longer an ICAO member during this period. The CKS Airport diagram is shown in Figure 1.10-1.

The original design of the airport did not include Runway 05R/23L, but rather included a parallel taxiway (identified as Taxiway A). It was determined during construction that an additional runway was necessary in the event that the primary runway, 05L/23R, was closed. Hence, Taxiway A was re-engineered and changed into Runway 05R/23L when CKS Airport was commissioned. At that time, green centerline lighting was installed on Runway 05R/23L.

Since 1971, the ROC was no longer recognized as a contracting State of ICAO. Although the CKS Airport had been constructed in accordance with the FAA specifications and ICAO SARPs, the CAA of ROC was no longer able to directly receive the ICAO SARPs information.

According to the CAA officials, the CKS Airport Runway 05R had been planned to be re-designated as Taxiway NC. The re-designation schedule was postponed due to a material procurement delay. In the meantime, the pavement between Taxiway N4 and Taxiway N5 of Runway 05R was closed for repair. Runway 05R was still a runway with its remaining portion used for aircraft taxi operations at the time of SQ006 accident.

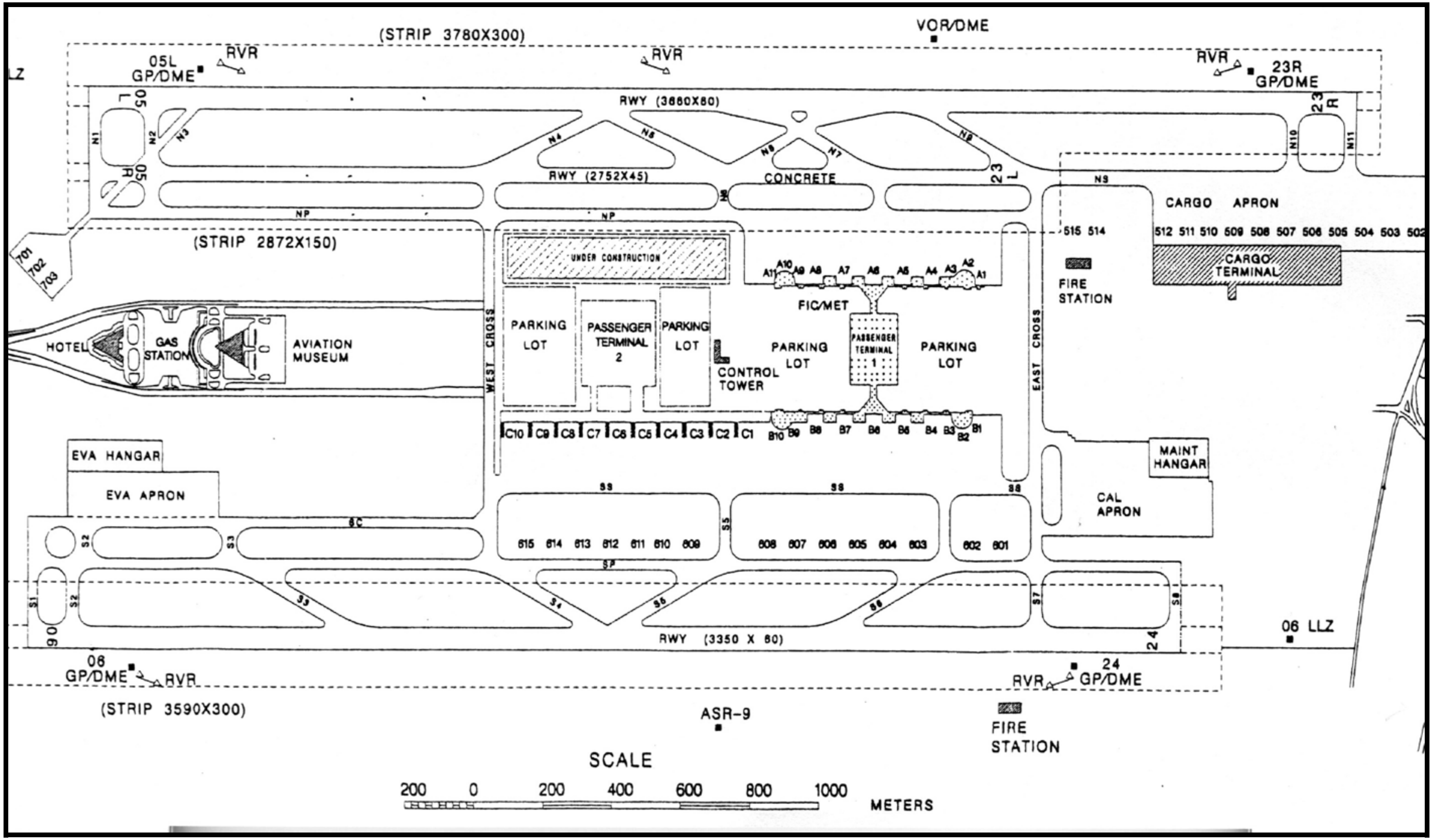


Figure 1.10-1 Layout of CKS Airport

1.10.2 Physical Characteristics at the Time of the Accident

1.10.2.1 Runway Configurations and Specifications

CKS Airport had three runways, two parallel runways on the north side and one on the south side of the passenger and cargo terminal buildings. On the north side, the primary runway was designated 05L/23R, and the parallel runway was designated 05R/23L. The north side runways were spaced 214 meters apart from the respective runway centerlines. The runway on the south was designated as 06/24.

Runway 05L/23R was 60 meters wide and 3,660 meters long and constructed of non-grooved Portland-cement concrete. It was equipped with an instrument landing system (ILS) and was authorized for Category II operations.

Runway 05R/23L was 45 meters wide and 2,752 meters long and was designated as a "non-instrument" runway. It was equipped with green taxiway centerline lights for taxi operations and white runway edge lights for takeoff operations. The runway was not available for landing but pilots were able request its use for takeoff. Pilots were required to obtain prior approval from both the CKS Airport and the ATC for the use of the runway. Typically, approval would not be granted when there were large aircraft on Apron 501-515 because of the lack of sufficient safety zone clearance. Further, the simultaneous use of Runway 05R/23L and the parallel Taxiway "NP" was prohibited if the crosswind component exceeded 22 knots (dry runway) or 17 knots (wet runway).

Runway 06/24 is 60 meters wide and 3,350 meters long, and constructed of non-grooved Portland-cement concrete. It is equipped with an instrument landing system (ILS) and is authorized for Category I operations.

1.10.2.2 North Taxiway Configurations

The north side of the CKS Airport was serviced by the following taxiways: NP, NS, N1, N2, N3, N4, N5, N6, N7, N8, N9, N10, N11, West Cross and East Cross.

Taxiway NP was 30 meters wide with 11-meter shoulders. The other taxiways (e.g. N1, N2 and rapid exit taxiways N4, N5, N7, N8…) were 35 meters wide with 11-meter shoulders.

NP was the taxiway that originated from the passenger air carrier apron located on the north side of the passenger terminal and extended parallel to and in close proximity with Runway 05R/23L. The taxiway was equipped with both green taxiway centerline lights and blue taxiway edge lights. The distance between the centerline of Taxiway NP and Runway 05R/23L was 110 meters.

Taxiway N1 was the perpendicular taxiway that extended from Taxiway NP across Runway 05R and terminated at Runway 05L. This taxiway was 110 meters long from Taxiway NP to Runway 05R and then 214 meters to Runway 05L for a total of 324 meters from Taxiway NP centerline to Runway 05L centerline. It was equipped with green taxiway centerline lights and blue taxiway edge lights.

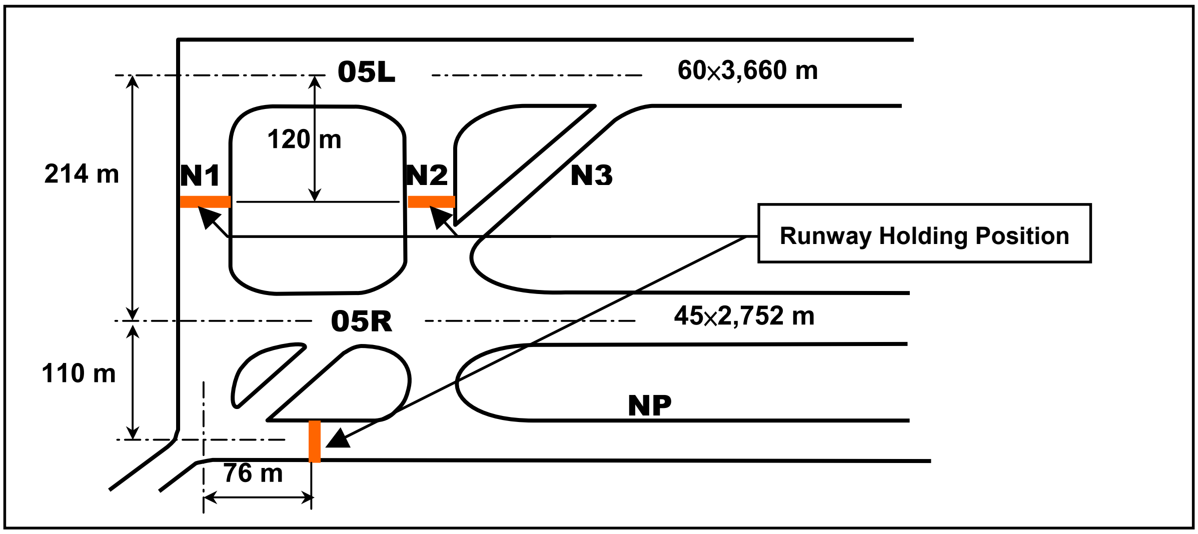
1.10.3 Visual Aids for Navigation at the Time of the Accident

1.10.3.1 Marking

1.10.3.1.1 Runway Holding Positions and Marking

CKS Airport has two runway holding positions for Runway 05L; one at Taxiway N1 and the other at N2. Both hold lines were located 120 meters to the south of the Runway 05L centerline.

A third runway holding position is located on Taxiway NP, 76 meters east of Taxiway N1 centerline. The locations of the runway holding positions and the actual marking are shown in the Figures 1.10-2



and 1.10-3.

Figure 1.10-2 Distance of runway holding positions (not to scale)

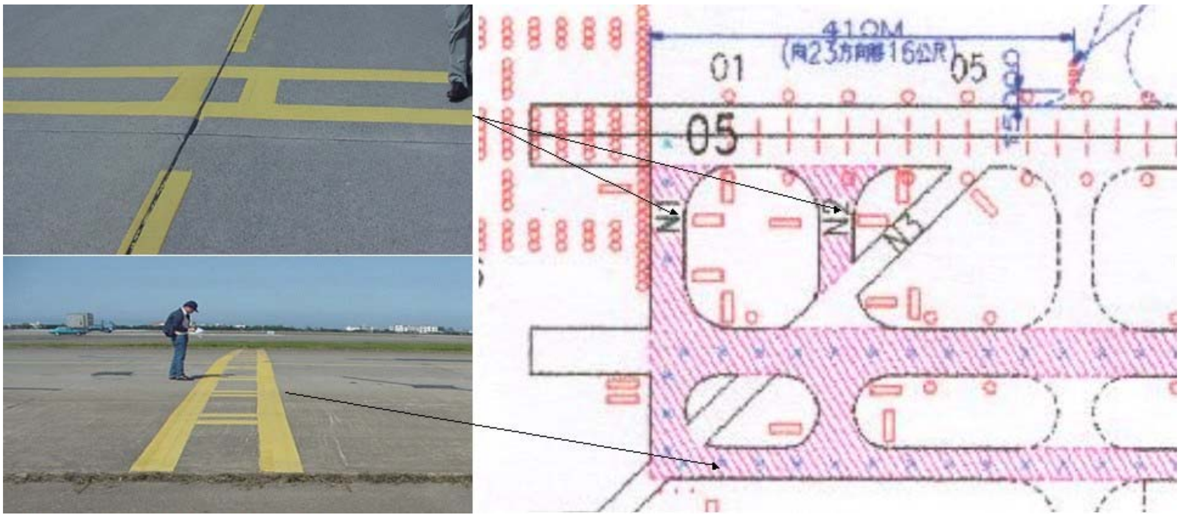


Figure 1.10-3 Runway holding position marking at Taxiway N1 and NP

According to ICAO Annex 14, vol. 1 paragraph 3.11.6, Table 3-2, the minimum distance from the runway centerline to a runway holding position for a non-instrument / takeoff runway is 75 meters and for a runway serviced with a precision approach, the distance is 90 meters, or an appropriate distance necessary to protect the critical/sensitive areas of ILS/MLS. Standards and Recommendation for runway holding position marking are described in ICAO Annex 14, vol. 1, paragraph 5.2.9.2, 5.2.9.3 and 5.2.9.5 respectively.

paragraph 5.2.9.2 (Standard):

> *"At an intersection of a taxiway and a non-instrument, non-precision or takeoff runway, the runway holding position marking shall be as shown in Figure 5-6*[12]*, pattern A."*

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[12] Refer to Figure 1.10-4

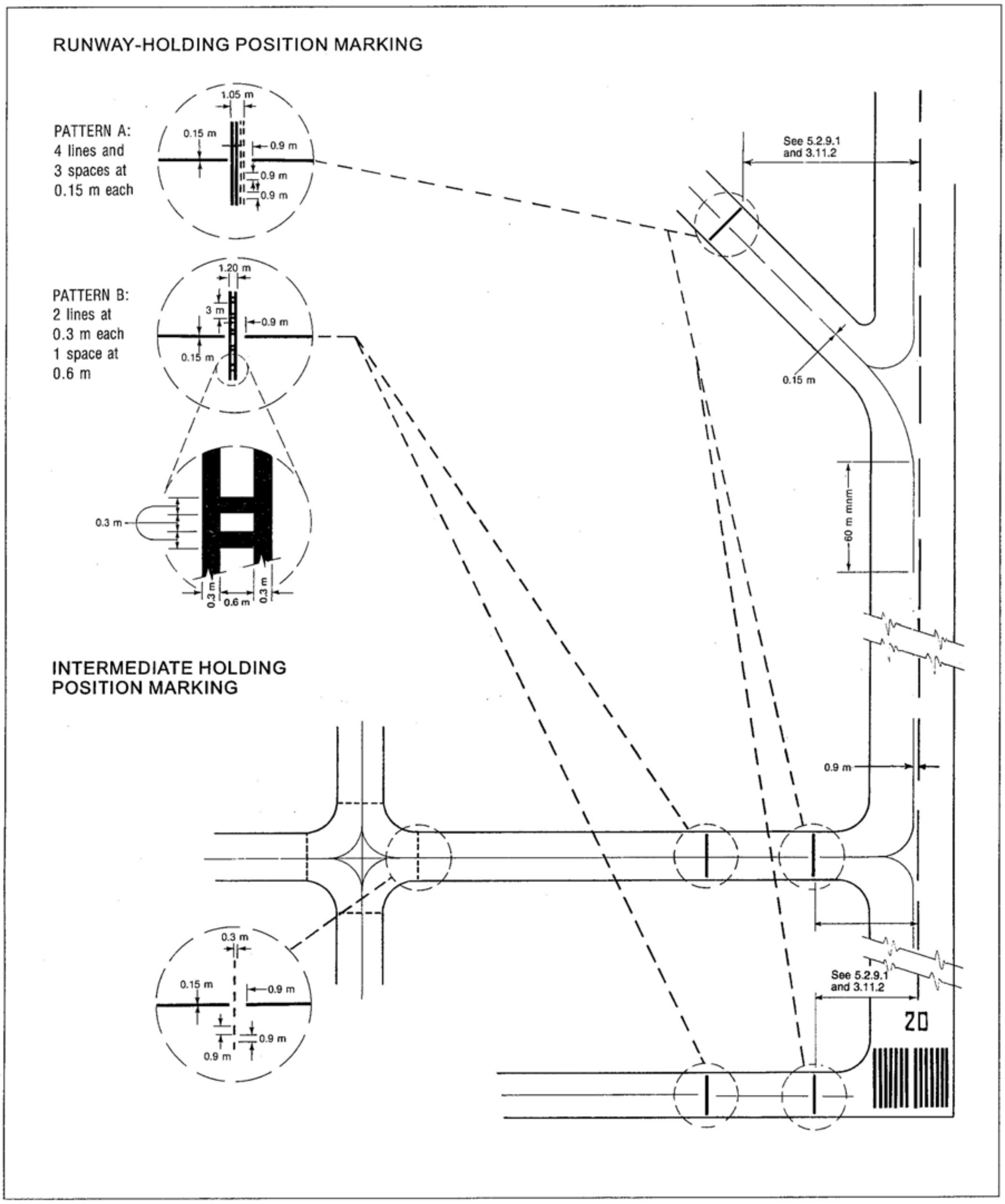

Figure 1.10-4 Extract from Figure 5-6 of ICAO Annex 14, vol. 1

paragraph 5.2.9.3 (Standard):

"Where a single runway holding position is provided at an intersection of a taxiway and a precision approach category I, II, III runway, the runway holding position marking shall be as shown in Figure 5-6, pattern A. Where two or three runway holding positions are provided at such an intersection, the runway holding position are provided at such an

intersection, the runway holding position marking closer to the runway shall be shown in Figure 5-6, pattern A and the markings farther from the runway shall be as shown in Figure 5-6, pattern B."

paragraph 5.2.9.5:

"Recommendation - Where increased conspicuity of the runway holding position is required, the runway holding position marking should be as shown in Figure 5-7[13]*, pattern A or pattern B, as appropriate."*

As described in the FAA AC (Advisory Circular) 150/5340-1H, the runway holding position markings "*consist of a set of 4 yellow lines and 3 spaces, each 15 cm in width."* The width of the lines has been doubled to 30 cm as an FAA standard since December 1, 2000.

The purpose of the holding position marking for ILS/MLS critical areas (similar to ICAO pattern "B" marking shown in Figure 1.10-5) is to *"identify the location on a taxiway or holding bay where an aircraft is to stop when it does not have clearance to enter ILS/MLS critical area. The critical area is the area needed to protect the navigational aid signal."*

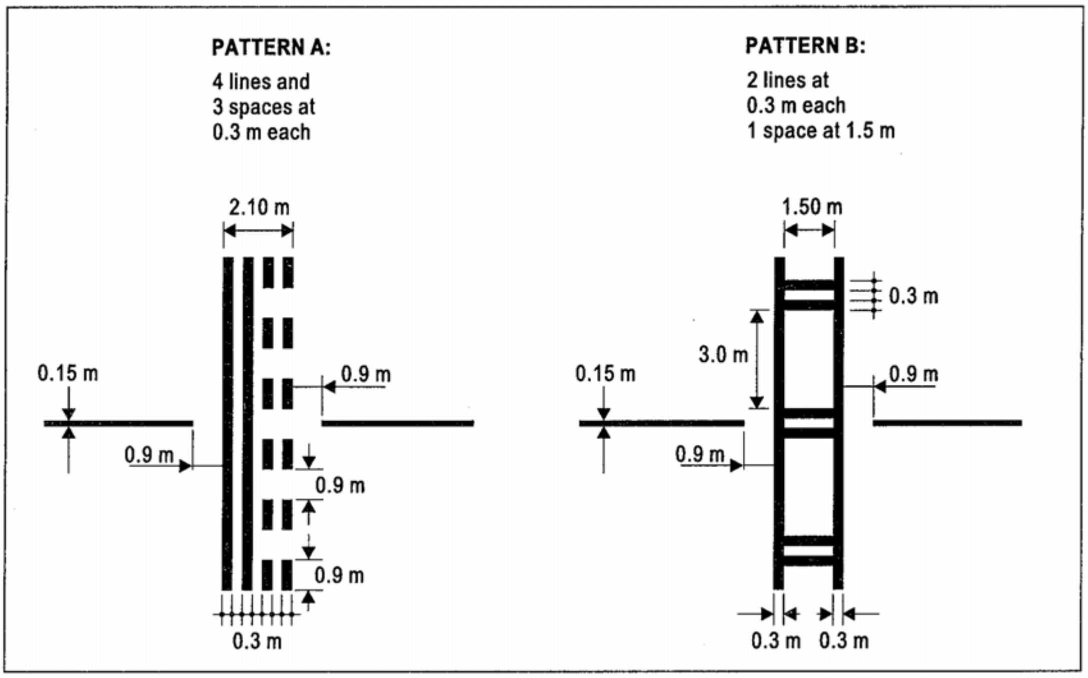

Figure 1.10-5 Extract from Figure 5-7 of ICAO Annex 14, vol. 1

[13] Refer to Figure 1.10-5

"Where the distance between the taxiway/runway holding position and the holding position for an ILS/MLS critical area is 50 feet (15m) or less, one holding position may be established, provided it will not affect capacity. In this case, the runway holding position is moved back to the ILS/MLS holding position and only the runway holding position markings are installed."

All *"runway holding position markings on taxiways are yellow and will be outlined in black on light-colored pavement."*

1.10.3.1.2 Taxiway Centerline Marking

The yellow taxiway centerline marking at CKS Airport was generally 20 centimeters wide and located on all pavement segments designated as a taxiway. The single-line taxiway centerline marking on N1 extended in a continuous arc from Taxiway NP to the approximate centerline entry point of Runway 05R. Further, there was an opposing, single-line, arcing taxiway centerline that extended from the approximate centerline of Runway 05R to N1 with its termination point at the runway edge line of Runway 05L, as shown in Figure 1.10-6. Part of the taxiway centerline marking on N1 that extended from NP to the south edge of Runway 05R and then from the north side of Runways 05R to 05L was not present.

Figure 1.10-6 Taxiway centerline marking near the threshold areas of Runway 05R

According to the CAA regulation on civil engineering standard (ATP-AE 100301) 3.8.5.1,

> *"…Whenever there are conflicts between the taxiway centerline and the runway threshold, designation, and touchdown zone markings, the taxiway centerline marking shall be interrupted. Distance between the cut off point and the runway threshold or designation marking should be 12 meters."* as indicated in Figure 1.10-7.

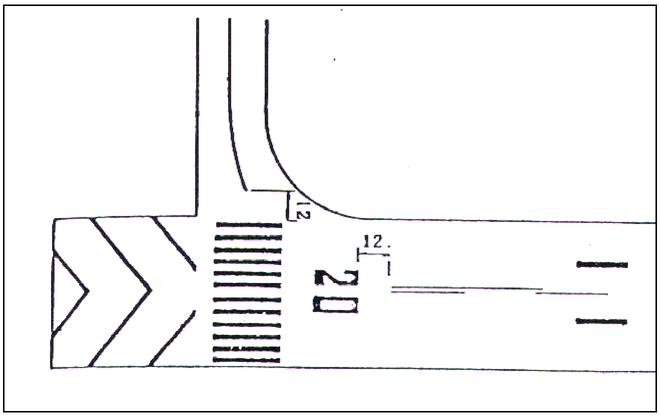

Figure 1.10-7 Taxiway centerline marking diagram

According to ICAO Annex 14, vol. 1 paragraph 5.2.8.1 (Standard):

> *"Taxiway centerline marking shall be provided on a paved taxiway, de/anti-icing facility and apron where the code number is 3 or 4 in such a way as to provide continuous guidance between the runway center line and aircraft stand."*

According to ICAO Annex 14, vol.1 paragraph 5.2.1.3 (Standard):

> *"At an intersection of a runway and taxiway, the markings of the runway shall be displayed and the taxiway marking shall be interrupted, except runway side stripe markings may be interrupted."*

In addition, FAA AC 150/5340-1H, suggests that at taxiways that intersect with runway ends, the taxiway centerline be terminated at the runway edge. An exception to this standard would apply when the taxiway route (as designated by the local air traffic control facility) crosses the runway, either straight across or offset, the marking may continue across the runway but will be interrupted for any runway marking.

FAA AC 150/5340-1H also indicates that for those taxiways used for low visibility operations, (RVR below 360 meters), taxiway centerline marking continues across all runway marking with the exception of the runway designation marking.

1.10.3.2 Lights

CKS Airport Runway 05/23 lighting systems are shown in Table1.10-1.

Table 1.10-1 The lighting system of Runway 05/23

Facility	Runway lighting circuits in use
Runway 05L/23R	Approach lights (white, CAT II with red side row barrettes) Runway centerline lights (white/red) High Intensity Runway edge lights (white/yellow), end lights (red), and threshold lights (green) Touchdown zone lights (white) PAPI (white/red) Taxiway edge lights (blue) at runway/taxiway intersections
Runway 05R/23L	Runway edge lights (white/yellow) and threshold/end lights (green/red) Taxiway centerline lights (green) Taxiway edge lights (blue) at runway/taxiway intersections

1.10.3.2.1 Runway Edge Lights and Runway End Lights

Runway edge lights (Omni direction with bi-directional converging lens) were provided for both Runway 05L/23R and Runway 05R/23L. These were spaced at between 55-60 meters apart. These lights were of identical make and model (Crouse Hinds L-862 elevated and L-852 inset, FAA specification). The lamps used on the elevated runway edge light fittings were found to be 6.6A/T4Q/CL/2PPF and Philips 6372/200W/6.6A/8L. Figure 1.10-8 shows the runway edge light installations at Runway 05R/23L.

Figure 1.10.8 Runway 05R/23L edge lights

Runway end lights were provided for Runway 05L/23R and 05R/23L at CKS Airport. There were 8 runway end lights at each location on Runway 05R/23L. These were linked to the runway edge light circuits and therefore shared the same activation button from the Control Tower. The runway end lights were located symmetrically about the runway centerline.

1.10.3.2.2 Runway Guard Lights

The Runway Guard Light (RGL) is one of the several components used in the Surface Movement Guidance and Control System (SMGCS). The fixture consists of a pair of elevated flashing yellow lights installed on both sides of a taxiway, or a row of in-pavement flashing yellow lights installed across the entire taxiway, at the runway holding position marking. Their function is to confirm the presence of an active runway and assist in preventing runway incursions.

According to ICAO Annex 14, vol. 1, paragraph 5.3.20.1 (Standard),

> "*Runway guard lights, Configuration A, shall be provided at each taxiway/runway intersection associated with a runway intended for use in: a) runway visual range conditions less than a value of 550 meters where a Stop bar is not installed; or b) runway visual range conditions values between 550 meters and 1200 meters, and where the traffic density is heavy.*"

FAA AC 120-57A, Surface Movement Guidance and Control System, Article 8 Visual Aid Requirements, b. Lights at Access to Active Runways (1) For operations below 1,200 feet RVR:

> *"All taxiways that provide access to an active runway (regardless of whether they are part of the low visibility taxi route) should have runway guard lights installed at the runway holding position on the taxiway."*

At the time of the accident, CKS Airport did not have runway guard lights installed.

1.10.3.2.3 Stop Bar Lights

The stop bar lights consist of elevated and in-pavement red fixtures that are installed at the runway holding position or ILS critical area holding position marking. Stop bar lights are controllable by ATC and include a system of in-pavement green taxiway centerline/lead-on lights at locations where aircraft will enter or cross a runway. The purpose of the stop bar lights is to hold aircraft or vehicles until a clearance is provided by ATC.

The stop bar lights are also one component of the SMGCS that is used to enhance taxiing capability in low visibility conditions and to reduce the potential for runway incursions or other unintended actions.

According to ICAO Annex 14, vol. 1, paragraph 5.3.17.1 (Standard), "A s*top bar shall be provided at every runway holding position serving a runway when it is intended that the runway will be used in runway visual range conditions less than a value of 350m, except where, a) appropriate aids and procedures are available to assist in preventing inadvertent incursions of aircraft and vehicles onto the runway; or b) operational procedures exist to limit, in runway visual range conditions less than a value of 550m, the number of: 1) aircraft on the maneuvering area to one at a time; and 2) vehicles on the maneuvering area to the essential minimum.*"

ICAO Annex 14, vol. 1, paragraph 5.3.17.2 (July 1999),

"Recommendation - A stop bar should be provided at every runway-holding position serving a runway when it is intended that the runway will be used in runway visual range conditions of values between 350m and 550m, except where:

a) appropriate aids and procedures are available to assist in preventing the inadvertent incursions of aircraft and vehicles onto the runway; or
b) operational procedures exist to limit, in runway visual range conditions less than a value of 550m, the number of:
1) aircraft on the maneuvering area to one at a time; and

2) vehicles on the maneuvering area to the minimum."

paragraph 5.3.17.3 also states: "*The provisions of 5.3.17.2 shall apply as a Standard as of 1 January 2001*."

FAA AC 150/5340-28, Low Visibility Taxiway Lighting Systems, contains FAA standards for stop bars:

"Stop bars are required for operations below 183m RVR at illuminated taxiways that provide access to the active runway."

At the time of the accident, CKS Airport did not have an SMGCS program and the runways were not equipped with stop bar lights.

1.10.3.2.4 Taxiway Centerline Lights

Taxiway centerline lights (L-852, FAA specification) were provided on all taxiways at the northern part of the airport. The southern part of the airport is not equipped with taxiway centerline lights. At exit and entry taxiways, these centerline lights also extended into the runway up to the runway centerline area. Taxiway centerline lights were also provided along the centerline of Runway 05R/23L

(No runway centerline lights were installed). On straight sections of taxiways, the centerline lights were found to be spaced 30 meters apart, the lights spacing on curved segments was 7.5 meters. On the curved taxiway sections, the taxiway centerline light fixtures were identical to those used along straight sections. All taxiway centerline lights were 65 watt, bi-directional lights that emitted a green light.

There were no alternate green/yellow taxiway centerline lights on exit taxiways to demarcate the limits of the ILS sensitive area. For an aircraft taxiing along Taxiway NP, the spacing of the green taxiway centerline lights on the straight portion of Taxiway NP was 30 meters. As it turned right into Taxiway N1, the spacing of taxiway centerline lights along the curved section was 7.5 meters up to the point of tangency with the Taxiway N1 centerline. The taxiway centerline lights continued into Runway 05R with a spacing of 7.5 meters up to the point of tangency with the Runway 05R centerline. Beyond that, the spacing of green taxiway centerline lights was 30 meters along Runway 05R/23L. Along Taxiway N1 towards Runway 05L, there were four taxiway centerline lights along the straight segment of Taxiway N1 up to the Runway 05L holding position. These taxiway centerline lights were located at a distance of 30 meters, 55 meters and 116 meters and 138 meters respectively from the point of tangency (where the curved taxiway centerline marking from Taxiway NP meets Taxiway N1). (See Figure 1.10-9)

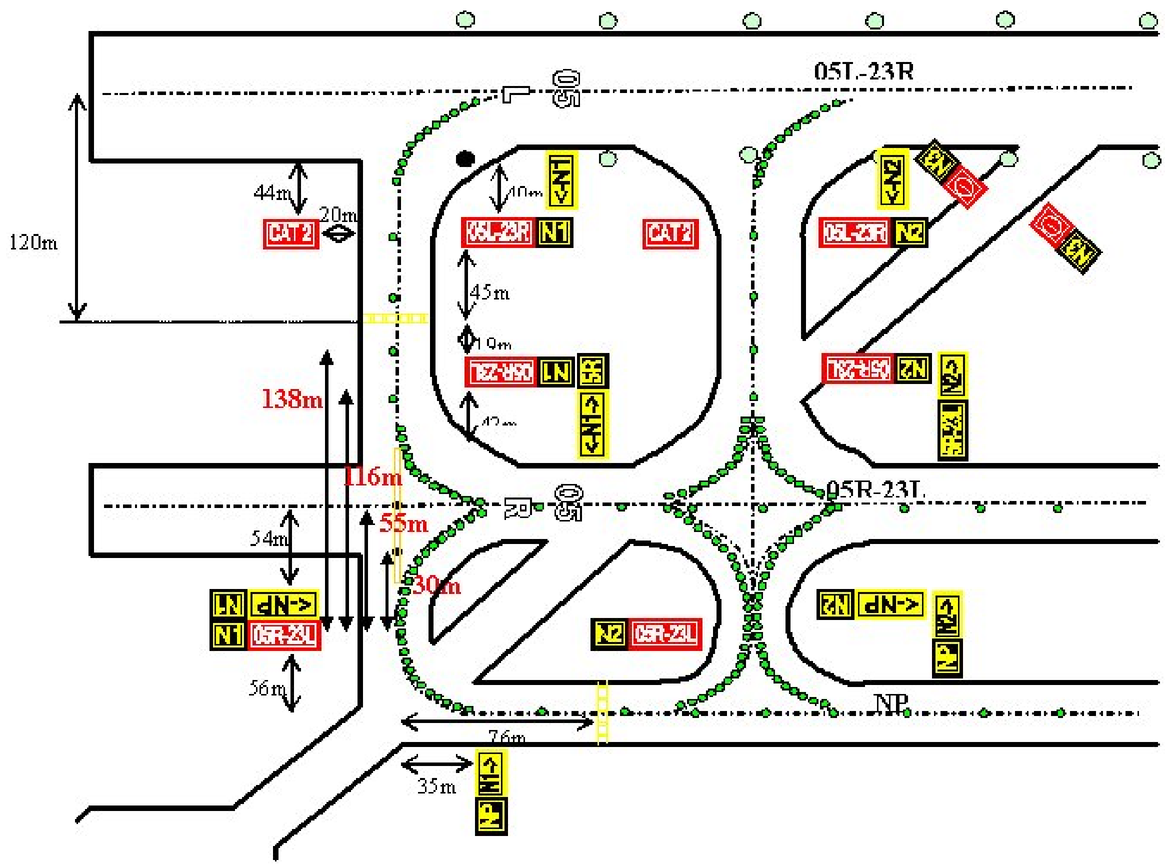

Figure 1.10-9 Taxiway N1 centerline lights spacing

During the site survey (on November 4, 2000), it was noted that the first taxiway centerline light after the point of tangency was unserviceable while the second light was less intense than the other lights. (See Figure 1.10-10)

Figure 1.10-10 Status of Taxiway N1 centerline lights close to the threshold of Runway 05R (picture taken on November 4, 2000)

According to ICAO Annex 14, vol. 1, paragraph 5.3.15.1 (Standard):

> *"Taxiway centerline lights shall be provided on an exit taxiway, taxiway, de/anti-icing facility and apron intended for use in runway visual range conditions less than a value of 350 m in such a manner as to provide continuous guidance between the runway center line and aircraft stands, except that these lights need not be provided where the traffic density is light and taxiway edge lights and center line marking provide adequate guidance."*

According to ICAO Annex 14, vol. 1, paragraph 5.3.15.2

> *"Recommendation - Taxiway centerline lights should be provided on a taxiway intended for use at night in runway visual range conditions of 350 m or greater, and particularly on complex taxiway intersections and exit taxiways, except that these lights need not be*

provided where the traffic density is light and taxiway edge lights and centre line marking provide adequate guidance."

According to ICAO Annex 14, vol. 1, paragraph 5.3.15.4 (Standard):

"Taxiway centerline lights shall be provided on a runway forming part of a standard taxi-route and intended for taxiing in runway visual range conditions less than a value of 350 m, except that these lights need not be provided where the traffic density is light and taxiway edge lights and centre line marking provide adequate guidance."

According to ICAO Annex 14, vol. 1, paragraph 5.3.15.7 (Standard):

"Taxiway centerline lights on an exit taxiway shall be fixed lights. Alternate taxiway centerline lights shall show green and yellow from their beginning near the runway centerline to the perimeter of the ILS/MLS critical/sensitive area or the lower edge of the inner transitional surface, whichever is farther from the runway; and thereafter all lights shall show green (Figure 5-20). The light nearest to the perimeter shall always show yellow. Where aircraft may follow the same centerline in both directions, all the centerline lights shall show green to aircraft approaching the runway."

According to ICAO Annex 14, vol. 1, paragraph 5.3.15.10,

"Recommendation – Taxiway centerline lights should normally be located on the taxiway center line marking, except that they may be offset by not more than 30 cm where it is not practicable to locate them on the marking."

According to ICAO Annex 14, vol. 1, paragraph 5.3.15.11,

"Recommendation - Taxiway centerline lights on a straight section of a taxiway should be spaced at longitudinal intervals of not more than 30m, except that:

a) larger intervals not exceeding 60m may be used where, because of the prevailing meteorological conditions, adequate guidance is provided by such spacing;

b) intervals less than 30m should be provided on short straight sections; and

c) on a taxiway intended for use in RVR conditions of less than a value of 350m, the longitudinal spacing should not exceed 15m."

According to ICAO Annex 14, vol. 1, paragraph 5.3.15.12, *"Recommendation - Taxiway centerline lights on a taxiway curve should continue from the straight portion of the taxiway at a constant distance from the outside edge of the taxiway curve. The lights should be spaced at intervals such that a clear indication of the curve is provided."*

According to ICAO Annex 14, vol. 1, paragraph 5.3.15.13,

"Recommendation - On a taxiway intended for use in RVR conditions of less than a value of 350 meters, the lights on a curve should not exceed a spacing of 15 meters and on a curve of less than 400 meters radius the lights should be spaced at intervals of not greater than 7.5 meters. This spacing should extend for 60 meters before and after the curve.

Note 1. - Spacings on curves that have been found suitable for a taxiway intended for use in RVR conditions of 350 meters or greater are:

Curve radius	*Light spacing*
up to 400m	*7.5m*
401m to 899m	*15m*
900m or greater	*30m"*

According to ICAO Annex 14, vol. 1, paragraph 9.4.20 (Standard),

"A light shall be deemed to be unserviceable when the main beam average intensity is less than 50 percent of the value specified in the appropriate figure in Appendix 84. For light units where the designed main beam average intensity is above the value shown in Appendix 84, the 50 percent value shall be related to that design value"

The FAA guidance for taxiway centerline lights can be found in AC 150/5340-28, Low Visibility Taxiway Lighting Systems. It is recommended that centerline lights continue across a runway for operations below 365 meters RVR where the taxiway is an often-used route. When taxiway centerline lights go across a runway, the lights are color-coded green/yellow starting from the center of the runway (AC 150/5340-28, paragraph 3b). Spacing on straight sections of a taxiway where operations are 365 meters RVR or greater is 30 meters between lights. When operations occur below 365 meters RVR, spacing on straight segments is 15 meters. The FAA guidance calls for lateral spacing of 0.6 meters from taxiway centerline. Taxiway centerline lights which are visible to aircraft exiting the runway ("lead off" lights) are color-coded to warn pilots and vehicle drivers that they are within the runway safety area or ILS critical area, whichever is more restrictive. Alternate green and yellow lights are installed (beginning with green) from the runway centerline to one centerline light position beyond the runway holding position or ILS critical area holding position, whichever is more critical.

At the time of the accident, the declared takeoff RVR minimum for Runway 05L/23R was 200 meters.

1.10.3.3 Taxiway and Information Signs

There were numerous signs installed at CKS Airport, and those installed at the taxiway transitions to runway entry points were of white letter inscription on a red background. These signs were internally illuminated and about 1.1 meter in height. In general, the signs at CKS Airport were found to be located approximately 20 meters from the nearest taxiway edge.

The sign installed on the left side of Taxiway N1, located about 54 meters south of the Runway 05R centerline, depicted the runway designation “5R-23L.”.

The sign installed on the left side of Taxiway N1, located about 75 meters South of the Runway 05L centerline and depicted “CAT2” operations for that runway. The sign installed on the right side of Taxiway N1, at the same level as the “CAT2” sign, depicted the runway designation “5L-23R|N1.”

ICAO Annex 14, vol. 1, paragraph 5.4.2, addresses the design and location placement of taxiway and informational signage. In particular, the following excerpted sections provide information about intersecting taxiway and runway signs, holding position signs, and runway designator and sensitive area signs:

Paragraph 5.4.2.8

> *“A runway designation sign at a taxiway/runway intersection or a runway/runway intersection shall be located on each side of the runway holding position marking facing the direction of approach to the runway.”*

Paragraph 5.4.2.9

> *“A category I, II, III holding position sign shall be located on each side of the runway holding position marking facing the direction of the approach to the critical area.”*

Paragraph 5.4.2.12

> *“Existing installations need not meet the requirement of 5.4.2.8, 5.4.2.10, and 5.4.2.11 to provide a sign on each side of the taxiway until 1 January 2001.”*

Paragraph 5.4.2.14

> *"The inscription on a runway designation sign shall consist of the runway designations of the intersecting runway properly oriented with respect to the viewing position of the sign, except that a runway designation sign installed in the vicinity of a runway extremity may show the runway designation of the concerned runway extremity only."*

Paragraph 5.4.2.15

> *"The inscription on a category I, II and III or joint II/III holding position sign shall consist of the runway designator followed by CAT I, CAT II, CAT III or CAT II/III, as appropriate."*

1.10.4 Airport Construction

1.10.4.1 Airport Construction Process

For all the airports in Taiwan, ROC, CAA initiates the necessary facility improvement projects. These projects were proposed based on input from various sources, including requests from departments at the CAA headquarters or through consultation with airport users or operators.

In addition, the CKS Airport Management (Ground Operations Department) that conducts bimonthly meetings with the Airport Operators Committee may also propose improvement projects. The meetings were formal and were typically attended by all operational units of the CAA, airline representatives, concessionaires, and appropriate government agencies such as Customs. Further, CKS Flight Operations, Cargo, and the Maintenance and Engineering sections were also represented at the meeting. The meeting provides a venue for the participants to discuss issues that affect airport operations and airport facilities.

Once an improvement project was determined to be necessary at the airfield, either the CKS Airport or the Aerodrome Division determined the budgetary implications of the project. Once approved, the project was awarded to private contractors and supervised by the CKS Maintenance and Engineering section. The compliance with all pertinent safety regulations was the responsibility of the contractor. Safety related measures were then reviewed and approved by the Flight Operations Section (FOS) of CKS Airport.

Airport users were notified about airfield construction that will affect operations through the issuance of NOTAMs. The NOTAMs were issued by the Flight Information Station of the airport, (which is also under the jurisdiction of Air Navigation and Weather Services, ANWS, CAA) and coordinated between the Maintenance and Engineering Section, FOS and the Control Tower prior to publication.

Operational requirements were taken into account prior to determining runway closure periods for different phases of the project.

NOTAM A0606 (see Appendix 1), applicable to the construction on Runway 05R/23L, was issued September 13, 2000. The NOTAM publicized that Runway 05R/23L was closed for takeoff operations due to scheduled construction work in the middle portion of the runway, between Taxiways N4 and N5; however, the portions of the runway that comprise the approach and departure ends, and the Taxiway N4 and N5 remained available for taxiing operations.

1.10.4.2 Visual Aids for Denoting Construction Areas on Temporarily and Partially Closed Runway

According to information provided by the CKS Airport, due to the high wind conditions and heavy rain associated with Typhoons at CKS Airport, the light plastic, frangible markers with red obstruction light markers may be either washed away or blown away, therefore posing a risk of foreign object damage (FOD) to aircraft. To prevent such occurrences, CKS Airport used concrete jersey barriers, about 0.8 meters high, and 1 meter long, placed in close proximity to construction zones. The blocks were painted yellow, orange, or a combination of yellow and black stripes. Battery-powered, flashing red warning lights spaced at a distance of two to five meters were installed on top of the blocks for night time use (See Figure 1.10-11).

Figure 1.10-11 Closed working area along Runway 05R/23L and Taxiway viewed from Runway 05L/23R

At the time of the accident, these jersey barriers were the only visual aids on the runway to identify the construction zone. Both approach ends of Runways 05R and 23L remained open and unobstructed because they were being used as taxiways.

According to ICAO Annex 14, vol. 1, paragraph 7.1.2,

> *"Recommendation - A closed marking should be displayed on a temporarily closed runway or taxiway or portion thereof, except that such marking may be omitted when the closing is of short duration and adequate warning by air traffic services is provided."*

According to ICAO Annex 14, vol. 1, paragraph 7.1.3 (Standard),

> *"On a runway a closed marking shall be placed at each end of the runway, or portion thereof, declared closed, and additional markings shall be so placed that the maximum interval between markings does not exceed 300 m. On a taxiway a closed marking shall be placed at least at each end of the taxiway or portion thereof closed."*

According to ICAO Annex 14, vol. 1, paragraph 7.1.4 (Standard),

> Note- "*When an area is temporarily closed, frangible barriers or markings utilizing materials other than paint or other suitable means may be used to identify the closed area.*"

According to ICAO Annex 14, vol. 1,paragraph 7.1.7 (Standard),

> "*In addition to closed markings, when the runway or taxiway or portion thereof closed is intercepted by a usable runway or taxiway, which is used at night, unserviceability lights shall be placed across the entrance to the closed area at intervals not exceeding 3 m (see 7.4.4).*"

According to FAA AC150/5340-1H chapter 1, section 4, it is suggested that,

> "*TEMPORARILY CLOSED RUNWAYS AND TAXIWAYS*
>
> *When it is necessary to provide a visual indication that a runway is temporarily closed, crosses are placed only at each end of the runway on top of the runway designation markings or just off the runway end when required by construction activity. The crosses are yellow in color and conform to the dimensions specified in the advisory circular. Since the crosses are temporary, they are usually made of some easily removable material, such as plywood or fabric rather than painted on the pavement surface. Any materials used for temporary crosses should provide a solid appearance. Since these crosses will usually be placed over white runway markings, their visibility can be enhanced by a 15 cm black border.*

A raised-lighted cross may be placed on each runway end in lieu of the markings described to indicate the runway is closed. Normally the raised-lighted cross would be located on the runway; however, it may be located in the safety area on the extended runway centerline.

Temporarily closed taxiways are usually treated as hazardous areas. However, as an alternative, a yellow cross that conforms to the dimensions in Figure 20[14] *may be installed at each entrance to the taxiway.*

If the runway or taxiway will be closed during nighttime, the runway lights will normally be disconnected so that they cannot be illuminated unless such illumination is needed to perform maintenance operations on or adjacent to the runway."

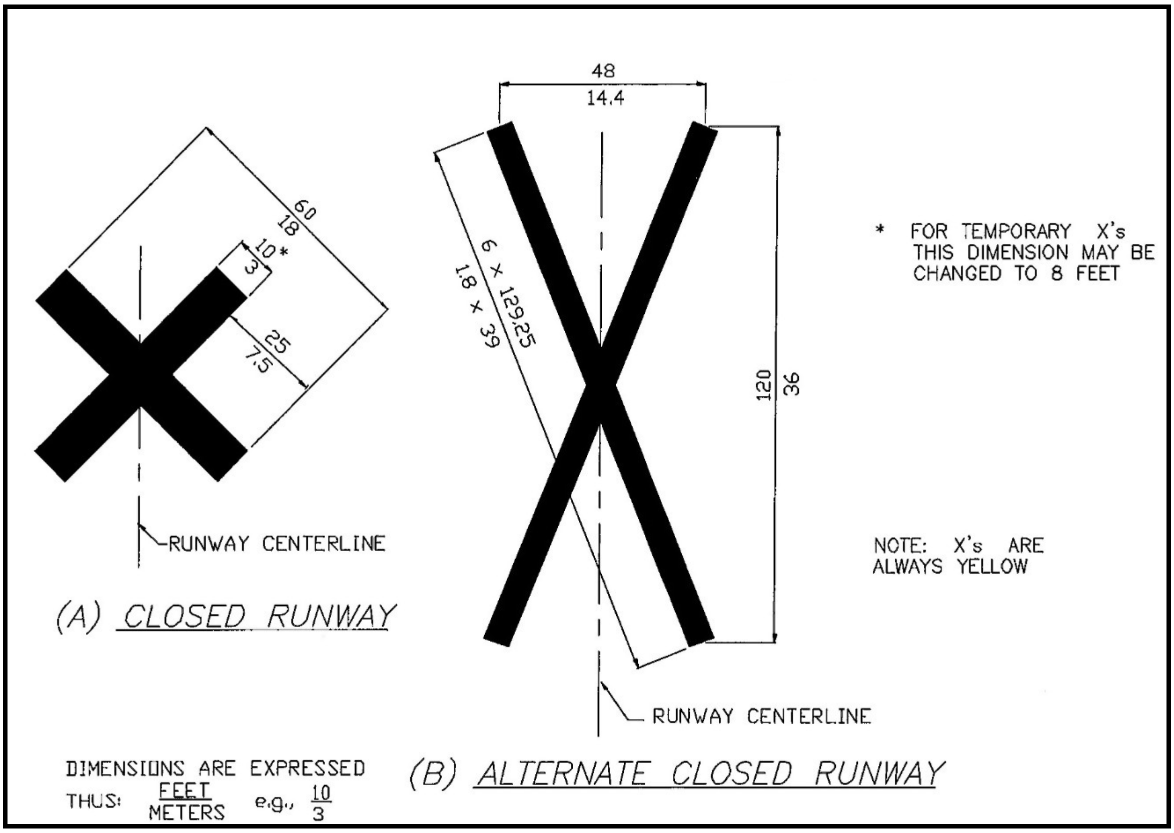

Figure 1.10-12 Extract from Figure 20 of FAA AC150-5340.1

[14] Refer to Figure 1.10-12

1.10.5 Equipment and Installations

1.10.5.1 Airfield Lighting Control and Monitor

1.10.5.1.1 Circuit Interlocking[15]

According to ICAO Annex 14, vol. 1 paragraph 8.2.3 (Standard),

> *"Where a runway forming part of a standard taxi-route is provided with runway lighting and taxiway lighting, the lighting systems shall be interlocked to preclude the possibility of simultaneous operation of both forms of lighting."*

The CKS airfield runway and taxiway lighting was controlled from the Control Tower by individual pushbuttons. A knob was provided for each of the circuits to enable the selection of different intensity levels for the airfield lights. Figure 1.10-13 shows the airfield lighting control panel in the control tower.

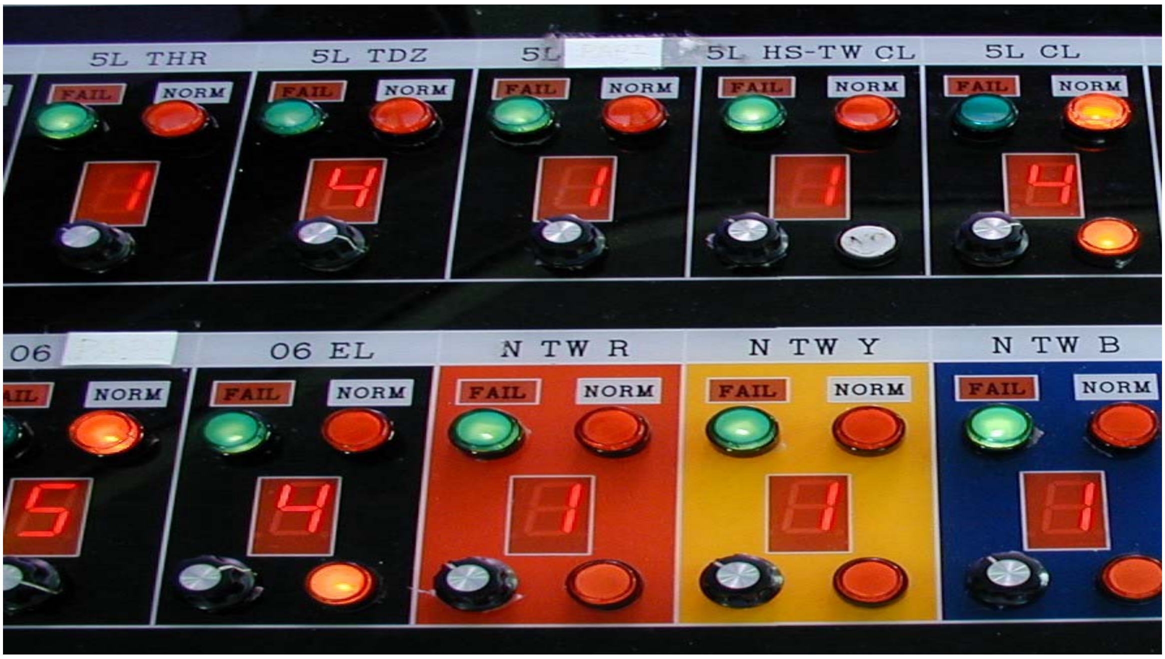

Figure 1.10-13 Airfield lighting control panel in the control tower

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[15] The interlock is a mechanical system that precludes the simultaneous operation of specific multiple lighting systems. For example, at CKS Airport the interlock would have controlled the Runway 05R edge lights and the taxiway centerline lights.

The lighting system, when installed in 1979, met ICAO Annex 14 SARPs at that time for which light control interlocks were not specified; and although the interlock has since been addressed in revised SARPs, the lighting system at CKS Airport was not equipped with an interlocking device.

According to the CKS ATC procedures, no aircraft operations were permitted on Taxiway NP when Runway 05R/23L was being used for takeoff operations. Simultaneous use of the Runway 05R edge lights and the taxiway centerline lights on that runway was not permitted. Because the Runway 05R and taxiway lights did not have an interlock, the ATC ground controller and the tower controller would coordinate and manually select the appropriate lights for the specific operation being conducted on the runway. (See Figures 1.10.13 and 1.10.14 for airfield lighting control panel and layout)

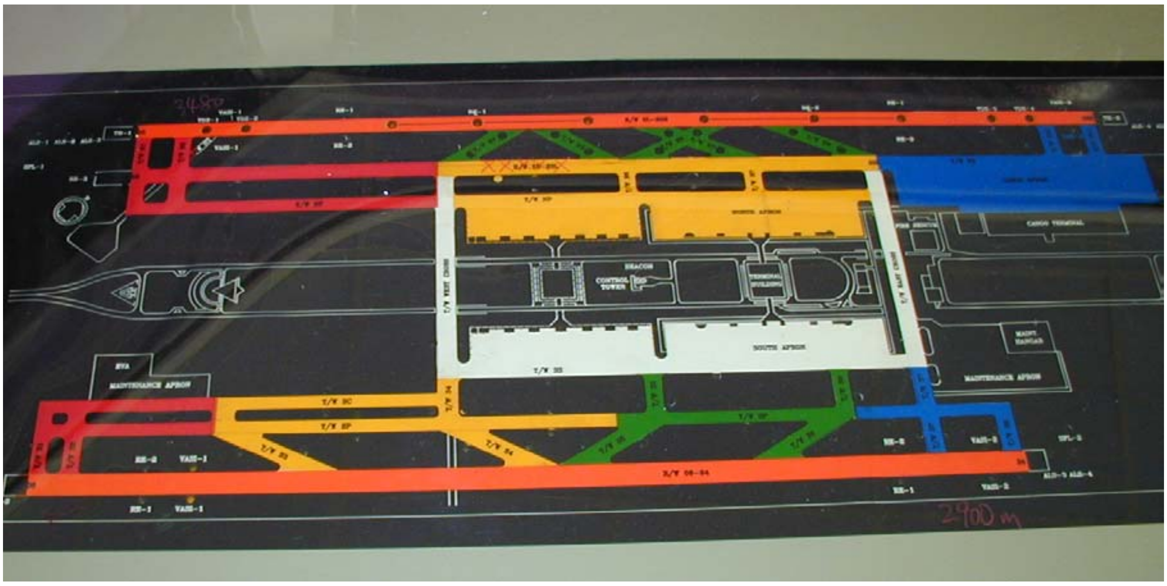

Figure 1.10-14 CKS airfield lighting layout

The accident occurred during nighttime. According to ATC operational procedures, when aircraft were turning from the Taxiway West Cross onto Taxiway NP, the switch for the Taxiway NP and N1 centerline lights should be turned on as to offer the pilot reference to the relevant taxi route.

1.10.5.1.2 Circuit Monitoring

According to ICAO Annex 14, vol. 1, *paragraph 8.3.3*

> *"Recommendation - For a runway meant for use in runway visual range conditions less than a value of 550 m, the lighting systems detailed in Table 8-1 should be monitored so as to provide an immediate indication when the serviceability level of any element falls below*

the minimum serviceability level specified in 9.4.26 to 9.4.30, as appropriate. This information should be immediately relayed to the maintenance crew."

Paragraph 8.3.4

"Recommendation - For a runway meant for use in runway visual range conditions less than a value of 550 m, the lighting systems detailed in Table 8-1 should be monitored automatically to provide an immediate indication when the serviceability level of any element falls below the minimum level specified by the appropriate authority below which operations should not continue. This information should be automatically relayed to the air traffic services unit and displayed in a prominent position."

The monitoring of the CKS airfield lighting system serviceability was accomplished both electronically and manually. The electronic monitoring occurred through hardwired relay contacts from a Constant Current Regulator that provided an indication or status of the related circuits. This provided feedback on the status of entire circuits. The normal or failure status for each lighting circuit was presented through two corresponding indicator lamps on the control panel in the Control Tower. There was no electronic monitoring of individual lights or the percentage of unserviceable lamps for any circuit.

Personnel from the ANWS section at CKS Airport also monitored the airfield lighting system. They needed to coordinate with the Control Tower for an available time slot to enter the taxiway/runway.

With the exception of the Runway 05L/23R RVR, there was no system of data documentation to record the actual status of the airfield lighting circuit and the selected circuits in use at any time. The Runway 05L RVR computer recorded the status of the runway edge lights to provide a parameter for calculating the RVR values that were displayed in the Control Tower. Around the time of the accident, the 05L/23R runway edge lights were selected at intensity level 3[16].

1.10.5.2 Surface Movement Guidance and Control System

ICAO Annex 14- paragraph 8.9.1 (Standard),

"A surface movement guidance and control system shall be provided at an aerodrome."

[16] The RVR recorded runway edge light intensity (level 3) is different from the runway edge light intensity level of 4 recorded in the ATC tower by controllers.

SMGCS provides guidance to, and control or regulation of, an aircraft from the landing runway to the parking position on the apron and back again to the takeoff runway, as well as other movement on the aerodrome surface. It comprises an appropriate combination of visual aids, non-visual aids, procedures, control, regulation, management, and information facilities.

There was no airport SMGCS plan for low visibility operations provided at CKS Airport.

1.10.6 Maintenance of Visual Aids

Like airport lighting, the CAA ANWS Facilities Division provided technical specifications for airport signs. According to the CAA officials, ICAO SARPs were adopted.

The ANWS also maintained CKS Airport signs. The daily inspection of airport signs took place concurrently with the inspection of the airport lights. Blown fluorescent tubes were replaced on the same day that they were identified. In addition to the daily checks and maintenance, weekly and monthly preventive maintenance was scheduled which could involve dismantling of signs for off-site repairs.

The CKS Maintenance and Engineering section was responsible for maintaining airport marking. Repainting of runway marking coincided with the removal of rubber deposits on the runways. Repainting of airport marking in other areas was carried out once every two to three years.

1.10.7 Conversion of Runway 05R/23L to Taxiway NC

In 1992, the CAA contracted the Institute of Transportation (a research organization of the Ministry of Transportation and Communications) to re-design the airport for extended use beyond the year 2000 to 2010. The Institute of Transportation then sub-contracted its work to the Netherlands Airport Consultants (NACO) Company. Because of budgetary issues and strong opposition by the residents surrounding the airport, the NACO plan was re-evaluated by the Asian Technical Consultants Inc. (ATCI) and the Canadian AirPlan Aviation Technical Services Inc.

In March 2000, ATCI suggested in their Phase 1 Development of CKS Airport Master Plan that "*for long term consideration, Runway 05R/23L can be relieved from its runway function, and to degrade it as a parallel taxiway of the Runway 05L/23R, hence to provide Runway 05L/23R with smoother taxiing operation.*" On October 3, 2000, CAA issued an AIP supplement (AIP SUPPLEMENT A007 C015/ 00), which stated: "*With effect from 1700 UTC 1 November 2000, Runway 05R/23L of Taipei/CKS Int'l aerodrome will be re-designated as Taxiway NC. The current runway centerline lights (color green) and edge lights (color white) will remain on the Taxiway NC until further notice. But the runway markings will be changed to taxiway markings.*" On October 23, 2000, CAA issued another NOTAM (NOTAM A0740) which stated: "*The re-designation of Runway 05R/23L was postponed until further notice*." According to CAA officials, as the conversion was commenced, it was found that the appropriate signage needed to be imported but the procurement process was unable to meet the date stipulated by the AIP supplement. Consequently, the originally scheduled conversion of Runway 05R/23L to Taxiway NC was postponed.

After the SQ006 accident, on December 28, 2000, CAA issued another AIP supplement (AIP SUPPLEMENT A010 C021/ 00) that stated: "*With effect from 0000 UTC February 1, 2001, Runway 05R/23L and Taxiway NS of Taipei/CKS Int'l Aerodrome will be re-designated as Taxiway NC. The old runway markings have been converted into taxiway markings. The runway edge lights (color white) have been disconnected while the current runway centerline lights (color green, space 30 m) will remain unchanged. The switch-over of Runway 05R/23L designation signs and related information signs to appropriate taxiway signs will be conducted with the last 36 hours before the runway officially re-designated.*"

1.11 Flight Recorders

The CVR and FDR were properly seated in the rack when the Safety Council personnel arrived at the accident site. There was no evidence of heat or impact damage on the exterior of the recorders and no evidence of contamination or damage caused by the rescue process.

The Ministry of Justice prosecutors viewed and recorded the model, part number and serial number of the recorders and then released them to the Safety Council on November 1, 2000.

An inspection of the exterior of both recorders was immediately conducted. There was no apparent damage found. The Safety Council recorder specialist then proceeded to open both recorders and found no evidence of damage to the internal mechanisms.

The recording was downloaded successfully.

1.11.1 Cockpit Voice Recorder

The aircraft was equipped with a Fairchild model A200S CVR, P/N S200-0012-00 and S/N 00744. The recording, which contained good quality audio information, consisted of four channels including the relief pilot's microphone, the first officer's microphone, the captain's microphone and the cockpit area microphone. The external surface and interior of the CVR was found without any damage or contamination.

The CVR was powered when the number one engine started. All of the flight crewmembers were using their hot microphone systems. Advanced audio filtering and amplification techniques were applied to enhance the readability of all data.

Timing of the CVR transcript was based on the correlated microphone keying common to CVR, FDR and the ATC recordings.

The CVR consisted of 123 minutes[17] of recording. Only the 16 minutes and 30 seconds of recording related to the accident flight was transcribed. The transcript started at 2300:53 when the first engine started, as the aircraft was pushed back from Bay B5 at CKS Airport. The recording continued uninterrupted until 2317:22, shortly after the first impact. The recording contained push back, engines start, taxi to Runway 05R via Taxiway SS, West Cross, NP and N1. The CVR did not record any of the cockpit preflight actions by the flight crew before push back and engine start. The complete transcript of the 16 minutes and 30 seconds is shown in Appendix 3.

1.11.1.1 Regulations Related to CVR Power ON/OFF

The following description is found in the SIA 747-400 maintenance manual regarding the CVR power on/off logic, Chapter 23-71-01, Voice Recorder System – Description and operation, Subject Voice Recorder Switch stated:

> *"(2) The purpose of the VOICE REC ENG CUT relay is to reduce wear on the voice recorder system by automatically turning the system off 5 minutes after all engines are cut… The voice recorder switch can be manually placed in the auto position, or will automatically switch to this position when at least one engine is running, for in-flight operation of the system."*

According to FAR 14 CFR - CHAPTER 1 - PART 91.609, the cockpit voice recorder

> *"Is operated continuously from the use of the checklist before the flight to completion of the final checklist at the end of the flight."*

According to JAR-OPS 1.700 - Cockpit Voice Recorders-1 (Date: July 1, 2000):

> *"(c) The cockpit voice recorder must start automatically to record prior to the aeroplane moving under its own power and continue to record until the termination of the flight when*

[17] The specified minimum recording capacity is 120 minutes.

the aeroplane is no longer capable of moving under its own power. In addition, depending on the availability of electrical power, the cockpit voice recorder must start to record as early as possible during the cockpit checks prior to engine start at the beginning of the flight until the cockpit checks immediately following engine shutdown at the end of the flight."

According to paragraph 37(3) of CAAS Air Navigation Order:

"On any flight on which a flight data recorder or a cockpit voice recorder is required by this Order to be carried - in an aero plane, it shall always be in use from the beginning of the takeoff run to the end of the landing run."

According to ICAO Annex 6.3.10 Flight Recorders -Operation 6.3.10.1 (standard):

"Flight recorders shall not be switched off during flight time".

According to ICAO Annex 1, regarding the definition of flight time:

"The total time from the moment an aircraft first moves under its own power for the purpose of taking off until the moment it comes to rest at the end of the flight."

From the system design aspect, the Boeing Company allows different operators to select different CVR power - on options based on each operator's own requirement.

1.11.2 Flight Data Recorder

The FDR was an AlliedSignal Solid-State Flight Data Recorder (SSFDR), P/N 980-4700-033 and S/N 1634. The readout was accomplished with the standard hardware and software including the AlliedSignal Hand-Held Download Unit (HHDLU), Aircraft Data Recovery and Analysis System (ADRAS), and Recovery, Analysis and Presentation System (RAPS). It recorded 318 parameters. The readout data were processed to assess the motion of the aircraft on the airport surface during taxi and the attempted takeoff, as well as the other conditions of the aircraft.

The recording started at 2300:00, when the aircraft was at Bay B5. The data revealed that the aircraft began to accelerate for takeoff at 2316:34, in a magnetic heading of 50.6 degrees. The recording stopped at 2317:12.16.

1.11.2.1 Quick Access Recorder

The Quick Access Recorder (QAR) was found during the site survey on November 5, 2000. The exterior of the QAR was seriously damaged. The Safety Council recorder specialist disassembled the QAR and removed the optical disk inside. The disk was contaminated but not damaged. After copying the raw data for backup, the Safety Council specialist sent the QAR disk to SIA and Penny & Giles Aerospace Ltd. for readout. The FDR group received the QAR engineering parameters from SIA on November 8, 2001. The data showed that the QAR data stopped at 2316:23 (before takeoff). The readout revealed that the FDR and QAR data were consistent.

Penny & Giles Aerospace Ltd. completed the QAR data (including the non-volatile memory) readout on November 22, 2001. They confirmed that the recording stopped at 2316:40 (before takeoff) and the FDR and QAR data were consistent.

1.11.2.2 FDR Ground Track and Satellite Map

Figure 1.11-1 shows the smoothed latitude and longitude position of the FDR data (yellow line), based on the related satellite image with respect to taxiways and runways. It also shows the ground scars and the wreckage distribution from the site survey.

The Safety Council combined the satellite map, CVR audio and FDR data to create a 3D animation using RAPS. Due to limitations of recorded latitude and longitude position, the Safety Council used the ground speed, magnetic heading, and drift angle to compute the ground track of the aircraft. The aerial photography was also used to correct the position of the aircraft's flight path (See Figure 1.11-2).

Figure 1.11-1 The combination of FDR data, site survey data, and the satellite map

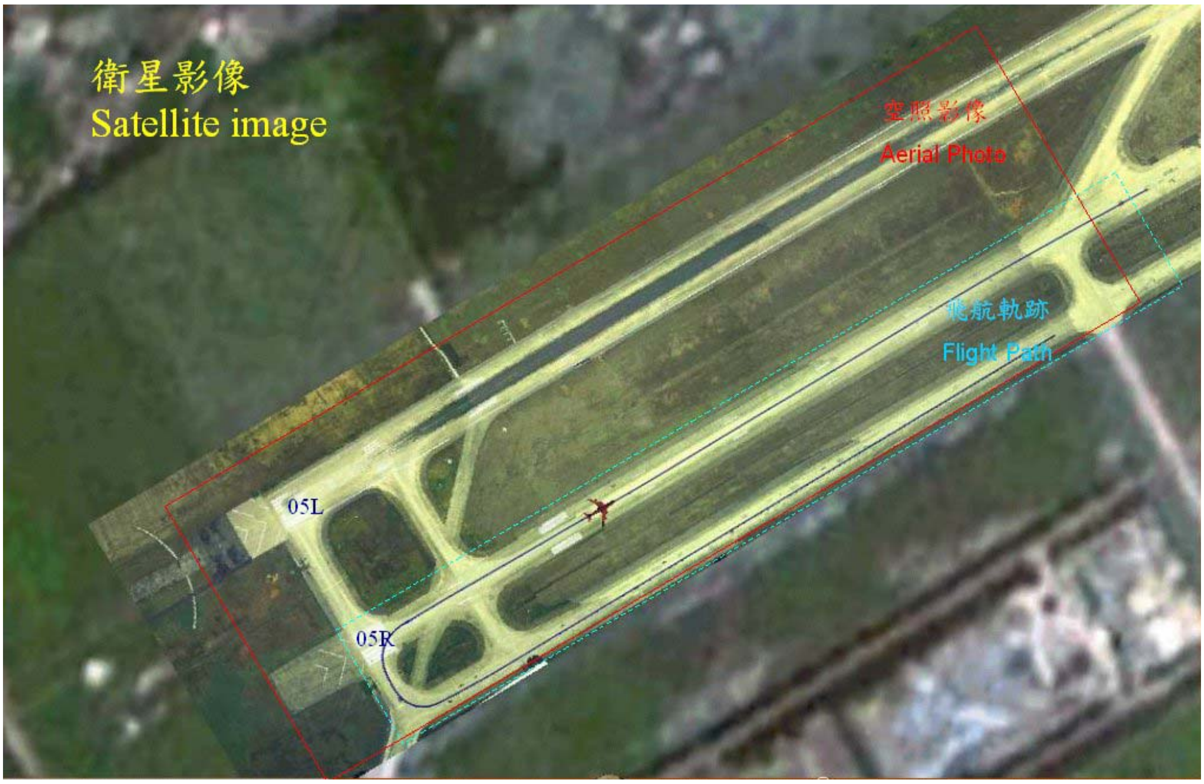

Figure 1.11-2 SQ006 superposition of flight path and digital map

1.12 Wreckage and Impact Information

Ground survey of the wreckage field, including aircraft wreckage and ground marks was conducted from Taxiway N1 through N8 along Runway 05R. The landing gear tire mark from the beginning of Taxiway N1 to the initial impact point was also documented. The tire marks were visible in the damp early morning but not visible in drier afternoon or when the runway was wet. (Figure 1.12-1)

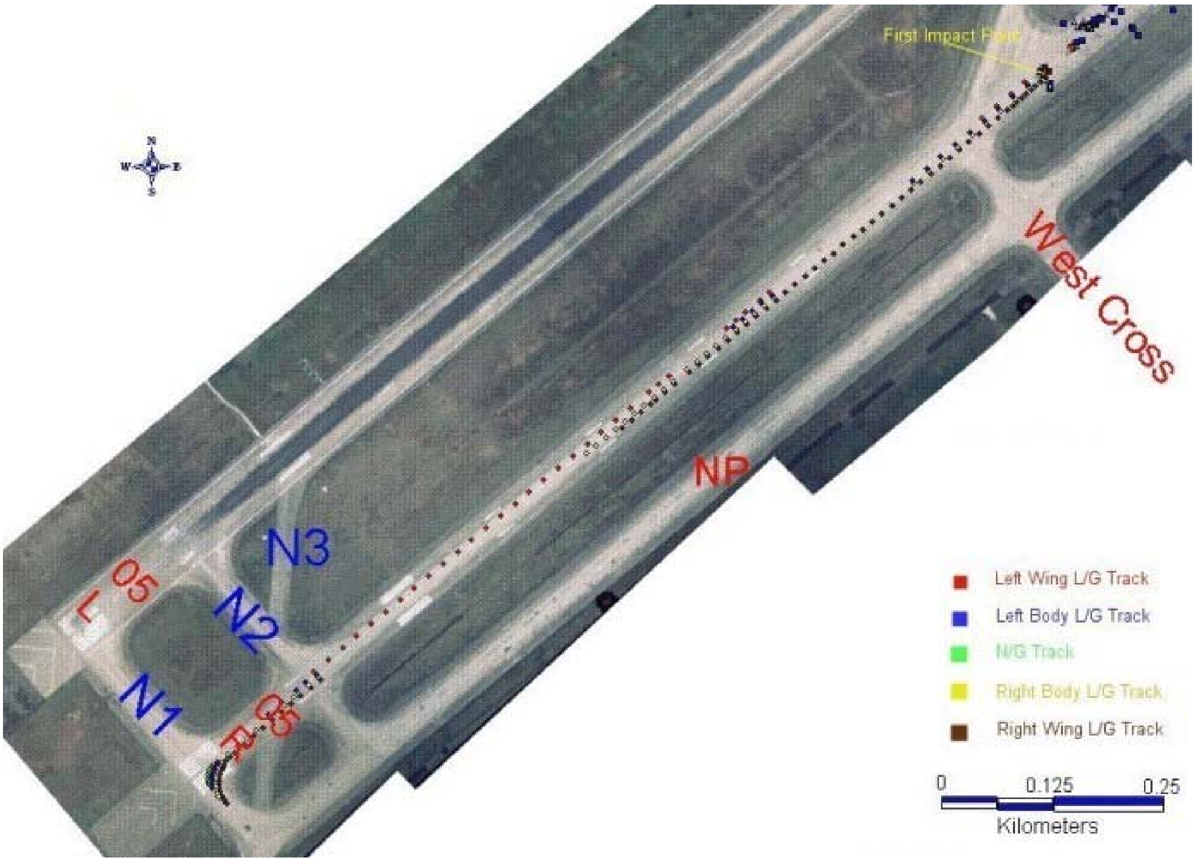

Figure 1.12-1 Tire marks map from site survey data

396 pieces of wreckage were identified and logged with details of part numbers (where required or available), and latitudinal and longitudinal co-ordinates were logged for each piece. They were also individually photographed with designated identification markings.

Except for parts that had been destroyed or consumed by fire, all major parts were accounted for and identified.

1.12.1 Wreckage Distribution and Impact Information

The aircraft wreckage was distributed along Runway 05R (Figure 1.12-2), beginning at the initial impact point (Figure 1.12-3) about 4,080 feet from the runway threshold. The aircraft broke into two main sections about fuselage Body Station 1560[18] and came to rest about 6,840 feet from the runway threshold. The left and right wings remained attached to the forward fuselage section, which came to rest on a heading of about 085°. The tail section (aft of Body Station 1560) was found upright on a heading of approximately 040degrees. It was reported that this section had been moved by the rescue personnel and high winds, and that the original orientation was on a heading of approximately 130 degrees resting on its left side (Figure 1.12-4~5). The rest of the major components were scattered along Runway 05R (Figure 1.12-2).

Figure 1.12-2 Related location of the wreckage and the airport

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[18] The B747-400 fuselage station and the wing section diagrams are shown in Appendix 4

Figure 1.12-3 Initial impact point (shown circled)

Figure 1.12-4 Wreckage distribution as seen opposite from the flight path

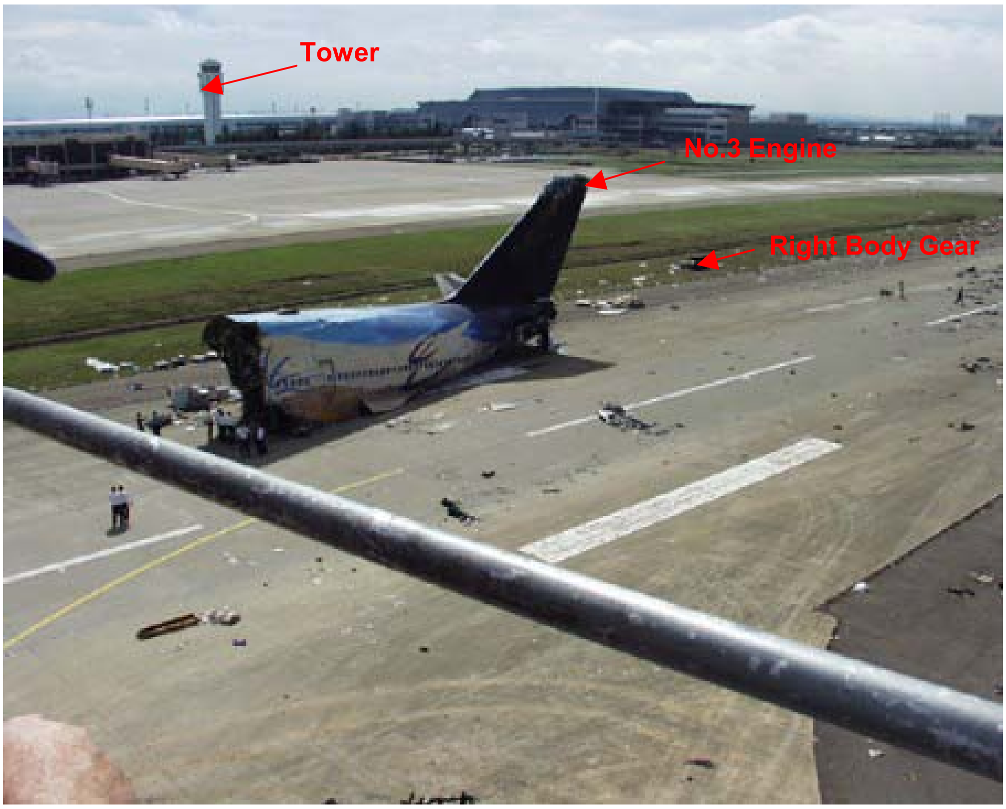

Figure 1.12-5 Wreckage distribution towards the end

1.12.2 Wreckage Examination

1.12.2.1 Front Portion

This portion comprised the remains of Sections 41 and 42, part of Section 44, and the wings, which came to rest on the left side of Runway 05R (Figure 1.12-6). Extensive fire damage to these sections was observed.

The right side of the fuselage from the forward pressure bulkhead up to the right side wing root area, the main equipment center, and forward cargo compartment had been completely damaged by fire. The left side of the fuselage above the main deck floor structure from Body Station 130 to approximately Body Station 1284 remained intact but in a badly burnt state.

Approximately 30 percent of the main deck floor structure from Body Station 320 to 1000 was visible but in a badly burnt and distorted condition.

The right wing was extensively damaged by fire. Some portions of the front and rear spars and the winglet were still visible. (Figure 1.12-7)

The profile of the left side wing was still visible with most of the fire damage occurring on the outer portion. The outboard portion of the left side wing outboard of Wing Station 1360 had broken off. (Figure 1.12-7).

Figure 1.12-6 Front portion of the aircraft

Figure 1.12-7 The left and right wings of the aircraft

1.12.2.2 Aft Portion

The aft portion that comprised part of Sections 46 and 48 of the aircraft came to rest on the right side of the centerline of Runway 05R. (Figures 1.12-8)

The fuselage broke off forward of Door 4, with a fracture running from approximately Body Station 1560 on the left side diagonally aft across the fuselage.

The left side of the belly skin, including supporting frames and stringers, had separated and the right belly skin was crushed, from door 4 all the way to door 5. There were severe skin abrasions and skin loss at the belly areas from Body Station 2410 to 2742. The left side of the fuselage had a large area of abrasion marks around the passenger window area and above.

Fire damage was visible at the Section 48 area and the empennage.

The right side horizontal stabilizer was still intact but was damaged by fire. The portion of the left side horizontal stabilizer outboard of approximately Stabilizer Station 270 had broken off. (Figures 1.12-9)

The vertical stabilizer was blackened by fire but was still attached to the fuselage. The upper portion had broken off.

There were no longitudinal scrape marks on the lower skin on Body Section 48.

Figure 1.12-8 Aft portion of the aircraft

Figure 1.12-9 The right and left horizontal stabilizer

1.12.2.3 Cabin Damage

The aircraft was equipped with 9 galleys. The forward galleys (G1, G2, G3, G3A, and G4) were consumed by fire. Galleys G5 and G6 had separated from the cabin floor and were found near the aft fuselage wreckage. The G7 and G8 galleys remained in the aft fuselage and were found leaning toward the left side of the cabin.

1.12.2.3.1 Cabin Crew Seats

The aircraft was configured with 19 cabin crew seats. The post-impact condition of the seats is described in Table 1.12-1.

Table 1.12-1 Condition of cabin crew seats

Crew Seat Position	Condition
Upper Deck Left	Consumed by fire
Upper Deck Right	Consumed by fire
Upper Deck Galley	Consumed by fire
Door 1L	Consumed by fire
Door 1R	Consumed by fire
Door 2L Outboard	Consumed by fire
Door 2L Inboard	Consumed by fire
Door 2R Outboard	Consumed by fire
Door 2R Inboard	Consumed by fire
Door 3L Outboard	Consumed by fire
Door 3L Inboard	Consumed by fire
Door 3R Outboard	Consumed by fire
Door 3R Inboard	Consumed by fire
Door 4L Inboard and Outboard	Forward inboard footing separated, significant structural damage surrounding the seat, inboard side of the seat frame separated from the seat back, seat pan was down and covered with debris. No fire or smoke damage.
Door 4R Inboard and Outboard	Burn damage, handset interphone disconnected, Seal broken on flashlight
Door 5L	Not damaged
Door 5R	Not damaged

1.12.2.3.2 Doors and Evacuation Slide/Rafts

Door 1L

Door 1L was found intact and in the “open” position. Its mode selection lever was in the “Automatic (Armed) position. The 1L evacuation slide was found partially deployed outside the aircraft. The fuse pins remained connected near the base of the girt skirts preventing the slide from fully deploying. There was significant fire burn damage on the top of the slide near the doorsill. No soot and fire damage was found at the inlet of the slide aspirators.

Door 1R

Door 1R was found with all the mechanisms damaged by post-impact forces. However, inspection of the Mode Selection lever mechanism revealed it to be in the “Manual” (i.e. Unarmed) position. The 1R slide pack was found undeployed adjacent to the doorframe structure. The slide pack appeared to have sustained minor burn damage.

Door 2L

Door 2L was found intact and in the “open” position. Its mode selection lever was in “Automatic” (Armed) position. The slide was found partially deployed outside the aircraft. The fuse pins remained connected near the base of the girt skirts preventing the slide from fully deploying. There was significant fire burn damage to the slide and it had burnt away from the girt bar. No soot or fire damage was found at the inlet of the slide aspirators. See Figure 1.12-10 below.

Figure 1.12-10 The aspirator of Door 2L slide

Door 2R and Door 3R

The remains of Door 2R and Door 3R were found located in a pile east of the main wreckage. The doors were badly burnt and only a small portion of the door mechanisms remained.

Door 3L

Door 3L was found intact and in the "partial open" position. Its Mode selection lever was in "Automatic" (Armed) position. The slide was found on the ground below Door 3L. The slide was not deployed/inflated and sustained moderate burn damage.

Left Upper Deck Door (UDL)

The UDL door was found intact and in the "opened" position. The bottom of the door structure was in contact with the ground. The mode selection lever was in "Automatic" (i.e. Armed) position. The slide was deployed but deflated outside of the aircraft. There was significant burn damage to the slide – only the top 7 feet of the 46.5 feet slide remained.

Right Upper Deck Door (UDR)

The UDR door was found west of the main wreckage. The mode selection lever was not found. The slide was not found.

Door 4R

Door 4R remained intact and was not opened. Its mode selection lever was found in "Automatic" (i.e. Armed) position. The slide was deployed (deflated) inside the aircraft and it extended laterally through the cabin to Door 4L. Soot and fire burn damage were found on the slide skin at the inlet of the slide aspirators. See Figure 1.12-11.

Figure 1.12-11 The aspirator inlet (left) and the inner fire damage of 4R slide (right)

Door 4L

Door 4L was intact and in the ”closed” position. According to interviews with the cabin crewmembers, the door handle was not touched during evacuation. Its mode selection lever was found in “Automatic” (i.e. Armed) position. The slide was found intact, and not inflated.

Door 5R

The cabin crewmember did not open Door 5R and it was found in the “closed” position. The Safety Council personnel who retrieved the flight recorders after the accident opened this door. The slide was found deployed in cabin but deflated with a 6-inch cut long at the bottom of the slide.

Door 5L

Door 5L was found intact and in the “closed” position. The slide was intact and not inflated.

The door 1L, door 2L and door 4R slides recovered from the accident aircraft were sent to the manufacturer, BF Goodrich, for testing. (See section 1.16 for test results)

The condition of the cabin doors and emergency evacuation slides are summarized in Table 1.12-2.

Table 1.12-2 Door and slide status

Doors	Status	Opened By	Slide Condition
UDL	Open	UDR crewmember	Fully Deployed and burnt
UDR	Open	UDR crewmember	Not found
1L	Open	1L crewmember	Partially deployed and burnt from surface skin of slide
1R	Closed		Minor burn damage, not deployed
2L	Open	2R (outboard) crewmember	Partially deployed and burnt from surface skin of slide
2R	Destroyed by fire		Not found
3L	Partially open	Unknown	Moderate burn damage, not deployed
3R	Destroyed by fire		Not found
4L	Closed		In package
4R	Closed		Un-commanded deployment in cabin. Soot and fire damage was found at the inlet of the aspirators to the inner skin of slide.
5L	Closed		In package
5R	Closed		Un-commanded deployment in cabin

1.12.2.3.3 Aft Fuselage Overhead Bins

The center overhead bins separated from the upper fuselage frames at the tie rod ends in the aft cabin between seats 54 D, F, G and H, and 60 D, F, G and H. Four of the fractured tie rods and one intact tie rod were removed for further metallurgical inspection and testing. (See section 1.16 for test results)

1.12.3 Powerplants

All four engines had separated from the aircraft during the impact sequence. None of the four engines exhibited any indication of an uncontained disk/blade separation, or of fire prior to impact. (See Figure 1.12-12)

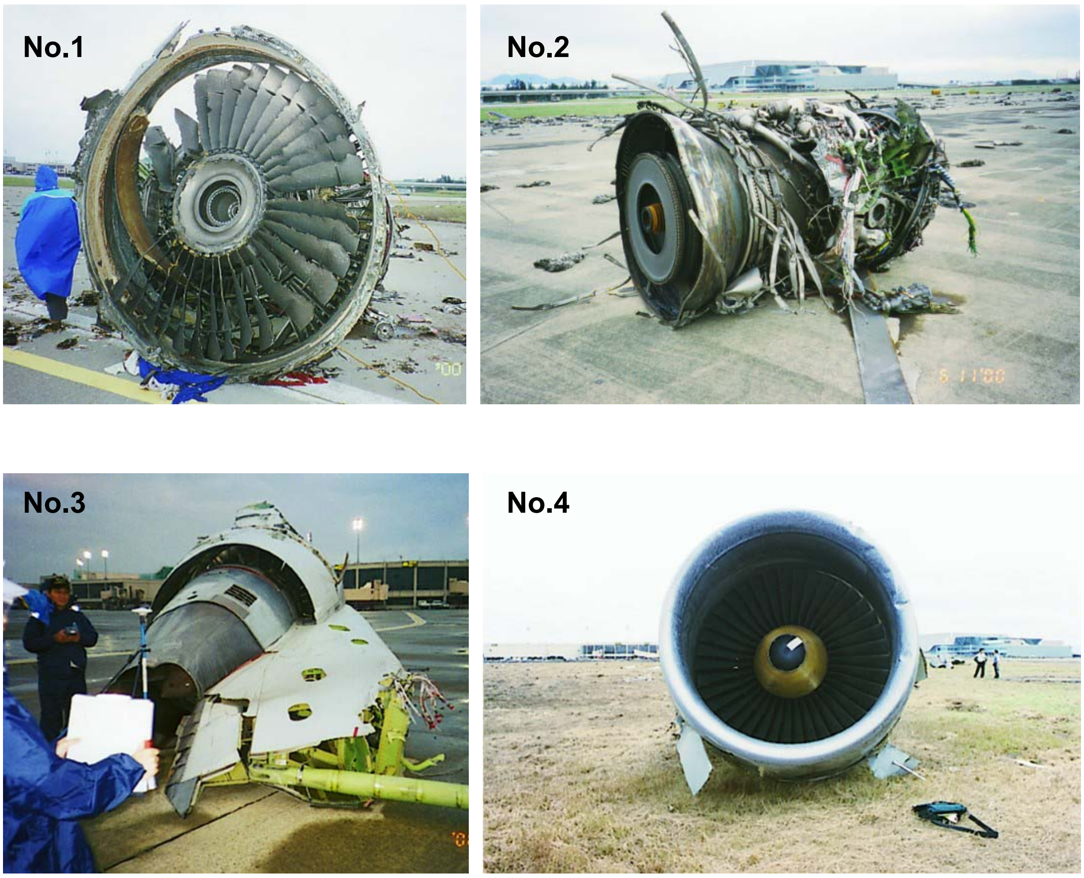

Figure 1.12-12 The four engines

1.12.4 Flight Controls

1.12.4.1 Left Wing

The left wing had substantial fire damage to the outboard section and lesser fire damage to the inboard section.

1.12.4.2 Right Wing

The right wing had substantial fire damage, and all control surfaces were consumed by fire.

1.12.4.3 Horizontal Stabilizer

The horizontal stabilizer trim actuator mechanism and jackscrew showed no visual signs of damage. The right horizontal stabilizer showed only minor fire damage.

1.12.4.4 Elevator

The elevator feel actuators and quadrant were not visibly damaged. The right elevator sustained only minor fire damage.

1.12.4.5 Vertical Stabilizer and Rudder

The vertical stabilizer and rudder sustained only minor fire damage.

1.12.4.6 Major Components

Major components scattered along the crash path on Runway 05R were heavily damaged by impact forces and post-crash fire.

1.12.5 Runway Edge Light Wire

Two runway edge light wires, with the power connector plugs attached were retrieved from the right and left side of Runway 05R at positions identified by grid locations RE239 and RE240, respectively. RE239 was found about 6,270 feet from the threshold of Runway 05R. RE240 was found about 6,670 feet from the threshold of Runway 05R. Both wires were found along the path where aircraft wreckage had passed during the accident. The relative locations of those two wires are shown in

Figure 1.12-13. Near the location of RE240, tire tracks from ground vehicles and wreckage pieces are shown in Figure 1.12-14.

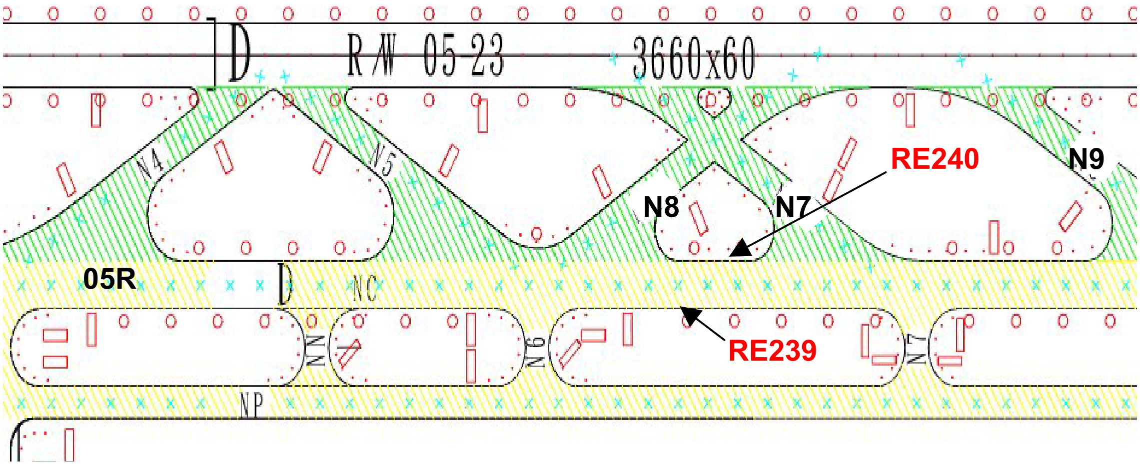

Figure 1.12-13 The positions of RE239 and RE240 on the runway

Figure 1.12-14 Wreckage and tire marks of the ground vehicles near RE240

The runway edge lighting wire found at the location of RE239 was not connected to the socket. It was found on the runway and could not be associated with any particular runway edge light fixture, although there were several broken light fixtures in the near vicinity.

At the location of RE240, the runway edge light fitting was fractured approximately 3.8 to 5 cm above ground level. The fracture was circumferential at a constant height. The base of the fitting remained bolted in place, but the upper portion was not located. No fragments of metal or glass were found in the immediate area. Two wires were observed protruding approximately 5 to 15 cm from the remaining portion of the light base. When the wires were lifted, the plug was found still connected to the mating receptacle under the ground. The wire was disconnected and tagged for identification purposes (Figure 1.12-15).

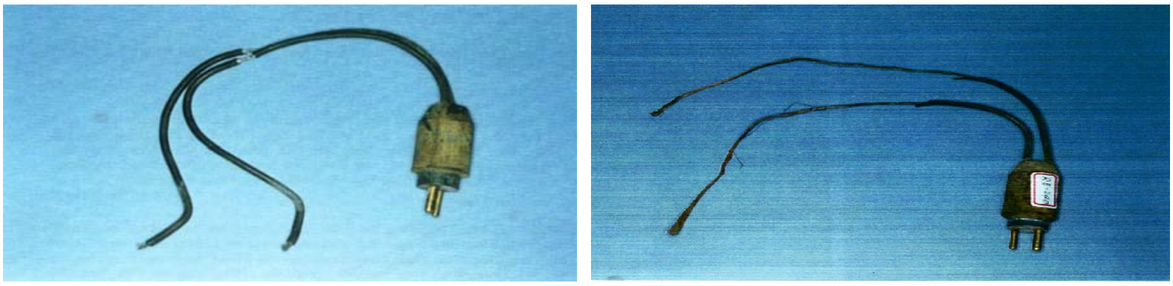

Figure 1.12-15 RE239 (left) and RE240 (right)

The runway edge light wires recovered from the locations of RE239 and RE240 consisted of two wire strands (identified as RE 239-1 and -2, and RE240-1 and -2). Both wires were sent to Chung-Shan Institute of Science and Technology (CSIST, Taiwan) and ATSB for further examination. See section 1.16.5 for the results of tests and research on the wires.

1.13 Medical and Pathological Information

1.13.1 Medical Treatment

The injured passengers were transported to the following hospitals: Ten-Chen Hospital and Lee-Shin Hospital at Chungli City, Ming-Sheng Hospital and Hsin-Yang-Ming Hospital in Taoyuan County, Veteran Memorial Hospital and McKay Memorial Hospital in Taipei, Chang-Gung Memorial Hospital at Linko. The crewmembers were sent to National Taiwan University Hospital in Taipei.

1.13.2 Autopsy

During the early stage of the investigation, the Safety Council investigators, together with a forensic science manager of NTSB, liaised with the prosecutor and the forensic pathologists regarding the medical and pathological needs of the accident investigation.

The Department of Forensic Pathology Institute of Forensic Medicine, Ministry of Justice conducted a total of 7 autopsies. Out of the 7 autopsies conducted, 6 died from severe burns and one died from impact injuries.

1.13.3 Alcohol and Drug Tests on the Flight Crew and Tower Controllers

There was no alcohol and drug testing of the three flight crewmembers of SQ006 and four tower controllers on duty after the accident and there was no evidence to suggest that alcohol or drugs were factors in the accident.

1.14 Fire

1.14.1 Regulations and Manpower

The CKS Airport's aerodrome category for Airport Rescue and Fire Fighting (ARFF) is 9. According to ICAO Annex 14, vol. 1, paragraph 9.2.19:

> "*Recommendation - The operational objective of the rescue and fire fighting service should be to achieve response times of two minutes, and not exceeding three minutes, to the end of each runway, as well as to any other part of the movement area, in optimum conditions of visibility and surface conditions.*
>
> *Note 1-Response time is considered to be the time between the initial call to the rescue and fire fighting service, and the time when the first responding vehicle(s) is (are) in position to apply foam at a rate of a least 50 percent of the discharge rate specified in Table 9-2"*

According to ICAO Annex 14, vol. 1, paragraph 9.2.29, Recommendation, the minimum number of rescue and fire fighting vehicle should be 3 for aerodrome category 9.

According to ICAO Annex 14, vol. 1, paragraph 9.2.10, Standards, the total amounts of water for foam production shall not be less than 36,400 Liters for aerodrome category 9.

According to ICAO Annex 14, vol. 1, paragraph 9.2.14 Standard, the discharge rate of the foam solution shall not be less than 13500L per minute for aerodrome category 9.

There were 8 foam tenders in CKS Airport. The total amount of water was 86,000L. The discharge rate of the foam solution was 42,000L per minute.

A response time test was conducted by the Safety Council from the ARFF south station to the Runway 05L threshold on Feb 29, 2001. It was achieved in 2 minutes and 48 seconds.

According the information provided from the chief of ARFF, at the time of the accident, CKS Airport had 68 fire fighters, 32 on duty during the evening of the accident. By comparison, two level-9 international airports, Chek-Lap-Kok Airport of Hong Kong and Changi Airport of Singapore, have 220 and 160 fire fighters respectively.

1.14.2 Post-Accident Fire

According to the interview with the CKS fire chief, the forward and mid sections of SQ006 burst into flames after the impact. As the fire fighter rushed to the site, they found the aircraft nose section, mid section and wings all on fire. The fire was intense under the gusty winds. The fire chief ordered the fire fighters to position at the up wind side of the wreckage to discharge the extinguishing chemical on the forward and mid-section of the aircraft. The fire fighters also sprayed chemical extinguishing agent into the cabin. Fire fighters rescued three passengers at the door 1L area. They also rescued several burnt passengers who jumped out of the forward cabin to the left side of the aircraft.

The CKS fire chief said that the fire was under control after 10 to 15 minutes, but flashback and re-ignition occurred. It was fully extinguished after 40 minutes. There was only minor exterior fire damage to the severed rear section.

1.14.2.1 Activation Phase

Based on interviews with the ARFF personnel at CKS Airport and the transcript of airport Channel 1 radio communications on October 31, 2000, the CKS South Fire Station audio crash alarm sounded immediately followed by an RT transmission from CKS Tower at 2317:36. A telephone call from ATC was subsequently made to ARFF personnel. The initial location of the crash site was given by ATC as on the runway in use (Runway 05L/23R).

1.14.2.2 Response Phase

The initial post-accident response by fire-fighting vehicles from South Fire Station was 2 rapid intervention vehicles, 4 foam tenders, 1 nursing truck, 4 ambulances and 2 lighting units.

During interview, the driver of the first arriving vehicle, Fire Tender No. 3 said that he was alerted by the sound of explosions and responded immediately in the general direction of Runway 05/23. The driver also noticed the appearance of fire prior to the alarm from the standby room. He encountered low visibility, strong winds, and heavy rain as he rushed to the accident site. He had to cut across an active runway (06/24) and a taxiway before entering the northern runway. They were guided by the green centerline taxi lights along Taxiway East Cross and the visual sighting of the fire at the crash site. On arrival at the site, he immediately took up a position on the upwind side, between the aircraft nose and the left wing. He quickly discharged Aqueous Film Forming Foam (AFFF) that was activated by a master switch from the driver cabin console panel.

Fire-fighting efforts were concentrated initially on the critical area at the left forward fuselage and left wing root area. The fire subsequently spread to the rest of the forward fuselage.

According to the Channel 1 communications transcript, at 2320:45, there was a transmission, "Shoot chemical first. Shoot chemical first." There was no record of the arrival time of the second and subsequent fire tenders. The first responding vehicle, Fire Tender No. 3, did not communicate with ATC for clearance to cross the active runway while en-route to the crash site.

At the time of the accident, the North Fire Station was closed for maintenance but the South Fire Station was operating 24 hours a day. Due to the closure of the North Fire Station, two fire tenders were stationed at the Domestic Terminal (located 0.5 km to the southwest of Runway 05L threshold) daily between 0900 and 2200 hours.

On February 21, 2001, the Chief of Flight Operations Section (CFO) provided the Safety Council with a chart indicating the positions of the fire tenders at the crash site. It indicated that upon arrival, all the fire tenders were positioned on the upwind side of the aircraft fire. They surrounded the forward fuselage in an arc formation from the northeast to the southeast.

Fire Tender No. 6 extinguished the fire in the Auxiliary Power Unit (APU) area at the aft fuselage/tail section within 40 to 60 seconds. Entry was made into the tail section after the fire had been extinguished; however, ARFF personnel reported that they did not find anyone inside. (The flight crew reported that a female passenger had been carried out of the tail section by ARFF rescuers).

Another 34 fire trucks, 54 ambulances and 7 lighting units from local fire stations, hospitals, police and military units subsequently arrived to support the fire fighting and rescue operations. The external supporting vehicles from other agencies arrived around 2340 from the North Entrance Gate. Some of these vehicles requested directions to the crash site.

No complimentary extinguishing agents, such as dry chemical powder, BCF or CO_2, were used in the entire emergency response operation.

1.14.3 Exercises of Airport Emergency Response

According to the airport emergency response planning, aircraft crash exercises at CKS Airport were conducted twice annually. One of these is a large-scale exercise involving all relevant agencies. The most recent large-scale exercise prior to the accident was conducted on July 5, 2000.

The fire fighting recurrent training was conducted once every three months in an open area, not in an aircraft cabin mock-up. During training, trainees wore breathing apparatus (BA) and other rescue equipment.

1.15 Survival Aspects

1.15.1 Evacuation

During the post-accident evacuation, the forward and upper deck cabin survivors evacuated from 1L, 2L and UDL exits while the tail section survivors evacuated from the fractured opening of the fuselage. The mid section was destroyed by the fire.

The Safety Council interviewed nineteen of the 80 surviving passengers. Additionally, a questionnaire was sent to all the surviving passengers. Four passengers those were not interviewed returned their questionnaires.

1.15.1.1 SIA Crewmembers' Emergency Evacuation Procedure and Training

SIA flight and cabin crews were given emergency procedure training in accordance with their Aircrew Safety Equipment and Procedures (ASEP) manual.

According to Singapore ASEP chapter 4, section 4, Land Evacuation:

> *"The primary focus of any emergency evacuation is to rapidly evacuate the occupants. To achieve this, crew should take steps to avoid incapacitation as far as possible. Evacuation procedures are based on minimum Primary Crew complement and any incapacitation will increase the passenger evacuation time. Use positive commands in a strong and forceful voice when directing the evacuation.*
>
> ***NOTE:*** *The initiation of an evacuation is the Commander's responsibility. Should a Cabin Crew consider that an evacuation is necessary, he should advise the Commander of the situation and await his decision. In cases, where it is obvious that an evacuation is imperative and no contact with the cockpit has been possible, the Cabin Crew should initiate the evacuation as soon as possible."*

According to the SIA ASEP manual, crewmembers should be completely familiar with each other's responsibilities, so that in the event one crewmember becomes incapacitated; another crewmember can perform his/her duties. In SIA, the CIC is responsible for ensuring that all ASEP duties and procedures are carried out under his/her command during the flight. The CIC shall also assign the Primary Crew and Assist Crew to assist her/him.

During the annual recurrent emergency evacuation training, a ground school review was conducted for both the fight crew and the cabin crew. There were approximately 15 to 20 people in each class.

After ground school, all crewmembers accomplished an emergency evacuation drill in the SIA cabin evacuation mock up.

The ground-school instructor set up different scenarios, such as a cabin fire or a forced landing for the training session. The flight crew, played the role of passengers, and were seated in the cabin. The cabin crew took their designated crew seats in the cabin. The communication service panel was programmed with a captain's PA to the cabin crewmembers and passengers: "prepare for an evacuation, brace for impact".. This pre-recorded announcement was activated by the instructor. After a simulated emergency landing, all crewmembers unfastened their seat belts and shoulder harnesses, stood up and shouted to passengers: "unbuckle your seat belts, come this way." The cabin crewmembers also checked outside of the exits to ensure that the exits were safe to open. As the cabin crewmembers opened the exit door in accordance with ASEP, they checked the automatic inflation of the slide/raft, and then grabbed the handle at the door side in the cabin to avoid being pushed out by the exiting passengers. To simulate equipment failure, the automatic slide inflation switch was de-activated, and the cabin crewmembers pulled the manual inflation strip to deploy the slide/raft. After confirmation of the slide/raft's inflation, the cabin crewmembers then directed the passengers to jump out.

In SIA's integrated recurrent evacuation training, all flight crewmembers acted as passengers in the passenger cabin. The flight crew did not practice giving the evacuation command using the PA or any other alternate method while they integrated with the cabin crew in the cabin mockup. Further, the flight crew's training did not include the failure of the PA system.

When observing SIA recurrent emergency training, the Safety Council observed that SIA crewmembers wore their uniforms when they first completed the emergency evacuation training but wore casual clothing for recurrent training.

1.15.1.2 Flight Crewmembers' Emergency Evacuation

According to an interview with CM-1, by the time he reached the upper deck exit areas, he noticed both exits were already opened. There was an intense fire on the right side of the aircraft. He noticed that passengers were evacuating from the UDL exit. He evacuated from the UDL after the passengers had evacuated, by grabbing the half- burnt slide and then jumping down to the ground.

According to the interview with CM-2, he saw CM-1 use the PA system; however the PA system was inoperative. After the evacuation checklist was accomplished they evacuated through the cockpit door. He heard CM-3 shouting, "follow the lights, follow the lights," referring to the PEEPLS. He could not see anyone because of the darkness. As he proceeded to the left upper deck door he saw light from the flames outside. He did not see the slide and decided to use the UDL to evacuate. Since no one took any action to evacuate, he decided to evacuate first and shout to the people at the left upper deck door, "stay here, stay here, I will jump first, I will jump first." After he jumped to the ground, he shouted to those who were standing at the left upper deck door to start jumping. One by one the passengers jumped out of the cabin.

According to the interview with CM-3, he was the first one to leave the cockpit. When he left the cockpit and entered the upper deck cabin, he saw smoke and thick flying dust in the upper deck cabin. He could only see 2 to 3 evacuating path lights ahead. He found the upper deck left exit already opened and there was an extensive fire outside. He remembered that there were several people, including a cabin crewmember (male), in front of the upper deck right side exit (UDR) trying to open the UDR exit. Passengers still remained in the upper deck cabin at that time. Initially, he wanted to go to the main deck cabin, but the stairwell area was filled with smoke. He then turned back and saw the left outside fire starting to diminish and he saw passengers jumping down through the UDL exit. CM-3 did not see CM-1 at that time, but he saw a female cabin crewmember shaking and weeping near the left side exit. CM-3 instructed her to jump out. He then climbed down the burnt slide/raft from UDL exit. CM-3 claimed that he was the last one to exit the aircraft. After CM-3 jumped out, he noticed that CM-2 was already on the ground.

1.15.1.3 Upper Deck Cabin Crewmembers' Emergency Evacuation

According to an interview with the passenger seated in 17A, who was facing the cabin crewmember assigned to the UDL, a male cabin crewmember opened both upper deck exits (UDR cabin crewmember). He also noticed that the UDR cabin crewmember directed the passenger to the main deck via stairs. This passenger mentioned that when the two upper deck exits were opened, a very bad burning smell and heavy smoke immediately entered the cabin from outside. The UDR cabin crewmember did not survive the accident.

According to the SIA ASEP, during an emergency evacuation, each crewmember is responsible for checking doors, ensuring that it is safe to open, checking that the slide/raft inflates, and then commanding and directing passengers to evacuate. According to an interview with the upper deck left cabin crewmember, she recalled selecting the Mode Selector lever to the "Automatic" position before takeoff and also crosschecked and confirmed with the UDR cabin crewmember. When accident happened, the upper deck cabin was immediately filled with heavy smoke and dust. The UDL cabin crewmember saw the UDR crewmember opened the UDR exit and the 17A passenger saw the UDR crewmember was forced to move backward because of the fire and smoke from the UDR exit immediately after opening this exit. The UDR cabin crewmember then opened the UDL door. As the UDL door was opened, the slide/raft inflated and the fire burnt and deflated this slide/raft soon. The UDL cabin crewmember also noted that the CIC showed up in the upper deck cabin for a short period, and then saw CM-2 going down the UDL deflated slide/raft (which was twisted like a bundle of cloth). The UDL cabin crewmember followed CM-2 and jumped out from the same exit.

The seat for the cabin crewmember in the upper deck galley was facing backward. Because the galley lamp could not be dimmed due to a malfunction of the light switch, this crewmember could clearly see the items in the galley bouncing forward during impact. After the aircraft came to rest, he did not hear any evacuation instruction. Nonetheless, he un-buckled his seat belt and shouted to the passengers to un-buckle their seat belts. By that time, he felt hot air coming from different directions and smoke surging upward from main deck. He passed a towel to the main cabin 2R cabin crewmember who ran upstairs to dodge the fire and smoke of the main deck. The upper deck galley cabin crewmember saw several upper deck passengers running to the stairs, going down and jumping out the aircraft. This upper deck galley cabin crewmember went downstairs as well and found the L2 exit open and jumped out of that exit.

The UDL cabin crewmember reported that her sandals were lost during the evacuation.

1.15.1.4 Main Deck Cabin Door 1, 2 and 3 Crewmembers' Emergency Evacuation

According to the interview with the surviving upper deck passengers and cabin crewmembers, the CIC went upstairs after the first impact. The CIC did not contact CM-1 or other flight crewmembers and did not issue an evacuation command. The CIC did not survive in the accident.

According to the interview with the main deck 1L cabin crewmember, he did not receive an instruction to evacuate the aircraft. After checking outside, he opened the 1L exit and pushed the slide/raft out of the aircraft. He immediately heard the sound of air leaking from the 1L slide/raft. After considering the height of 1.5 meters above ground and noticing the smoke emanating from the aft end of the cabin without seeing another available exits, he directed 8 forward passengers (including 3 from business class) to jump from the 1L exit. Cabin visibility was about 1 meter. Fire and heavy smoke came into the cabin intermittently. He stated that when he could see no more passengers, he then evacuated from the 1L exit.

According to the interview with the 1R cabin crewmember, she monitored the conditions outside of the 1R exit and saw intense fire after the accident occurred. She did not open the 1R exit. She then shouted to the passengers to unbuckle their seat belts. Together with the 1L cabin crewmember, she directed the passengers to evacuate from the 1L exit.

All 5 first class passengers evacuated from the 1L exit. One person received minor injuries and the other four were not injured.

When the accident occurred, the 2L outboard cabin crewmember heard two big bangs from the right wing. Her seat was facing backward. She saw fire burning in the rear section of aircraft. Without receiving any evacuation instruction, she unbuckled her seat belt and moved to the left forward aisle and then ran upstairs. This cabin crewmember used a towel that was handed to her by the UDG crewmember to cover her nose and then returned to the main deck to join the 2R cabin crewmember after the aircraft stopped. She evacuated from the 2L exit. She did not execute any listed procedure from ASEP.

The 2R outboard crewmember saw flames entering the cabin from both sides of the ventilation duct at the sidewall. He went upstairs to avoid the fire. He noticed that someone was trying to open the UDL exit. He then returned to the main deck. He noticed that there was fire on the right side of the aircraft so he did not open the 2R door. He opened the 2L exit and pushed the slide/raft out. He heard the slide/raft inflate, but soon heard the leaking-air sound. He did not hear any evacuation instruction, nor did he command an evacuation. He evacuated from 2L exit.

The crewmembers seated at 3L and 3R did not survive the accident.

1.15.1.5 Main Deck Cabin Door 4, 5 Crewmembers' Emergency Evacuation

According to the 4R outboard cabin crewmember, oxygen masks and miscellaneous objects were dropping down from the ceiling when the accident happened. The whole cabin was dark and he could not see any emergency lights. He unbuckled his seat belt quickly and jumped into the galley. He saw a fireball entering the aisle of the cabin but it soon disappeared. The fireball touched the inboard cabin crewmember who was seated right next to him. He noticed that the aircraft had fractured when it stopped. He left the fractured opening immediately and met the 4R inboard cabin crewmember.

According to the 4R inboard cabin crewmember, after the aircraft stopped, the galley containers in the area shifted, the container doors opened and several oxygen masks dropped out. The observation window of the 4R exit door was cracked. After several seconds, the 4R slide inflated automatically and trapped this cabin crewmember on her seat. She almost suffocated. She felt heat and was burnt. She was seriously injured by fire. At that time the slide/raft started to deflate because of the fire. She could not see the emergency lights in cabin. She unbuckled her seat belt and evacuated from the fractured opening of the aircraft. When she stepped out onto the concrete, she saw another cabin crewmember and a female passenger standing on the ground. After she had assisted several passengers to evacuate, she ran to a distant vehicle. There were approximately 20 survivors in the vehicle. The fire fighting had already started as she evacuated from the fractured part of the aircraft

According to the 4L inboard cabin crewmember, when the accident happened, he noticed oxygen masks falling out. A few seconds later, all cabin lights went out. A fireball from the left rearward aisle approached her and burnt her left leg. When the aircraft stopped, she smelled fresh air coming from the fractured opening. The 4L inboard cabin crewmember was asked by the 4L outboard cabin crewmember to stay outside of the aircraft to assist in the evacuation of passengers. This crewmember led 6 to 8 passengers from the wreckage to the terminal building.

According to the 4L outboard cabin crewmember, the galley was tilted to the left, and the 4L emergency exit light illuminated. When he unbuckled the seat belt, he found himself standing on the 4L exit door (the aircraft tail section fuselage was resting on its left sidewall after a longitudinal 90 degrees counter clockwise rotation). After he pushed aside some clothes, he discovered an opening at the aircraft fracture and jumped out. He then asked the 4L inboard crewmember who followed him out to stay on the ground to assist passenger evacuation. He then returned to the cabin and yelled to the passengers, "come this way." He saw the 5L cabin crewmember using a flashlight to direct the passenger to the fractured opening. The 4L outboard cabin crewmember was a senior crewmember. He left the wreckage after all the passengers had been evacuated.

According to the 5R cabin crewmember, when the accident happened, there were fires outside Door 3 and 4. She was trapped and almost suffocated in her seat by the uncommanded inflation of the 5R slide/raft and could not see the other passengers. She then unbuckled her seat belt to untangle herself from the inflated slide. She told the nearby passengers to move forward and look for an exit. She and more than ten passengers seated in the tail section evacuated from the fractured opening of the aircraft.

According to the 5L cabin crewmember, after an explosion, she saw the ceiling, upper compartment, and other objects collapsing. Smoke was everywhere. Passengers rushed to the 5L exit area and requested her to open the door, but the exit door was resting against the ground and could not be opened. The cabin was very dark; therefore, she took the flashlight from the crew seat and aimed it forward to direct the passengers to evacuate. Later on she heard the 4L outboard crewmember instructing passengers to move forward. This crewmember directed about 15 passengers to go forward and evacuate from the fractured opening. She also helped passengers to cross the ditch and continue to the airport terminal.

A piece of the lower part of the skirt that belonged to a cabin crewmember was found stuck in the inlet of the 4R slide air blower.

Most of the survivors said they suffered from smoke inhalation during evacuation. Survivors seated in the main and upper deck cabins all said that they had to lie down for fresh air. The 2L and upper deck galley cabin crewmembers used wet towels to cover their noses and mouths to aid in breathing.

1.15.1.6 Emergency Equipment

From interviews with the flight crewmembers, the Safety Council found that, CM-3 and the 5L cabin crewmember carried their torch during the evacuation. CM-2 carried his own small flashlight with him. The other crewmembers did not carry the torchlight from their station during evacuation.

None of the crewmembers used a megaphone to assist passengers to evacuate.

Based on the interview data, when the accident happened, the escape path lights on the floor and exit lights appeared dim in heavy smoke and dust.

1.15.2 Post Evacuation

Based on interviews with the rear section cabin crewmembers and passengers, several cabin crewmembers and passengers had to cross a ditch and find their way to the temporary Casualty Clearance Station (CCS) located at the terminal building. A bus picked up some of them halfway between the ditch and the terminal building. A review of the videotape taken during the time of the accident by a passenger onboard another B-747-400 aircraft showed that some SQ006 passengers walked to the terminal building. Crewmembers and passengers stated that there was little assistance provided at the Terminal Building. Most of the assistance they received was from their fellow crewmembers and passengers. When medical people arrived, there was inadequate co-ordination in handling the injured people in the CCS.

1.15.3 Airport Emergency Response and Medical Activity

1.15.3.1 On Scene Command and Control

A bus was set up about 50 meters northeast of the tail section of the aircraft as a mobile command post approximately one hour after the accident. The vehicle was manned by the Chief Flight Operations (CFO) officer of the airport authority. All fire fighting and medical personnel used Channel 6 radio frequency for communication. The rescue personnel from different supporting agencies used their own individual radio frequencies to communicate with their own units at the site.

The airport police, who were subsequently assisted by the local military police, handled the security of the accident site initially.

1.15.3.2 Rescue Operations

The Casualty Clearance Station (CCS) could not be established at the scene of the accident because of the strong wind and heavy rain associated with the approaching typhoon "Xangsane" Consequently, the CCS was established at the CKS Airport Flight Operations Center located adjacent to Gate A9 in Terminal 1.

According to interviews with CKS ARFF personnel, after the fire engines had arrived at the accident site, four fire fighters formed a rescue team. These rescue personnel had received Level 1 or basic Emergency Medical Training (EMT 1). Initially, they rescued three passengers near the 1L slide and the 1L door. Those three passengers sustained severe burn injuries and were sent to the hospital in ARFF ambulances. There was no record of any other rescue operations at the early stage of the fire fighting effort, either by fire hose operators, or by any rescue personnel entering the forward fuselage. The wind-whipped fire burnt fiercely around the front fuselage (Figure1.15-1). In contrast, the separated rear fuselage was relatively unaffected by fire. The fire fighters did not use breathing apparatus during the initial rescue attempt. The CFO explained that breathing apparatus was not used for a number of reasons; first, the heat of the fire was too intense for the fire fighters to approach and enter the forward cabin, the fire fighters needed to maintain a safe distance from the unexpected explosion and intense heat; second, all the fire fighters were positioned upwind of the flames and therefore, had no difficulty breathing unaided. Finally, the CFO commented that the breathing apparatus hood would fog up during the fire suppression and rescue activities and restrict the fire fighters field of vision.

Figure 1.15-1 The heavy fire areas of the front fuselage about 30 seconds after the aircraft came to rest[19]

Survivors from the crash site were transported to the CCS by ground service vehicles, airport authority vans and ambulances. Some passengers were drawn by the flashing beacon lights of the emergency vehicles and walked to the CCS. According to the CFO, he picked up 7 or 8 passengers with minor or no injuries but suffering from shock. He sent them to the CCS.

The first 10 survivors were sent directly to Chang-Gung Memorial Hospital at Linko (30 km away). The injured passengers were not examined on site before being rushed to the hospital. There were no medical personnel attending to the injured passengers during the entire ride. ARFF personnel were unable to recall the time when the first casualty was picked up or when the first ambulance departed with the casualties. The other ARFF rescue vehicles took passengers to the hospital in the same way. The subsequent casualties were sent to the CCS.

The ambulances and the ARFF rescue vehicles both had emergency medical kits on board. As the vehicles were driving back and forth between the crash site and the hospital, those first aid kits stayed with the vehicle and were not left at the CCS.

[19] This picture was taken by a passenger aboard another B747-400 aircraft from the gate A4 area.

During the accident, water and blankets were provided to the survivors at the CCS. No one directed any rescue personnel to fetch the medical facilities and first aid at the north fire station. No one directed rescue personnel to bring medical equipment and first aid kits from the north fire station.

The person assigned by Ming-Sheng Hospital to set up a station at the CKS Airport clinic office was an ex-military medical doctor with no civilian certificate. He was not advised that his job was to be an airport emergency medical coordinator. After the ARFF ambulances were dispatched to the local hospitals, medical aid was provided at the CCS by a Ming-Sheng Hospital staff and a nearby Air Force Base medical doctor.

1.15.3.3 Medical Coordinator and Temporary Medical Coordinator

In 1995, the CKS Airport authority contracted individually with the Chang-Gung Memorial Hospital at Linko, Ming-Sheng Hospital in Taoyuan, and others as backup, to provide medical services at the airport. Further, the Ming-Sheng Hospital established an Airport Medical Clinic in 1996. All airports in Taiwan are required by the CAA to establish medical services contracts for accident and incident response on and off the airport.

During the accident, Ming-Sheng Hospital's clinic at CKS Airport had the responsibility for medical treatment at the CKS Airport. Generally, doctors were available at the clinic from 0830 to 1730. During off-duty hours, only a clinic staff member was available at the clinic. According to the contract between the CKS Airport and the Ming-Sheng Hospital, the clinic had the responsibility for handling emergency medical situations. The clinical staff was designated as medical coordinator. No training was given for the position of medical coordinator nor were the doctors aware of medical coordinator responsibilities. The CKS Airport was not equipped to provide comprehensive medical treatment. There were two nurses stationed at the fire station during the working hours (0830 to 1730). Those two nurses were not designated medical coordinators.

ICAO Doc 9137, part 7, section 3.6.3 recommended,

> "*A medical co-ordinator should be assigned to assume control of the emergency medical operations at the accident site. If airport services exits, the medical co-ordinator may be designated from the airport medical staff. In some cases, it may be necessary to appoint an interim medical co-ordinator, to be relieved when the designated medical co-ordinator arrives on site. The interim medical coordinator can be designated from the airport rescue and fire fighting personnel.*"

1.15.3.4 Triage and Medical Treatment

The CFO, who was the on-scene commander, established the flight crew check-in lobby (900 square meters) at the Flight Operation Center as the CCS, located just below the A9 boarding gate of Terminal 1. There were limited medical facilities initially at the CCS. Two staff members from the Flight Operations Section were tasked to take charge of the CCS and to inform all supporting medical agencies where the CCS was. Command authority of the CCS was subsequently handed over to the medical personnel from the airport clinical staff, the Ming-Sheng Hospital's doctors, then the Chang-Gung Memorial Hospital's doctors and then to the manager of the Bureau of Hygiene and Health in Taoyuan County.

The "CKS Airport Civil Aircraft Accident Handling Procedures and Regulations" provides a brief description of injury examinations, classification and medical treatment:

> *"After going through triage procedure, he or she should assist in arranging for the transportation of other injured persons to the appropriate hospitals."*

The Safety Council found that many injured and uninjured survivors were sent to the hospitals directly without going through any triage process.

1.15.3.5 Hospital Information

ICAO Doc 9137, Airport Emergency Planning (AEP), section 3.7.1 recommended:

> *"...It is mandatory to establish in advance an accurate list of surrounding hospitals. They should be classified according to their effective receiving capacity and specialized features, such as neurosurgical ability or burn treatment. In most circumstances, it is unwise to deplete the most proximate hospital to the accident site of essential medical and nursing personnel."*

ICAO AEP section 4.1.7 recommended that a hospital co-ordinator should be responsible for the following:

a) immediately provide and transport doctors and medical teams skilled in trauma care to the accident site upon notification of the emergency;

b) provide medical care to the casualties when they arrive at the treatment area; and *c）ensure that adequate doctors and nurses, operating rooms, intensive care units, surgical teams, blood and blood volume expanders are available for emergency situations, including aircraft accidents.*

The Medical Support Hospital listed in the "CKS Airport Civil Aircraft Accident Handling Procedures and Regulations" contained no special features such as neurosurgical ability.

1.15.3.6 The Relevant Procedures and Regulations for Emergency Operations

The relevant procedures and regulations for emergency operations are found in the ICAO AEP.

ICAO AEP, section 1.1.9 stated:

"Recommendation - The stabilization and emergency medical treatment of casualties is of equal importance. The speed and skill of such treatment is crucial in situations where life hazards exit. An effective rescue effort requires adequate preplanning for emergency as well as execution of periodic practice exercises."

ICAO AEP, section 3.6.1 stated:

"Recommendation - The purpose of the medical service during an accident is to provide triage, first aid and medical care in order to:

(a) save as many lives as possible by locating and stabilizing the most seriously injured, whose lives may be in danger without immediate treatment.
(b) provide comfort to the less seriously injured and to administer first aid; and
(c) transport casualties to the proper medical facility."

ICAO AEP, section 3.6.3 stated:

"Recommendation - A medical co-ordinator should be assigned to assume control of the emergency medical operations at the accident site. ...In some cases, it may be necessary to appoint an interim medical coordinator, to be relieved when the designated medical coordinator arrives on site. The interim medical co-coordinator can be designed from the airport rescue and fire fighting personnel."

ICAO AEP, section 4.1.6 stated:

"Recommendation - It shall be the responsibility of the medical co-ordinate to supervise the medical services and to:

a）verify the notification of mutual aid medical and ambulance services and their subsequent arrival at the rendezvous point or staging area;
b）organize the necessary actions for triage, treatment of the casualties, and their eventual evacuation by appropriate means of transportation;
c）control the flow of casualties and ensure, together with the transportation officer, the dispatch of the casualties to the appropriate hospitals by all available means of transportation;
d）maintain an accurate list of the casualties including their names and their final disposition;
e）co-ordinate the transaction of the uninjured to the designated holding area with the aircraft operator concerned;
f）provide medical evaluation of ambulatory and uninjured survivors;
g）arrange for the replenishment of medical supplies, if necessary; and

organize, with the police, reception facilities for the dead."

ICAO AEP, section 9.2.3 stated:

"Recommendation - The first qualified, medically trained person to arrive at the site must immediately begin initial triage. This person(s) will continue performing triage until relieved by a more qualified person or the designed airport triage officer. Victims should be moved from the triage area to the appropriate care holding areas before definitive treatment is rendered. Casualties should be stabilized at the care holding areas and then transported to an appropriate facility."

ICAO AEP, section 3.3.1 recommended:

"Recommendation - The Prime responsibility of airport rescue and fire fighting personnel is to save lives. Property endangered by aircraft incidents and accidents occurring on or near the airport should be preserved as far as practicable. To achieve this objective, fire should be suppressed and any re-ignition prevented. There are aircraft accidents, however, where fire may not occur, or where the fire may be rapidly extinguished. In every case, the procedures should provide for the most rapid evacuation possible of survivors of the accident."

According to the "Aircraft accident handling procedure of CKS Airport," the operation zone is divided into the on-airport procedure and off-airport procedure. The on-airport procedure is then divided into two categories: 1. A damaged aircraft that did not explode and no personnel injuries; and 2. An explosion occurred and there were injuries to personnel. The procedures related to the fire fighting and rescue of the second item are stated in the following:

(1) Fire engines and the rescue vehicles must proceed to the crash site simultaneously to commence the fire and rescue operation; and

(2) After the fire is under control, priority shall be given to rescue the passengers, and to provide initial treatment to the injured. The fire engines shall continuously guard the crash site to prevent second occurrence of fire/explosion

The procedures related to the rescue and medical treatment of the second item are stated in the following:

(1) The Ming-Sheng Hospital's clinic at CKS Airport shall immediately respond to the call and dispatch the station doctor and nurse to the accident site and organize a medical team. The medical team shall establish a CCS and triage area to carry out the initial medical assistance.

(2) The Ming-Sheng Hospital's clinic at CKS Airport shall coordinate with those medically trained personnel requested from Tao Yuan Area Emergency Medical Dispatch Center arriving subsequently to perform the appropriate medical service.

(3) The designed medical team shall arrange that the injured, once cleared through the triage are to be sent to the appropriated hospitals for further assessment and treatment.

These procedures are also stated in the CKS Airport Flight Operations Division's fire fighting handling procedure:

a. After the fire engines are properly situated, the team leader shall immediately turn on the turret nozzle located on the top of the vehicle, and apply foam jet directly to the aircraft to reduce the skin temperature of the aircraft with either half volume or full volume, to reduce the potential extension of the fire, and to safeguard the personnel aboard the aircraft a speedy escape from the burning aircraft.

b. The fire hose operators shall immediately pull out the fire hose located in front of the vehicle and directly apply the misty foam substances at the exit portions of the aircraft *and to coordinate with the nozzle operators to create a safe passage for the medical personnel safely aboard the aircraft.*

c. *The rescue team shall follow the fire hose operators with the necessary rescue tools to approach the aircraft via safe passage to rescue the personnel on board the plane and handed it over immediately to the medical personnel for emergency medical treatment.*

1.16 Tests and Research

1.16.1 Taxi Route Simulation

On November 6, 2000, at approximately 0400, the Safety Council used a Boeing 747-400 Freighter[20] to study the conspicuity of taxiway and runway signs and marking from the cockpit. In addition, the taxi simulation was used to examine the cockpit instrument indications that would have likely been available to the flight crew on the evening of the accident. At the time of the observations, the weather at CKS Airport was Visual Meteorological Conditions (VMC), with visibility more than 10 kilometers with light rain. The observations also enabled investigators to familiarize themselves with the taxi route of SQ006.

Video and sound recordings were made from the cockpit during the taxi reenactment. One video camera was held by the right seat pilot and aimed forward. An observer who was positioned between the two pilot seats close to the Captain's right ear held a second video camera. That camera was also aimed forward.

The following marking and signs were observed by occupants of the flight deck in the vicinity of the approach end of Runway 05R:

(a) A black/red sign marked "N1/5R-23L" on the southwest side of N1;
(b) a white marking on the Runway 05R indicating "05" and "R.";
(c) a red "CAT 2" sign on N1 between 05R and 05L;
(d) a red/black sign marked "5L-23R/N1" on the northeast side of N1;
(e) Runway 05R threshold marked "White Threshold Marking";
(f) the green taxiway centerline lights that led to Runway 05L on Taxiway N1 (Figure 1.16-1); and

20 The freighter was not equipped with a PVD.

(g) the taxiway centerline lights emanating from the left side of Runway 05R and merging into the Runway 05R centerline lights about 100 meters ahead of the runway threshold. (Figure 1.16-2)

Figure 1.16-1 Taxiway centerline lights leading to Runway 05L (field of view from Boeing 747-400 cockpit-captain side)

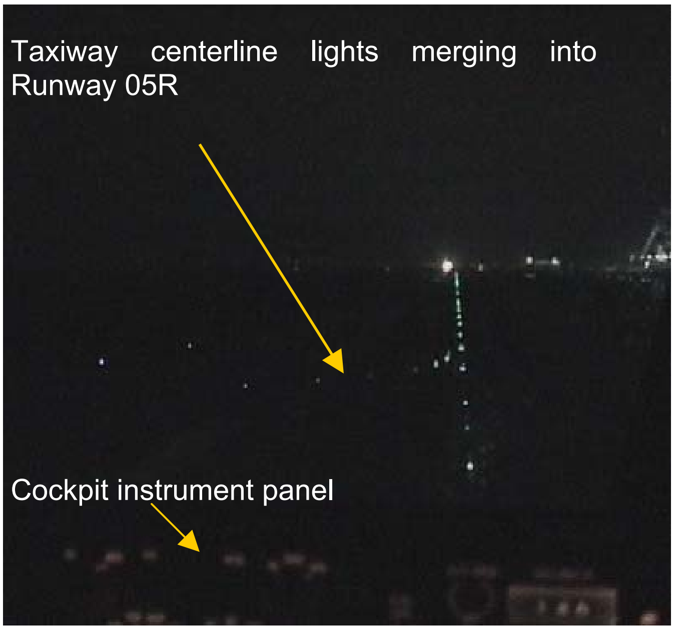

Figure 1.16-2 Taxiway centerline lights merged onto Runway 05R from Taxiway N2 (field of view from Boeing 747-400 cockpit-captain side)

Additional Observations:

(a) The ILS localizer needle on both Primary Flight Display (PFD) indicated full left deflection;
(b) the rising runway symbol on both PFD was off center and shifted to the left of the display;
(c) the glide slope indicator showed one dot high on the left PFD and one dot low on the right PFD;
(d) the Navigation Display (ND) at the 10 NM range showed a small map error;
(e) there was no change (no map shift) on the Flight Management Computer (FMC) latitude and longitude when Takeoff/Go-Around (TOGA) button was activated;
(f) runway lights on Runway 05L were difficult to see at intensity level 1 and 2 set by CKS Tower. (Runway 05L runway edge lights, touchdown zone lights and centerline lights have five intensity level steps. The lights were set at intensity 3 on the night of the accident);
(g) there was no marking to indicate that the runway was closed;
(h) lights on obstructions and obstacles on Runway 05R were not visible from the cockpit;
(i) runway marking "05" and "R" were visible from the flight deck when the aircraft was turning from Taxiway N1 onto Runway 05R; and
(j) after the aircraft had lined up, the runway marking "05" and "R" were no longer visible from the flight deck.

1.16.2 Emergency Exit Lights Test

Four emergency light battery packs were removed from the over-door fairings at Door 4L, 4R, 5L, and 5R. The fifth battery pack in this area was not recovered in the wreckage.

The battery packs were tested at the China Airlines workshop at CKS Airport to determine their state of charge following the accident. Each of the four packs was subjected to a 7 amp light load, as is used during functional testing of serviceable batteries. When each battery pack was connected to the load, the voltage across the terminals briefly rose to approximately 5.2 volts DC, and then dropped to less than 0.1 volts DC within 10 seconds. These readings are consistent with battery packs that are fully discharged. All four battery packs behaved the same way. Examination of the emergency lights, including the Passenger Emergency Evacuation Path Lighting System (PEEPLS) and the floor proximity emergency lighting system positioned between Doors 4 and 5 (Figure 1.16-3), revealed that all of the four battery packs were completely discharged.

Figure 1.16-3 Illuminated floor proximity lights in aft fuselage section during testing

A serviceable and fully charged battery was obtained and used to sequentially test the emergency lights in the aft fuselage. The results are listed in Table 1.16-1.

Table 1.16-1 Emergency light testing results

Location	Light	State
4L	Exit sign above and beside door	Off
	Floor light adjacent to attendant seat forward of door	Off
4R	Ceiling mounted emergency light in over door fairing	On
5L	Exit sign above and beside door	On
	Exit sign above aisle just forward of Door 5L	On
	Floor proximity lights on outboard side of left aisle	On from 4L to 5L
5R	Exit sign above and beside Door 5R	On
	Floor proximity lights on outboard side of right aisle	On aft of Row 57
	Exit sign above aisle just forward of Door 5R	On

1.16.3 Evacuation Slide/Raft Examination

The L1, L2 and R4 slides were sent to the manufacturer for inspection on February 15, 2001. During the examination, the investigation team found no abnormalities and each of the slides met the manufacturer's specifications. A further examination of the slides was conducted on November 9, 2001. The investigation team found soot and fire damage at the inlet of the aspirators of R4 slide. It revealed that the fire damage to the R4 slide was initiated from the inner surface of the slide. There were no soot and fire damage at the inlet of the aspirators on the L1, L2 and UDL slides.

1.16.4 Aft Fuselage Overhead Bins Tie Rod Testing

All the removed tie rods were sent to Aeronautical Research Laboratory of CSIST for metallurgy tests. The results of the tests showed that the tie rods broke because they were overstressed during impact.

1.16.5 Runway 05R Edge Light Wire Test

The Runway 05R edge light wires recovered at locations RE239 and RE240 were examined by the CSIST and by the ATSB to determine if there was evidence to indicate whether the edge lights were illuminated at the time of the accident.

The results of the wire examination using a Scanning Electron Microscope (SEM) at CSIST revealed that the wire strand end fracture surfaces from locations RE239 and RE240 were not formed by tension but caused by a shear force at the crimp. The clamp marks and shear surface features were noted under SEM examination of both wires. The insulation layer of RE239 was found broken by tension with some evidence of fire damage near the wire strand ends. The insulation layer of RE240 was burnt away about 16 cm from the strand ends with evidence of severe fire to the strands.

Three beads were found on the RE240-1 strand ends (Figure 1.16-4). According to the CSIST report, these beads indicate that local melting occurred, which was most likely the result of electrical arcing. The CSIST report also mentions that SEM/EDS analysis of the contaminative deposition on the strand ends indicates that the three beads were formed after all of the other strand ends had been contaminated. There was a "crater" on the surface of the melted bead of the RE240-1 wire end which was cleaner than the fracture surfaces of the strands without localized melting (Figure 1.16-5).

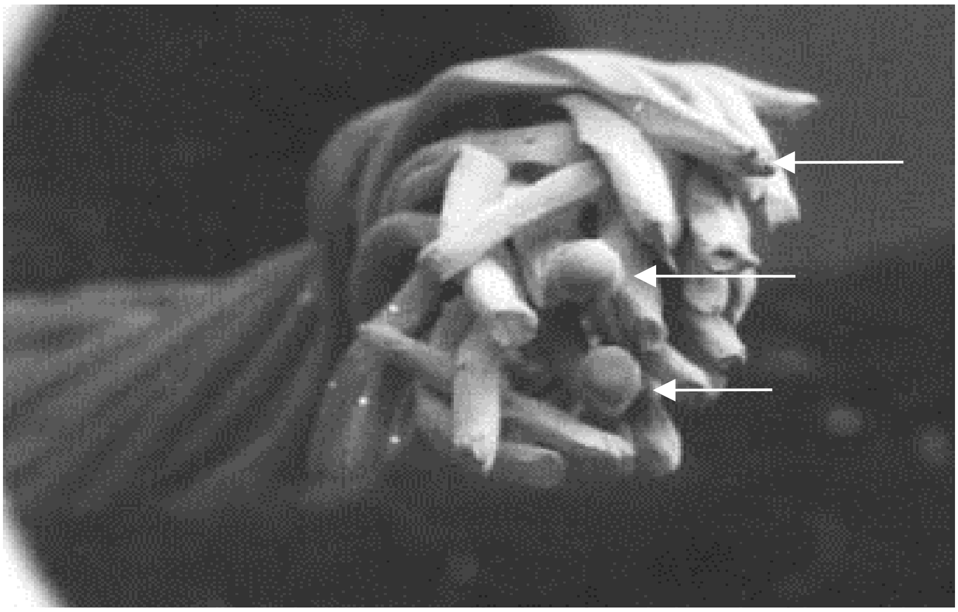

Figure 1.16-4 Three beads on the RE240-1

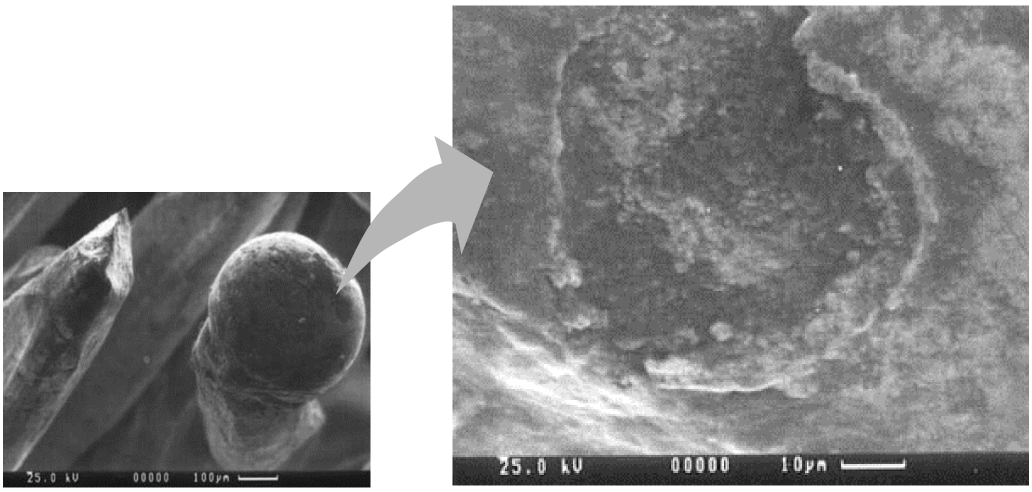

Figure 1.16-5 "crater" on the surface of the melted bead of the RE240-1 wire end

The RE239 test results from the ATSB revealed that the free ends of both wires from RE239 had been pulled out of the crimp. The ATSB report stated that there was characteristic segmented flattening of individual strands created by the crimping process, and each strand displayed features consistent with a "wire cutting process." The ATSB report stated that the insulation covering for RE239 had been fractured at a point about 11 cm from the end of the plug molding, and a correspondence existed between the insulation fracture surfaces of each wire. It also stated that it was apparent that a section of the insulation at the free end of the wire had moved toward the wire end by tension force applied to the wires. The ATSB report stated that there were chevron-like tears observed in the insulation of both wires of RE239 about 7.5 cm from the end of the plug molding. There was no evidence of arcing on RE239.

With respect to RE240, the ATSB report stated both wires had been pulled out of a crimped wire terminal fitting, similar to RE239. Several strands of both wires had been affected by localized melting, consistent with an intense heat source, e.g. “an electrical discharge” (Figure 1.16-6). The report also mentioned that the insulation had been lost from the majority of the wires by “some unknown process.” The insulation was missing from the free ends of the wires to a point about 8 cm from the plug molding. The remaining insulation displayed no evidence of surface bubbling or charring. The ATSB report stated that the “most notable feature of the remaining insulation was the acute angle created at the insulation end. It is apparent that insulation to this point had been affected by fire and that the acute angle at the ends represents a boundary effect created by the plug end being immersed in a liquid or some stratified combustion process.”

The ATSB report identified localized melting indicative of electrical arcing at the RE240 wire strand ends and about 9.5 cm from the end of the plug moulding, near the remnants of the insulation (Figure 1.16-7), but there was no arcing (melting) evidence found on the wire strands of RE239.

Figure 1.16-6 RE240-1, some of the melting beads formed at wire ends.

Figure 1.16-7 RE240-1, localized melting near the boundary of insulation that was lost.

Both reports indicated that the timing of the arcing occurrence found on RE240 could not be determined by the tests.

For further verification about how electrical arcing would produce metal globules on the wire end, the Safety Council arranged and ran tests with same type of runway edge light under the same electrical load. The tests were conducted on July 20, 2001, at the laboratory of CSIST. The results of the tests indicated that the globules on wire RE240-1 could be produced either when the wire was separated from a power source, or when the broken wire strands momentarily contacted metal to ground when power was available.

1.16.6 Cockpit Field of View Model

CM-2 and CM-3 stated in interview that, because of the rain on the windshield, they were unable to clearly see through the area not swept by the windscreen wipers. Upon the request by the Safety Council, Boeing conducted a Field of View model that presented the visible areas from the Boeing 747-400 cockpit through the wiper area. The study was based on the following assumptions:

1. Weight and balance of the aircraft unknown;
2. Windshield wiper obscuration not shown;
3. No head movement taken into account;
4. Straight vision calculated, (refraction/angular deviation not accounted for);
5. Taxiway and runway assumed flat;
6. Nose strut/tire inflation status unknown, presumed nominal;
7. Use theoretical Computer Aided Design (CAD) Model for wiper geometry;
8. AB post padding[21] obscuration not included (small part of pilot's left inboard field);
9. Distance circles based on pilot's eye (which is 21 inches outboard from centerline of the aircraft).

The study represented the view from a single point. The actual field of view will be better when the pilot moves his head. Figure 1.16-8 and 1.16-9 show the ground visibility from the field of view study.

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[21] The AB post is the center post between the captain's and first officer's #1 windows. The "padding" is a decorative cover over the window post structure. The covering (padding) is used on 747-400 aircraft. From the captain's eye reference position, the part does not obscure the view from the captain's #1 window, but does cover a portion (estimated to be 1/16 of an inch) of the inboard portion of the first officer's #1 window.

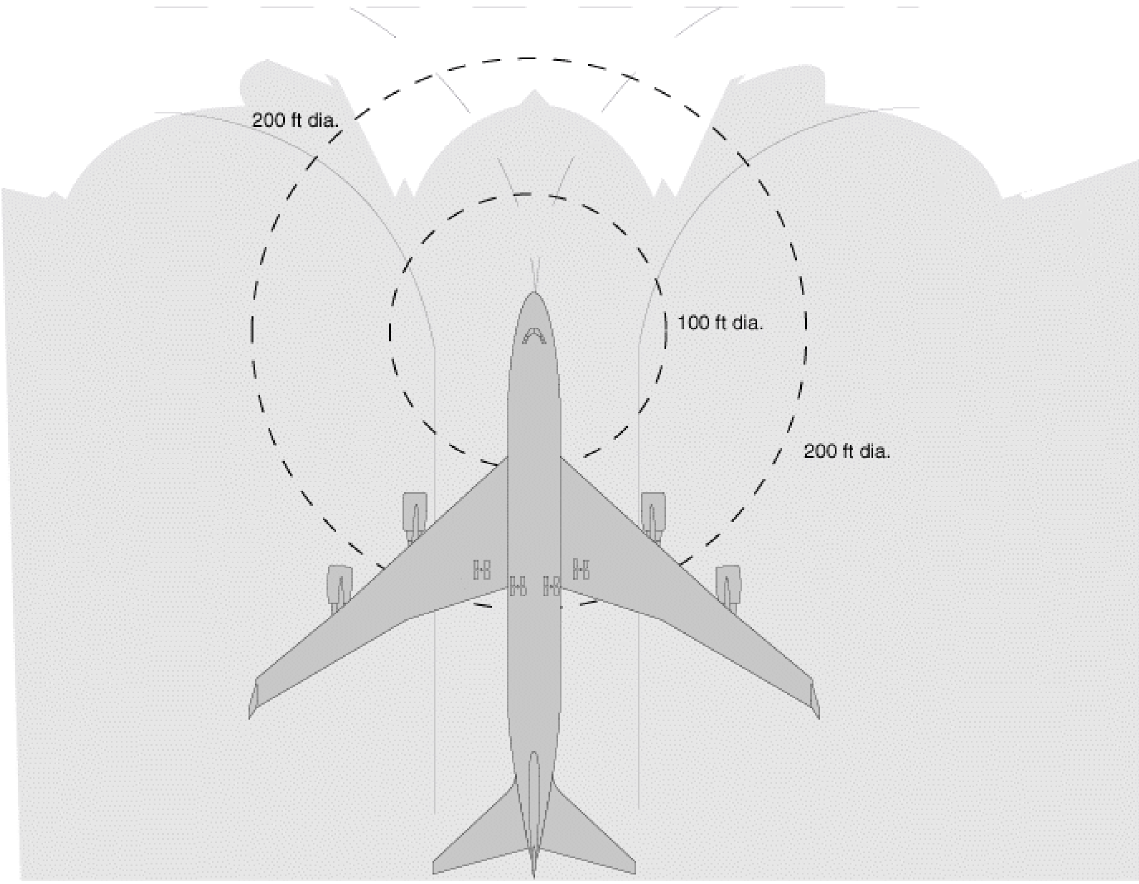

Figure 1.16-8 The ground visibility for Captain and First Officer's eye reference points – wiper area only. The gray area represents the area not visible from Captain and First Officer's eye reference points. The concentric circles do not represent the perceptual range of the human eye.

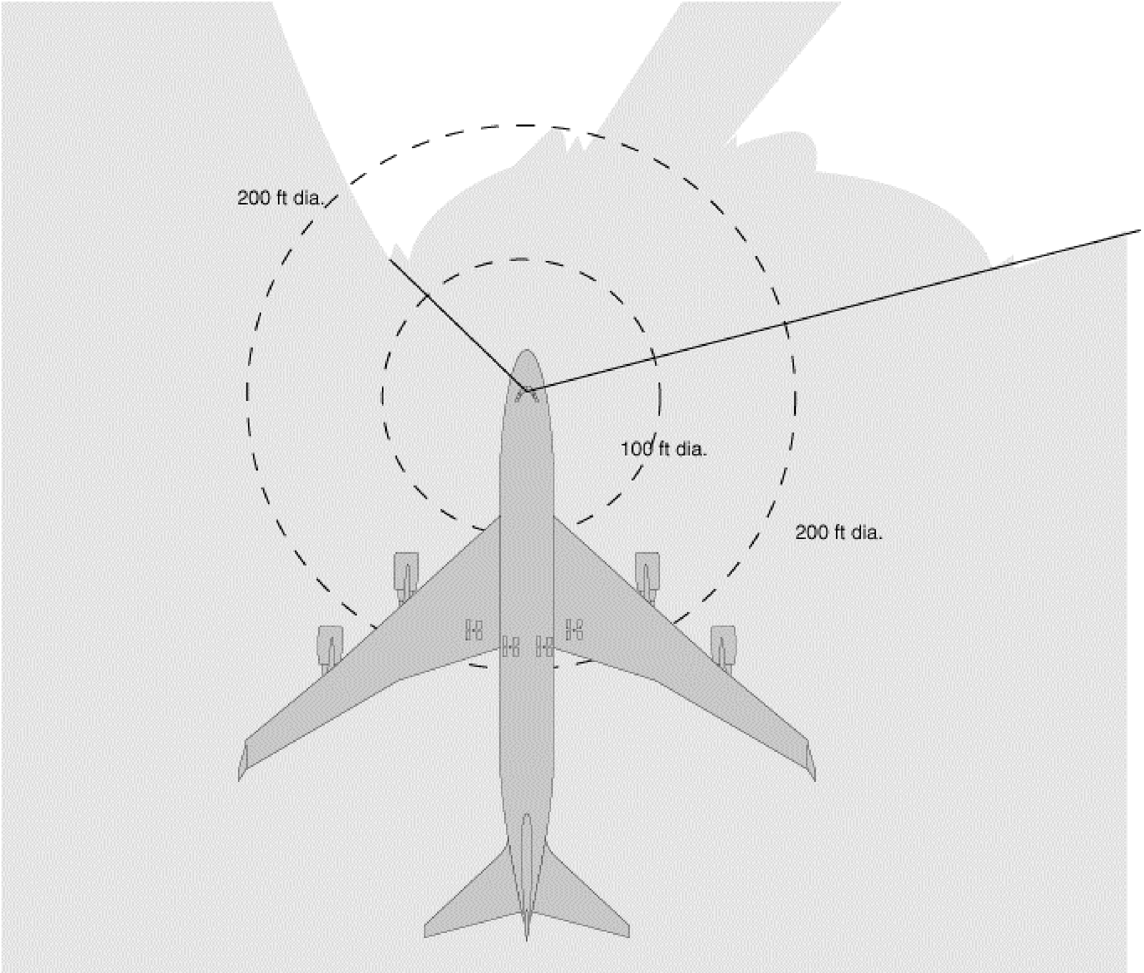

Figure 1.16-9 The ground visibility for Captain's eye reference points – wiper area only. The gray area represents the area not visible from Captain's eye reference points. The concentric circles do not represent the perceptual range of the human eye.

1.16.7 Data Reduction of Raw RVR Information

The automated weather observation system for CKS Airport is called the Airport Weather Advisor (AWA). The AWA comprises anemometers, forward scatter sensors (RVR sensors), ceilometers, barometers and temperature/dew point sensors. The RVR sensors were located at the approach ends of Runways 05L/23R and 06/24, and at the midpoint of Runway 05L/23R.

RVRs are obtained from the raw data (Extinction Coefficient, Runway Light Setting and Background Light) by the AWA but only the latter were archived. The following table was calculated by the manufacturer from the raw data of RVR sensors after the accident.

Table 1.16-2 Visibilities of CKS Airport Runways 05

Time	Runway 05 Visibility[22] (meter)	Mid-Point 05/23 Visibility (meter)
2312	518	475
2313	504	604
2314	923	420
2315	450	236
2316	360	168
2317	444	192

1.17 Organizational and Management Information

1.17.1 Organization and Management of CAAS

1.17.1.1 Roles and Responsibility

The Civil Aviation Authority of Singapore (CAAS) is a statutory board under the Ministry of Communications and Information Technology (MCIT) of Singapore. CAAS is the body responsible for the safety regulation of civil aviation in Singapore, and also for Singapore's aircraft operating outside of Singapore.

CAAS aviation safety regulatory role and responsibilities cover the following:

(a) Regulating the operations and airworthiness of Singapore registered aircraft;
(b) regulating the aerospace industry in Singapore;
(c) licensing of flight personnel and maintenance engineers; and
(d) advising Government on civil aviation matters.

[22] The visibilities were 1-minute mean values.

1.17.1.2 Regulating the Operations and Airworthiness of Singapore-Registered Aircraft

1.17.1.2.1 Air Operator Certificate

CAAS issues an Air Operator Certificate (AOC) to Singapore operators for aircraft to be operated for the purpose of public transport in Singapore. CAAS established AOC requirements in accordance with ICAO Annex 6 – Operation of Aircraft and published the Air Operator Certificate Requirements (AOCR).

1.17.1.2.2 Operations Supervision

All aspects of aircraft operation, including the management structure, adequacy of ground and flight crews and arrangements for their training, premises, equipment and aircraft are assessed in relation to the scale, scope and circumstances of the operations. The operator is required to comply with, among other requirements, ICAO Annex 6 SARPs.

CAAS has a regular plan for inspection visits to each operating base (aircraft ramp inspections and hangar maintenance inspections) and the operator's line stations. These checks are conducted to assess the suitability of an operator's organization, base facilities, overall standard of operation and level of compliance with regulatory and operations manual requirements.

Flight inspections are also carried out. The purpose of these checks is to assess the adequacy of the procedures and facilities provided by the operators to enable the crews to perform their duties both in the air and on the ground; to examine the standard of flight deck management and operations by the crews; and to assess the level of compliance with regulatory and operations manual requirements. The CAAS also observes tests given by CAAS authorized examiners during the crew training.

1.17.1.3 Engineering and Maintenance Support

CAAS also assesses the operator's arrangements for engineering and maintenance support for the number, type and complexity of the aircraft and the area and type of operations before issuing or re-issuing an Air Operator Certificate.

CAAS performs regular safety oversight of the operators and their maintenance organization to ensure that aircraft are airworthy for flight and are operated safely in accordance with ICAO and Singapore airworthiness requirements. Regular inspection visits and audits are conducted on the operator, maintenance organization and line stations.

1.17.2 Accident Investigation Roles and Responsibilities

1.17.2.1 Relationship Between Singapore Government and SIA

SIA is a public company registered in Singapore. According to their financial report of the year 2000, 57 percent of the SIA share was owned by Tamasek Group, which is a Singapore government owned holding company. Among the 11 board members, other than the Chairman of the Board and the Chief Executive Officer, four board members were Singapore government officials.

1.17.2.2 MCIT Accident Investigations

In addition to being the regulatory authority of transportation, the MCIT is also responsible for the investigation of accidents that occur in Singapore and outside of Singapore involving Singapore registered aircraft. CAAS operations and airworthiness inspectors, as well as managers, who develop and enforce the CAAS regulations and provide safety oversight of Singapore civil aviation are assigned to the MCIT teams that conduct the investigations.

1.17.2.3 Independent Investigation Authority

Paragraph 5.4 in ICAO Annex 13 specifies, in part, "The accident investigation authority shall have independence in the conduct of the investigation and have unrestricted authority over its conduct, consistent with this Annex." Paragraph 5.4.1 in ICAO Annex 13 recommended that, "Any judicial or administrative proceedings to apportion blame or liability should be separate from any investigation conducted under the provisions of this Annex."

In order to achieve the independence of investigations, many States have formed agencies that are fully independent of the agency (Ministry) that regulates and provides regulation and safety oversight of aviation. States that currently have established independent aviation investigation authorities include, Australia, Canada, The Commonwealth of Independent States (representing 12 States, including Russia), Finland, Korea, The Netherlands, New Zealand, Sweden, ROC, United Kingdom, and the United States.

Further, on November 21, 1994, the Council of the European Union (EU) adopted a directive that all EU Member States would ensure, within 2 years, that aviation accident and serious incident investigations were conducted or supervised by a permanent body or entity that is functionally independent of the national aviation authorities responsible for regulation and oversight of the aviation system. According to EU officials, all 15 Member States have complied with this directive, or are moving toward full compliance by establishing independent investigation bodies.

The U.S. Congress stated in its legislation that established the National Transportation Safety Board in 1974:

> *"Proper conduct of the responsibilities assigned to the Board [NTSB] requires vigorous investigation of accidents involving transportation modes regulated by other agencies of Government; and calls for the making of conclusions and recommendations that may be critical of or adverse to any such agency or its officials. No Federal agency can properly perform such functions unless it is totally separate and independent from any other department, bureau, commission, or agency of the United States."*

With regard to the need for independence of transportation accident investigations, in a paper presented at the European Transport Safety Council meeting in Brussels[23], Pieter van Vollenhoven stated, in part:

> *"In some cases, to ensure 'independence' of an investigation, the government appointed a special committee, chaired by an independent person, such as a judge. But, the committee was usually made up of government inspectors, or people working for them. After all, they had the expertise that was needed. And society usually accepted this procedure, because, as I have already pointed out, government and safety were regarded as two sides of the same coin. What is more, it was often the only way possible of carrying out an investigation, apart from calling in a private agency or university. It was not until much later that the public began to question the significance or worth of such investigations. For, if the intention was to learn from them, and if so many conflicting interests were involved, they had to meet one very basic condition. They had to be carried out independently of all interests but one. And that one interest was safety. There could not be even the slightest suggestion that any other interest influenced the findings of the investigation, or the committee's recommendations.*
>
> *Increasingly, people began to realize that government inspectors were not independent. After all, they were closely involved in drafting regulations, and monitoring compliance. They were, in fact, both judge and jury."*

Mr. Van Vollenhoven also stated in his paper that,

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[23] Independent Accident Investigation: Every Citizen's Right, Society's Duty," Pieter van Vollenhoven, Chairman of the International Transportation Safety Association, Brussels, Belgium, January 23, 2001.

"…a permanent independent organization not only guarantees the independence of the investigations. It can also ensure that follow-up is given to its recommendations. And, since prevention is better than a cure, it can carry out the incident studies."

1.17.3 SIA Organization-Flight Operations Division

Flight Operations is one of the eight Divisions of Singapore Airlines Limited, the main company within the SIA Corporate Group. The other seven Divisions are Treasury, Finance, Corporate Affairs, Cabin Crew, Personnel, Engineering, and Commercial.

The Flight Operations Division is headed by a Senior Vice President (SVP) and is divided into several departments and sections in accordance with the Flight Administration Manual. The SVP Flight Operations stated in interview that the prime objective of Flight Operations and throughout the company is safety and efficiency.

The main departments within Flight Operations are Line Operations, Flight Crew Training, Safety, Security and Environment, Technical and Flight Control Center. All departments within SIA Flight Operations are managed by senior SIA pilots.

1.17.3.1 Line Operations

The Acting Divisional Vice President (Line Operations) is responsible for line management issues. There are four aircraft types in the SIA fleet and each type is managed by a Chief Pilot. The four Chief Pilots manage and oversee the day-to-day operation of their respective aircraft fleet.

The Line Operations Department is responsible for:

- all technical and operational matters related to line operations of the company's aircraft fleets;
- compliance with all Singapore and International regulations pertaining to line operations;
- liaison with the aircraft manufacturers on operational matters;
- the performance, efficiency, conduct and discipline of all line pilots;
- efficient assignment of pilots on all fleets;
- welfare of all staff in the Department;
- validity and currency of all operational manuals and documents;
- flight crews compliance with the procedures in accordance with the Flight Administration Manual and Operations Manual;
- modernization of existing and crew management systems;

- formulation of procedures and line operations policy; and
- other duties assigned by the SVP Flight Operations.

SIA uses the Flight Operations Manual (FOM) provided by the aircraft manufacturers; therefore, the Boeing 747-400 manual is the basis for the SIA FOM. SIA Line Management develops only the Operational and Fuel Policy procedures. The Normal Procedures and Checklists are customized to incorporate SIA changes. The SIA generated procedures are submitted to CAAS for approval.

The line management personnel also monitor and ensure compliance with the AOCR by:

(a) Checking the Crew Operating Pattern (COP) for compliance with the approved flight time limitation scheme, e.g., maximum permitted duty and minimum rest periods;
(b) using computerized check-in system (Flight Reporting and Messaging System [FRAMS]) for flight crews to ensure validity of flight crew licenses, Base Checks, Line Checks and Safety Equipment and Procedures Training Competency Certificate and recent experience requirements before operating any flight;
(c) reviewing flight records to ensure compliance; and
(d) conducting all proficiency tests required by the AOCR (Base Checks, Instrument Rating Checks, Line Checks, CAT III/Low Visibility validation etc.) on each crewmember to ensure their competency.

1.17.3.2 Training Department

The Flight Operations Training Department is responsible to the company through the Divisional Vice President (Training) and the SVP Flight Operations for:

- all staff training and development in the division;
- managing the Flight Crew Training Center which is responsible for all pilot conversion to license endorsement;
- the conduct of all proficiency testing (base checks, instrument ratings and line checks);
- the fidelity, approval and maintenance of the flight simulators;
- all safety equipment training, certification and continued proficiency for all pilots and cabin crews;
- selection, appointment and standards of all instructors (flight and ground training);
- overall welfare of the SIA Training Center staff;
- formulation of divisional policy on operations, training and other matters; and
- other duties as assigned by the SVP Flight Operations.

The training department provides joint safety and emergency procedures training and ARM training for cabin crews. The training department also carries out command training for first officers selected for promotion to commanders and transitional training from piston engine aircraft to jet engine aircraft for those pilots who have graduated from ab-initio training with a minimum of 200 flying hours.

Selected training department personnel are also delegated by CAAS to carry out Authorized Flight Examiner responsibilities (Check Airmen) and to conduct ground school examinations on behalf of CAAS.

The Training Department conducts the Base Checks twice a year and the annual Instrument Rating Tests for all pilots in accordance with CAAS requirements.

The department provides the following pilot training:

(a) Aircraft Type Training;
(b) reactivation Training;
(c) recurrent Training;
(d) recency Training;
(e) reinforcement Training; and
(f) low Visibility Training.

Aircraft Type Rating Training (Conversion Training)

The normal aircraft type training comprises the following:

(a) Two to 3 weeks of Computer Based Training on aircraft systems, aircraft performance and safety and emergency procedures.
(b) Ten to 15 simulator sessions covering Normal and Abnormal procedures, including wind shear, CFIT, FANS, CAT 3, TCAS, Unusual Attitude Recovery and Takeoff Safety Training.
(c) Aircraft Base Training which includes engine-out approach, go-around and landing.
(d) At the end of the Ground/Simulator training phase, candidates will be required to pass the Aircraft Rating Flight Test, Instrument Rating and an initial line check before commencing route training for four to five weeks.
(e) At the end of route training, candidates will be required to pass a final line check prior to being cleared for line duties.

Reactivation Training

This training is conducted for pilots who are returning to an aircraft type they had flown previously or for familiarizing newly employed crewmembers to SIA operational procedures and policy. The course comprises an abbreviated version of the Aircraft Type Rating Training (Conversion Training).

Recurrent Training

The department also provides a recurrent training program for all pilots twice a year. The program consists of 6 lessons that include Line Oriented Flying Training (LOFT) scenarios to refresh pilots on significant supplementary Normal and Abnormal procedures not covered during the aircraft rating tests. The emphasis in the LOFT focuses on flight deck management, situational awareness, and leadership and resource management.

Recency Training

Recency Training is provided to pilots who have not operated an aircraft for more than 28 days. The Recency training can be carried out in an aircraft or in an approved simulator.

Reinforcement Training

The training department provides training for pilots who failed their proficiency tests and those who need extra training to address weaknesses.

Low Visibility Training

Low Visibility Training is given to pilots to qualify for CAT-III and Para-Visual Display operations. It covers topics such as ILS Critical Areas, lighting systems, runway and taxiway marking and the required equipment. Pilots are also required to view a video tape on low visibility operations. They also received takeoff and landing training in an approved Level 2 simulator. There was no low visibility taxi training.

1.17.3.3 Safety, Security and Environment Department

The Safety, Security and Environment Department (SSE) is administered by the Flight Operations Division. It is headed by the Vice President, Safety, Security, and Environment (VPSSE) who reports to the SVP of Flight Operations. The VPSSE may also report directly to the CEO on matters that he/she may deem necessary.

The SSE is responsible for flight safety, and when necessary, investigates major incidents and occurrences that arise from line operations. The SSE is also responsible for the safety and security of company premises in Singapore and all overseas stations throughout the SIA network. In addition, the Department investigates all ground incidents and accidents.

The SSE provides support services and training for flight safety (including cabin safety), handling of dangerous goods, ground safety (e.g. ramp, engineering), industrial and fire safety, ground and flight security, and environment protection issues. The department develops standards and procedures for training on safety equipment for technical and cabin crews. These procedures pertain to items including emergency egress, ditching, fire, security, and disruptive passengers. The department does not conduct audits, or promote any specific risk management philosophy. The SSE department does not formulate policies for flight operations because these are the responsibility of each fleet Chief Pilot.

The SSE department is responsible for the mandatory incident reporting system. On minor matters such as bird and lightening strikes, no further action is necessary; however, most operational matters are investigated and the SSE generally needs to refer to the related fleet management or other divisions such as engineering or cabin crews or marketing or the other support companies for further information verification or clarification. When the incident is considered major or substantive, the SSE may convene a full Incident Inquiry/Investigation committee. In such instances the person(s) involved and witnesses will be called to ascertain the cause of the incident and a report is then submitted to the appropriate management level and division for remedial action.

The company informs CAAS of all incidents and, when requested, the outcome of the investigations committee findings and the remedial actions taken. All incident reports are reviewed every two months by a SIA Air Safety Committee. A bi-monthly summary of incidents is published in the Flight Safety Review, an in-house safety magazine, for review and action. This committee, which is chaired by the SVP Flight Operations, consists of representatives from flight operations, cabin crews, engineering, and marketing. Committee members review the reports, and close cases as appropriate. The Committee may require further investigation if they deem that the investigative actions are incomplete or insufficient. The closed reports are then published and promulgated to all crewmembers and relevant staff in the company's Flight Safety Review magazine. The Flight Safety Review magazine also contains, on the back page, an anonymous reporting form to allow crewmembers to anonymously report any safety related occurrences.

The SSE also manages a confidential Flight Data Analysis Program (FDAP) which identifies occurrences when flight parameters are exceeded. A Committee comprising management and union pilots meet once a month to review and track exceedences that are recorded. The FDAP is conducted on aircraft that are equipped with a QAR for such monitoring. In SIA, 90 percent of all flights have QAR capability. If the program identifies a pilot with a history or tendency for such exceedences then he is spoken to privately by either the union representative on the Committee, if he is a member of the union, or by the VPSSE if he is not a union member.

The Fleet Management holds "Fleet Meetings" about twice a year to discuss operational matters. During such meetings, safety issues are highlighted and discussed as the needs demand. In addition, day-to-day safety issues are made known to crewmembers via FRAMS whenever departing from or arriving in Singapore. The FRAMS is an electronic system used by pilots to sign-in and off duty. It is also used as a medium to remind crewmembers of the status of their license validity, as well as to provide crewmembers with urgent operational information and other company matters, such as roster changes, latest documentation revisions, flight safety issues, as deemed necessary by management.

Interviews with senior SIA management pilots indicated that the Flight Operations Division currently does not have a dedicated unit for quality assurance and is working to establish a unit on Quality Assurance in the coming year. Among the systems being considered for adoption are the guidelines provided by the US Department of Transportation. As another safety enhancement, the company plans to implement a Confidential Human Factors Incident Reporting Program that encourages crewmembers to report human factor incidents.

1.17.3.4 Flight Control Center

The primary function of the SIA Flight Control Center (FCC) is to ensure that SIA services operate with the least possible disruption or delay. If services are disrupted or delayed, these services are rescheduled with the least possible inconvenience to passengers and at minimal cost consistent with safety, efficiency and service. This is achieved by conducting regular evaluations of route and operational information, such as the serviceability of navigation aids, curtailment of airport facilities, refueling facilities, meteorological warnings, crew duty and flight time limitations and other matters of immediate operational significance.

The Flight Control Center is responsible for the following decisions:

(a) Cancellation of flights;
(b) rescheduling flights due to weather, airport limitations, civil disturbances, crew duty time or sector limitations;
(c) over-flights due to weather, airport limitations, crew duty time or sector limitations; and
(d) other issues related to delay, aircraft diversions, re-routing, rescheduling and recalling of flights, re-allocation of aircraft, and repositioning of crews.

The center provides flight planning and associated dispatch services for flights operating out of Singapore, and for flights at line stations and planning flight re-routings as a result of tropical depressions, volcanic eruptions and airspace closures. This includes ensuring crew duty time and changes to crew operating patterns (as a result of flight delays or schedule disruptions) do not infringe any statutory requirements.

The center also ensures that manuals, documents and charts carried on board each aircraft are current.

In accordance with the SIA's Flight Administration Manual 2.1.2, to ensure effective operational decision-making, the FCC must be informed immediately by aircraft Commanders and SIA Station Managers if any event is likely to disrupt or delay scheduled or non-scheduled services. Information of this nature includes but is not limited to:

- Weather warnings;
- Airport closures or limitations; and
- Other information of possible delay or service disruption.

The FCC operates 24 hours and comprises about 94 staff members. There are five FCC teams each consisting of 15 to 20 members, depending on the time of shift. Larger teams man the center during peak daytime periods. Smaller teams man the FCC during off peak night shifts (generally defined as after midnight). Further, the senior FCC duty controller works a 12-hour shift with breaks for meals.

The FCC comprises 4 sections:

- Flight control;
- Flight services/planning;
- Crew scheduling; and
- Aircraft documentation.

In addition, interviews with staff from the SIA FCC indicated that FCC liaises closely with fleet, marketing and engineering divisions on the commercial and technical aspects of each major delay.

The FCC is the communication, information and coordinating arm of the company in general, and flight operations in particular. FCC maintains a 24 hours flight watch and flight following for all services operated by SIA and other airlines that have purchased such services. FCC also performs flight dispatch, and the rescheduling of pilot rosters. The Documentation Section within FCC provides centralized updating of all documents used for line operations, such as Aircraft Operations Manuals and Jeppesen Route charts. The department head is the Senior Manager, FCC (SMFCC).

1.17.4 Relevant Issues in Flight Operations

1.17.4.1 Crew Resource Management

The line operations/project Divisional Vice President is a senior management pilot who is responsible for Projects. In that capacity, he has oversight of the SIA Crew Resource Management (CRM, known as Aircrew Resource Management, ARM in SIA) training program. He was also the Chief Pilot of the B777 fleet. SIA developed its first CRM course, ARM 1, in 1984. This was followed by ARM 2 in 1987 and ARM 3 followed this in 1998.

Interviews with senior SIA management pilots and instructor pilots indicated that ARM 1 focuses on crew behavioral styles, effective communication and teamwork by emphasizing synergism to address potential problems in multi-cultural cockpits[24]. The course also emphasized individual values and personal relationships. ARM 2 presents information on pilot decision-making, including topics on group decision-making, consensus decision-making and autocratic decision-making. It also includes a segment on the importance of spouse support[25]. ARM 3 was designed to develop a commander's leadership capabilities with an emphasis on a commander's personal development and leadership qualities. Each ARM module is usually covered in three to four days.

According to the Divisional Vice President (Projects), the SIA ARM courses have not been updated to reflect the advances in CRM and human factors (HF) research. During interviews with SIA management pilots, the Flight Operations management has been considering the development of ARM 4. The proposed ARM 4 will focus on error management.

All ARM courses are conducted by an American Professor of Psychology outside of Singapore. A management pilot assists as a course facilitator. The courses are designed to cover concepts that crewmembers should apply on the line. Instructor Pilots look for application of these concepts during training and proficiency checking sessions on the flight simulator or the aircraft. They sometimes critique the crewmembers on the CRM issues during flight or simulator checks debriefings. Apart from these observations by the Instructors, the company currently has no formal mechanisms to evaluate if crewmembers have acquired such skills.

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[24] See also Karlins, M., Koh, F., McCully, L., & Chan, C. T. (1997). The aircrew behavioral compass: A descriptive model for categorizing and understanding the personal behavioral styles of pilots. In R. S. Jensen & L A. Rakovan (Eds.), Proceedings of the Ninth International Symposium on Aviation Psychology (pp. 1116-1119). Columbus, OH: Ohio State University Press.

[25] *Karlins, M., Koh, F., & McCully, L. (1989).* The spousal factor in pilot stress. *Aviation, Space and Environmental Medicine, 60, 1112-1115.*

1.17.4.2 The Role of Relief Crewmembers

The B747-400 aircraft was designed to be operated by two pilots (captain and first officer). Depending on the length of the sectors on a trip, additional pilots may be added to relieve the captain and first officer during long sectors. There are various crew complements that SIA aircraft may carry. For example, according to the SIA B747-400 Chief Pilot, the normal crew complement on the B747-400 is a two-member flight crew, which includes one captain and one first officer. Some B747-400 operations may require one captain and two first officers, or two captains and one first officer, or two captains and two first officers. These crewing combinations depend upon a number of factors such as crew flight time and duty limitations.

The SIA B747-400 Chief Pilot stated that the role of the relief crew is subject to the discretion of the designated aircraft commander for the trip. For example, the commander can ask the relief crewmember to stay in the cockpit during takeoff and landing. SIA had no clearly documented duties for relief crewmembers when they are not occupying a required pilot station. An interview with a senior company pilot indicated that the effective interaction and use of resources on the flight deck between relief crewmembers and the primary crew depend upon the individual aircraft commanders.

1.17.4.3 Briefing Package Preparation for Crew

In a contract agreement between EVA and SIA for SIA Taipei operations, EVA performs the ground handling service including modified dispatch functions. The contract states that EVA will furnish the SIA crews with an adequate briefing.

EVA personnel handle all computer flight plans and dispatch documentation for SIA flights departing from CKS Airport. The SQ006 pilots were provided with a standard pre-flight briefing package. This contained weather information, NOTAM (from CKS Flight Information Service), the company INTAM and Scandinavian Airways Systems (SAS) NOTAM.

The EVA personnel include both licensed dispatchers and non-certificated staff members. The licensed dispatchers prepare weather and aircraft performance information that is included in the pre-flight briefing package. The EVA personnel also provide dispatch information for SIA flight crews, which are prepared by the SIA FCC in Singapore. The licensed Flight Dispatchers check the documents to ensure compliance with SIA company policy before sending a dispatch release to its Operations Officer at CKS Airport. The Operations Officer then delivers the pre-flight briefing documentation to the flight crew.

The EVA dispatchers were trained using SIA's dispatch policies and procedures (P&P). The SIA FCC stated during an interview that the briefing service at Taipei was a "full verbal brief" provided by the dispatcher. Both the SIA flight crew and the EVA dispatch service stated that it was a self-briefing service with the dispatcher being available for questioning by the crew if required before departure.

The dispatching service contract did not specifically state whether a full verbal brief was required. Further, according to the SIA Taipei Station Brief (SIA Nightstop Information-TPE, 1 Mar 2000, TPE-2-2), the briefing is to be conducted at the aircraft side. The flight crew of SQ006 received the pre-flight briefing package in the corridor leading to the holding area at the aircraft's parking bay B5 on the evening of the accident at about 2153. CM-1 signed for the briefing package. The flight crew had no questions for the dispatcher. The EVA Airways Operations Officer stated that he highlighted (using a highlighter pen) the relevant and important information of the weather forecast and the official NOTAM on paper for the flight crew.

1.17.4.4 Aircraft Documentation

The FCC aircraft documentation section ensures that all SIA manuals and flight documentation are current and correct for the date of the flight. Each crew is issued a current set of charts and documentation before each departure from Singapore. This documentation comprises a complete set of current charts and manuals pertaining to the actual flight, destination station, and specified alternates. If there is an amendment or revision to a chart or manual during the course of a flight, both forms of the document amendment will be included in the package provided to the crew before departure. With reference to the flight concerned, the crew was issued with the current CKS aerodrome chart, which indicated the presence of Runway 05R and 05L.

1.17.4.5 SIA Taxi Procedures

The SIA B747-400 Flight Crew Training Manual provides information and recommendations on aircraft maneuvers and techniques. On page 8.26 of the manual, there is a section describing "Taxiing in Poor Visibility":

> *Bear in mind that, in very low RVR values, one would expect to see bright lights at a safe distance but not unlit or poorly lit obstacles, such as aircraft tails or wing tips. From certain angles, their navigation lights do not show up well. Since aircraft movement rates will be low in these conditions, taxi as slow as necessary for safety. Do not hesitate to request from ATC the positions of other taxiing aircraft or to ask for a " follow me" car.*
>
> *Use utmost care to taxi according to the issued clearance. That is, use the correct taxiway and runway. Switch on taxi/landing lights, even in daylight conditions, to make you more visible to other aircraft and vehicles.*

The SIA Flight Instructor Manual, page 5.8 - Line Training/Checks section requests instructors to teach pilots about the "taxi routing and situational and environmental awareness," but there are no detailed guidelines for taxiing in low visibility conditions.

There was no specific procedure for low visibility taxi described in the SIA B747-400 Operations Manual.

1.17.4.6 Out-Station Audits

When queried about the auditing of out station dispatch services, the FCC indicated that SIA crew through the Voyage Record system provides the primary source of quality assurance information on out station dispatch services. The SMFCC indicated that CAAS conducts regular audits of SIA ETOPS line out-stations. In particular, CAAS conducts quarterly audits of flight documentation provided by dispatch (flight plans, INTAMs, NOTAMs, briefing packages). This documentation is kept for 3 months. This is essentially a paper work audit. Non-ETOPS out stations, such as Taipei, are audited on an ad-hoc basis. The FCC indicated that it was not aware of any problems being reported by flight crews about the EVA dispatch service.

CAAS has an annual work plan and conducts regular audits/inspections on line stations. The target time interval to cover each station is at least once every three years. As for Taipei, CAAS conducted a flight operations inspection of the station on February 29, 2000 and an airworthiness audit on May 31, 2000.

At the time of the accident, SIA had been operating into CKS for more than 20 years. When queried about its evaluation of airport infrastructure to ensure compliance with international safety standards, such as ICAO Annex 14 SARPs, before operating into an airport for the first time, MCIT replied that SIA has procedures for evaluating a new station prior to commencing services. However, CAAS and SIA were unable to provide the Safety Council with any report of an inspection made before SIA first flight into CKS Airport or inspections subsequent to the first operation to it. In addition, MCIT staff stated that CAAS procedure for approving an operator's new station was in line with procedures of other major authorities. MCIT staff stated that they believed that the assessment of new stations by major authorities did not include assessment of the airport infrastructure to determine if it meets ICAO Annex 14 SAPRs. They said that compliance with Annex 14 should be monitored by the state aviation authority responsible for the airport concerned.

1.17.4.7 Flight Delays

Interviews with management pilots, instructor pilots, the accident flight crew, and FCC staff indicated that, in the case of poor weather at the departure aerodrome, the aircraft commander can decide on whether to delay a flight or not. Management pilots and FCC staff commented that the aircraft commander has the option to call FCC directly for consultations about the weather. The FCC can also transfer the commander to a management pilot if there is a technical issue to be discussed. If the intentions of an aircraft commander are unclear with reference to a possible flight delay, FCC may ask the commander to confirm his intentions.

When asked about the FCC procedure for flight cancellation, the B747-400 Chief Pilot stated that if a flight delay was to be considered excessive, FCC will consult engineering and marketing. Fleet provides very little input into canceling a flight. However, fleet is informed if the reason for the delay involves aircraft unserviceability.

The aircraft commander did not contact FCC or fleet Chief Pilot prior to departure on October 31, 2000 nor was he required to do so.

1.17.5 EVA Airways Flight Control Department

There are two divisions in the EVA Flight Control Department (FCD); one is Flight Dispatch, and the other is Flight Watch. The function of Flight Dispatch is to ensure that all flights are following CAA regulations and the company's policies, and operate in a safe, economic, and efficient way. The function of Flight Watch is to monitor all EVA flights and ensure that any relevant changed information is passed to the aircraft, and to respond to crew requests for information or assistance. The Flight Watch service is only provided to EVA's flights. EVA FCD does not follow the status of SIA flights.

The responsibilities of EVA FCD on handling SIA flights are mainly on the Flight Dispatch and Freighter Load Sheet operations. The detailed information regarding EVA's handling of SIA operations in Taipei is listed in the Operation and Training manual provided by the Principal Dispatcher of FCD.

From interviews with EVA FCD staff, EVA FCD usually communicates with SIA through telex. If there is a special condition, such as a need to use Island Reserve Fuel due to weather, FCD will contact FCC via telephone for SIA's approval.

EVA has a Typhoon Procedure in their operations manual. This Typhoon Procedure is only for EVA's flights; it does not apply to SIA's operations. During interviews, the FCD managers and dispatchers commented that they were not aware of SIA's Typhoon Procedures and they did not know the contents of SIA's Typhoon Procedures. The Principal Dispatcher also stated that SIA did not require EVA to report any typhoon information to the FCC in any form. He indicated in the interview that when SIA came to Taiwan in 1995 to train EVA's dispatchers for SIA's operations, the SIA instructor did not mention anything about typhoon procedures. Moreover, the SIA typhoon procedures were not included in the training material provided to the SIA responsible ground-handling agent in Taipei nor in the service contract.

At 1821, on October 31, 2000, EVA FCD telexed to all the airlines that EVA represents and services at TPE (including SIA) the typhoon warning information. This information has been provided in the telex dated 311021 (October 31, 2000).

The EVA Operations Control Section (OCS) at CKS Airport telexed SIA with the accident information at 2325, October 31, 2000 (Telex dated 311525).

The Principal Dispatcher and the dispatcher on duty on the night of the accident stated that SIA did not communicate with the FCD regarding the typhoon information or typhoon precaution on October 31, 2000 [note: during interview with the SMFCC, he stated that SIA FCC informed all affected stations including TPE by telex of typhoon condition II at 2155].

1.17.6 SIA Taipei Station

According to an interview with the SIA Taipei Station Manager, the main responsibility of the SIA station manager is to ensure all flights depart punctually and safely. On incoming flights, the station ensures that passengers get their baggage. In addition, the SIA Taipei Station is responsible for all the crew's accommodations, welfare, sickness, or other issues. The Taipei Station will report any emergencies and problems with crew flight time limitations that may result in crewmember replacements to SIA in Singapore.

There is a total of 86 staff members in the SIA Taipei Station. All passenger handling, cargo loading, catering service, and gate checking are handled by SIA personnel. The flight operation aspects which include flight dispatch, flight planning, fuel, and freighter loading, are handled by EVA Airways. Engineering and maintenance are handled by China Airlines.

The SIA Taipei Station needs to report all SIA flight movements through their station to SIA FCC. The "flight movement telex" includes information such as aircraft registration and the flight arrival and departure times. The communication is usually done by phone, telex, or email.

During interviews, the SIA Taipei Station Manager stated that when the Taipei Station received the typhoon information, the station checked all the hotels for room availability. The station also planed for securing and parking the aircraft, and loading as much fuel as possible to increase aircraft weight to maximize the aircraft's ability to withstand strong winds.

During interviews, the SIA Taipei Station Manager commented that the Taipei Station generally does not inform the flight crew about the typhoon condition. The SIA Taipei Station Manager also mentioned that the flight crew would be informed of the typhoon status by EVA during the pre-flight briefing. If the airport is closed due to weather conditions, the Station Manager will call the crews to tell them not to come to the airport. All flight operations logistics are the ground handling agent's (EVA's) responsibility. The SIA Taipei Station is responsible for passengers and cargo. When the SIA Taipei Station received notification of the typhoon condition on October 31, 2000, from the FCC, the station's action was to check the hotel availability. The SIA Taipei Station did not inform the flight crew of the typhoon status.

1.17.7 Typhoon Procedures

According to the SIA Flight Administration Manual section 3.41.1, the SIA typhoon warnings are categorized into four conditions. A specific typhoon condition is declared by the Flight Control Center after taking into account information from the affected station. The out station and Singapore meteorology office normally inform FCC if a typhoon is approaching a SIA station. FCC will then inform all affected stations by telex of the typhoon condition.

The typhoon conditions are defined as follows:

Condition I--Typhoon within 48 hours and deemed a potential threat to a station.

Condition II--Typhoon within 24 hours of a station.

Condition III--Typhoon within 12 hours of a station or imminent.

Condition IV--Winds have abated after passage or near passage of a typhoon. The onset of Condition IV can be taken as effective termination of typhoon conditions.

According to the Typhoon Warning issued by the Taipei Aeronautical Meteorological Center on October 31, 2100, the civil airports warning status at TPE airport was W24 (typhoon within 24 hours of the station). This would constitute a Condition II typhoon situation for SIA FCC.

The Condition II typhoon procedures in SIA's Flight Administration Manual relevant to this accident are as follows:

- *The responsible agent should ensure that relevant amendments and changes, whether favorable or adverse, are passed immediately to the FCC as they become available;*
- *The responsible agent should ensure that the Commander of any aircraft on the ground is fully and immediately informed of the situation;*

- *FCC will inform the relevant fleet Chief Pilot(s), Singapore station or Departure station, Destination station, Diversion station, Senior Manager Ground Services, Manager Schedules and SIA Engineering Co. that Condition II exists; and*
- *The Commander of a flight to an affected station is to be briefed on all available information regarding the typhoon, including ground handling plan at destination station and diversion plan. The briefing should be given before the Commander reports for duty. Where necessary, he shall consult FCC on all matters pertaining to the flight. In offering assistance, FCC must take into account Marketing and Engineering considerations.*

A Condition II typhoon warning is not sufficient to cancel a flight as long as the ambient conditions at the station are within the limits specified by the type specific (B747-400) SIA Flight Operations manual.

FCC stated that the standard means for communicating with out stations is by telex. Telephone contact will only be initiated by FCC if there is an urgent problem. The FCC telexed the Taipei SIA Station manager for typhoon Condition I at 1839 on the evening of the accident. EVA FCD was not informed by FCC of SIA's typhoon Condition I.

At 2155, all parties (including Taipei station and EVA FCD) were informed by telex of the typhoon Condition II. [When a typhoon telex is distributed, it does not necessarily mean that certain parties will be able to immediately view the information.].

The SIA FAM 3.41.1.6 stated that all communications pertaining to typhoon procedures must be followed by telexes addressed URGENT and MUST be acknowledged. In this case, FCC did not receive any responses from the affected stations after the Condition II telexes were sent. According to the FCC, an acknowledgement or response is not required from a station unless they are unprepared for the typhoon. On the night of the accident, FCC did not receive an immediate response from Taipei, nor were they expecting an immediate response.

After the accident, Condition III was declared by FCC at 0159 Nov 1, 2000.

During interviews, the SIA B747-400 Chief Pilot stated that the fleet does not actively involve itself in the decision-making of the crew after a typhoon declaration. The aircraft commander makes the operational decisions pertaining to typhoons of all classifications; however, the option to consult FCC and/or the fleet Chief Pilot is available to the commander. The commander may delay a flight if unsure about the safety of the flight; however, flight cancellation is a commercial issue, which is decided by the fleet Chief Pilot, marketing, and engineering.

With reference to poor weather situations, the Chief Pilot stated that he left it to the aircraft commander to decide on the weather conditions being within the limits specified by SIA. If the operational situation contains uncertainty or ambiguity with reference to the severity of the weather, the Chief Pilot commented that the aircraft commander might consider delaying the flight to see how the weather evolved. Further, the Chief Pilot commented that cancellation is the last resort. If the weather exceeds the limitations stipulated by SIA, FCC, marketing and the fleet Chief Pilot will make the decision concerning flight cancellation.

1.17.8 Voyage Record

According to SIA Flight Administration Manual 3.28.1, a voyage record will be completed for every flight on the voyage record form. The commander will be responsible for the accuracy of the information in the voyage record.

When a delay occurs, circumstances giving rise to such delays must be entered in the voyage record, with sufficient relevant details for the causes to be clearly identified, such as details regarding weather, ATC, technical, ground handling, and Custom, Immigration and Quarantine (CIQ).

According to the interviews with SIA pilots, there was a requirement for aircraft commanders to submit a report if any delay exceeds 3 minutes. Generally, captains were not questioned further as to why the flight was delayed when satisfactory reasons were provided.

1.17.9 Organization of CAA

As shown in Figure 1.17-1, CAA of ROC was headed by the Director-General assisted by two Deputy Directors-Generals.

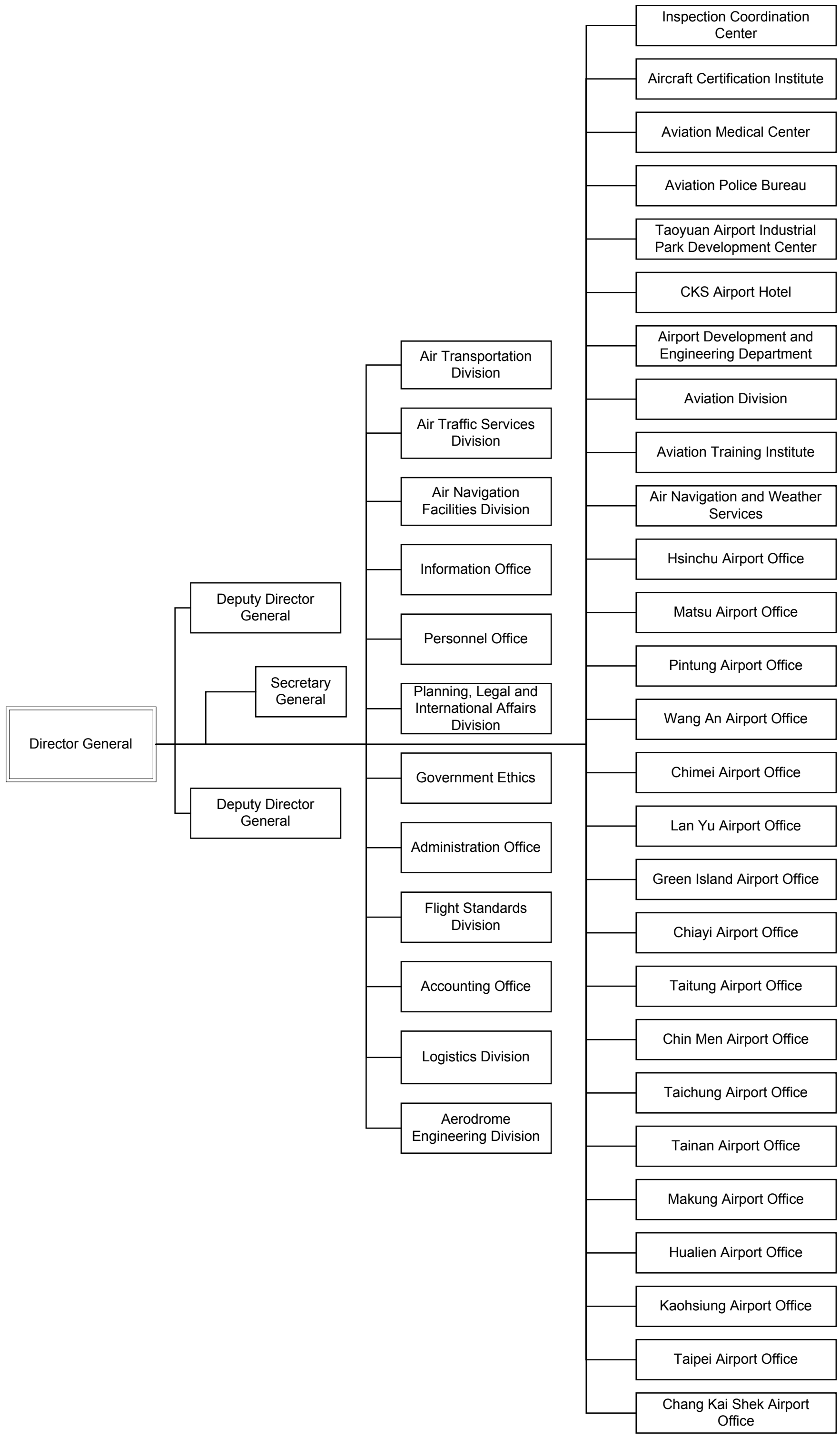

Figure 1.17-1 Organization of CAA[26]

[26] The Aerodrome Engineering Division later on was revised into Aerodrome Division by CAA.

The CAA was divided into the headquarter divisions and the field divisions. The work of the headquarter divisions were mainly the rule making and supervision functions (such as policy making, external communicating, etc.) of the field divisions focus on the implementation and services (such as airport facilities maintenance). Based on their individual functions, the headquarter divisions take responsibility for supervising the field divisions, such as: Flight Standards Division supervises the area in Flight Operations and Fire Fighting and Rescue operations of the airports, etc., Air Transport Division supervises the airport operations and coordinates with Airport Police, Air Navigation Facility Division supervises the ANWS and all other airport's NAVAID facilities. Aerodrome Division supervises the Maintenance and Engineering Section and airport construction etc. There were designated personnel in all headquarter divisions in charge of planning and coordination of all business concerned, each field division also has the point of contact for the same purpose.

1.17.10 Planning, Legal and International Affairs Division

According to the "Job Functions of the CAA of MOTC," legal duties which are delegated to the Planning, Legal and International Affairs Division (PLIAD), are stipulated in Items 4, 7, and 8 of Article 5 as follows:

Article 5

Item 4 *Research, consultation, co-reviewing and handling of business related with international regulations and contracts.*

Item 7 *Legalization, promulgation and compilation of civil aviation regulations.*

Item 8 *Assistance and handling of CAA's legal-related business.*

Regulations derived from Civil Aviation Law were established, modified and updated based on each individual division's needs (e.g. Flight Standards Division stipulates the aircraft flight operation regulations). The technical draft, following the due process of public hearings and review, was then given to the PLIAD for the completion of its final legalization procedure. The PLIAD thus facilitates the legalization of regulations initiated by each responsible division of the CAA. Each individual division of the CAA was responsible for making the regulations within its jurisdiction. All new regulations must be approved by the MOTC.

CAA's knowledge of most updated civil aviation related laws and regulations were impaired by its absence from participation in major international organizations, including ICAO. Limited access to certain civil aviation resources also causes some problems. Regulations originating with the USA's FAA, enacted by one division, may conflict with regulations derived from the JAA of EU, enacted by the other division. In some cases, the shortage of resources leads to difficulty in the implementation of some rules and regulations, in a timely fashion.

1.17.11 The Aerodrome Division

The Aerodrome Division (AD) was responsible for stipulating technical standards for the design of airfield facilities such as taxiways and runways. This includes specifications on the marking of taxiways and runways. CAA generally uses ICAO SARPs, although it adopts the FAA specifications in some areas.

The AD has previously compiled a manual on airport design standards in 1987. Prior to the SQ006 accident, the Division had commenced reviewing the aerodrome design specifications and standards for the development of a new ROC standard that clearly reflects the compliance with international standards; the new manual had not been completed at the time of the accident.

CAA headquarters undertakes civil engineering work that costs between 50 million and 100 million NT dollars (equivalent to 1.4 million to 2.8 million US dollars). The AD may use outside consultants to design airfield facilities, such as runways, taxiways and passenger terminal buildings. (For example, AD engaged a company called AirPlan Consultancy to design the airport master plan.)

1.17.12 The Air Navigation and Weather Services

The ANWS was responsible for providing flight information, ATC, aeronautical telecommunication and aeronautical meteorological services. The ANWS also manages the control towers, Flight Information Center (i.e., aeronautical information service) and meteorological service of airports in Taiwan including CKS.

The ANWS was responsible for the runway and taxiway lighting system as well as airfield signs. It has a maintenance unit in CKS Airport. This maintenance unit was responsible for checking and replacing the runway / taxiway lights and signage. It also maintains the lighting control system and Constant Current Regulator (CCR) power supply system

1.17.13 CKS Airport Management

CKS Airport Management was responsible for the day-to-day operation of the airport facilities. Two key departments involved in airside operations and maintenance were the Flight Operations Section (FOS) and the Maintenance and Engineering Section (MES). The FOS was responsible for ensuring smooth operations and enforcing safety on the ground. Its role includes licensing of drivers, airfield inspections, checking for obstacles, foreign objects and animal hazards, etc. The section has duty officers on shift round the clock. Three airfield inspections were scheduled each day. Any requests for airfield pavement repair work was channeled to the MES for follow up.

According to the "CKS Airport Operations Manual," Article 2"Ground Safety," Item 5"Airfield Safety Inspection and Cleaning," the tasks of the FOS also include:

a. The duty Flight Operations Officer must check and document the airfield status periodically and document that for future review; and
b. To avoid foreign object damage on the aircraft, all personnel should follow airport ground surface handling notes and clearly assign and execute their duties.

The MES was responsible for maintaining the airfield pavement, including the runway / taxiway repair work, and painting of obscured marking in the airfield. From the inspection reports made by the inspection team from the FOS, the MES assigns priorities to the projects, and then the contractor will do the repair / repainting work. The MES undertakes civil work less than 50 million NT dollars. The MES follows CAA design criteria stipulated by the AD; however, it does not report to the AD. The MES was responsible for supervision of the worksite to ensure that its contractors complied with safety regulations (including marking and lighting of obstacles). The MES has a staff to conduct pavement inspections. It was currently looking into safer alternatives to the Jersey blocks, something that is frangible and lighter, and yet can withstand strong winds / typhoons.

CKS Airport Management was required to submit reports on surface damage to the AD. The AD monitors the progress of the repair work, and conducted inspections on airports every 4 to 6 months.

1.18 Additional Information

1.18.1 Summary of Interviews

1.18.1.1 Interviews with the Flight Crew

1.18.1.1.1 The Captain (CM-1)

During interviews with the flight crew of SQ006, CM-1 stated that during his dispatch briefing on the previous day at Singapore for his flight to Taipei, he knew that typhoon "Xangsane" was approaching CKS Airport. He also mentioned that SIA was tracking the path of the typhoon and he noted that the typhoon would arrive at Taipei after the next day's scheduled flight. He read the NOTAM and INTAM regarding the partial closure of Runway 05R between Taxiway N4 and N5 and the closure of the section of the northern ramp between and behind parking bays A1 and A2.

CM-1 reported that his focus was mainly on the strong cross winds and the low visibility. He wanted to know if these were within company limits. He worked on the crosswind calculations with the other two pilots. On ascertaining that these were within the company's departure limits, he proceeded to consider the Computer Flight Plan (CFP) and to determine the fuel required for the Los Angeles sector. The fuel uplift was passed to the EVA Operations Officer assisting in the dispatch.

During interviews, CM-1 commented that he had initially intended to give the TPE-LAX sector to CM-2 but because of the weather at Taipei, he decided to do the takeoff and to allow CM-2 to do the landing at LAX. He informed CM-2 about his decision and then the three pilots boarded the aircraft.

CM-1 commented that CM-3 volunteered to do the external checks. CM-1 reported that he copied the latest ATIS and was working out the crosswind component. CM-1 stated that CM-2 performed the pilot flying preflight preparation so that CM-1 could concentrate on the weather conditions. CM-1 stated that he crosschecked CM-2's preparation to ensure it was correct. CM-1 stated that both he and CM-2 loaded the FMS and checked the radio frequencies.

CM-1 stated that he continued to monitor the weather on the ATIS. He also heard ATC giving weather information to two other flights (Cathay Pacific and China Airlines) that were departing around the same time. CM-1 stated that the visibility appeared to be improving and "better for us." The China Airlines flight was also using Runway 05L. Cathay intended to use Runway 06.

CM-1 reported that he had operated into CKS Airport on more than 10 occasions using various runways, and he had performed about 10 night takeoffs from CKS Airport. He commented that SIA flights usually use Runway 06 because this runway was closer to the parking bays used by the company. CM-1 chose Runway 05L because its CAT II category permitted a lower visibility minimum especially when the RVR was declared. In addition, Runway 05L was longer and would afford better performance margins for the prevailing wet runway conditions.

CM-1 stated that he had experienced worse weather conditions than those that were present at CKS Airport on the evening of the accident. He gave as an example a departure from Anchorage where he encountered strong crosswinds, blowing snow and icy runway conditions. He had last been in Taipei about 2 to 3 weeks prior to the date of the accident, but he reported that it had been between 2 to 3 years since he had used Runway 05L.

CM-1 stated that he was aware of the NOTAM, which applied to work in progress on the northern apron and on Runway 05R.

CM-1 conducted the procedural briefings including, but not limited to, EGT limits, taxi and departure routings. He anticipated the taxi routing to proceed via SS, eastwards to East Cross, continuing East

Cross to Runway 05R (because of the closure of a portion of the ramp between bays A1 and A2); backtrack on Runway 05R to N7, then taxi to the end of NP, turn onto N1 and then to Runway 05L.

The actual ATC taxi clearance that was issued to the crew was a different routing. CM-1 re-briefed the crew accordingly. The ATC clearance required the crew to taxi westward on SS to West Cross, then to join NP, proceed to the end of NP to Runway 05L.

CM-1 reported that he felt no time pressure on the evening of the accident. He commented that he had told the other pilots not to hurry, to “slow down” and to do their checks correctly. According to CM-1, the crew had sufficient time to complete the checklist and prepare for the departure. He was concerned about the weather because he knew the typhoon was inbound to Taiwan.

CM-1 stated that the departure and pushback from the gate were normal. Shortly after taxiing, CM-1 called for Flaps 20. He checked the rudders and CM-2 checked the ailerons and elevators. He then called for the Before Takeoff Checks. CM-2 went through the checklist.

CM-1 put the windshield wipers to LO [low speed] during taxiing. The wiper cleaned most of the windscreen and he could see through almost the whole windscreen.

CM-1 had asked CM-3 to monitor the ATIS and to check the wind component. As the aircraft taxied towards the end of Taxiway NP, CM-3 received the latest ATIS and calculated the wind component to be 28.5 knots from the left. The crew was at the end of NP turning onto N1 at the time. This was still within the company crosswind limit of 30 knots (for a dry runway). CM-1 reported that both the wind and visibility were not so bad and he could see where he was going.

CM-1 reported in the interviews that he told himself to be more alert than usual and to be especially aware of the situation. During taxi, the crew discussed potential alternates if they had to turn back after takeoff. CM-3 informed him that Kaohsiung and Hong Kong were closed. They could also return to Taipei because the weather was within the CAT II landing minima for Runway 05L. CM-1 commented that if the winds had exceeded the company operating limits, he would have postponed the takeoff. He also mentioned that he was concerned that the weather over Taipei would get worse before it would get better.

As the aircraft crossed the holding line on NP passing N2, prior to the completion of the Before Takeoff Checklist, CM-1 told CM-2 to inform Tower that they were ready. On receiving the call, the Tower cleared them into position and hold. At this point during the taxi sequence, CM-1 expected the tower to have seen the aircraft before issuing the takeoff clearance. CM-1 turned the aircraft right onto Taxiway N1and was focused on the image of the runway to his right. He did not notice any further green lights ahead and along the extension of N1. He stated that he followed the curved centerline lights leading onto Runway 05R. During the turn, he had a flash view of the “piano keys”.

He commented that he was attracted to the bright centerline lights leading onto the runway. As he turned, he did not recall seeing any runway identification signboard or the runway identification marking on the runway. On the runway, CM-1 engaged the parking brakes, activated all the landing lights and switched the wipers to HI. CM-1 indicated that he felt that his visibility was not impaired by the rain, even in the areas not swept by the wipers.

CM-1 recalled that as he turned right from N1 onto Runway 05R, he remembered being very careful to maintain a taxi speed of five knots, so as not to skid on the painted "piano keys."

As the aircraft was lining up, he thought that the image before him was that of a runway. He reported that he could see the centerline light running down the runway and was 80 percent sure that he also saw the runway edge lights.

During interviews, CM-1 stated that he was convinced that he was on Runway 05L. He reported that he did not see any objects obstructing the runway in the distance. CM-1 said that the takeoff clearance issued by ATC when the aircraft was approaching the runway threshold reinforced his expectation that the Tower had him in sight. The aircraft heading was around 050 degrees on line up, which was the expected direction for takeoff, and from his perspective, the picture outside in the heavy rain and with the landing lights ON was that of a normal runway.

When asked to describe his mental picture of a closed Runway 05R, CM-1 replied that closed Runway 05R would not be expected to be lighted up like a runway, would have normal barricades or crosses after the piano keys, and runway signs at the beginning of the runway.

CM-1 stated that sometime during the turn to line up, CM-2, who was completing the Before Takeoff Checklist, remarked that the PVD had not activated. CM-3 stated that the PVD would arm only within 45 degrees of the runway heading. After lining up, the PVD was still shuttered. CM-1 stated that he believed the PVD is a most useful aid for low visibility takeoff. He said that he decided that there was no requirement to use the PVD for centerline guidance during the takeoff because the visibility was sufficient for a visual takeoff.

CM-1 stated that he had received training for low visibility takeoffs but not for taxi.

CM-1 reported that he has no difficulties working with colleagues and supervisors. During interviews, CM-1 commented that he had flown with CM-2 and CM-3 before. He reported a satisfactory working relationship with CM-2 and CM-3. CM-1 also mentioned during the interviews that he believes in maintaining open communications with his colleagues on the flight deck and he tries to promote a relatively relaxed but disciplined cockpit environment.

In the subsequent interview, CM-1 responded to the following issues:

Dispatch

The briefing at CKS Airport by EVA was always a self-brief unless there was an operational issue that needed clarification by the dispatcher.

CM-1 did not recall seeing any INTAM highlighted on the paperwork that was provided by the ground-handling agent. He could not recall with certainty sighting highlighted sections on the NOTAM. He stated that some weather information might have been highlighted. CM-1 remembered the information regarding Runway 05 in the NOTAM and, in particular that a portion of Runway 05R between N4 and N5 was closed and that a portion of the northern apron was also closed. He did not recall seeing any NOTAM or INTAM regarding Runway 05R lighting.

Wet vs. Contaminated runway

CM-1 stated that it was the responsibility of the airport authority to inform pilots on runway surface conditions. CM-1 commented that runway surface conditions are usually reported on the ATIS. For example, if there is water accumulation on the runway, snow, slush or other contamination. No specific information on runway surface conditions was provided to the flight crew through ATIS or the Tower controllers on the evening of the accident.

Typhoon Procedure

CM-1 was aware of the SIA typhoon procedures. In Taipei, the dispatcher did not brief CM-1 about the incoming typhoon when CM-1 was still in the hotel; however, CM-1 reported that he was fully aware of the incoming typhoon.

Decision as to delay flight or continue

CM-1 said that he considered several factors when making a decision about whether to delay a flight or not. CM-1's considerations included general weather, wind, visibility and factors such as other aircraft taking off. The meteorological parameters must be within company limits before a decision is made to continue the flight.

PVD

CM-1 reported that he was visual with the runway; therefore, he did not consider the shuttered PVD as an issue to pursue further.

General Navigation: From pushback to runway

CM-1 generally utilized the following information for navigation during taxi:

1. Charts for preflight briefing and for navigation;
2. green centerline lights especially in poor visibility and bad weather;
3. signboards;
4. cross-check with FO;
5. tower guidance--ATC will monitor taxi;
6. ground radar; and
7. "follow me" vehicle (if available, and mainly used for guidance after landing in low visibility especially if there is no ground radar).

Focus of Attention

On the night of the accident, CM-1's focus was mainly on the green taxiway centerline lights. CM-1 stated that these would normally lead him to the takeoff runway. He also commented that he was unable to clearly make out taxiway and runway signage because of the heavy rain and poor visibility.

CM-1 commented that he was preoccupied with the poor visibility, heavy rain, and high wind velocity on the evening of the accident. CM-1 wanted to make sure that the conditions were within company limits for takeoff.

Points to note by CM-1

CM-1 thought that the green centerline lights on Taxiway NP led to Runway 05R. He also commented that there was no continuity of the taxiway line and lights to Runway 05L and "this was the trap."

CM-1 re-iterated that he was not sure if the Runway 05R edge lights were illuminated at takeoff. He recalled seeing very bright centerline lights. He also mentioned that he depends more on the runway centerline lights than on the runway edge lights for guidance in low visibility conditions.

1.18.1.1.2 The First Officer (CM-2)

On the flight into Taipei the previous day, CM-2 had noted that the weather was poor. During interviews, CM-2 reported that the aircraft broke through the clouds at 1,000 feet, and the winds were strong, especially the headwind. CM-2 commented that CM-1 performed a good landing. He said that CM-1 did not think the TPE-LAX flight would be cancelled, and he also remembered thanking CM-1 for offering him the next sector (TPE-LAX). The next day, prior to the TPE-LAX flight, CM-2 stated that he had reviewed the NOTAMs and weather in the hotel.

According to CM-2, the flight crew discussed the in-flight rest arrangements during transit from the hotel to the airport on the evening of the accident. CM-2 also mentioned that CM-1 had decided to perform the takeoff from TPE because of the strong winds associated with the inbound typhoon. CM-2 was instructed to fly the approach and landing into LAX. During the dispatch briefing, CM-1 and CM-3 reported that they calculated the crosswind components for takeoff, and after checking the results they decided to go ahead with the flight.

While walking to the cockpit, he noticed that the catering people were having difficulty loading the catering due to the weather. CM-2 reported that CM-1 had told them to slow down and take their time. CM-2 commented that he felt that CM-1 had set the tone for the crew not to rush.

During the cockpit briefing, CM-1 briefed the flight crew on the taxi route he expected to take, which included backtracking on Runway 05R. CM-2 thought that Runway 05R was closed and CM-3 clarified that Runway 05R was only partially closed. CM-1 and CM-3 stated that they were concerned about the winds, whether the wind components were within limits, as well as the slippery runways. They also discussed the alternates for the departure airport and the visibility for a landing back at TPE if required.

CM-2 stated that CM-3 completed the external checks. When CM-3 returned to the cockpit, his shoes were wet, and he asked permission to take them off and to wear "sockettes" instead. CM-2 completed the "bug card" with some input from CM-3. CM-3 corrected the speeds for the wet runway takeoff. While CM-1 and CM-3 were looking at the crosswind calculation, CM-2 decided to set up the cockpit. He switched on the PVD. CM-2 stated that he felt good when he noticed that CM-1 had also turned on his PVD. CM-2 reported that he was acutely aware of how gusty the winds were, and that they were blowing hard and perceived to be changing direction rapidly. CM-2 noted the effects of the wind on his speed trend vector as well as CM-1's speed trend vector indication, which was different from his. CM-2 commented during interview that he was thinking of the speed trend vector system and the source of data contributing to this indication.

When ATC issued the taxi route, CM-1 briefed the crew on the new routing. CM-2 expressed that he felt the taxi route was better than the anticipated route because it was an easier route to navigate. CM-2 stated that he had not been to TPE for quite some time. CM-2 was concerned about how he would support CM-1. He stated that if he had been asked to do the takeoff, he would have asked CM-1 to do it because he felt the more experienced pilot should do it.

CM-2 stated that he felt confident in CM-1 and CM-3, and that the crosswind components were within the documented limits for takeoff. After pushback and while taxiing along SS, he set flaps to 20, and checked the ailerons and elevators. He checked the flight controls twice to confirm that the controls were free. He was also purposeful in his flight control check actions. He performed the instrument checks and double-checked to ensure they were working properly. During this time, he stated that he was using his taxi chart to monitor taxi progress. He also said that he handled the radio communications throughout taxi.

As the aircraft was taxiing on Taxiway West Cross, CM-2 was completing the first part of the Before Takeoff Checklist in addition to the radio communications. He did not notice lights in the distance in front of the aircraft. During the taxi along NP, he stated that he remembered waiting for the hand off to the tower controller for line up and takeoff clearances. Approaching the N2 turn, he said “next right” and was prompted by CM-1 to say “second right” instead. At this point, ATC calls came in for line up and takeoff.

CM-2 then commenced the “below the line” Before Takeoff Checklist. CM-2 reported that while going through the checklist, CM-1 was with him. He also mentioned that CM-1 was quick to respond to the checklist items. Going through the checklist, CM-2 noted that CM-1 had switched on the strobe and the landing lights. CM-2 stated that he was careful to make sure each checklist item was completed, but was also glancing out periodically to monitor CM-1’s taxiing. CM-2 mentioned that he then checked the ground speed and focused inside the cockpit at this time. He once again noted that CM-1’s PFD speed trend vector indication was different from his and the difference caught his attention. As he finished the checklist, he saw the aircraft lining up with the runway.

During line-up, CM-2 noticed that the PVD had not activated. CM-3 explained to the other pilots that the PVD would not be active until the aircraft was aligned within 45 degrees of runway heading. CM-2 stated that CM-1 decided the PVD would not be required for the takeoff because he was comfortable with the visibility along the runway. CM-2 was satisfied with CM-1’s decision because he saw very bright centerline lights when he looked up at the runway ahead of him. He could not recall seeing any runway edge lights. He also commented that he saw the green lights leading onto the runway to the right [when aircraft was turning onto the runway]. He did not notice any other lights, but he saw the “piano keys” on the threshold and remembered they appeared “scratchy.”

CM-2 reported that he did not notice any displacement of the localizer on the PFD.[27] He also mentioned that he had previously used the PVD in the simulator but he had not used the PVD for an actual assisted takeoff during line operations.

CM-2 turned on the weather radar and noticed that the entire area was painting green because of the rain. He also checked that the wipers were on “HI,” and noticed that CM-1 had already switched it on. The aircraft lights were working, but visibility was not as good as clear conditions.

CM-2 reported that he was aware that only Runway 06 and Runway 05L were active and that Runway 05R was closed. When asked to describe his mental picture of a closed Runway 05R, he replied that a

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[27] There is no requirement for this to be checked in either the SIA or the Boeing 747-400 operating procedures.

closed runway should be ”black” and have no lights. Further, he commented that any work in progress on the aerodrome should have warning lights.

CM-2 described the factors that made him think that he was on Runway 05L. He said the runway picture was “correct.” He recalled seeing lights down the middle of the runway and they were very bright. He reported that there were no visible obstructions ahead of the aircraft. He estimated that he could see a distance of about 200 to 300 meters down the runway. The taxi lights led into the runway. Apart from the curved taxiway lights leading onto the runway, CM-2 reported that he did not notice any other lights. He did not see any runway identification signboard [box], or the runway identification marking. CM-2 stated that the visual cues indicated that the aircraft was on an active runway. There was no operational requirement to use the PVD for runway centerline guidance during a visual takeoff. CM-2 indicated during interviews that he was prepared to tell CM-1 not to take off if the runway picture was not right. He also recalled that there were strong winds and very heavy rain from push back to takeoff. CM-2 recalled that apart from the portion that was cleared by the wiper, the rest of the windshield was obscured by rain.

CM-2 reported that he has no difficulties relating to colleagues and supervisors. During interviews, CM-2 commented that he had flown with CM-1 before. He reported a satisfactory working relationship with CM-1. In particular, CM-2 commented that there were no cultural problems among the crewmembers.

In the subsequent interview, CM-2 responded to the following issues:

Dispatch

The pre-flight briefing in Singapore was a self-briefing system. In Taipei, the ground-handling agent provided the crew with a self-briefing package and the dispatcher was available to answer queries.

CM-2 did not recall seeing any information highlighted on the paperwork provided by the ground-handling agent. He did not recall seeing any NOTAM or INTAM regarding Runway 05 or taxiway and runway lighting.

Discussion on alternates

He could not recall the details of the discussion pertaining to alternates during taxi; however, he remembered that it included a return to Taipei. He commented that the alternates are normally discussed during pre-flight briefing and not during taxi.

PVD

CM-2 said that he had just remarked that the PVD was not on. CM-3 had an immediate answer; therefore, he put that issue out of his mind. After that, he did not consider the implications of the PVD not unshuttering on runway line-up.

<u>General Navigation: From pushback to runway</u>

In general his navigation and orientation was based on the following

1. Charts;
2. On taxiway--junctions; ascertain direction and path;
3. Signage;
4. Lights; Centerline lights on taxiway: Guide for them to follow closely. Expected to take him to the runway;
5. Prominent buildings; Certain airports only; and
6. Compass rose to confirm correct heading (macro orientation).

<u>Points to note by CM-2</u>

On the night of the accident, he was exercising additional caution because of the difficult weather and poor visibility. He wanted to get to know the layout of the taxiways at CKS. The night before the accident, he was already familiarizing himself with the layout of CKS taxiways and runways. He tried to correlate the chart with the taxiways. He remembered seeing the West Cross signage during taxi but he could not recall the NP sign. After that, he commented that he was relying upon the green centerline lights for navigation because of poor visibility and bad weather. On Taxiway NP, near Taxiway N2, he called out "next right" and was corrected by CM-1 who asked him instead to use the terms, "first right" and "second right". After that, CM-2 completed the pre-takeoff checklist. At that point he reported that the rain also felt heavier (increased paltering), and was coming from many directions.

CM-2 stated that it was a normal experience to have the green taxiway centerline lights to lead to the takeoff runway and, on landing, to lead to the parking bay.

1.18.1.1.3 The Relief Pilot (CM-3)

Interviews with CM-3 revealed the following information: CM-3 was involved with the self-briefing of the flight documents at the gate. He also reported reading the NOTAM, INTAM, and the Fuel Flight Plan. He conducted the external preflight checks that took about 15 minutes. This took slightly longer than usual because of weather conditions. CM-3 stated that CM-1 asked him to monitor the ATIS and keep a check on weather. CM-1 asked him to check the winds during taxi and to calculate the crosswind component. He also monitored CM-2 to ensure that all checklists and procedures were properly completed. CM-3 stated that he took out the spare copy of the Taipei CKS Airport chart and was monitoring the taxi route. He stopped monitoring the taxi route when he received the latest wind information from the ATIS[28]. He then put the chart aside to calculate the crosswind component for takeoff.

CM-3 had experienced the weather conditions during the external aircraft checks. He commented that he elected not to inform CM-1 of his assessment of the environmental conditions because he did not want to place additional pressure on CM-1. CM-3 stated that the crosswind for takeoff was within the company limits. He knew the typhoon conditions would get worse the longer the flight was delayed. He felt comfortable about the aircraft taking off in those weather conditions. CM-3 thought that CM-1's decision to do the takeoff was the correct one.

CM-3 felt that his primary duty as the relief pilot was to be the third pair of eyes and to support CM-1 and CM-2 by monitoring their actions. He also mentioned that he felt comfortable about the manner in which CM-1 and CM-2 were managing the flight. He noted that CM-1's initial taxi briefing was different from what was given by ATC. In addition, he stated that he was aware that Runway 05R was to be used only for taxiing. CM-3 stated that his last operation from CKS Runway 05L was about 2 to 3 years ago. He had flown with CM-1 once before and that was his first time flying with CM-2.

He stated that he had a good understanding of the CKS taxiways. If the winds or visibility exceeded operational limits, he was prepared to voice his concerns to CM-1; however, at that time the visibility was good. CM-3 stated that he could only see ahead of the aircraft because he was seated in the jump seat (first observers seat) behind and in between the two other pilots.

CM-3 stated that everything was "going as planned" as they taxied the aircraft. When on Taxiway West Cross, approaching NP, he noted bright green lights across and ahead, and then pitch black. As the aircraft taxied along NP, CM-3 recalled hearing a radio communication between the Tower and Cathay Pacific departing for Hong Kong from Runway 06, and a radio communication with another carrier that winds were gusting up to 50 knots. He was worried about the wind gust information until he checked the crosswind component and found that it was still within company operational limits.

When the ATC clearance was issued to the flight crew to line up on Runway 05L and hold, he did not have an expectation that the Local Controller could see the aircraft.

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[28] According to CVR, the latest wind information the flight crew received was from ATC takeoff clearance.
1515:22 - TWR Singapore Six, runway zero five left, wind zero two zero at two eight, gust to five zero, clear for takeoff.

As the aircraft approached Taxiway N1 and N2, CM-3 stated that he was concentrating on calculating the latest crosswind component for takeoff. CM-3 indicated that his mental focus was inside the cockpit at this point in the taxi sequence. The rain was very heavy but the wipers were able to clear the windshield; however, the visibility from the side windows was considered substantially degraded. The wind was very gusty. CM-3 said that CM-1 was in control of the situation.

As the aircraft began to turn onto N1, CM-3 received another wind report from ATIS [ATC], and he calculated the crosswind component again. He noted that the winds were close to the maximum crosswind limit. When he looked up after checking the crosswind component, the aircraft was turning onto the runway. CM-3 reported that he saw a very bright environment. He noticed the centerline lights, but did not notice the runway edge lights. He said that the visibility was sufficient and good enough for takeoff. He noticed that CM-2's attention was drawn to the fluctuating speed trend vectors. CM-3 stated that he looked at the PFD and saw that the ILS frequency was correct.

When CM-2 mentioned that the PVD had not activated (that is, unshuttered), CM-3 stated that he explained that the aircraft alignment was not within 45 degrees of the runway heading. CM-3 stated that he was not concerned about the PVD indication because the visibility was sufficient for takeoff, and the PVD is only required for Category III weather conditions. CM-3 noted that he felt CM-1 was comfortable about going ahead without the PVD. CM-3 also stated that he thought the aircraft was sitting on the runway with bright lights. According to CM-3, the runway appeared to be like a typical runway with bright lights down the centerline of the runway. From where he was sitting, CM-3 reported that he could not see the "piano keys," runway signboards or marking.

CM-3 was aware that only two runways were active. These were Runway 06 and Runway 05L. He knew that Runway 05R was closed but was available as a taxiway. When asked to describe his mental picture of a closed Runway 05R, CM-3 said that the runway lights should not be illuminated. He further stated that there should also be obstruction lights and barricades for the work in progress area, and illuminated no-entry signs.

CM-3 reported that he has no difficulties relating to colleagues and superiors. In particular, CM-3 commented that there were no cultural problems among the crewmembers.

In the subsequent interview, CM-3 responded to the following issues:

<u>Dispatch</u>

CM-3 did not recall seeing any INTAM highlighted on the paperwork provided by the ground-handling agent; however, he remembered seeing some highlights on the NOTAM. CM-3 also remembered the information regarding Runway 05R in the NOTAM. In particular, he recalled that Runway 05R between N4 and N5 was closed. He also recalled seeing some information in the

NOTAM or INTAM about a green centerline on Runway 05R. He did not communicate this information to any of the other two pilots. He did not know if any of the other two pilots were aware of that information.

Use of taxiway lights:

CM-3 said that at night and in poor visibility, ATC would light up the green centerline taxiway lights all the way to the takeoff runway.

PVD:

When the aircraft was turning to line up on the runway, CM-2 commented that the PVD had not unshuttered. CM-3 told the other crewmembers that the aircraft was not lined up within the 45 degrees of runway heading for the PVD to come on. CM-1 reported that he was visual with the runway and the crew did not consider the shuttered PVD an issue to pursue further. CM-3 said that he was thinking of other issues at the time and dismissed the shuttered PVD.

General Navigation: From pushback to runway

In general for navigation and orientation, he would use the following

1. Charts;
2. Signage;
3. General orientation including buildings; and
4. Taxiway centerline lights.

Role of relief crewmember

CM-3 said that there were no formal procedures dictating the role and/or duties of a relief crewmember. The role of the relief crewmember is at the discretion of the aircraft commander. Generally, the relief crewmember would be on the flight deck during takeoff and landing.

1.18.1.2 Interview with Pilots Who had Flown with or Checked the SQ006 Pilots

Interviews were conducted with SIA pilots who had recently flown with or checked the SQ006 pilots. Their views were consistent for each of the pilots and are summarized below:

(a) CM-1—A disciplined and skilful pilot who is thorough with his work. He is one of the better pilots in SIA. He is also a friendly and approachable person on and off duty.

(b) CM-2—An above average and disciplined pilot. He is also mature and would not hesitate to speak out on safety issues on a flight.

(c) CM-3—A mature and disciplined pilot with good flying skills. He is also forthright and respectful. He has the potential of becoming a commander in due course.

1.18.1.3 ATC Interviews

The air traffic control positions and legend used in the roster in CKS Airport Tower at the time of SQ006's accident are as follows:

1. Controller A - Local Control (LC);
2. Controller B - Ground Control (GC);
3. Controller C - Flight Data (FD);and
4. Controller D - Clearance Delivery (CD)

The ATC Group interviewed Controller A and B on November 4, 2000, Controller A on November 10, 2000, Controller B and C on November 29, 2000 and Controller D on November 30, 2000. Controller A and B were interviewed together on November 4, 2000. The Chief of Air Traffic Services Management Office and the Tower Chief were present during all interviews.

1.18.1.3.1 Interviews with Controller A

According to Controller A, weather conditions were poor when he took over the Local Control Position. SQ006 was taxiing out for departure and there were two other aircraft pushing back from the parking bays at the time.

SQ006 contacted Taipei Tower on frequency 129.3 MHz at about the time the aircraft turned from Taxiway West Cross onto Taxiway NP. Controller A could only see the aircraft's lights which gradually disappeared as the aircraft taxied towards Taxiway N1.

As there was no other aircraft on approach or taxiing, Controller A cleared SQ006 for takeoff from Runway 05L when the crew reported ready. The crew read back Runway 05L correctly. Controller A said that he could not see SQ006 line up for takeoff when it began its takeoff roll because of the low visibility. His first eye contact of the aircraft after he issued the takeoff clearance was when he saw sparks, followed by an explosion. Controller A said that he pressed the crash alarm immediately and that Controller C transmitted initial instructions to the rescue and fire fighting crew on a hand-held radio (Channel 1). He also said that Controller B notified the approach radar controller of the accident.

Controller A said that the intensity of the Runway 05L runway lights and the red and yellow zone taxiway lights had been selected in accordance with a matrix (lighting intensity setting table) displayed near the lighting console[29].

The ATC Group interviewed Controller A for a second time on November 10, 2000. During the second interview, Controller A explained that the maintenance unit daily inspects the airport lights. He said that one zone of the airport is examined at a time. The lights of each zone are switched on/off according to the maintenance unit's request.

Controller A stated that he arrived for work at the Tower at 1840 on October 31, 2000. He worked through cycling shifts of 40 minutes on duty and 20 minutes rest thereafter. At 2300, he took over Controller A position after completing a rotation through the flight data/clearance delivery position. Controller A managed only one aircraft namely, SQ006. He checked that the taxi lights were already "On" (Runway 05L centerline and edge lights were both already turned on with the intensity level set at 4). He remembered that the Red zone (labeled N TW R) and Yellow zone (labeled N TW Y) taxiway lights were also turned on [these were the Ground Controller's responsibility]. He also recalled seeing that the indicator lights at the red and yellow sectors of the airport were illuminated but he was unable to recall the intensity level of the lights.

There was a flight strip holder next to the lighting control panel to remind controllers that Runway 05R/23L was currently not in use. The strip had a white background with "Runway 05R/23L" in black letters and "currently not in use" (Chinese characters) in red.

There were four people working in the tower on the night of the accident: the Local Controller (LC), the Ground Controller (GC), the Flight Data position (FD) and the Clearance Delivery (CD) position. Controller A recalled that the Runway Visual Range (RVR) was 450 meters when he took over SQ006. SQ006 had pushed back and was taxiing at the time. SQ006 was handed off to him at the junction of Taxiways, West Cross and NP. Controller A reported that he could not see the aircraft shortly after it started to taxi along Taxiway NP. Controller A had instructed SQ006 to hold short Runway 05L. Controller A also provided SQ006 with the most recent wind velocity information. He asked the flight crew of SQ006 for their intentions but he did not receive an immediate reply. A few seconds later, a SQ006 crewmember called to say that they were ready for takeoff. Controller A subsequently cleared SQ006 for takeoff, because there were no other aircraft in the vicinity.

There were no ATC Tower equipment malfunctions such as the radio communication controls, the runway lighting controls, the wind and weather display and the radar display.

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[29] Refer to ATP-88, Para. 3-4-10,TAB. 3-4-4.

Shortly after Controller A issued the takeoff clearance, he heard an explosion and saw fire in front of him, near Taxiway NP and Runway 05R. He immediately pushed the emergency alarm, while another controller contacted the fire department. Concurrently, the GC closed down Runway 05L. Subsequently, the Airport Authority called the Tower and told them to close the airport. Controller A closed the runways for arrivals and departures. Controller A reported that he did not touch any of the runway lighting controls.

Controller A recalled the visibility that night was poor. Prior to the accident, he could not see the centerline lights and the edge lights on Runway 05R. Similarly, he could not see anything between him and Runway 05L (inclusive of the construction area on Runway 05R). The weather was poor with winds of such magnitude that they sent tremors along the suspension lights above him in the Tower cab.

Controller A reported that on a typical clear night he would normally be able to see the end of the runways and even the runway sign boxes; however, he commented that he would not be able to read them. He stated that he was able to see the obstruction lighting on the work in progress on Runway 05R on clear night.

One tag had been placed over the Runway 05R runway light switch since the middle of September 2000 to prevent inadvertent activation. A similar tag was placed over the Runway 05L runway light switch after the SQ006 accident. Both tags were designed to remind the controller not to turn on these lights.

Controller A was aware that the CKS Airport had already planned for a postponement of the NOTAM with respect to the instruction on converting Runway 05R to Taxiway NC; therefore, the operating instructions for the night of the accident were to remain the same.

1.18.1.3.2 Interviews with Controller B

When Controller B took over the GC Position at 2300, only SQ006, and two other aircraft were on frequency 121.7 MHz. Controller B said that he cleared SQ006 for taxi to Runway 05L via Taxiways SS, West Cross, NP and N1.

As a GC, he was responsible for activating the appropriate taxiway lights. He had activated the taxiway lights for the White, Yellow and Red zones. He added that Controller A was responsible for the runway lights. As a general rule, these lights are switched on when landing aircraft are about 15 nautical miles from touchdown. For continuous landings, the approach and runway lights are left on and there is no frequent switching on and off of the lights. The SOP for runway lighting did not require the approach lights to be switched on for departures.

The second interview conducted with Controller B was to clarify the actions that ATC carried out in relation to the Runway 05R centerline and edge lights after the Senior Flight Operation Officer (SFOO) had requested the closure of Runways 05L/R and thereafter.

During interview, Controller B stated that the lights for Runways 05L/R were switched according to the following sequence of events:

1. Immediately prior to the SQ006 accident, Runway 05L edge and centerline lights were on and the Runway 05R edge lights were off. The Runway 05R centerline lights were on.
2. After the SFOO called for the closure of Runway 05 after the SQ006 accident, the GC switched off all the edge and centerline lights for Runway 05L, the centerline lights for Runway 05R, and all taxiway lights.
3. When the SFOO found that Runway 05R (accident site) was too dark for rescue operations, he asked for more lights. The GC then switched on all the edge and centerline lights on Runway 05L and Runway 05R, and all the taxiway lights.

1.18.1.3.3 Interviews with Controller C

Controller C recalled that she had been in the GC Position prior to taking over the FD position. While in the GC Position, she handled SQ006. She had initially informed SQ006 to expect Runway 06 but subsequently approved SQ006's request for departure from Runway 05L. The pilot offered no reason for the request.

After the accident occurred, Controller C instructed the Ground Controller to inform Taipei Approach that SQ006 had crashed and that Runway 05L was closed. She then took over from the Local Controller, who asked to be relieved.

Controller C said that she did not turn on any of the lights during her shift because it was not her designated duty. It was the duty of the Ground Controller to switch on the taxiway lights and the duty of the Local Controller to switch on lights associated with the runway.

Controller C said that she did not switch any of the runway / taxiway lights on or off after she took over Controller A Position subsequent to the accident. Regarding the request by the "Yellow Vehicle" driver for the lights to be switched on, she said she knew that the Ground Controller at the time had responded to the request, but she did not know which lights he selected.

Regarding the maintenance of airport lights, Controller C explained that there was no pattern to the requests by maintenance to switch on any particular set of lights for checking. The requests were, to her knowledge, quite random, and Tower staff would turn on and off the lights as requested. On the night of the accident she had not performed any light switching for maintenance purposes.

1.18.1.3.4 Interviews with Controller D

According to the rotation of staff, Controller D was on his rest break at the time of the accident. He was also monitoring the Clearance Delivery frequency[30].

Controller D said that just as he completed making the ATIS broadcast, he heard a loud explosion and saw fire on one of the runways. He immediately alerted the fire department via the radio.

He did not notice which taxiway lights had been selected because he was kept busy answering the various telephone calls that followed the accident. Controller D said that he did not know if the Runway 05R edge lights had been selected on prior to the accident.

Controller D explained that according to the SOP for CKS Tower, the taxiway and runway lights should be switched off if there is no traffic. When asked whether the approach lights for Runway 05L were on at the time of the accident, he said that according to the SOP the approach lights for Runway 05L should have been switched off because there was no arrival traffic.

1.18.1.4 Interviews with Senior Flight Operations Officer

The Senior Flight Operation Officer (SFOO) from Flight Operations Section was on Apron B at the time of the accident. He was the driver of the yellow vehicle. He said that he rushed to the accident scene via the shortest route he could find. He thought that he traveled via Taxiway N7 for the runway [Runway 05R].

The SFOO said that some time after the accident, he asked the Control Tower to switch on all the runway lights of Runway 05 (he did not specify 05L or 05R). When the lights came on, he realized that he was on the grass patch beside Taxiway N6.

1.18.1.5 Other Interviews

1.18.1.5.1 The Aircraft Taxiing for Departure at the Time of the Accident

At the time of the accident, an Asia-Pacific airline’s Boeing 747-400 flight was taxiing via Taxiway NP to takeoff on Runway 05L. The Pilot-In-Command (PIC) reported that wind conditions were gusty and it was raining heavily. The PIC stated that the performance calculations for takeoff had

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30 Although Taipei AIP states that the Clearance Delivery position is suspended after 2200 daily, the radio frequency for Clearance Delivery was still monitored.

been based on a contaminated runway. The PIC also stated that the visibility was not too bad and he did not think it was as bad as the RVR reported on the ATIS. He also recalled that from Gate A7 he could see all the way to the end of Taxiway NP.

The PIC reported that when his aircraft was abeam Gate A7 he saw an aircraft's landing lights on Runway 05R, followed almost immediately by an explosion. He did not switch on his windshield wipers because the visibility was not bad. He said that the accident aircraft's landing lights were visible, but the rest was pitch dark. He could not see any lights on Runway 05R or 05L. The Taxiway NP lights were illuminated.

The PIC stated that during his three years operating into CKS Airport, he had not seen Runway 05R used for takeoff and landing. He did not remember seeing Runway 05R edge lights illuminated. The PIC also said that one has to have local knowledge and an alert mind otherwise one could mistakenly line up on Runway 05R.

1.18.1.5.2 The Flight Departed 16 Minutes before SQ006

An Asia-Pacific airline's Boeing 747-400 flight had departed 16 minutes before the accident. The PIC recalled that he pushed back from either Gate A5 or A7 and that he had been issued a taxi clearance along Taxiway NP to Runway 05L. The PIC reported that he had made the takeoff calculations on the basis of ½ inch standing water on the runway. It was raining heavily at the time of his departure.

The PIC recalled that the airport was below landing minima and that the tower controller appeared to lose visual contact with his aircraft as he taxied along NP in the vicinity of the Taxiway West Cross. He recalled that the tower had requested his position at that time.

The PIC recalled that the wind was quite erratic in both strength and direction and would momentarily exceed the permitted crosswind component for his aircraft. There appeared to be a pattern with the wind gusts and there were periods during which the wind speed would reduce and the crosswind would be within limits for his aircraft. When the PIC received the takeoff clearance, the crosswind component was in excess of the maximum permitted, so he lined up and held on the runway threshold and waited for the wind conditions to improve. He stated that if the wind conditions improved he would depart; if the wind conditions did not improve he would return to the gate.

The PIC did not require high intensity runway lighting for his departure because the visibility in the vicinity of the runway was estimated to be at least 600-700 meters.

The PIC recalled that he saw Runway 05L as he turned from NP onto N1. The lights appeared to be at a normal level of brightness. He confirmed that all lights were on for Runway 05L and the lights looked normal for a CAT II runway. These lights consisted of runway edge lights, runway centerline lights, and touchdown zone lights. The PIC could not recall if the runway edge lights were on or off for Runway 05R.

1.18.1.5.3 The Flight that Departed Eight Days before SQ006

About 2245 on October 23, 2000, a MD-11 freighter had been given clearance to taxi for a takeoff on Runway 05L via Taxiway NS, back taxi on Runway 05R to Taxiway N6, left turn on Taxiway N6, and a right turn on Taxiway NP to Taxiway N1 for Runway 05L.

As the PIC taxied along Runway 05R prior to Taxiway N6, he noticed that the centerline and edge lights were both lit up in the direction of the Runway threshold as well as the end of the Runway 05R. The PIC stated that the weather on that evening was rainy with some wind. The visibility was degraded due to the moderate rain.

The first runway that the PIC encountered when he was on Taxiway N1 was Runway 05R. He recalled that he felt compelled to take Runway 05R as the active runway because Runway 05R was brightly lit with centerline and edge lights. He could not see the barriers nor the lights on the barriers further down Runway 05R.

He was able to reject the compelling information because of the following conflicts: Runway 05R was too narrow; there were no touch down zone lights; and he realized that the centerline lights were green on the runway.

The freighter Captain did not report his incident to CKS air traffic controller. The freighter Captain contacted Singapore MCIT on December 2000. At the request of MCIT, a telephone interview with the MD-11 Captain was conducted on Feb 16, 2001, and a second interview was conducted on July 19, 2001, at ASC headquarters. According to the CKS weather record, about 2300 on the night of October 23, 2000, was wind 050 at 7 knots, visibility more than 10 km, few clouds at 2,500 feet, and broken clouds at 30,000 feet, with no rain.

1.18.2 ATC Operations

1.18.2.1 ATC Staffing

At the time of accident, the CKS Airport Control Tower was staffed with four controllers: one local controller, one ground controller, one clearance delivery controller and one flight data controller.

There is no cab coordinator working on the night shift. The supervisor at approach control assumes this responsibility when the traffic situation requires.

1.18.2.2 ATC Workload

During the course of the event, the Local Controller communicated with the accident aircraft, which was the only traffic under his jurisdiction and the Ground Controller communicated with two other aircraft starting engines. The Local Controller pressed the crash alarm in response to the accident as he observed the event. The remaining controllers were working at the CD and FD positions.

1.18.2.3 ATC Procedures

The Standard Operating Procedures for Ground Control and Clearance Delivery Positions of the CKS Control Tower required the ground controller to inform the aircraft on the movement area when visibility dropped to below 2,000 meters:

The relevant phraseology was as follows: (Ref: Para.3.5.6, SOP, CKS Approach and Tower)

> *"PART OF AIRPORT IS INVISIBLE FROM TOWER, TAXI SLOW DOWN WITH CAUTION."*

There are procedures in ATP-88 for the controller to issue progressive taxi / ground movement instructions when:

1. Pilot/operator requests.
2. The controller deems it necessary due to traffic or field conditions, e.g., construction or closed taxiways.
3. As necessary during reduced visibility, especially when the taxi route is not visible from the tower.

SQ006 was the only traffic in the maneuvering area. The controller provided routine taxi instructions to the flight crew of SQ006 and they accepted the clearance without requesting progressive taxi instructions.

During interviews, the Chief of Tower stated that the primary consideration for ATC during low visibility operations is to protect the active runway(s). In particular, ATC tries to ensure that the aircraft are expedited from the active runway after landing and that taxiing aircraft do not enter active runways until cleared to do so.

Second, the Tower Chief commented that it is very important to ensure aircraft separation during taxi. If there are two or more aircraft on the movement area at one time, ATC will request aircraft to hold at various taxiway intersections to ensure separation. This process may involve asking to report their location on the airfield during taxi. If there are no other aircraft on the airfield during taxi, ATC does not have specific procedures or practices to assist flight crew's navigation. The Tower Chief stated that under these conditions, it is the flight crew's responsibility to ensure accurate navigation around the airfield. ATC will advise them of low visibility conditions and to taxi with caution. In very poor weather, where the CKS ATC is unable to visually confirm the location of the aircraft, the only method that ATC has available to determine the aircraft's position is through radio transmission position reports from the crew.

1.18.2.4 Airport Surface Detection Equipment (ASDE)

ATP-88 states:

"3-6-1 EQUIPMENT USAGE

Use ASDE to augment visual observation of aircraft and/or vehicular movements on runways and taxiways, or other areas of the movement area:

- *a. When visibility is less than the most distant point in the active movement area, and*
- *b. When, in your judgment, its use will assist you in the performance of your duties at any time.*
- *c. ASDE-3 shall be operated continuously between sunset and sunrise regardless of visibility.*

3-6-2 INFORMATION USAGE

- *a. Use ASDE derived information to assist with:*
    1. *Formulating clearances and control instructions to aircraft and vehicles on the movement area.*
    2. *Determining when the runway is clear of aircraft and vehicles prior to a landing or departure.*
    3. *Positioning aircraft and vehicles using the movement area.*
    4. *Determining the exact location of aircraft and vehicles, or spatial relationship to other aircraft/ vehicles on the movement area.*
    5. *Monitoring compliance with control instructions by aircraft and vehicles on taxiways and runways.*
    6. *Confirming pilot reported positions.*
    7. *Providing directional taxi information on pilot request.*

PHRASEOLOGY-

TURN (left/ right) ON THE TAXIWAY/RUNWAY YOU ARE APPROACHING.

- *b. Do not provide specific navigational guidance (exact headings to be followed) unless an emergency exists or by mutual agreement with the pilot.*

NOTE-

It remains the pilot's responsibility to navigate visually via routes to the clearance limit specified by the controller and to avoid other parked or taxiing aircraft, vehicles, or persons in the movement area.

3-6-3 IDENTIFICATION

To identify an observed target on the ASDE display, correlate its position with one or more of the following:

a. Pilot's report.

b. Controller's visual observation.

An identified target observed on the ASR or BRITE/DBRITE display."

The airport surface detection procedures clearly state that ASDE could determine the exact location of aircraft and vehicles on the movement area. During interviews, the duty controllers stated that it may help prevent an occurrence such as the SQ006 accident, if CKS Tower was equipped with ASDE or an equivalent system.

The first time that the CAA had a budget to procure ASDE was in 1994 when a request was submitted to the ANWS to begin the process of installing ASDE at CKS. The ANWS declined the request because of the limited use of ASDE at CKS in foggy seasons and suggested that CAA withdraw the request. The CAA then asked the ANWS to reconsider the need to install ASDE at CKS Airport. The ANWS reiterated to the CAA that to install such equipment at the CKS Airport was not necessary because of the relatively infrequent occurrence of fog did not merit such a system. Consequently, according to the ANWS, the view from the control tower was not obstructed on a regular basis. The ANWS also explained that, even if there was a need for ASDE, a concrete structure had to be built at an appropriate location because the platform for the existing tower structure was not designed and constructed to bear the weight of ASDE. The ANWS added that the cost would be too high within the existing budget limits. CAA then submitted a letter requesting the MOTC to suspend the ASDE procurement process and returned the budget.

In 1996, the ANWS requested CAA to install ASDE at CKS Airport for the enhancement of flight safety and air traffic services. In its request, the ANWS advised CAA that due to the increasing aircraft and ground vehicles traffic at CKS Airport, the tower controllers would have limited capability to monitor the movement of aircraft and vehicles during reduced visibility conditions. After a joint survey, the CAA and the ANWS were in agreement in selecting the site to build a new tower to accommodate the installation of ASDE at CKS Airport.

In 1998, the CAA instructed the ANWS to complete the procurement program for the ASDE installation before May 1998, and to include the ASDE installation in the budget for the year 2000. In early 2000, CAA decided to delay the ASDE procurement for a year because of budgetary constraints and the workload of installing 3 air route surveillance radars, 2 airport surveillance radars and the replacement of weather radar at CKS Airport. The ANWS then requested that the ASDE procurement be included in the 2001 budget. The CAA instructed the ANWS to carry out the ASDE procurement project in stages, starting in 2002.

On February 1, 2001, the CAA requested approval from the MOTC to escalate the ASDE procurement process to a date earlier than the first part of 2001. The MOTC replied in two weeks, asking the CAA to submit the ASDE procurement and installation plan for evaluation. The CAA then submitted the plan to MOTC on April 24, 2001. Again, the MOTC asked CAA to modify the ASDE procurement and installation plan. The CAA submitted the modified plan and the MOTC finally approved the plan on August 15, 2001.

1.18.2.5 Safety Management (Incident Reporting and Tracking)

Incidents are required to be reported by pilots, ATC and airport management. Serious incidents are also reported to the ASC and the CAA.

The CAA requires pilots to either directly report an incident on an ATC frequency or to file a "Pilot Ground Report" at Flight Information Stations or Flight Operation Sections (FIS/FOS) at any airport. The FIS/FOS, after receiving the incident report(s), will register and fax the report(s) to CAA headquarters without delay. The responsible division will investigate the incident and submit a preliminary investigation report to headquarters. After reviewing the investigation report, the CAA will then report back to the pilot/reporter on any progress being made.

The Safety Council obtained six reports of incidents that had occurred at CKS Airport since March 1998 (See Appendix 5).

1.18.2.6 NOTAMs and AIP Supplements

1.18.2.6.1 NOTAMs

On August 31, 2000, Taipei published NOTAM A0606 (replacing NOTAM A0604) stating that a portion of Runway 05R/23L between Taxiway N4 and N5 would be closed with effect from 0900 (0100 UTC) on September 13, 2000, until 0900 (0100 UTC) on November 22, 2000. It stated that Taxiway N4 and N5 would remain available.

On November 1, 2000, NOTAMs A0758 and A0759 were published on the closure of Runway 05L/23R and Taxiway NP and NS "due to FOD."

On December 22, 2000, Taipei issued NOTAM A0907 (replacing A0860). It stated that with immediate effect, Runway 05R/23L was to be changed into Taxiway NC. Takeoffs and landings were prohibited.

1.18.2.6.2 AIP Supplement

AIP Supplement A007 C015/00 dated October 3, 2000, stated that Runway 05R/23L would be re-designated Taxiway NC with effect from 0100 on November 2, 2000 (1700 UTC November 1, 2000). The runway centerline lights (green) and the edge lights (white) would remain on Taxiway NC until further notice. Runway marking would be changed.

On October 23, 2000, the Air Traffic Services Division of the CAA published a NOTAM stating that the re-designation of Runway 05R/23L to Taxiway NC would be postponed until further notice.

1.18.2.7 Lighting SOP - ATP-88

According to CAA ATP-88, section 4, Airport Lighting, the approach and runway lightings procedures were as following:

3-4-4 APPROACH LIGHTS

Operate approach lights:

a. Between sunset and sunrise when one of the following conditions exists:

1. They serve the landing runway.
2. They serve a runway to which an approach is being made but aircraft will land on another runway.

b. Between sunset and sunset when the ceiling is less than 1,000 feet or the prevailing visibility is 8 km or less and approaches are being made to:

1. A landing runway served by the lights.
2. A runway served by the lights but aircraft are landing on another runway.
3. The airport, but landing will be made on a runway served by the lights.

c. As requested by the pilot.
d. As you deem necessary, if not contrary to pilot's request.

NOTE-In the interest of energy conservation, the ALS should be turned off when not needed for aircraft operations.

3-4-10 HIGH INTENSITY RUNWAY, RUNWAY CENTERLINE, AND TOUCHDOWN ZONE LIGHTS

Operate high intensity runway and associated runway centerline and touchdown zone lights in accordance with the TBL 3-4-4 except:

a. Where a facility directive specifies other settings to meet local conditions.
b. As requested by the pilot.
c. As you deem necessary, if not contrary to the pilot's request.

TBL 3-4-4

HIRL, RCLS, TDZL Intensity Setting		
Step	*Visibility*	
	Day	*Night*
5	*Less than 1,600m.**	*When requested*
4	*1,600m to but not including 3,200m*	*Less than 1,600m.**
3	*3,200m to but not including 4,800m*	*1.600m to but not including 4,800m.**
2	*When requested*	*4,800m to 8,000m inclusive.*
1	*When requested*	*More than 8,000m*
**and/or appropriate RVR equivalent.*		

1.18.2.8 CKS Approach / Tower Operations Manual

The CKS Approach / Tower Operations Manual provides detailed guidance on energy conservation without jeopardizing flight safety. It is stated that the airport lights should be switched off when not in use.

1.18.2.9 Runway Visual Range

The RVR printout on October 31, 2000, indicates that Runway 05L lights were switched on at 2313 (1513 UTC) and switched off at 2324 (1524 UTC). The lights had been set at level 3 out of 5 levels.

1.18.3 Airport Chart

The Jeppesen navigation charts that the pilots used during the flight were located in the cockpit, but were destroyed by post-accident fire. According to the interview reports with the pilots, CM-1 and the other 2 pilots all stated that the charts used on October 31, 2000, showed Runway 05R and 05L. Jeppesen chart, dated "7 JUL 00" of CKS Airport, reflects Runway 05R as a runway (Figure 1.18-1).

Illustration not Available

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Jeppesen-Sanderson can be reached at:
www.jeppesen.com
55 Inverness Drive East
Englewood, CO 80112-5498

Figure 1.18-1 Jeppesen chart, dated "7 JUL 00" of CKS Airport

The Jeppesen chart provided to the flight crew did not include a yellow page supplement that contained information on the work in progress on Runway 05R.

A revised version of the CKS Airport Jeppesen chart dated “27 OCT 00” and effective 1 NOV 1700Z, no longer depicts Runway 05R. The former Runway 05R was changed to Taxiway NC.

1.18.4 Runway Condition and Crosswind Limitation

The CKS ATC controller did not provide the flight crew of SQ006 with information regarding the condition of the taxiways or runways, nor was he or she required to do so. Also, the flight crew did not request any information regarding the condition of the taxiways or runways from ATC. There were no pilot reports applicable to Runway 05L.

According to interviews with several ATC controllers, CKS Airport does not have equipment to measure the depth of standing water on the runway. Any runway condition determinations are made either by the pilots using the runway and providing ATC with pilot reports, or by CKS Airport operations or maintenance personnel who may periodically observe runway conditions and provide those observations to the controller.

When queried about the determination of a contaminated runway, the SIA B747-400 Chief Pilot stated that ATC should provide information to the crew on the condition of the runway. When asked if SIA had a procedure to assist pilots to assess the state of a water affected runway when ATC did not provide such a service, the B747-400 Chief Pilot stated that flights crews rely upon ATC to provide this information. The Chief Pilot commented that flight crews are not in a position to accurately assess whether a runway is contaminated. Further, the Chief Pilot commented that most runways (unless defective) are designed with adequate drainage to prevent an excessive accumulation of water on the runway surface.

When asked about the crosswind limits for the B747-400, the Chief Pilot confirmed the following guidance stipulated by the SIA Flight Crew Training Manual and that these were training guidelines only:

- 30 knots dry runway;
- 25 knots wet runway; and
- 15 knots for a contaminated runway.

The SIA Operations Manual stated that the crosswind limit was 30 knots, and did not differentiate between wet and dry runways. This was in accordance with the limit specified by the Boeing 747-400 flight manual. SIA operates according to the Boeing procedures and performance limitations and has adopted the Boeing Operations Manual as its official operational document. SIA has added its own chapters on operational and fuel policy, and has modified the Boeing normal checklist to make it more compatible with its own operational requirements.

1.18.4.1 SIA Runway Condition Definition

The Operational Policy, section 4.10, in the SIA B747-400 Operations Manual defined a contaminated runway as:

> *4.10.1 A contaminated runway is a runway that is partially or entirely covered with standing water of more than 1 mm, slush, snow or ice, or a "wet" runway with sand or dust.*

A wet runway is defined as:

> *4.11.1 Wet runway is a runway that is well-soaked but with no standing water.*

No procedures for determining a "wet" or "contaminated" runway were provided in the SIA B747-400 Operation Manual, or any other SIA publication which formed part of the company flight operations manual.

1.18.4.2 Other Airlines' Policies of Determining Runway Conditions

According to an Asia-Pacific airline's FOM Chapter 5 Operating Policy, A contaminated runway was defined as:

> *A runway where more than 25 percent of the required field, within the width being used, is covered by standing water or slush more than 0.125 inch (3.2mm) deep, or that has an accumulation of snow or ice.*

This airline also has a policy to assist pilots to assess the runway condition. The policy to determine a runway condition was, in part:

> *While flight planning, pilots should anticipate runway conditions for planned departure and arrival airports. Generally, non-grooved runways will be considered to be "wet" if moderate rain (RA or SHRA) is forecast at or shortly before the time of departure or arrival. If heavy rain or thunderstorms are forecast, standing water should be expected. The presence of standing water, snow, slush, or ice generally indicate the need for application of contaminated runway performance adjustments.*

Another Asia-Pacific airline's B747-438 Operations Manual also provided guideline to assist pilots to assess the runway condition, in part:

> *When in doubt about the condition of the runway, be conservative.*

When landing in very heavy rain on runways which are not grooved…, the runway should be treated as "contaminated" with "poor" braking.

1.18.5 Para-Visual Display (PVD)

1.18.5.1 Operational Concept

According to the SIA B747-400 Flight Crew Training Manual (FCTM, page 8.32), the PVD is a display that allows the pilot to receive directional information from a peripherally located display whilst maintaining eyes forward and out the window looking for familiar visual cues. The two PVD elements are mounted on the coaming centrally in front of each pilot; one on the right side and one on the left side. Figure 1.18-2 shows the location of the PVD on CM-2's side. The inset in the lower left corner of this figure shows a single PVD up close.

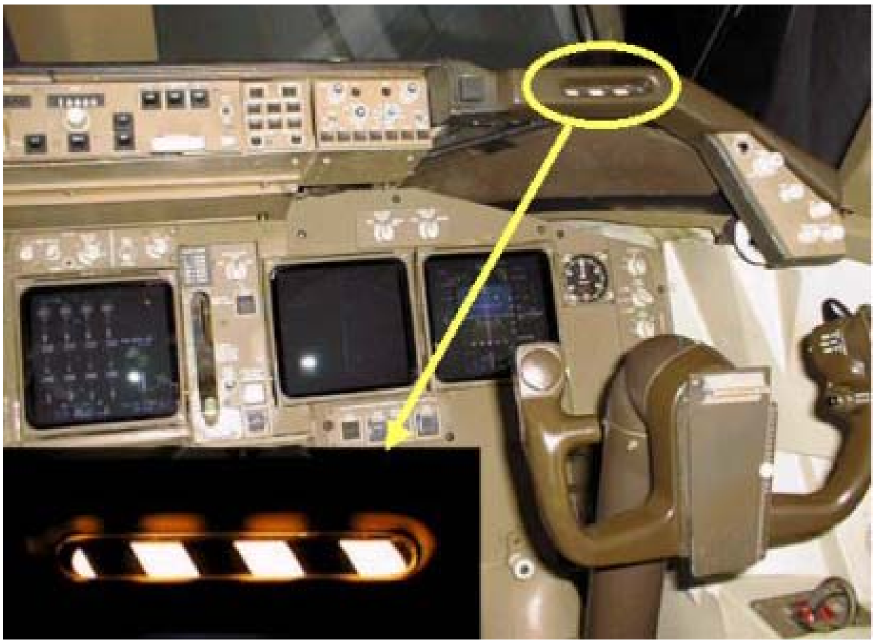

Figure 1.18-2 Para- Visual Display.

Each PVD unit is actually a mechanical device incorporating a rotating rod or pole that has black stripes on a white background (like a "barber pole"). Rotation of the pole gives the impression of lateral motion, or streaming, to the left or right.

The PVD becomes a valuable indication in the case that runway visibility is poor (less than 50 meters) during takeoff. The PVD is tuned to the takeoff runway's ILS signal. As long as the aircraft is on the runway centerline, the "barber pole" indication is stationary; however, when the aircraft diverges left or right of the centerline, the barber poles streams to guide the pilot's steering. For example, if the aircraft is to the right of the centerline, the PVD will stream left to guide steering left toward the centerline.

The PVD is a high-reliability reversionary aid to runway steering—the primary aid being the pilot's normal visual cues from runway marking and lights. The PVD should unshutter and begin functioning correctly as the aircraft is aligned with the runway centerline, and remain functioning as long as the controlling parameters remain valid. The PVD remains shuttered when it is not in use or when the ILS signal is not being picked up (e.g., out of range, signal blocked, system failure).

There is no procedure or requirement in the SIA Boeing 747-400 Operations Manual for the PVD indications to be used as a means of identifying a correct runway for takeoff.

According to another airline that has installed PVD on their fleet, their B747-400 Operations manual (amendments dated June 12, 1998 and February 11, 2000) stated that "Using the runway localizer tuned on the Navigation Radio page, the PVD provides guidance to runway centerline during ground operations."

1.18.5.2 Operational Procedure

According to the SIA B747-400 FCTM (page 8.33), pilots should select the PVD on when they have taxied to the "hold" Position. It is also necessary that the ILS localizer for the takeoff runway be tuned in. When the PVD is selected on, the computer will run pre-takeoff self-tests. These tests open the shutter and stream the display in each direction for 1.5 seconds. The crew should monitor this test for any anomalies. The crew should also adjust the brightness of the PVD display, if it is needed.

The memo messages PVD CAPT ON, PVD F/O ON, or PVD BOTH ON appear on the main Engine Indication and Crew Alerting System (EICAS) display when either one or both PVD have been selected on. If either PVD system fails during normal operation, the advisory message PVD SYS CAPT or PVD SYS F/O will appear on the main EICAS display.

1.18.5.3 PVD Supplement

According to the Boeing 747-400 Airplane Flight Manual (AFM), section 1, page 15:

> *"PARA VISUAL DISPLAY (PVD) SYSTEM*
>
> *If operating under Civil Aviation Authority of Singapore jurisdiction then refer to Civil Aviation Authority of Singapore (CAAS) Supplement for information which supercedes the data in the following paragraph.*

Low weather minima operations shall not be predicated on the use of the PVD system, since the FAA has not evaluated the PVD system."

By reviewing the Boeing 747-400 Airplane Flight Manual provided by MCIT, the Safety Council found no such Supplement in the AFM. According to the MCIT, the Supplement was approved by the CAAS on October 31, 1994, and was located in the Supplement Section in Book 2 of the AFM. Revision 15 of the Supplement was the revision current at the time of the accident. The CAAS Supplement, section 3, page 1 contained the statement (See Appendix 6):

"The flight crew should confirm that when the PVD is selected ON, the display streams right, left and then stops momentarily. The display will then either provide guidance to the localizer centerline or will shutter dependent upon whether the airplane is in a position for takeoff or not."

CAAS stated that SIA had earlier applied to CAAS to certify the use of the PVD system on its B747-400 aircraft. CAAS initially consulted the FAA on this matter and was informed by the FAA that it had not certified the PVD system since there were no US carriers using it. The FAA also advised the CAAS to consult other authorities that had certificated such system for their carriers. The CAAS consulted the UK CAA and the German Luftfahrt-Bundesamt (LBA) for guidance regarding their certification experience and to ensure that the CAAS approval was consistent with international best practices. According to the Preface of the AFM, the PVD system on SIA's B747-400 aircraft was approved.

CAAS also stated that it is the policy of CAAS to accept an AFM that is approved by the State of Design. Hence, the aircraft manufacturer shall obtain approval of the AFM from the State of Design before submitting the AFM to CAAS. Upon acceptance of the AFM, CAAS will issue a Flight Manual Approval to the Operator. This policy applies to amendments to the AFM that are approved by the State of Design. For equipment that is not approved by the State of Design (such as the PVD system), the CAAS will carry out certification for the equipment and its operation. After the CAAS is satisfied with the certification, it will require the aircraft manufacturer to publish an AFM Supplement for CAAS approval.

1.18.5.4 PVD Reliability

Because the PVD is a reversionary (back-up) instrument, it must be highly reliable. The reliability information is from several sources: SIA 747-400 pilots, other air carriers using the PVD, and the PVD manufacturer, Smiths Industries. Boeing itself does not maintain reliability information on this instrument.

During several interviews with SIA pilots (five SIA Captains and one First Officer), the following information was obtained: Except for one interviewee who had heard of some pilots' having problems with the PVD, all the others were clear that the PVD is a reliable system if the runway is appropriately certified for PVD departures or as long as there is no shielding of the LLZ/ILS signal. They have not heard of any failures of the system. Even the one exception could not specify the type or nature of apparent problems with the PVD he had heard about.

When the Safety Council contacted the air carriers who have purchased the PVD option for their 747-400s or 767s, there were no reported failures of the PVD system.

The PVD manufacturer, Smiths Industries, provided repair data for 13 PVD computer units which were returned to them in the period from January 1998 to November 2000. During that period, one PVD unit was returned because it did not activate on takeoff. A second PVD was returned because it tripped off during takeoff with EICAS and status messages displayed. The remainders were returned for various status and maintenance messages, including seven returned to incorporate an upgrade. Smiths Industries was not able to find faults in any of the 13 returned units.

1.18.6 PFD Indications

When the ILS is tuned for the takeoff runway (as required to use the PVD), two other indications appear on the Primary Flight Display (PFD). Figure 1.18-3 shows these PFD indications for two cases: on the left is the case when the aircraft is aligned with the centerline, and on the right is when the aircraft is not aligned with the centerline. The first indication is a localizer pointer and scale that appears on the bottom of the Attitude Indicator. The pointer is a solid magenta diamond that shows the aircraft's position relative to the localizer position.

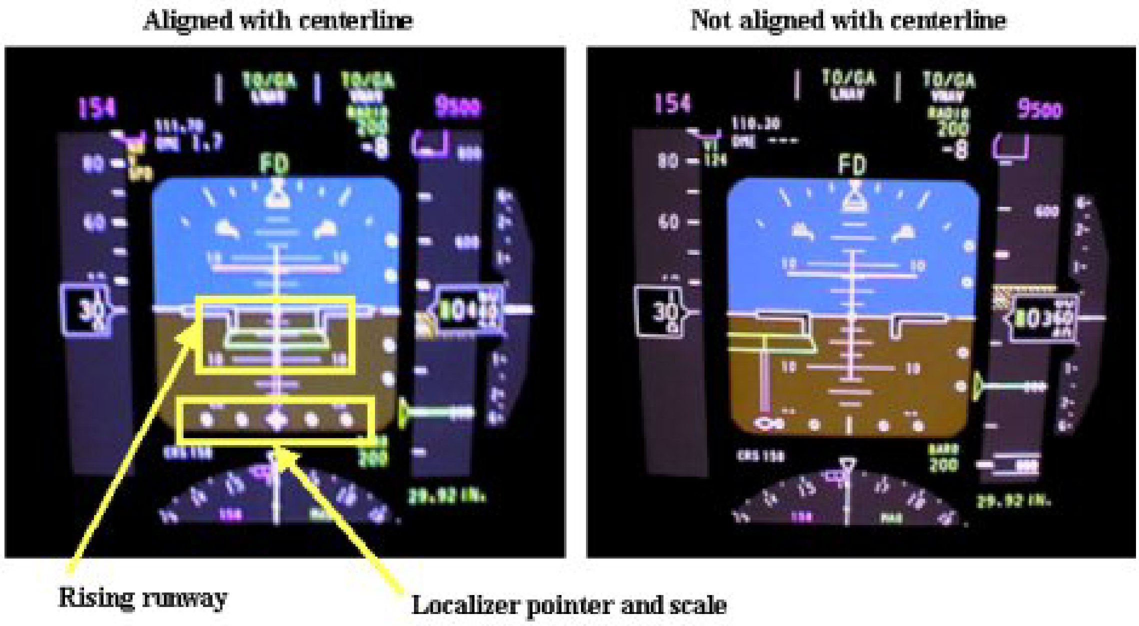

Figure 1.18-3 PFD indications associated with tuning the ILS.

Note that when the aircraft is not aligned with the centerline, the localizer diamond is shifted to the left side of the scale and is not filled in. The second indication is the rising runway symbol, which is a green trapezoid (a square with perspective) with parallel magenta lines extending down from it. This runway symbol should appear just below the horizon and centered. Note that when the aircraft is not aligned with the centerline, this rising runway is shifted off center.

1.18.7 Navigation Display (ND)

The ND provides an integrated display to enable accurate navigation of the aircraft. This includes lateral and vertical navigation pointers, a map, weather radar, radio facilities, wind speed and direction, groundspeed, true airspeed, and a display of the predicted path of the aircraft. It also includes an aircraft symbol and the current aircraft track. When a runway is selected, the ND will also display a runway symbol. The position of the aircraft relative to the selected runway is shown by the aircraft symbol. The selectable range of the ND is from 10 to 640 nautical miles. The size of the runway and aircraft symbols are proportional to the range selected. The greater the range selected, the smaller the size of the symbols.

During the taxi route simulation on November 6, 2000, the simulation team had selected Runway 05L ILS frequency for departure. Consequently, the runway symbol for Runway 05L was displayed on the ND, and was labeled "05L." Because the aircraft had lined up on Runway 05R, the aircraft symbol on the ND appeared on the right edge of the 05L runway symbol but the label "05L" remained unchanged. The investigation team was unable to determine what range had been set on the ND for

SQ006 prior to or on runway line-up. Figure 1.18-4 shows the ND when the aircraft was lined up on Runway 05R.

Figure 1.18-4 The display of the ND when the aircraft was lined up on Runway 05R

1.18.8 Surface Guidance and Navigation Technology

Recent technological advances have generated opportunities to increase the safety and efficiency of commercial airline operations, particularly in low visibility conditions. Moreover, experimental surface guidance cockpit technologies such as Electronic Moving Maps (EMMs) coupled to Head-Up Display (HUD) have been found to reduce flight crew navigation errors on airport maneuvering areas by up to 100 percent.[31] Empirical evidence has also indicated that these types of systems, such as the Taxiway Navigation and Situation Awareness (T-NASA) system, have reduced the navigational workload of pilots during taxi, increased flight crew situation awareness, and reduced taxi time compared to experimental conditions that simulated current methods for navigating an aircraft around

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[31] McCann, R. S., Hooey, B. L., Parke, B., Foyle, D. C., Andre, A. D., and Kanki, B. (1998). An evaluation of the Taxiway Navigation and Situation Awareness (T-NASA) system in high-fidelity simulation. *SAE Transactions: Journal of Aerospace, 107,* 1612-1625.

the movement area.[32,33] However, even though real-time accurate positioning information is available from global positioning systems (GPS), generating and displaying accurate surface movement information to flight crews on cockpit display also requires extensive infrastructure, including airport and terrain databases, advanced terminal area systems, and data link[34].

A cockpit navigation display for low-visibility surface operations is an interface that provides flight crews with information on the aircraft's exact position on the airfield. For example, the EMM superimposes the aircraft's position on a map of the airport surface, which includes features such as runways, taxiways and terminal areas. The aircraft depiction moves as it taxis along the airport surface, visually portraying information that is currently provided in a less complete format, such as paper charts and progressive taxi instructions. The human performance value of a moving map display is that it integrates a variety of complex data into a clear and precise representation of aircraft position on the airfield with reference to a pre-planned course. The moving map depiction facilitates the development and maintenance of a pilot's situation awareness by providing the pilot with an accurate picture of the aircraft position, especially in low visibility conditions. According to industry representations, the Safety Council is aware that the technology for such systems is quite mature.

1.18.9 Videotapes Regarding Crash Scene

1.18.9.1 Videotape Provided by Passenger

The passenger that provided the video tape was seated in the upper deck Row 12 of another Boeing 747-400 aircraft during the time of the accident (see section 1.18.1.5.1). The aircraft had pushed back from Bay A5 and was taxiing along Taxiway NP toward N1 when the crash occurred. The taxiing aircraft then turned into and parked at Bay A8. Duration of the recording was approximately one minute. The videotape showed the crashed aircraft burning on the runway. Passengers were escaping from the broken tail section. There were no Runway 05R edge lights visible during the entire length of the tape.

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32 Andre, A. D., Hooey, B. L., Foyle, D. C., and McCann, R. S. (1998). Field evaluation of T-NASA: Taxi Navigation and Situation Awareness system. *Proceedings of the AIAA/IEEE/SAE 17th Digital Avionics System Conference, 47, 1-8.*

33 Hooey, B. L., Foyle, D. C. and Andre, A. D. (2000). Integration of cockpit display for surface operations: The final stage of a human-centered design approach. *Proceedings of the AIAA/SAE World Aviation Congress* (Paper 2000-01-5521). SAE International: Warrendale, PA.

34 McCann, R. S., Hooey, B. L., Parke, B., Foyle, D. C., Andre, A. D., and Kanki, B. (1998). An evaluation of the Taxiway Navigation and Situation Awareness (T-NASA) system in high-fidelity simulation. *SAE Transactions: Journal of Aerospace, 107,* 1612-1625.

1.18.9.2 Videotapes Provided by CKS Airport Office

Several airport security videotapes recorded around the time of the accident were also reviewed.

Security Camera No. 77 was located at the building at Gate A6 facing the apron and Taxiway NP. The time shown on the frame showing the accident aircraft explosion was 2316:17 in the screen while the B747-400 aircraft taxiing from Bay A5appeared in the screen with same background was at 2318:05. Elapsed time was 1 minute and 48 seconds.

Camera 77 captured what appeared to be aircraft lights of SQ006 in the distance (2315:23). The definition of the lights improved as the aircraft moved along the runway until a flash was seen (2316:17) and almost at the same time a white shape was observed followed by an explosion just out of camera view.

Figure 1.18-5 shows the position of camera No. 77 and the position of the taxiing Boeing 747-400 where the passenger was on.

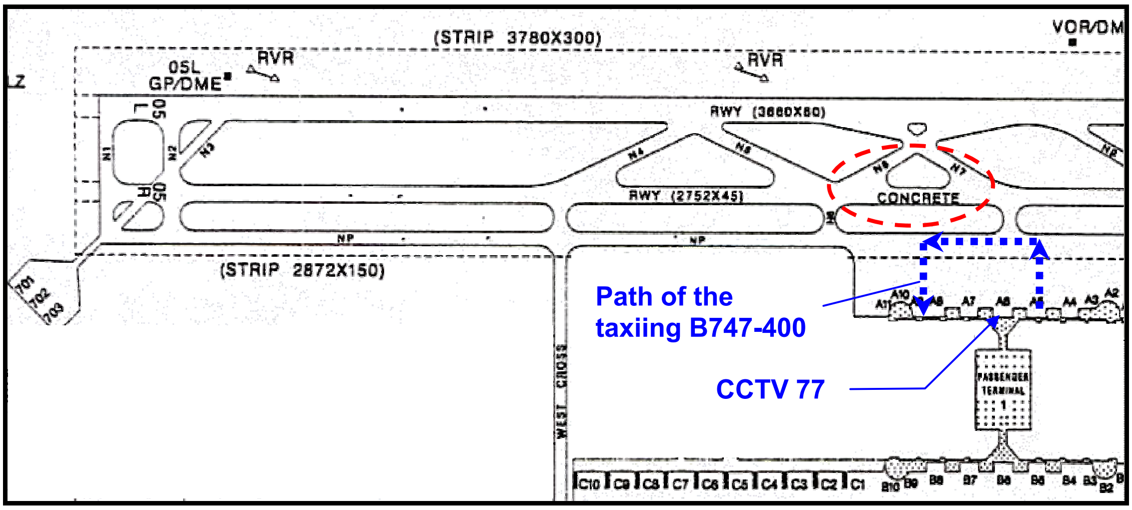

Figure 1.18-5 Position of No.77 security camera and the path of the taxiing aircraft

On camera 92, which was located at the domestic terminal near Taxiway N1, aircraft lights could be seen at time 2314:21 when SQ006 turned from Taxiway NP to Taxiway N1 and at 2315:16 when the aircraft turned into Runway 05R. There were no runway lights visible.

2 Analysis

This chapter provides an analysis of the information documented in Chapter 1 of this report, which is relevant to the identification of cause related findings and conclusions. It also provides an analysis of safety deficiencies identified in the course of the investigation that may or may not be related to the accident but nevertheless involve risks to safe operations. By highlighting those deficiencies, or risks, along with the cause related findings, the Safety Council serves the public interest. It also discharges its moral responsibility to publish whatever it learns in the course of an investigation that others may use to reduce risk and the probability of accidents.

Chapter 2 starts with a general description of the factors that were ruled out from the investigation as it is shown in section 2.1. Section 2.2 provides the necessary structural failure sequence of this accident. Section 2.3 and 2.4 analyze the condition of the airport at the time of the accident, the ATC procedure during the accident sequence, as well as the organizational, and management factors of the CKS Airport and the CAA of ROC. Section 2.5 analyzes the crew performance and the related crew training, coordination, and crew actions. Section 2.6 provides an analysis of the post accident fire, rescue operation, and survival factors. Section 2.7 provides the analysis of the safety issues that are deemed important for the improvement of aviation safety.

In accordance with ICAO Annex 13 and international practices, the Safety Council has employed a systemic approach to the SQ006 accident investigation. The approach examined all aviation system elements in accordance with the general guidelines in ICAO Annex 13, the ICAO Human Factors Training Manual[35] and the work of Reason[36]. As an applied example of a systemic approach to

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[35] Human Factors Training Manual. 1998. International Civil Aviation Organization Montreal, Quebec.

runway safety concerns, the FAA's *National Blueprint for Runway Safety*[37] clearly states that "no single entity 'owns' runway incursions and no single entity owns the cure." (p. v). Moreover, the *Blueprint* argues that improvements in each system element are required if runway safety is to be enhanced. For example, the *Blueprint* recommends improvements to flight crew and air traffic controller training, communications, procedures and associated surface technologies. The *Blueprint* also recommends improvements to airport infrastructure such as signs, marking and lighting, and the continual development of safety management systems with improved data capture and analysis capabilities. The Safety Council has addressed these complex and interactive issues, including organizational factors, throughout the analysis.

In situations where information is unavailable, incomplete, or absent, the use of inductive reasoning can facilitate a logical approach to developing a sound explanation of events. In addition, all information in the analysis has been subjected to various information tests. Part 2, chapter 4, sections 4.3.43 to 4.3.54 of the ICAO Human Factors Training Manual provides a limited guide for assessing the relevance and utility of air safety investigation data.

2.1 General

The pilots were properly certificated and qualified in accordance with applicable CAAS regulations, company requirements and ICAO SARPs. Records of crew duty time, flight time, rest time, and off duty activity patterns did not find any evidence of pre-existing medical, behavioral, or physiological factors that were likely to have impaired the flight crew's performance on the day of the accident.

The cabin crew was qualified in accordance with SIA training program.

The air traffic controllers involved with flight SQ006 were properly certificated and qualified. The evidence from CVR, FDR, interviews with ATC controllers and the flight crew indicated that the ATC taxi instructions and takeoff clearance did not mislead the crew into taking off from the partially closed Runway 05R. ATC procedures, airport infrastructure issues and the performance of CAA management are discussed later in this chapter.

The aircraft was certificated, equipped, and maintained in accordance with CAAS regulations and approved procedures, and ICAO SARPs. There was no evidence of pre-existing mechanical malfunctions or other failures of the aircraft structure, flight control systems, or power plants that

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36 Reason, J. 1997. Managing the Risks of Organizational Accidents. Ashgate Publishing Company.
37 National Blueprint for Runway Safety. 2000. Federal Aviation Administration.

could have contributed to the accident. The accident aircraft was considered airworthy before the accident.

The Safety Council has concluded that there was no evidence to indicate that there was any undue organizational pressure placed upon the flight crew to take off on the night of the accident.

2.2 Structure Failure Sequence

Based upon the wreckage distribution, the Runway 05R scratch marks, the ground equipment distribution, and the on-scene survey, the Safety Council derived the structure failure sequence. The following is the sequence of SQ006 as it took off from Runway 05R as shown from Figure 2.2-1 through 2.2-8.

1. The right body gear strut door (most likely the right side) impacted, and knocked over a jersey barrier. The left body gear traveled over pit #1 and the forward tires impacted the north edge of the pit, causing at least one tire to fail. (#1 pit as shown in red).

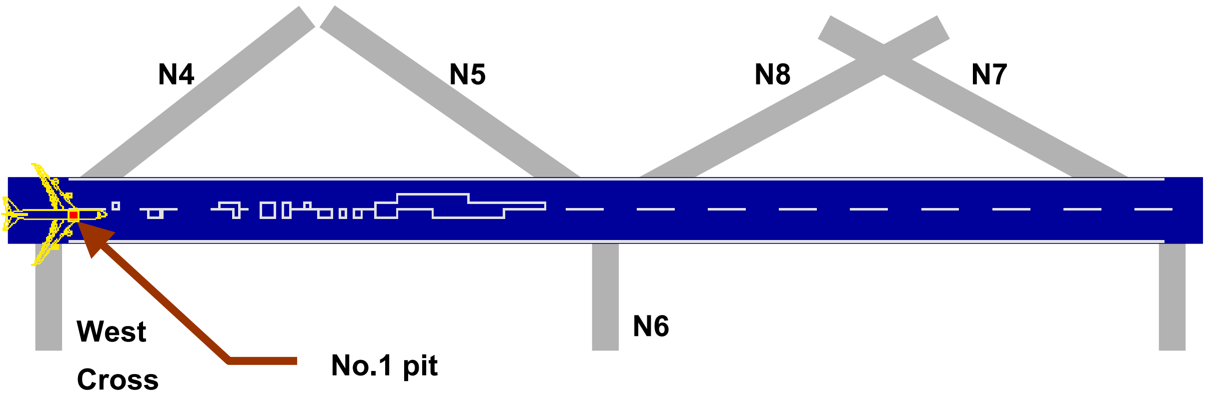

Figure 2.2-1 Structure failure sequence-1

2. #1 excavator (as shown in red) rolled/progressed down the lower left side of fuselage and damaged the Main Equipment Center and lower left side of fuselage and damaged the avionics bays cargo holds, and other components located below the main passenger cabin floor.

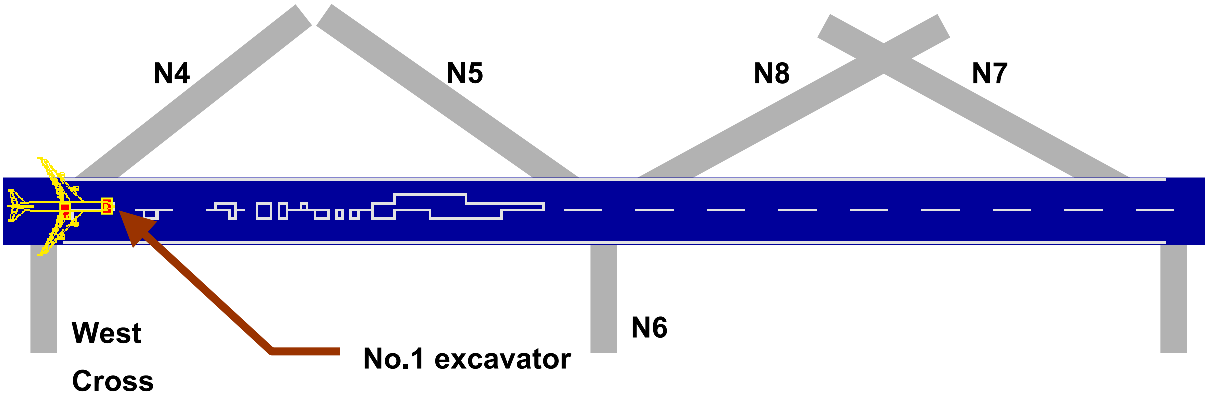

Figure 2.2-2 Structure failure sequence-2

3. The #1 excavator impacted the stabilizer as it rolled out from underneath the aircraft. The bucket or other structure impacted the leading edge, subsequently causing the stabilizer to fail and compromising the stabilizer fuel.

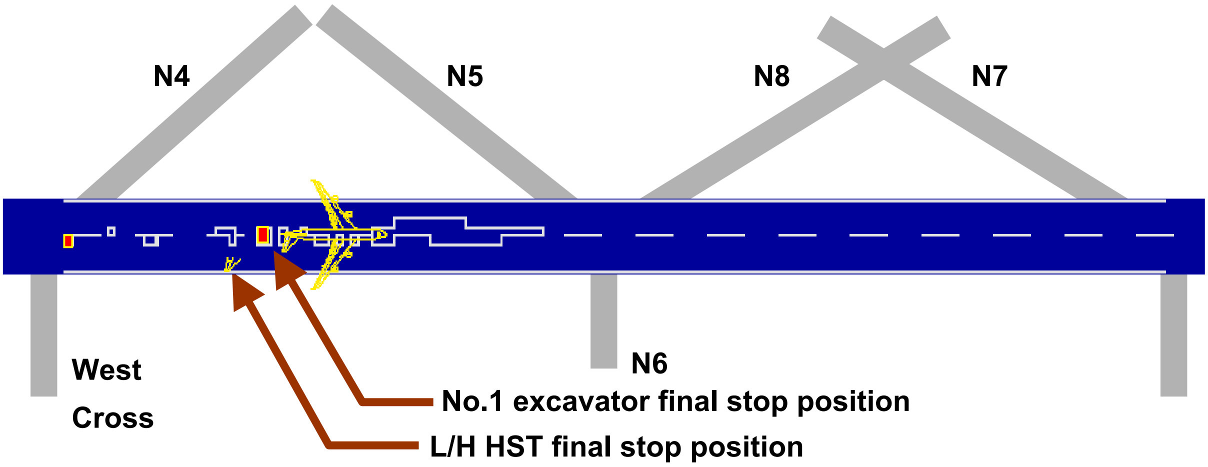

Figure 2.2-3 Structure failure sequence-3

4. The #1 engines struck the pile of rebar beside pit #11 and the #2 engine struck the second excavator (shown in red) in pit #11, causing both to separate from the left wing. The impacts on the left side and asymmetric thrust began a counter-clockwise rotation of the fuselage. At about the same time, the #3 engine struck the ground, separated from the wing, and continued onward towards the terminal building.

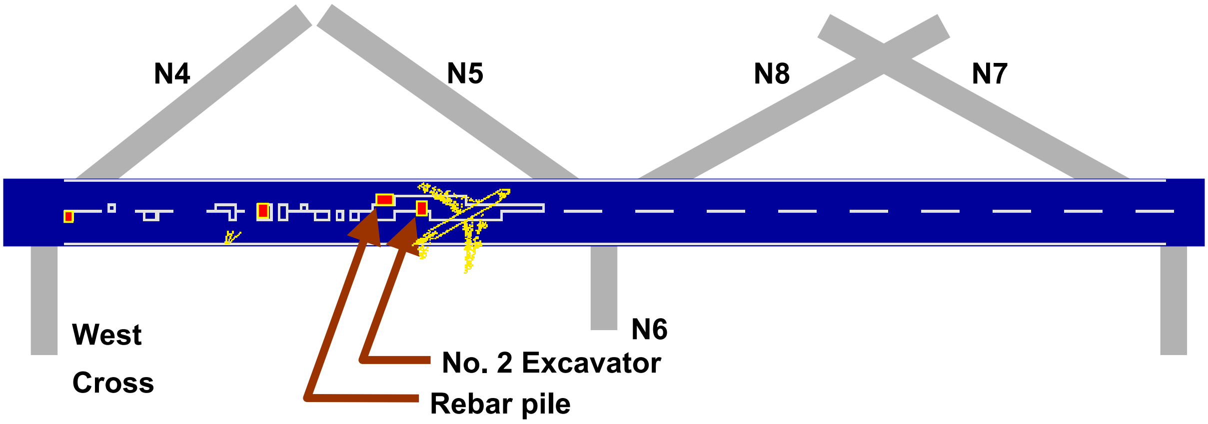

Figure 2.2-4 Structure failure sequence-4

5. After striking 2 Steam Rollers (as shown in red), the aft fuselage most likely broke away from the front fuselage prior to Taxiway N6 and almost immediately rolled onto its left side. The grass besides the eastern runway showed signs of burning, beginning at approximately 1,430 feet from the first point of impact along with burnt cargo items.

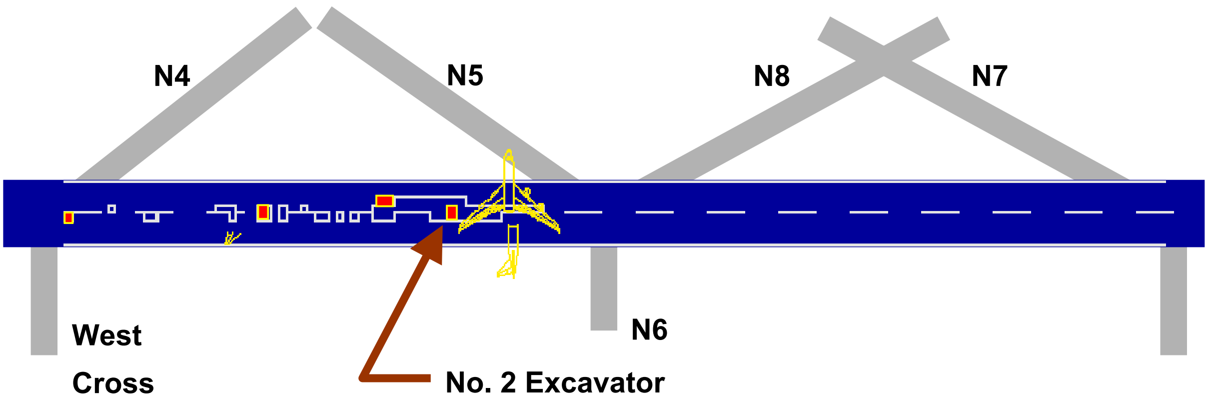

Figure 2.2-5 Structure failure sequence-5

6. As the aircraft was traveling backwards and rotating counter clockwise, the outboard section of the left wing was sheared off after hitting the southern manhole vaults (as shown in red). This stopped the CCW rotation and caused the aircraft to continue along the path backwards. The grass besides the eastern runway showed signs of burning beginning at approximately 2,000 feet from the first point of impact.

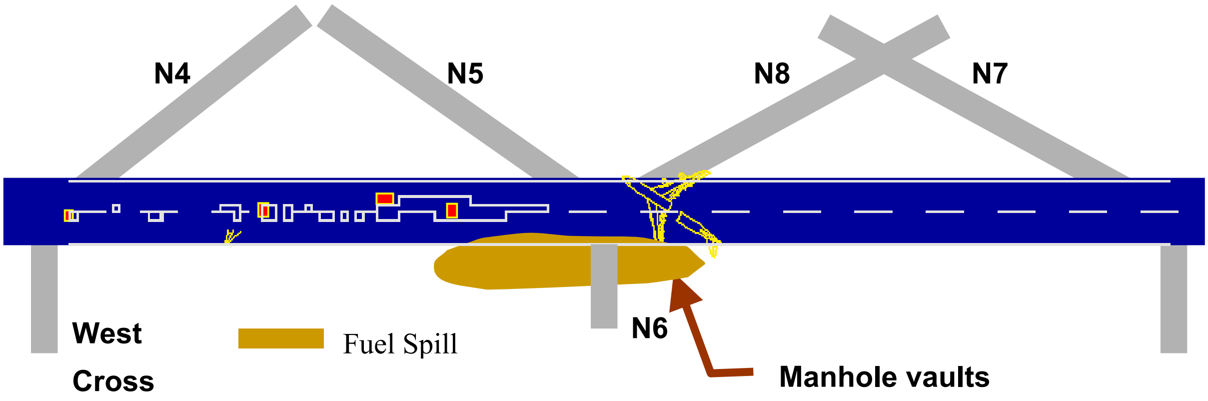

Figure 2.2-6 Structure failure sequence-6

7. As the aircraft was traveling backwards, the #4 engine impacted the concrete pad (as shown in red), separating it from the right wing.

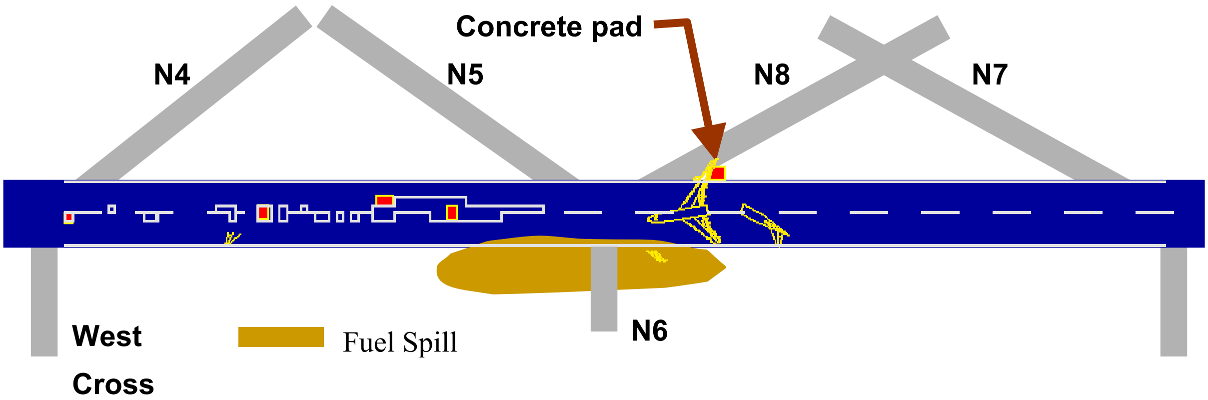

Figure 2.2-7 Structure failure sequence-7

8. When the #4 engine impacted the concrete pad, a counterclockwise force was applied to the forward fuselage section, rotating the aircraft to its final heading when it came to rest.

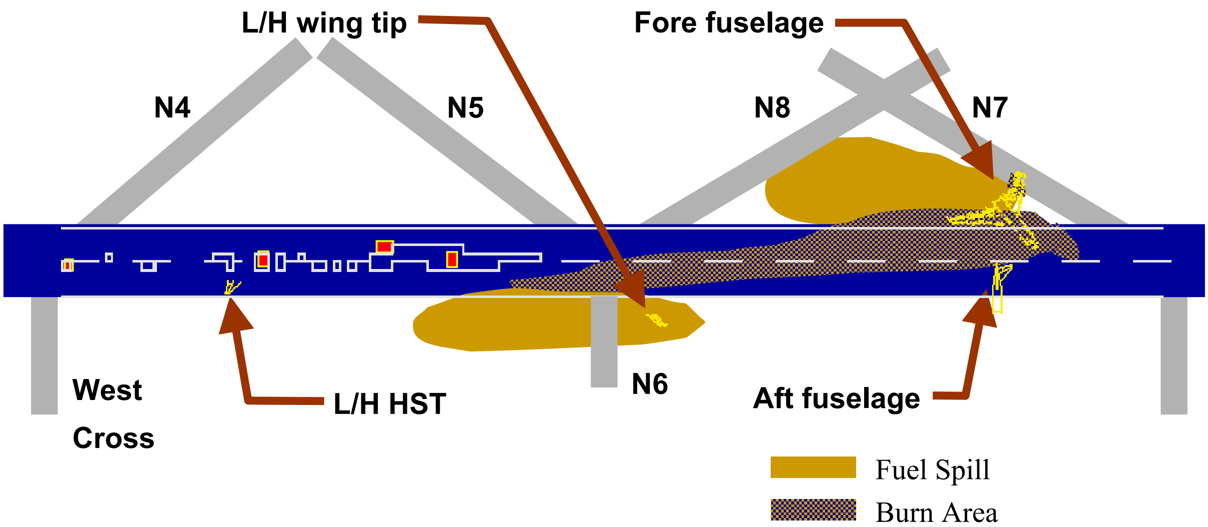

Figure 2.2-8 Structure failure sequence-8

2.3 CKS Airport at the Time of the SQ006 Accident

At the time of the accident, the CKS Airport Runway 05R, between Taxiways N4 and N5, was closed due to work in progress. Before the day of the accident a decision was made to re-designate Runway 05R to Taxiway NC but it had not been implemented at the time of the accident. Therefore, Runway 05R remained as a runway with part of it used for taxi purpose only.

2.3.1 Taxiway N1 Centerline Marking and Centerline Lighting

2.3.1.1 Design of Taxiway N1 Centerline Marking

The CAA's civil engineering specifications, ICAO Annex 14 and the FAA AC all provide standards and guidance on the design and installation of taxiway centerline marking as stated in section 1.10.

The distance between the south edge of Runway 05R and the tip of the curvature where the N1 centerline made a turn into Runway 05R, was 32 meters and the distance between the north edge of the Runway 05R and the tip of the curvature where the taxiway centerline marking turned away from Runway 05R to join Taxiway N1, was 35 meters. According to the CAA civil engineering specifications (ATP-AE 1000301: 3.8.5.1), the N1 centerline marking should have a 20-meter extension from the tip of the curvature toward Runway 05R and a 23-meter extension away from Runway 05R toward Runway 05L.

According to the CAA civil engineering specifications, the Taxiway N1 centerline should have been extended all the way down to the Runway 05L threshold marking, with an interruption beginning 12 meters before the Runway 05R threshold marking and ending 12 meters after the Runway 05R threshold marking.

The FAA Advisory Circular 150/5340-1H indicated that the taxiway centerline marking should stop at the edge of a runway.

It is apparent that the Taxiway N1 centerline marking of the CKS Airport did not meet the CAA's own specifications, the ICAO standard and the FAA AC. This inconsistency was never noticed during design verification, work completion certification, and in day-to-day operations. The Safety Council believes such discrepancy was due to the lack of an airport facility specialist that would be responsible for safety surveillance of the airport and the lack of a safety oversight mechanism by the CAA.

2.3.1.2 Taxiway N1 Centerline Lighting

2.3.1.2.1 Taxiway Lighting System Interlock with Runway 05R Lighting Systems

According to ICAO Annex 14, vol. 1, paragraph 8.2.3 (Standard),

> *"Where a runway forming part of a standard taxi-route is provided with runway lighting and taxiway lighting, the lighting systems shall be interlocked to preclude the possibility of simultaneous operation of both forms of lighting."*

As mentioned in 1.10, the CKS Airport Runway 05R/23L was originally designed solely for taxiing only; therefore, the runway was equipped with green taxiway centerline lights. Because it was also used as a runway, it also had white runway edge lights. According to the ICAO Standards at the time of the design (1973), it was not necessary to provide an interlock mechanism between these two types of lighting systems to preclude both systems operating simultaneously; however, in 1995, ICAO Annex 14 SARPs were revised to include the requirement for the installation of an interlock mechanism. The CKS Airport equipment was not upgraded to meet the required change. The Safety Council believes that the reason for not being able to keep up with the updated ICAO Standards was due to the lack of a clearly designated unit responsible for periodically reviewing ICAO Standards and updating local regulations.

2.3.1.2.2 Spacing of Taxiway Centerline Lighting

ICAO Annex 14,vol. 1, paragraph 5.3.15.13,

> "*Recommendation* - *On a taxiway intended for use in RVR conditions of less than a value of 350m, the lights on a curve should not exceed a spacing of 15m and on a curve of less than 400m radius the lights should be spaced at intervals of not greater than 7.5m. This spacing should extend for 60m before and after the curve.*"

The curve radius from Taxiway NP through Taxiway N1 to Runway 05R was 60 meters; therefore, in order to meet that latest ICAO recommendation, the taxiway centerline lights should have been spaced at intervals no greater than 7.5 meters.

The distance of the Taxiway N1 centerline lights from the tangent of the curve as it turned into Runway 05R and extended further towards Runway 05L (at the reciprocal curve tangent from Runway 05L along Taxiway N1 towards 05R) was 114 meters. The minimum RVR for takeoff on Runway 05L at the time of the accident was 200 meters. In accordance with the ICAO recommended practice there should have been a total of 16 lights along that section; however, there were only four lights spaced in uneven distances, which did not meet ICAO SARPs.

The Safety Council considers that the spacing of the taxiway centerline lights at the time of the accident increased the risk of the safety aircraft operations, as it will further be discussed in section 2.5.

2.3.1.2.3 Unserviceable Taxiway Centerline Lights

ICAO Annex 14, vol.1, paragraph 9.4.23 indicated that two adjacent unserviceable lights were not permitted when the RVR was less than 350 meters. The Safety Council found during the site survey on November 4 (four days after the accident) that the second light after N1 departed from the tip of the taxiway curvature, was out of service. In addition, the third light's luminance intensity was substantially degraded; however, there were no reports from the CKS Airport Flight Operations Section, Airfield Lighting Maintenance Group, or any other flight crew taking off from Runway 05L on the evening of the accident stating that there were two adjacent unserviceable lights along Taxiway N1. Further, no flight crews had submitted safety concerns or reports about the Taxiway N1 lighting prior to the evening of the accident.

The Safety Council concluded that although the second Taxiway N1 light was not serviceable and the third light was less intense on the evening of November 4, 2000, the status of these N1 taxiway lights on the night of the accident might or might not have been the same.

2.3.2 The Installation of Runway Guard Lights (RGL)

ICAO Annex 14 (third edition-July 1999) vol. 1, paragraph 5.3.20.1, stated that a configuration A Runway Guard Light (Figure 2.3-1) shall be provided as a standard. FAA AC 120-57A paragraph 8b suggests: runway guard lights to be provided when operating below RVR 365 meters. AC 150/5340-28 also mentioned: RGL provides a distinctive warning to anyone approaching the runway holding position that they are about to enter an active runway. The CKS Airport did not install configuration A RGL. Therefore, it did not meet the ICAO standard.

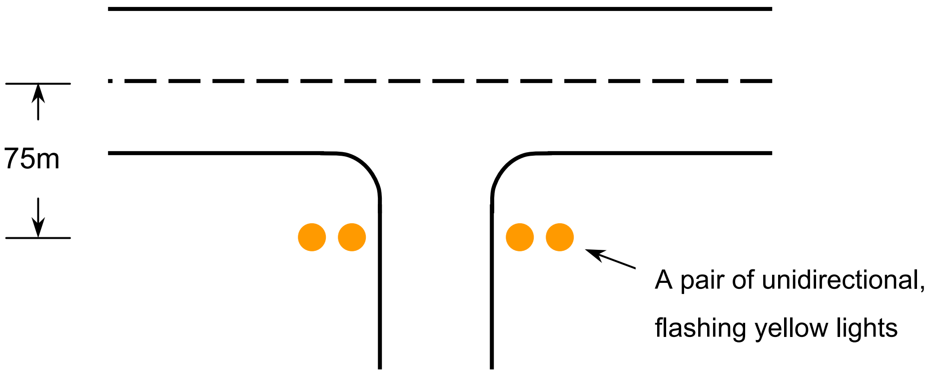

Figure 2.3-1 RGL of configuration A

If CKS Airport had installed RGL on both the left and right sides of Taxiway N1 as required by the ICAO standard, that is, 75 meters from the centerline of Runway 05L, the distance from that location to the centerline of Taxiway NP would be 249 meters and the distance to the intersection on Taxiway N1 that turns into Runway 05R would be about 175 meters. Since the RVR on the night of the accident was 450 meters, the crew could have had one indication that the CAT II Runway (05L) was still ahead of them. This will be discussed further in section 2.5.

2.3.3 Safety Considerations for Temporarily and Partially Closed Runway

According to statements of CAA officials, when the construction project began on Runway 05R, the remaining routes, other than the construction area along Runway 05R were designated for taxiing. It was very useful for aircraft that landed on Runway 23R to exit via either Taxiway N2 or N1, then taxi eastbound onto Runway 05R to the apron. The other end of Runway 05R/23L was also the main taxi route for freighters parked at the cargo apron to use when taxiing westbound before joining taxiway NP, and then taxiing to Runway 05L for takeoff (Figure 2.3-2). The use of Runway 05R for taxiing beyond the construction area could definitely increase taxiway capacity and ensure safe separation of aircraft.

The Safety Council believes that total closure of Runway 05R would reduce the taxiway capability of CKS Airport during the period of construction along Runway 05R.

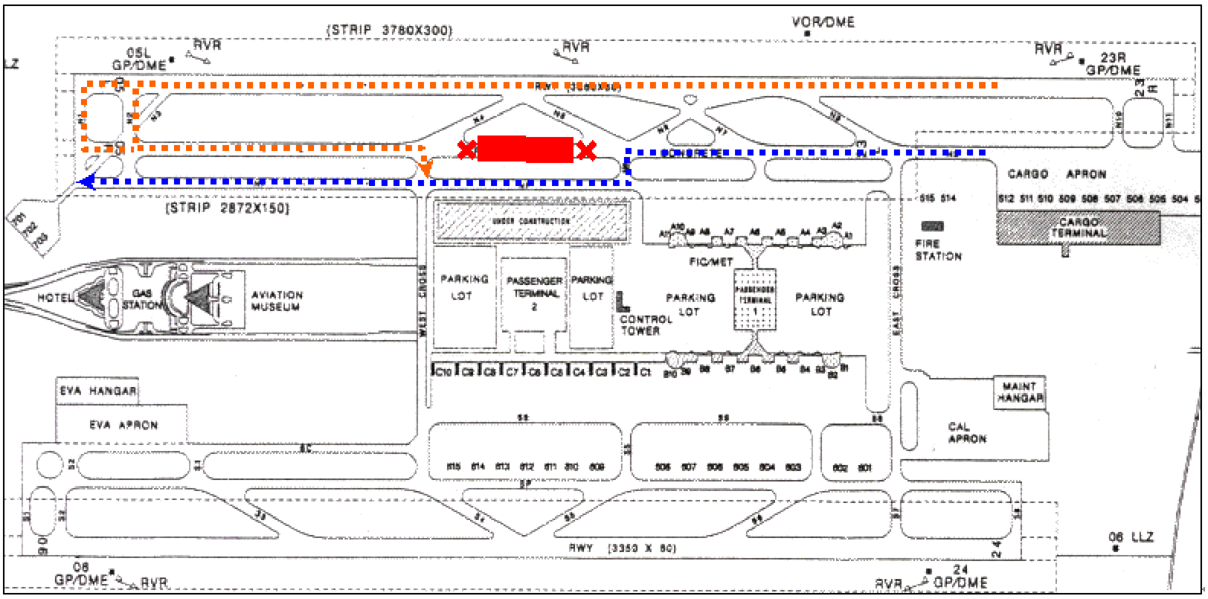

Figure 2.3-2 Taxi route during Runway 05R under construction

However, with regard to the construction area on Runway 05R, the Safety Council identified two safety deficiencies. First, according to ICAO Annex 14, vol. 1, paragraph 7.1.3 (Standard), there should have been closure markings adjacent to the construction site (Figure 2.3-2); however, there was no requirement to place runway closure markings near the threshold of Runway 05R. Secondly, according to ICAO Annex 14, vol. 1, paragraph 7.1.4, (Standard), the barriers placed at the construction site, should have been frangible. The concrete barriers did not meet the intent of ICAO SARPs. It should be stated that neither of these deficiencies was involved in the circumstances regarding the SQ006 accident.

Another deficiency identified by the Safety Council pertains to ICAO SARPs guidance for marking a temporarily closed runway or taxiway, or a portion thereof. The Safety Council believes that the provisions of ICAO Annex 14, vol. 1, paragraph 7.1.2, are vague, since it mentions that marking "…may be omitted when the closing is of short duration and adequate warning by air traffic services is provided." Annex 14 does not define or explain what is considered "short duration." Nor does the guidance address a temporarily closed runway that remains open, in part, for taxi operations. Therefore, there were no ICAO SARPs that would have required or recommended the placement of warnings at the entrance to Runway 05R.

Nevertheless, the Safety Council believes that the circumstances regarding the planning and execution of the construction project on Runway 05R suggest that CKS Airport management should have taken steps, as part of a risk analysis, to reduce the risk that flight crews might inadvertently attempt to takeoff on a partially closed runway. The issuance of NOTAMS, AIP notices, and ATIS information about the runway closure was according to ICAO SARPs, and a good measure to reduce the risk; however, more significant warning indications would have been more effective. The Safety Council acknowledges that permanent runway closure barriers at the entrance to Runway 05R would have been impractical, since they would have adversely affected taxi operations. However, temporary measures, such as clear warnings/alerts or markings/indications, along Taxiway N1 and N2, and on either side of the entrance to Runway 05R would have provided an important defense against pilots mistakenly entering the wrong runway. The existence of such temporary measures could also have been noted on the ATIS, in the AIP, and in NOTAMs. Therefore, the Safety Council concludes that the lack of adequate warnings at the entrance to Runway 05R did not provide a potential last defense, from an airport infrastructure perspective, to prevent flight crews from mistakenly entering Runway 05R.

2.3.4 Power Status of Runway 05R Edge Lights at the Time of the Accident

2.3.4.1 Evidence Regarding Status of Runway 05R Edge Lights

The Safety Council reviewed all available data to determine if the Runway 05R edge lights were powered at the time SQ006 taxied onto the runway and commenced its takeoff.

Although videotapes from airport security cameras and from a passenger's video camera aboard a B747-400 aircraft taxiing for departure recorded events in the general location of Runway 05R about the time of the accident, Runway 05R edge lights were not perceptible at the time immediately before, or after, the accident. It was stated in section 1.18 that the exterior lights of SQ006 were visible on airport security camera no.77. If the Runway 05R edge lights were on, they should have been visible on the video as well. Although the quality of the videos in the prevailing weather conditions precludes a definite conclusion regarding the status of the edge lights, this evidence strongly suggests that the Runway 05R edge lights were not on during takeoff roll.

The absence of an interlocking system to prevent simultaneous operation of the edge lights for Runways 05R and its centerline lights made it possible for both to be powered at the time of the accident. Statements from the ATC controllers indicated that none of them had turned on the Runway 05R edge lights. Although this evidence is not conclusive that the lights were off, it is plausible because there was no need for the edge lights on Runway 05R to be illuminated at the time of the accident. Hower, the Safety Council concludes that the ATC controllers' recollection may not be accurate.

Two Captains operating at CKS about the time of the accident were questioned about their observations of Runway 05R lighting. The Captain of the B747-400 aircraft, which was taxiing along Taxiway NP for takeoff on Runway 05L when SQ006 crashed, stated that he first saw SQ006 when his aircraft was abeam gate A7. He said that SQ006 was already on its takeoff roll. He could see the accident aircraft's landing lights, but could not determine if the aircraft was airborne. He also said that visibility was good, but the rain was heavy at the gate, although it was "on and off." The Captain said that he did not see any lights on either Runway 05R or 05L, although he did recall that Taxiway NP taxi lights were on. He stated that SQ006's landing lights were visible as it moved down the runway, but "the rest was pitch dark." Since the landing lights of SQ006 during its takeoff roll were visible to him, it is very likely that the Runway 05R edge lights were not on or he would have seen them, since they were only about 110 meters from Taxiway NP.

The Captain of another B747-400 aircraft, which departed from Runway 05L about 16 minutes before the accident, could not recall if the edge lights were on or off on Runway 05R when he passed it.

Records for the runway lighting systems were kept for Runway 05L/23R only for calibration and maintenance of the RVR equipment. The RVR printout of the Runway 05L lighting system status revealed that they were powered on about 2313 (about 4 minutes before the accident), about the time when SQ006 was switched from Ground Control to Tower frequency as the flight was taxiing along Taxiway NP. The RVR printout of the Runway 05L lighting system also indicated that the lights had been turned off shortly after the accident when the airport authority declared that the CKS Airport was closed. There was no RVR equipment installed for Runway 05R/23L because it was used for non-instrument takeoffs only. Consequently, no records were kept regarding the power status of the edge lights for Runway 05R/23L.

According to ATC recorded transmissions, about 40 minutes after the accident, the CKS SFOO called the CKS tower using his hand-held radio and requested that all runway lights of Runway 05 be turned on (he did not specify 05L or 05R). This statement makes it clear that the edge lights for Runway 05R were off at that time; however, the RVR printout revealed that Runway 05L edge lights were also off at this time and came on shortly after the SFOO requested all runway lights to be turned on. Based on these two evidences, the Safety Council is unable to conclude what the status of the edge lights was at the time of the accident.

The tests and research conducted on the two runway edge light wires from locations RE239 and RE240 revealed conflicting evidence. The absence of arcing damage on the wire strands from RE239 suggests strongly that the light was not powered when it was damaged by aircraft debris during the accident, or by AFFR vehicles shortly after the accident. The absence of arcing more likely indicates that the light at location RE239 was not powered when SQ006 commenced its takeoff.

The evidence of arcing on the wire strand ends and along a length of wire from location RE240 reveals that, at some point, the wires were connected to a power source and arcing damage occurred. The examinations of RE240 and tests conducted after the accident suggest the possibility of damage due to arcing. Assuming that the edge light at location RE240 was on when wreckage or fire and rescue vehicles passed over it, the arcing could have occurred when the wire separated. That scenario could easily explain the arcing noted on the wire strand ends; however, it does not explain the arcing damage along the wire lengths that would have been protected by insulation until the post-accident fire burnt the insulation away. The ATSB laboratory report suggests that the fire damage to the wire strands of RE240 involved a "boundary effect" whereby the plug end of the wire was immersed in a liquid, which protected it, while the remainder of the wire insulation burnt away. If that were the case, arcing evidence on the wire lengths would have to have occurred sometime after the insulation burnt away, possibly after power was re-applied to the lighting system about 40 minutes after the accident. Further tests conducted by CSIST revealed that arcing at the strand ends where globules were found could occur after the wire strands had separated from the cramp and were subsequently grounded with power available.

Regarding the arcing damage found on the length of the wires and the globules found on the wire strand end, the Safety Council developed a probable scenario to explain their origin.

1. When the light fixture at location RE240 was struck by moving objects (aircraft wreckage or ground vehicles), the wire ends separated from the crimped wire terminal fitting and the connector plug remained in the socket. The wire insulation would have been intact at this point.
2. The wire insulation on the connector was exposed to fire/heat and a portion of it was lost.
3. About 40 minutes after the accident, the SFOO requested activation of Runway 05 lights to illuminate the accident site.
4. Fire fighting and rescue operations or strong winds caused both wires to chafe against each other after power was restored, resulting in arcing damage on the length of the wires and wire strand ends.
5. At the same period of time, the wire strand ends contacted metal (like aircraft debris) to ground, and therefore produced arcing and formed the globules.

2.3.4.2 Summarized Analysis of the Status of Runway 05R Edge Lights

All direct and indirect evidence regarding the Runway 05R power status are summarized in Table 2.3-1.

Table 2.3-1 Synthesis of the Runway 05R edge lights power status

Source	Data	Supports	Detracts
1. Controller interview	Did not turn on Runway 05R edge lights	No particular reason to turn on runway edge lights. Procedures, training and practice not to turn on edge lights when 05R is a taxiway	Recollection may not be accurate
2. CKS SFOO requested lights to be turned on	About 40 minutes after the accident, the lights were on	At the time he asked to turn the lights on, runway edge lights were off	Lights could be on then off. Runway 05L lights turned off about 7 minutes after the accident when airport closed
3. Wire RE239	No electrical arcing	Not powered when separated by wreckage from the aircraft	Cannot be positive when the wire separated from the socket
4. Wire RE240	1) Shows arcing along length of the wire 2) Found globules on the wire strand end	1) Possible only when insulation burned away 2) Produced when wire separated from cramp, or momentary contact metal to ground after lights turned back on.	Can not determine which event took place
5. Airport security camera No.77 videotape record	Explosion flame and the taxiing aircraft in view	No perceivable runway edge lights shown during takeoff roll, SQ006 landing lights visible	Poor visibility
6. Video tape from taxiing B747-400 aircraft passenger	Taken 30 seconds after explosion (duration: 58 seconds)	No perceivable runway edge lights shown 30 seconds after explosion	Did not know the status 30 seconds prior to the video picture
7. Captain of the taxiing B747-400 aircraft	Observed SQ006 landing lights while taxiing on NP near A7 gate toward 05L for takeoff	Did not see any lights on Runways 05L and 05R, NP centerline were on	Recollection could be inaccurate
8. Flight crew recollections	None sure whether edge lights were on	CM-3, when on West Cross, noted bright green lights ahead and pitch black ahead.	CM-1 thought he remembered Runway 05R edge lights was on (about 80 percent sure)

In summary, although some of the evidence regarding the status of the Runway 05R edge lights at the time of the takeoff of SQ006 is inconclusive, the Safety Council believes that the preponderance of evidence indicates more likely that the runway edge lights were off during the SQ006 takeoff.

2.3.5 Organizational Issues Related to CAA and CKS Airport

2.3.5.1 Issues Related to CAA

The coordination between two regulatory units of equal rank of different divisions (such as division-to-division or airport-to-airport) was the responsibility of the personnel who managed regulatory projects or tasks. If unresolved issues arise or coordination problems developed between units, the project coordination would be forwarded up the chain-of-command to each unit's senior supervisors or managers. If difficulties persist, the issues might be forwarded directly to either the Deputy Director General or Director General for resolution.

When there was not a clear demarcation of task or work responsibility between two regulatory units (such as Flight Standards Division and Airport Flight Operations Section), the CAA headquarters division could direct a specific field unit to undertake a particular task or project. The investigation found that ambiguity often existed between regulatory job assignment and work distribution amongst field units. For example, regulatory personnel were uncertain about airfield facilities work distribution between the Aerodrome Division and each airport. The investigation found that the resolution of work distribution and tasking responsibilities was often protracted and overly bureaucratic. For example, the subordinate units of the field divisions did not have the authority to directly communicate with other parallel units and this often caused delays in project implementation. All communications followed strict hierarchical protocols.

2.3.5.2 Mechanism of Rule Making and Modification of Civil Aviation Regulations

2.3.5.2.1 Making, Revising and Updating of Civil Aviation Regulations

Each individual division of the CAA was responsible for making the regulations within its jurisdiction; however, most of the staff members in each division had no legal background. This resulted in rules or regulations that were inadequately written, delaying the entire approval process. In addition, CAA's access to certain civil aviation resources are impaired by its absence from participation in major international organizations, including ICAO. This also causes some problems in modifying some rules and regulations in a timely fashion.

Taking advantage of the resources of airline operators (such as the legal department) in making rules and regulations was sometimes done. Some asserted that this results in unfairness to some carriers, especially the small ones.

The CAA had not clearly designated which organization was responsible for collecting and reviewing the latest ICAO documents and FAA regulations to aid in the modification and updating of local regulations. Further, individual divisions did not have designated personnel responsible for modifying and updating local regulations.

2.3.5.2.2 Current Status of Modification and Updating of Local Regulations

On September 3, 1987, the CAA published its "Civilian airport civil engineering design standard and specifications" and "Airfield air navigation lighting specification." The CAA regulations have not been regularly revised to reflect the most recent amendments to ICAO SARPs. Interviews with CAA personnel indicated that an effort to modify domestic regulations to reflect the most recent ICAO SARPs did not begin until 1999. CAA was planning to complete a revision to the civil aviation regulations by the end of 2001. Adherence to international standards and recommended practices is an essential component of aviation safety; however, because of political reasons, ROC is not an ICAO signator and receives no direct help or information from ICAO. This isolation from the primary international aviation advisory and standards body has had an adverse bearing on ROC's ability to conform to ICAO SARPs.

2.3.5.3 Maintenance Supervision and Safety Oversight of CKS Airport

2.3.5.3.1 Maintenance Supervision of Airport NAVAID Facilities

The CKS Power Group was responsible for the maintenance of the CKS Airport NAVAID lighting system and was supervised by the CKS Facilities Sector, which was a subordinate unit of the ANWS. The ANWS and all airports hold an equivalent rank within the CAA. The Safety Council believes that although the CKS Airport authority was in charge of the operation and management of the airport, it did not have jurisdiction over the NAVAID facility's maintenance and the associated operational personnel (this authority belonged to the ANWS). Further, the Air Navigation Facility Division of the CAA had no jurisdiction over the ANWS, although it was responsible for the technical supervision of the maintenance of CKS NAVAID facilities.

2.3.5.3.2 Safety Oversight- Safety Preventive Measures during Pavement Construction Period

As described in section 1.17.13, airfield safety is the responsibility of the CKS Airport Flight Operations Section during construction work. The contractor is responsible for providing safety plans and having them checked and approved by the Flight Operations Section. Interviews with personnel from the Flight Operations Section and the Maintenance and Engineering Section revealed that they were not familiar with ICAO SARPs pertaining to safety measures when there are airfield construction works in progress.

2.3.6 Summary of Organization and Management Related Airfield Deficiencies

Based on the analysis as illustrated in 2.3.1 to 2.3.5, the following is a summary of the organization and management-related deficiencies of the CKS Airport facility at the time of the accident:

1. Deficiencies that met the ICAO standards at the time of design but failed to keep up with subsequent revisions:

   - Runway and taxiway lighting systems interlock mechanism;
   - Installation of stop bar lights;
   - Installation of runway guard lights.

2. Deficiencies that did not meet ICAO SARPs at the time of design and were not identified during construction specification review, acceptance at work completion and routine maintenance and operation.

   - Mandatory Instruction Signs;
   - Taxiway centerline marking and lighting.

3. Deficiencies caused by inadequate administrative management:

   - Safety measures during airfield work in progress;
   - Process of converting Runway 05R into Taxiway NC;
   - Failure to revise CAA regulations to reflect updated ICAO SARPs.
   - Lack of a SMGCS plan for low visibility operation.

The Safety Council concludes that the inadequacy of the CAA organizational structure and its management were factors that caused these deficiencies to exist.

2.4 Air Traffic Control Procedures and Defenses

2.4.1 Low Visibility Taxiing and Ground Movement Instruction

Air Traffic Control Procedures (ATP-88) require the controller to issue progressive taxi/ground movement instructions when a pilot/operator requests this service or the controller deems it necessary due to traffic or field conditions, such as construction or closed taxiways. Progressive ground movement instructions include step-by-step routing directions. The procedures also require tower controllers to issue such instructions during reduced visibility conditions, especially when the taxi route is not visible from the tower. The primary purpose of the ATC system is to prevent a collision between aircraft operating in the system. The controller provided the flight crew of SQ006 with a routine taxi instruction from the terminal apron to Runway 05L. Although the visibility was reduced due to weather and SQ006 was the only aircraft moving on the airport, the guidance provided in ATP-88 requires the controller to issue progressive taxi instruction if requested by the pilot. ATP-88 also indicates that if the pilot does not request progressive taxi instructions, the controller, at his or her discretion may issue progressive taxi instructions. The Standard Operating Procedures of CKS Airport Tower require the ground controller to inform the aircraft by using the phraseology "PART OF AIRPORT IS INVISIBLE FROM TOWER, TAXI SLOW DOWN WITH CAUTION," when visibility drops below 2000 meters. The duty controller did not use the phraseology when transmitting to SQ006.

According to the Chief of CKS Control Tower, the purpose of the ATC low visibility taxi procedure was to prevent aircraft accidentally taxiing into each other. When the CKS Ground Controller issued the taxi clearance to SQ006, SQ006 was the only aircraft taxiing in the area. In addition, the Ground Controller stated that he was able to maintain visual contact with SQ006 until the aircraft was handed off to the Local Controller on Taxiway NP; therefore, the Ground Controller did not inform the crew that part of the airport was invisible from the tower and to slow down the taxi with caution. Further, the Chief of Tower stated that according to the ICAO Procedures for Air Navigation Services (ICAO Doc 4444) and the Manual of Surface Movement Guidance and Control Systems (ICAO Doc 9476), there is no requirement for a Ground Controller to advise pilots that they are not visible from the tower.

The weather data indicated that the visibility at the time SQ006 taxied towards Runway 05L was 600 meters (RVR was 450 meters for Runway 05L). The distance between CKS Control Tower and the threshold of Runway 05L is about 2,000 meters. It was clear that the controllers in CKS Tower were not able to see SQ006 when it was approaching the Runway 05R threshold; however, CM-1 stated in interview that he had the impression that CKS Tower controllers could see the aircraft because the takeoff clearance was issued when the aircraft approached the end of Taxiway NP. The Safety Council was unable to determine what effect, if any, there would have been on the accident had the CKS Ground Controller told the pilots that part of the airport was invisible from the tower; however, the Safety Council believes that if the CKS Ground Controller had told the pilots that the controllers would not be able to see the aircraft from the tower, CM-1 might not have had the false impression that the tower controllers were able to see the aircraft. CM-1 may have been more aware of the aircraft's location.

It is apparent that the controller did not issue progressive ground movement instructions and did not use the low visibility taxi phraseology to remind the aircraft to slow down its taxi. Based on the evidence, including the comments made by the flight crew on the CVR about taxi speed, the Safety Council concludes that the taxi speed of SQ006 did not contribute to this accident and the effects of issuing progressive taxi instructions to the accident aircraft are not known. However, if the controller had issued progressive taxi instructions to the flight crew, there would have been one more indication to the crew of their position and there is a possibility that the crew may have remained conscious of their position beyond Taxiway NP..

2.4.2 Airport Surface Detection Equipment (ASDE)

CAA has been in the process of acquiring ASDE since July 19, 1994. Despite the existing operational requirements for ATC facilities and ASDE procedures stipulated in the ATP-88, the procurement and installation of ASDE was delayed; however, it is not clear whether the installation of ASDE at CKS would have prevented the accident involving SQ006.

In conditions of heavy rain, the presentation of an ASDE display can be diminished considerably by rain. There was extensive precipitation at CKS Airport because of the approaching typhoon weather at the time of accident; therefore, it is not clear whether the ASDE could have provided useful information to the controllers to prevent the accident; however, during the interview, Controller A believed that ASDE could have prevented this accident. Nonetheless, there is a possibility that had ASDE been installed and used by the controllers, it might have alerted them to the incorrect taxi route of SQ006.

Had the ASDE been in service, the tower controllers at CKS Airport definitely could have used ASDE-derived information to assist in the determination of the exact location of aircraft and vehicles, or the spatial relationship to other aircraft and vehicles on the movement area. It would also be useful in monitoring compliance by aircraft and vehicles with ATC’s instructions; therefore, the Safety Council concludes that the CAA should accelerate its procurement and installation of ASDE at domestic airports with high traffic volume. The Safety Council also recommends that the CAA, as well as ICAO, list ASDE or equivalent equipment as standard equipment for civil airports, especially those airports with heavy traffic and occasional poor visibility.

Four months after the SQ006 accident, the CAA requested the MOTC to approve the ASDE procurement process in the first part of 2001. The request was not approved until August 15, 2001, which is ten months after the SQ006 accident. The safety action to install ASDE was not taken in a timely manner because the MOTC did not fully realize the significance of such an installation. The lack of knowledge about navigational aids and not being proactive in supporting CAA’s safety enhancement project also played a role.

2.5 Flight Crew Performance Related Issues

2.5.1 Overview

This section addresses the human factors and organizational issues associated with flight crew performance. In particular, it addresses information that was available to the flight crew, flight crew training, SIA procedures, airport infrastructure, crew situational awareness, and other pertinent organizational safety concerns. The integration of human factors and flight operations material was adopted to avoid the duplication of information and to facilitate a more coherent, logical, accurate and parsimonious analytical structure for flight crew related issues. This approach has provided a clear platform to better understand some of the causal and risk-related factors that were present on the evening of the accident. This approach has also provided a means for developing meaningful and helpful accident prevention measures or safety actions for aircraft operators.

2.5.2 Documented Airport Information Available to the Flight Crew

2.5.2.1 NOTAMs and INTAMs

According to interviews with the SIA-contract dispatchers (EVA dispatchers), the flight crew was provided numerous documents prior to takeoff. These documents included a Computer Flight Plan (CFP), CAA NOTAMs, SAS NOTAMs, SIA INTAMs, and weather information. The dispatchers stated that they highlighted parts of the operational documentation to help summarize important information for the flight crew. For example, on the evening of the accident, the EVA operations officer highlighted relevant and important aspects of the weather forecast and the official NOTAMs. The SIA INTAMs also contained information about the status of the Runway 05R centerline lights and edge lights, but this information was not highlighted. Follow-up interviews with the flight crew on November 3, 2000, indicated that neither CM-1 nor CM-2 recalled any INTAM regarding Runway 05R and CKS Airport taxiway lighting.

The flight crew was provided with information contained in various documents prepared by EVA dispatchers. The format of these documents often makes the extraction of key information difficult. It is likely that the flight crew was unable to discern the information about the Runway 05R lighting. The dispatchers' procedure of highlighting "important" information may have also drawn the attention of the flight crew away from the lighting data. If highlighting by dispatchers occurred often, it might have also induced a tendency in the flight crew to routinely focus primarily on the highlighted components of the documents received from EVA dispatchers. Nonetheless, the flight crew reported that they were fully aware that sections of Runway 05R were only available for taxi and there was work in progress on Runway 05R.

2.5.2.2 CKS Airport Chart

According to interviews with the flight crew, all three pilots stated that the charts used on the day of the accident depicted Runway 05R and 05L. The Jeppesen CKS Airport chart, dated 7 JUL 00 (Figure 1.18-1) depicted Runway 05R as a runway. The revised version of the chart dated 27 OCT 00 and effective 1 NOV 00, 1700Z, no longer depicted Runway 05R because it had been changed to Taxiway NC. Although the charts in the cockpit of SQ006 were destroyed in the fire, the evidence as stated in section 1.18 indicated that the pilots had the 7 JUL 00 version of the CKS Airport chart in the cockpit.

On the night of the accident, there was no yellow page supplement depicting the work in progress on Runway 05R. According to Jeppesen, Jeppesen may issue a temporary yellow sheet to alert pilots about temporary approach procedures, special events, or when a major runway construction is scheduled in pre-announced phases; however, the production of a yellow sheet is not mandatory.

The yellow page supplements, colloquially known as yellow sheets, are issued by Jeppesen based on information provided by the respective airport authority of that country. A yellow sheet for CKS Airport would have provided the crew with an airport diagram, which clearly showed the location of the work in progress and the section of the runway, which was closed, and other relevant information to supplement the NOTAMs. Jeppesen had not produced a yellow sheet supplement for CKS Airport because they were revising the CKS Airport chart to reflect the change of re-designation of Runway 05R/23L to Taxiway NC as stated in AIP supplement A007 C015/00. There was no information in the supplement regarding construction. Nonetheless, the flight crew reported that they were fully aware the work in progress on Runway 05R.

2.5.3 Preflight Preparation

As noted in the previous section, the flight crew reported that they were fully aware that sections of Runway 05R were only available for taxi and there was work in progress on Runway 05R. The information was made available through NOTAMs, INTAMs, and the ATIS broadcast. In addition, CM-1 provided a briefing to CM-2 and CM-3 prior to SQ006's departure from CKS Airport, which included the portion of Runway 05R that was closed.

On the night of the accident, CM-1 planned for and requested Runway 05L for takeoff. Interviews with the crew indicated that CM-1 planned to use Runway 05L on the basis of the extra operational length available and the lower minimum visibility published for takeoff from this runway. At that time, the takeoff visibility, wind speed, and crosswind component were within SIA Company limits for Runway 05L. Considering the weather and the runway conditions, it was appropriate for the flight crew to use Runway 05L for takeoff.

During preflight preparation, the flight crew familiarized themselves with the airport chart and the briefed taxi route from the parking bay to the departure runway; however, the taxi route was changed by Air Traffic Control. As part of the preflight planning process, flight crews construct mental pictures of the taxi path, check points, and intersections that will be crossed along the taxi route. Interviews indicated that on the night of the accident, CM-1 re-briefed the flight crew on the revised taxi route as "…taxi to the end of NP, turn onto N1 then to Runway 05L." According to CVR data, there was no discussion between the flight crew during taxi regarding the crossing of Runway 05R before reaching Runway 05L. It was likely that CM-1 did not consider using the crossing of Runway 05R as a mental cue to aid in navigating to Runway 05L. Instead, he made a continuous turn from Taxiway NP onto Runway 05R; however, the interview with CM-1 indicated that he had initially briefed a taxi route that included taxiing on Runway 05R parallel to Runway 05L to reach the 05L threshold. Therefore, he was aware of the relationship between Runway 05R and 05L at one point prior to taxiing.

2.5.3.1 Time Pressure to Take Off Before the Arrival of the Typhoon

At the time of the occurrence, typhoon "Xangsane" was approximately 360 kilometers south of CKS Airport and moving NNE at 12 knots. CKS Airport was experiencing heavy rain, low visibility, and strong wind. The conditions were expected to worsen when the typhoon got closer to the airport in several hours.

Although CM-1 had reported in the interview that he felt no time pressure on the evening of the accident, CVR and interview data indicated that during taxi, the pilots were discussing the typhoon status[38] and they were aware that the weather conditions were going to deteriorate. Further, CM-1 stated that he was concerned that the typhoon was closing in and the weather would only deteriorate further if he delayed the flight. CM-3 had expressed similar concerns. The crew's concerns about the typhoon and the desire to avoid it may have enticed them to hasten their departure without appropriate attention to details that would correctly identify and confirm the correct runway prior to takeoff. This could have occurred despite the CM-1's instructions for the crew to take their time and to be careful with checklists and other procedures.

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[38] CVR 15:10:21, CM-3 said "Yah, it【typhoon】is coming in ah, the longer they delay the worse it is lah." CM-1 replied "Yah, worse if we are going to get out, if don't take off ah ….."

2.5.4 Taxi Navigation Cycle

The FAA Advisory Circular (AC) No. 120-74 dated June 2001, provides guidelines for the development and implementation of SOPs for conducting safe aircraft operations during taxi. Moreover, the AC addresses the activities that occur within the cockpit during taxi. Sections of the AC provide a useful frame of reference for assessing the low visibility taxiing performance of the flight crew of SQ006. Flight crew procedures are addressed in Part 5 of the AC. The following paragraphs have examined the performance of the flight crew of SQ006 against relevant criteria outlined in the AC. Measured against the guidelines set out in AC 120-74, the performance of the flight crew revealed some areas in their performance and that of SIA procedures or training that needed improvement. Neither the flight crew nor SIA met the basic benchmarks of this AC in their entirety.

2.5.4.1 Taxiing

According to the FAA AC, the basis of good navigation during taxiing is to "Use ALL resources available, including heading indicators, airport signs, marking and lighting, and airport diagrams to the fullest extent possible in order to keep the aircraft on its assigned taxi route." In addition, the *FAA Runway Safety* website safety tips state, "Use your instruments to verify your orientation on the airport." In the case of the SQ006 flight crew and CKS Airport, the use of these resources and some of the infrastructure was deficient at the time of the accident.

On the night of the accident, the flight crew followed the taxi checklist and procedures in accordance with the SIA B747-400 Operations Manual and navigated accurately until the aircraft approached the end of Taxiway NP. When the aircraft turned from Taxiway NP onto Runway 05R, CM-1 and CM-2 started to execute the before takeoff procedures and tasks, CM-3 started to calculate the crosswind component. The crew did not monitor the final phase of taxi in accordance with the airport chart and associated heading indications. Further, the crew did not check the taxiway and runway signage and marking to help verify the position of the aircraft when the aircraft turned from Taxiway NP onto Runway 05R via Taxiway N1. The pilots' field of view during the critical turn from NP onto Runway 05R will be discussed in section 2.5.7.1 of the report.

2.5.4.2 Flight Crew Awareness

FAA AC 120-74 states:

"*Flight crews should use a continuous loop process for actively monitoring and updating their progress and location during taxi. This includes knowing the aircraft's present location on the route that will require increased attention. For example, a turn onto another taxiway, an intersecting* *runway, or any other transition points. As the 'continuous loop' is updated, flight crewmembers should verbally share relevant information with each other.*"

Reference to the CVR shows that the information was shared and crosschecked between crewmembers as the taxi progressed, until the most critical point during the taxi from Taxiway NP through Taxiway N1 and onto Runway 05R.

According to interviews with the pilots and CVR data, at the time the aircraft was turning onto Runway 05R, CM-1 was engaged with the Before Takeoff Checklist. His attention was focused on the completion of checklist items, following the green taxiway centerline lights, and keeping the aircraft's groundspeed to about 5 knots to ensure control on the slippery runway in high wind conditions[39]. He did not recall seeing any sign or runway marking except the "piano keys" on the runway. He did not recall with certainty seeing any lights other than the centerline lights running down the runway.

CM-2 was focused on the Before Takeoff Checklist when the aircraft was turning onto Runway 05R. When CM-2 completed the checklist, the aircraft was half way through the turn and lining up on the runway. He had commented to CM-1 that the PVD had not unshuttered. CM-2 stated that his attention was focused on the PVD. The focus of CM-2's attention inside the cockpit reduced CM-2's opportunity to scan outside the aircraft. He did not notice any runway designation marking or runway signs; however, he recalled seeing lights leading onto the runway and CM-1 following the lights onto the runway. CM-2 stated that he saw bright lights in the middle of the runway and that it was the "correct picture" for him.

CM-3 stated that while the aircraft was taxiing onto the runway, he was checking the wind component chart to ensure that the crosswind component was within the company limitation of 30 knots. When he finished the calculation, the aircraft was lining up on the runway. He said that he saw centerline lights on the runway, but he could not see the ground. In addition, during taxi, he was unable to see the taxiway lights in close proximity to the aircraft because he was seated in the jump seat.

It is clear that all three pilots were not aware of the position of the aircraft when CM-1 turned onto Runway 05R. The attention of CM-2 and CM-3 was directed "inside" the cockpit for the checklist and crosswind component calculation. CM-1 was concentrating on maintaining the minimum taxi speed and following the green lights onto the runway. The crew essentially lost awareness of their location during the taxi. None of the three pilots had directed their attention to the runway marking and signs during the turn.

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[39] CVR 15:15:52 CM-1 stated "It going to be wet slippery I am going to slow down a bit slow turn here"

A loss of situational awareness can be due to a failure to attend to and perceive the information that is necessary for people to understand a given situation. The acquisition and maintenance of situational awareness is particularly important for individuals in complex, dynamic, socio-technical industries such as aviation. Research has indicated that humans have limited working memory and attention resources;[40] therefore, increased attention to some elements (such as crosswind component, low visibility, slippery runway, following the green lights, checklist), results in less attention to other elements (such as runway signs and marking, and Taxiway N1 centerline lights leading to Runway 05L). A loss of situational awareness occurs once the information-processing limit is reached or attention saturation occurs due to high concurrent task load and environmental stressors.

According to the CVR and linguistic discourse analysis[41] data, the main topic of communication between the flight crew was the weather conditions, and more specifically the wind speeds, general weather, and visibility. Thirty eight percent of the CM-1's intonation units[42] were concerned with weather and seventeen percent of the CM-2's intonation units were concerned with weather. As for CM-3, 81 percent of his intonation units were concerned with the weather. Although the fixation on the weather conditions may appear reasonable, crew tasking or work distribution could have been optimized to ensure that other operationally significant information was attended to with equal vigor.

The Safety Council concludes that under the severe weather situation experienced by the crew, the flight crew's attention had overly narrowed and focused on the weather information to the detriment of other critical operational information. Therefore, the crew could have missed the airport infrastructure information that may have made them aware that they were taxiing onto the incorrect runway.

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[40] Endsley, Mica. 1996. Situation awareness in aircraft. In Brent J. Hayward and Andrew R. Lowe (Eds.), Applied aviation psychology: achievement, change, and challenge: proceedings of the Third Australian Aviation Psychology Symposium. P403-417. Aldershot; Brookfield, Vt: Avebury.

[41] The linguistic discourse analysis was conducted by Dr. Frances Trix, an anthropological linguist specializing in oral discourse analysis, along with Carolyn Psenka, a graduate student in anthropology who has been conducting research in aviation and aerospace, both of Wayne State University, USA.

[42] Intonation unit is a stretch of speech uttered under a single intonation contour.

2.5.4.3 Intra-flight Deck/Cockpit Verbal Coordination

FAA AC 120-74 also states that "Before entering a runway for takeoff, the flight crew should verbally coordinate to ensure correct identification of the runway and receipt of the proper ATC clearance to use it."

Although the crew had verbally coordinated to ensure they all knew that Runway 05L was the takeoff runway, and they had received ATC clearance to use it, the crew did not confirm whether they were actually on 05L. Further, as CM-1 taxied into position for takeoff, the crew accepted that they were on Runway 05L without verifying their position using the aircraft instrument indications, taxiway/runway signage, or the runway environment.

2.5.4.4 Taxi Procedures

Analysis of the procedures in the SIA B747-400 Operations Manual, the FDR parameters, and the CVR transcript, indicated that the taxi clearance which the pilots received, taxi path, taxi speed, and cockpit conversation, were generally routine. One exception to the routine was the flight crew's discussion of alternates during taxi. The CVR transcript, the audio transcripts from the CKS Airport tower, and interviews with the 3 pilots, confirmed that the revised clearance was to taxi to Runway 05L via Taxiway SS, Taxiway West Cross, and Taxiway NP. Taxiway N1 was not specified in the clearance[43]. The taxi checklist and procedures performed by the flight crew was in accordance with the SIA B747-400 Operations Manual with the exception of the period when the aircraft turned from Taxiway NP onto Runway 05R. Further, the flight crew did not request progressive taxi instructions to augment their navigation accuracy in low visibility conditions.

As stated in section 1.17.4.5, SIA instructs pilots to use the correct taxiway and runway. Such admonishments are typical in complex socio-technical industries but exhorting people to comply with such directives is generally an ineffective accident or incident countermeasure unless specific methods to achieve the objective are provided[44]. The SIA Flight Instructor Manual requests instructors to teach pilots about "taxi routing and situational and environmental awareness," but there are no detailed guidelines for taxiing in low visibility conditions. There was no specific procedure for low

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[43] CKS Ground Control issued the taxi clearance to SQ006 as "…taxi to Runway 05L by Taxiway SS, West Cross and NP." The controller did not include "cross Runway 05R" in the clearance. According to CAA ATP-88 Chapter 3-7-2 b., when authorizing an aircraft to taxi to an assigned takeoff runway and hold short instructions are not issued, specify the runway preceded by "taxi to," and issue taxi instructions if necessary. This authorizes the aircraft to "cross" all runways/taxiways, which the taxi route intersects except the assigned takeoff runway.

[44] Reason, J. (1997). Managing the risk of organizational accidents. Aldershot, UK: Ashgate.

visibility taxiing described in the SIA B747-400 Operations Manual. The MCIT submissions to the investigation team indicated that taxiing an aircraft is a part of basic airmanship. There is no specific technique to be applied for taxiing in low visibility. Moreover, SIA stated that there were no specific requirements for low visibility taxi training for pilots stipulated in ICAO SARPs, JARs, FARs or promulgated by the major manufacturers and that SIA was following industry best practice.

2.5.4.5 SIA Low Visibility Taxi Training

Although there was no industry benchmark set for low visibility taxi training before the accident, it was found (from the CVR) that the flight crew of SQ006 did not measure up to the guidelines in the FAA Advisory Circular AC 120-74 on taxiing practices (p. 8). The SIA Operations Manual did not provide guidelines for operations in low visibility conditions. The SIA Flight Crew Training Manual's (FCTM) low visibility training section instructs flight crews to "…taxi slowly as necessary for safety. Do not hesitate to request from ATC the positions of other taxiing aircraft or to ask for a follow me car." However, CM-1 stated that he did not receive low visibility taxi training.

The FAA's *National Blueprint for Runway Safety* clearly recommended that training was needed for flight crews to help them recognize situations in which they needed help orienting themselves on the airport surface. In addition, the *Blueprint* recommended that all pilot checks, certifications, and biannual flight reviews incorporate evaluations of ground operations performance and tests of knowledge of airport signs, marking and lighting. Standardized training materials and training programs are required to address these issues (p.14). Moreover, the *Blueprint* explicitly recommended the development and implementation of surface movement training programs to emphasize good operating techniques and specific pilot actions that can reduce the potential for runway incursions. Such recommended training materials included the following items:

- Low visibility taxiing (using cockpit simulators whenever appropriate);
- Communication;
- Crew Resource Management;
- Standard Operating Procedures;
- Airport surface signs, marking, and lighting;
- Pavement configuration;
- Closely spaced parallel runways; and
- Holding position visual aids.

The flight crew was not fully aware of how weather at the aerodrome might have affected their ability to accurately navigate on the ground. It must be emphasized that in any complex system breakdown, there are many factors that contribute to the outcome. The FAA's *National Blueprint for Runway Safety* offers initiatives that address all system elements including flight crews, ATC operations, and airport infrastructure and safety management systems. With reference to flight crew performance, SIA did not have a comprehensive surface movement training program.

2.5.4.6 Summary

Measured against the guidelines in FAA AC 120-74, it was determined that the flight crew of SQ006 exhibited some performance deficiencies and that SIA procedures and training needed improvement. Neither the flight crew nor SIA met the FAA AC benchmarks in their entirety. On the basis of the evidence, there were many factors that led to the aircraft lining up on Runway 05R instead of 05L. Some of these factors were related to the performance of the flight crew. In summary, the SIA low visibility taxi training and procedures did not contain all the elements of what is currently regarded as the safest and best practice in this area.

2.5.5 Before Take-Off Check

The CVR indicated that none of the flight crew orally confirmed whether the runway they entered was Runway 05L. When an aircraft receives a clearance for takeoff, the flight crew's confirmation that they are on the active runway provides an additional measure of safety. On runway line-up, the flight crew did not cross reference their outside picture with the information on the CKS Airport chart.

The flight crew was aware that the particular runway view should have included white centerline lights and that there should have been an area of bright TDZ lights on the runway. Evidence for this fact is contained in the CVR transcript indicated that the flight crew briefed the use of Runway 05L as a "return alternate" because it was equipped for a CAT II approach. All CAT II lighting had been illuminated on Runway 05L for the takeoff of another Asia-Pacific operator's Boeing 747-400, 16 minutes prior to SQ006's departure. This is standard practice at CKS Airport to turn on the TDZ lights in night operations[45].

The SIA B747-400 Operations Manual did not include the phrase, "confirm active runway check," as a before takeoff checklist item. The absence of this check permitted the introduction of undetected runway selection errors in the operational environment. The inclusion of this check provides the flight crew with an additional tool to confirm the aircraft is at the correct runway. A review of the SIA Boeing 747-400 Operations Manual, CVR transcripts and FDR parameters confirmed that the flight crew was following their approved procedures.

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[45] According to ATP-88 issued by CAA dated 03/01/99 section 3-4-10, Runway 05L touchdown zone lights shall be turned on during night or during daytime when visibility is less than 4,800 meters. See section 1.18.2.7 CKS Airport Lighting Procedures.

2.5.6 Aircraft System Information Available to the Crew

2.5.6.1 Primary Flight Display

The ILS localizer indicator and the rising runway symbol on the PFD provided information to the flight crew regarding the position of the aircraft. During the taxi simulation, the Safety Council noted that when the aircraft was positioned at the threshold of Runway 05R, with the localizer tuned to the frequency for Runway 05L, the ILS localizer indicator and the rising runway symbol indicated full scale left deflection on both the Captain's and First Officer's PFD.

Prior to takeoff, the ATIS indicated that the cloud base was about 200 feet. The flight crew would make a transition from visual to instrument flight within a few seconds after lift-off. The key information necessary to fly the aircraft (such as attitude, track, heading, altitude, rate of climb, airspeed and other data) was shown on the PFD in front of both pilots. With the intended runway centerline being 214 meters (650ft) to the aircraft's left, the Instrument Landing System azimuth (localizer) indication would have shown a left turn command with the indicator fully deflected. Similarly, the rising runway symbol, instead of being in the center of the display would have been deflected to the left. These deflections would have indicated that the aircraft was not in the correct position for takeoff.

Pilots routinely use the ILS localizer indicator and the rising runway symbol on the PFD as a runway alignment reference during landing. There were no SIA procedural requirements for the flight crew to check these indications before takeoff.

2.5.6.2 Navigation Display

The navigation information necessary to fly the aircraft (such as track, waypoints and lateral and vertical navigation pointers, wind speed and direction, and other data) was shown on the Navigation Display (ND) in front of both pilots. When a runway is selected, the ND display a runway symbol, which appears as two parallel white lines. The position of the aircraft relative to the runway is shown by the aircraft symbol (white triangle) and identifier or label such as 05L. Runway 05L had been selected for departure. With the intended runway centerline being 214 meters (650ft.) to the left, the aircraft symbol would have appeared to the right edge of the runway symbol, indicating that the aircraft was possibly not aligned with Runway 05L. Also, the Runway 05L label would have remained unchanged.

During the taxi trial, the ND at the 10 nautical mile (nm) range showed a small map error. The selectable range of the ND is from 10 to 640 nm. There was no change (no map shift) on the Flight Management Computer (FMC) latitude and longitude when the TOGA button was activated during the taxi trial. Even though the ND aircraft symbol misalignment indicated that the aircraft was not in the correct position for takeoff, the ND aircraft misalignment indication was almost imperceptible at the 10 nm range. In addition, the Runway 05L identification label remained unchanged. Finally, the flight crew did not recall the range setting of the ND during taxi, runway line-up and takeoff on the evening of the accident.

2.5.6.3 Para-Visual Display

2.5.6.3.1 Para-Visual Display (PVD) Information

The CAAS approved supplement to the Boeing 747-400 AFM, section 3 Normal and Abnormal Procedures, page 1 states:

"*The flight crew should confirm that when the PVD is selected ON, the display streams right, left and then stops momentarily. The display will then either provide guidance to the localizer centerline or will shutter dependent upon whether the aircraft is in a position for takeoff or not.*"

The procedure is not specified as related to Category III operations, rather, it is a general procedure for use of the PVD. The CAAS approved AFM supplement indicates that the PVD assists the flight crew in determining "whether the aircraft is in a position for takeoff or not."

CVR, FDR, and interview data indicated that when SQ006 was turning from Taxiway N1 onto Runway 05R, CM-2 had noticed that the PVD had not unshuttered. CM-2 then informed CM-1 and CM-3 that the PVD had not lined up. CM-3 responded that the PVD would not unshutter until the aircraft was within 45 degrees of the runway heading[46]. When the aircraft lined up on Runway 05R, the PVD was still shuttered. CM-1 stated that since he had a good view of the runway, the failure of the PVD to unshutter was not a concern to him[47]. Therefore, CM-1 did not consider why the PVD was still shuttered and he proceeded with the takeoff. CM-1 could see the runway and since it was not a PVD assisted takeoff, he relied upon the primary visual cues in the form of the centerline lights and proceeded with the takeoff.

As part of the investigation, information was obtained from other Asia-Pacific B747-400 operators regarding the use of the PVD (they have been de-identified for commercial reasons). In particular, one operator's B747-400 Operations Manual stated that "Using the runway localizer tuned on the

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[46] CVR 15:16:07 CM-2 "And the PVD hasn't lined up ah"
CVR 15:16:10 CM-1 "Yeah we gotta line up first"
CVR 15:16:12 CM-3 "We need forty five degrees"

[47] CVR 15:16:23 CM-1 "Not on yet er PVD huh never mind we can see the runway, not so bad…"

Navigation Radio page, the PVD provides guidance to runway centerline during ground operations." The operator's information was consistent with the CAAS approved B747-400 AFM supplement, which indicated that the PVD assists flight crews in determining "whether the aircraft is in a position for takeoff or not."

SIA was not operating in accordance with the CAAS approved B747-400 AFM PVD supplement. The supplement information was not reflected in SIA procedures, practice and training documentation. Neither the flight crew of SQ006 nor the other company pilots who were interviewed, including senior management pilots, indicated that they were cognizant with the CAAS approved AFM PVD Supplement.

2.5.6.3.2 Operational Use of PVD

Interview data and the SIA Boeing 747-400 Operations Manual indicated that the PVD was a high-reliability reversionary [backup] aid to runway steering in low visibility weather conditions. The Operations Manual also indicated that the B747-400 was authorized to be operated to an RVR of not less than 100 meters when taking off utilizing the PVD in conjunction with a category III localizer. CKS Airport Runway 05L is a category II runway; therefore, a PVD assisted takeoff was not authorized. In addition, the SIA Boeing 747-400 Operations Manual stipulated that a PVD assisted takeoff was not permitted when the runway cross wind exceeded 10 knots; therefore, the SQ006 flight crew was not permitted to conduct a PVD assisted takeoff from Runway 05L. Under the above environmental and operational conditions, the PVD can only be used for a practice PVD assisted takeoff. CM-1 and CM-2 elected to activate the PVD as an additional reference. There were no documented restrictions on the use of the PVD as an additional reference for a practice PVD assisted takeoff.

The PVD is validated about once every 28 days for each aircraft in the fleet that is fitted with a PVD. PVD validation is conducted through practice PVD assisted takeoffs in environmental conditions above the minima and for actual PVD assisted takeoffs in low visibility conditions. The PVD cues are validated by comparing them against the visually acquired centerline of the runway. There was no requirement in the SIA Operations Manual to formally declare a practice PVD assisted takeoff. Further, there was no evidence that the use of the PVD by the flight crew on the evening of the accident was for validation purposes.

Interviews with a selection of SIA pilots, including the SQ006 flight crew, indicated that they had never conducted a PVD assisted takeoff in actual low visibility Category III weather conditions during line operations. The SQ006 flight crew reported that, on average, they had practiced a PVD takeoff 3 to 4 times per year during line operations. In addition, there are only 10 countries in the world that are listed in the SIA B747-400 Operations Manual and approved by SIA for PVD assisted takeoffs. SIA pilots perform at least 4 practice PVD assisted takeoffs annually to fulfill CAAS regulatory requirements.

Interviews with several SIA instructor and management pilots indicated that if they were confronted by an unshuttered PVD indication on runway line-up, they would have considered the implications of the PVD not unshuttering. Moreover, the selection of company pilots stated that they would have attempted to examine the unshuttered PVD further before proceeding with flight. Although there is a risk of hindsight bias in such discussions, some of the company pilots did state that they might have discounted the unshuttered PVD because it was not required and using visual cues for takeoff was the primary means of tracking down the runway.

The Safety Council was unable to determine how well the pilots of SQ006 understood the PVD system. The flight crew did not mention the CAAS approved supplement to the Boeing 747-400 AFM which indicated that the PVD will shutter depending on "whether the aircraft is in a position for takeoff or not." In accordance with the CAAS approved Boeing 747-400 AFM PVD supplement information, the Safety Council concludes that the failure of the PVD to unshutter should have indicated to the flight crew that the aircraft was not at the correct position for takeoff. The routine operational context of PVD usage led the flight crew to discount the unshuttered indication further.

2.5.6.3.3 PVD Procedures

No information was provided in the SIA B747-400 Operations Manual or other parts of the company operations manual to deal with situations in which the PVD was inoperative.

The SIA B747-400 Quick Reference Handbook, page NNC.10.6, Non-Normal Checklists – Flight Instruments, Display indicates:

EICAS message > PVD SYS CAPT, F/O

This message means that the PVD system has malfunctioned. There was no action required to solve the problem. Pilots can conduct a non-PVD-assisted takeoff if the visibility is sufficient.

The PVD is a simple instrument that provides a visual indication for runway centerline guidance in the event that the aircraft deviates from the ILS centerline. The instrument also provides pilots with some valuable information. For example, when an aircraft is aligned with a runway and the PVD has unshuttered, this will mean that the aircraft is located within a valid localizer region (signal not shielded), the aircraft heading is within 45 degrees of runway heading, the ILS frequency is correctly selected, and the aircraft is on the ground. In contrast, when the aircraft has lined up with the runway and the PVD is still shuttered, this may indicate that:

- the ILS frequency is not correctly selected; or
- the aircraft is not within the valid localizer region; or
- the aircraft heading is not within 45 degree of the runway heading; or
- the PVD has malfunctioned; or
- an aircraft is blocking the ILS signal.

When an aircraft equipped with a PVD system lines up in takeoff position on the runway and the PVD has not unshuttered, if the ILS frequency is correctly selected and no message appears on the EICAS, the PVD information indicates to the flight crew that the aircraft is not in the correct position for takeoff.

In this occurrence, the PVD was still shuttered when the aircraft lined up on Runway 05R. The PVD did not unshutter because the PVD was not within the valid localizer region for Runway 05L. The PVD information was an indication that the aircraft was not on the correct runway for takeoff. The MCIT and the CAAS made numerous submissions to the Safety Council investigation team to emphasize that the PVD was not intended to be used as a runway identifier; however, despite this very strong sentiment from Singapore, the language in the CAAS approved PVD supplement clearly stated that the PVD display will "shutter dependent upon whether the aircraft is in a position for takeoff or not.” The language in the CAAS approved PVD supplement did not reflect the sentiment that the PVD was not to be used as a runway identifier. Rather, the language in the CAAS approved PVD supplement indicated that the PVD will provide the crew with information as to whether the aircraft is in a position to takeoff or not.

Had the information in the CAAS approved PVD supplement been distributed in SIA training and had this information been reflected in operational practice, the flight crew of SQ006 probably would have investigated the situation further and might have realized that the aircraft was not on the proper runway for takeoff. The assessments and actions of the flight crew on the evening of the accident were indicative of their limited knowledge of what the PVD system was indicating, the operational context of PVD usage, the competing demands for their attention, the high task load, and degraded environmental conditions.

2.5.6.4 Aircraft Heading Reference

During taxi and runway line-up, the flight crew was presented with aircraft heading indications on the magnetic compass and the aircraft’s heading indicators which were located on the Primary Flight Display (PFD). Taxiway NP paralleled Runway 05R/23L. The aircraft heading indication during the taxi along Taxiway NP would have indicated about 230 degrees magnetic. When the aircraft turned from Taxiway NP onto Taxiway N1, the flight crew needed to maintain a heading of about 320 degrees magnetic for about 270 meters to reach Runway 05L. Instead of making a 90 degree turn from NP onto N1 as the airport chart indicated, CM-1 turned the aircraft 180 degrees from a heading of about 230 degrees magnetic to a heading of about 050 degrees magnetic, directly onto Runway 05R.

The FAA *Runway Safety* website contains safety tips to help pilots maintain their orientation during taxi. In particular, the FAA runway safety tips state, “The heading indicator is as useful on the ground as it is in the air. Use it together with the taxi chart to maintain orientation.” In addition, the safety tips state, “Use your instruments to verify your orientation on the airport.” The FAA Advisory Circular 120-74 elaborates further by stating, “The aircraft’s compass or heading display is an excellent tool, as a supplement to visual orientation, for confirming correct taxiway or runway alignment. Refer to it as frequently as necessary, but especially at complex intersections and where the takeoff ends of two runways are close to one another.” (p. 8).

Although CM-2 stated that the compass rose can help maintain orientation during taxi, he did not mention the use of the aircraft’s heading indicators and/or the compass to verify visual orientation during the critical phase of the taxi when SQ006 turned from Taxiway NP through Taxiway N1 directly onto Runway 05R. During interviews, CM-1 and CM-3 did not mention the use of the aircraft’s heading indicators and/or the compass to supplement visual orientation during taxi. The compass and heading indicators were useful aids available to the flight crew to enhance their orientation and navigational accuracy during taxi, especially in the low visibility conditions. It is standard industry practice to utilize the heading indicator and/or compass to assist surface navigation during complex taxi routing and/or degraded visibility.

2.5.7 CKS Airport Surface Configuration Issues

2.5.7.1 Marking and Signage

During interviews with the flight crew of SQ006 after the accident, they stated that they did not recall seeing any marking and signage except the “piano keys” when the aircraft was turning from Taxiway NP onto Runway 05R.

During the airport site survey, the following marking and signage were located in the vicinity of the approach end of Runway 05R:

- A black/red sign marked “N1/5R-23L” was on the southwest side of Taxiway N1; located 54 meters from Runway 05R centerline and 20 meters from the left edge of Taxiway N1;
- a white marking on Runway 05R indicating “05” and “R”, located about 60 meters from Taxiway N1 centerline on Runway 05R;

- a red “CAT 2” sign was on the left side of Taxiway N1 between Runway 05R and 05L, located about 140 meters from Runway 05R centerline and 20 meters from the left edge of Taxiway N1; and
- a red/black sign marked “5L–23R/N1” on northeast side of Taxiway N1 between Runway 05R and 05L, located about 140 meters from Runway 05R centerline and 20 meters from the right edge of Taxiway N1.

The field of view study showed that the pilots’ field of view outside the cockpit through the areas swept by the windscreen wipers was limited; however, the study found that the following items would have been visible from the cockpit at intervals throughout the turn from Taxiway NP through Taxiway N1 onto Runway 05R: the Taxiway N1 sign and Taxiway N1 centerline lights leading to Runway 05L; the Runway 05R sign; the Runway 05R threshold marking and designation; and the Runway 05L signage. In particular, the study indicated that the “N1/5R-23L” signage was visible from CM-1’s eye reference point through CM-1’s windshield when the aircraft was turning from Taxiway NP onto Taxiway N1 (Figure 2.5-1). The clear areas in the diagram present the visible areas available to CM-1 during taxi. CM-1 stated that he had his eyes directed outside of the cockpit during the turn from Taxiway NP onto the runway because he was taxiing the aircraft with reference to the taxiway lights during the turn.

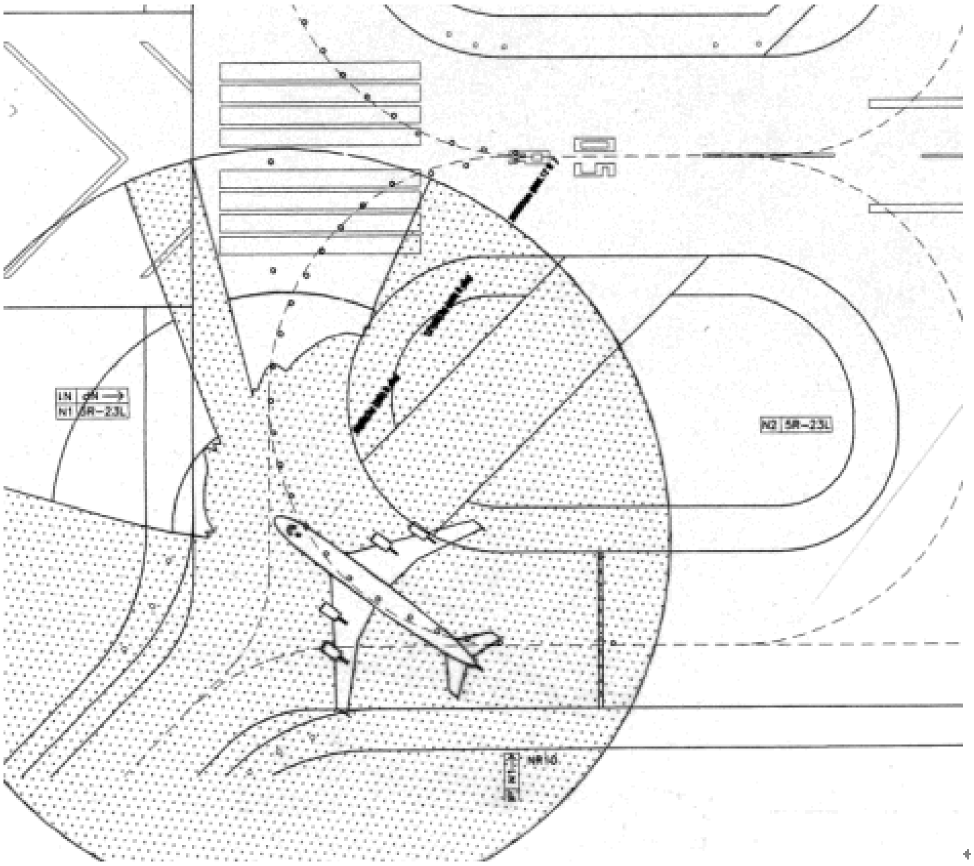

Figure 2.5-1 Captain's Field of View turning from Taxiway NP onto Taxiway N1 approaching the threshold of Runway 05R. (The circle around the aircraft represents a 100 meters radius from CM-1's eye reference point. The diagram is based on the pilot looking forward and not moving his head)

In addition, the "N1/5R-23L" signage was internally illuminated. The distance between the signage and the cockpit was about 60 meters when the aircraft was turning. With a RVR of 450 meters, the signage would have been visible from the cockpit when the aircraft was turning from Taxiway NP onto Taxiway N1.

When the aircraft taxied through Taxiway N1 and was just about to turn onto Runway 05R (Figure 2.5-2), "the piano keys" on Runway 05R and the Taxiway N1 centerline lights leading to Runway 05L would have been visible from CM-1's eye reference point through CM-1's windshield. The runway marking "05" and "R" would also have been visible from CM-1's eye reference point through CM-2's windshield. The distance between the cockpit and the Runway 05R marking, Taxiway N1 centerline lights leading to Runway 05L, and the Runway 05R "piano keys" were all within 120 meters.

Based on the above evidence and the taxi simulation data, the Safety Council concludes that the visibility at the time the crew turned from Taxiway NP and entered Runway 05R was sufficient for them to see the markings and signage, if they had looked for them to help locate their position and to correctly navigate the aircraft to the correct runway.

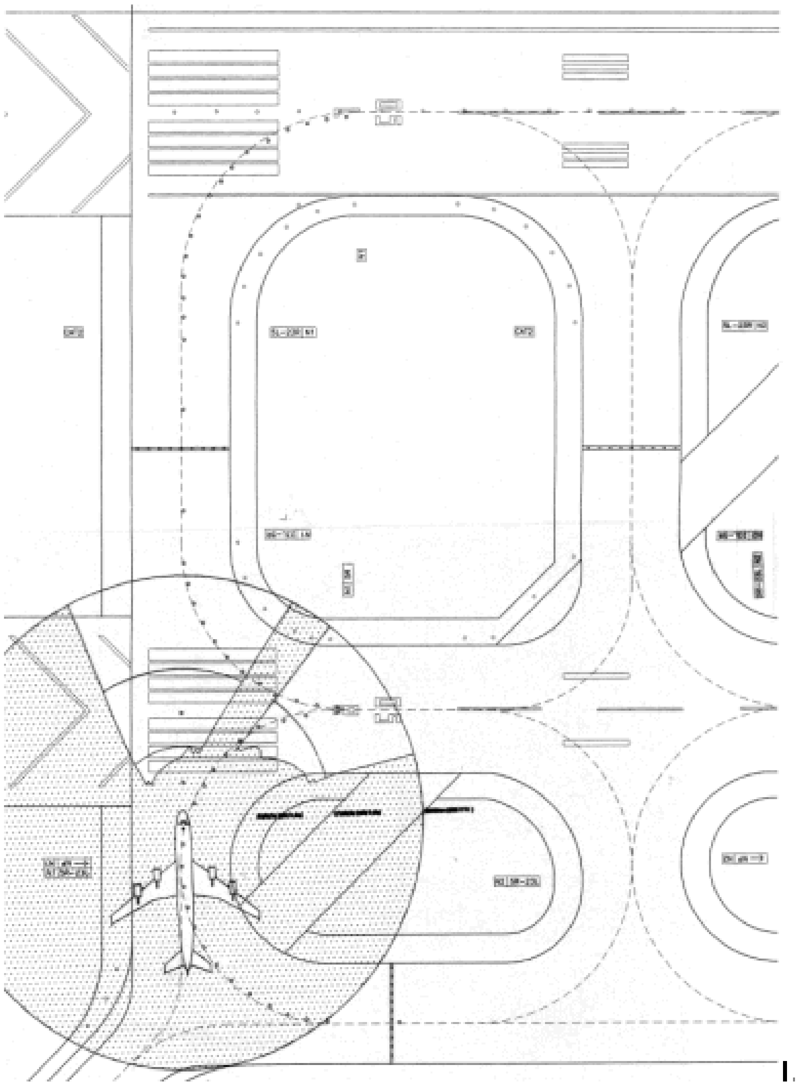

Figure 2.5-2 Captain's Field of View along Taxiway N1 approaching the thresholds of Runway 05R and 05L (RVR for Runway 05L was 450 meters. Taxiway N1 between Runway 05R and 05L was 214 meters. The diagram is based on the pilot looking forward and not moving his head)

2.5.7.2 Taxiway Lighting

2.5.7.2.1 Taxiway Centerline Lights

When the aircraft turned onto Runway 05R, the taxiway centerline lights on Taxiway N1 that led to Runway 05L would have alerted the flight crew that the location of Runway 05L was further northwest of the position of the aircraft. In the previous section, the Safety Council concluded that the taxiway centerline lights located between Runway 05R and Runway 05L would have been visible from the cockpit on the evening of the accident (the prevailing visibility was 600 meters and Runway 05L RVR was 450 meters); however, interview data indicated that when the aircraft was turning from Taxiway NP onto Taxiway N1 and then continuing the right turn onto Runway 05R, the flight crew did not notice any green lights ahead and along the extension of Taxiway N1.

As discussed in section 2.5.4.2, CM-2 and CM-3's attention was directed "inside" the cockpit for the checklist and crosswind component calculation during the turn onto Runway 05R. In addition, CM-1 was concentrating on maintaining the minimum taxi speed and following the green lights onto the runway. The crew's attention was not optimized to fully process cues and information that would have helped them maintain situational awareness while taxiing in challenging conditions. The flight crew's limited attentional resources were likely occupied by: checklist and procedural requirements; taxiing accurately in slippery conditions; degraded visibility and fluctuating but poor weather conditions; concerns about the approaching typhoon; cross wind calculations and company requirements; and PVD indications during the turn onto the runway. Consequently, the flight crew did not comprehend the available information nor did they prioritize the information to ensure that positive runway identification was achieved prior to takeoff.

2.5.7.2.2 Spacing of the Taxiway Centerline Lights

The spacing difference between the taxiway centerline lights on Taxiway N1 (that led to Runway 05L) and those that turned right onto Runway 05R may have been a factor that influenced the flight crew to believe that they were taxiing into position on the "correct" runway. According to site survey data of the CKS Airport, the only lighting system installed on Taxiway NP is the green taxiway centerline lights. As the taxiway turns right into Taxiway N1, the spacing of the taxiway centerline lights along the curved section to Runway 05R was 7.5m; however, the spacing of the taxiway centerline lights on Taxiway N1 between Runway 05R and Runway 05L was 4 times wider than the spacing of the taxiway centerline lights turning from Taxiway N1 onto Runway 05R. Therefore, the taxiway centerline lights that diverged onto Runway 05R were more salient than the lights that continued to Runway 05L because the spacing of the turning lights was smaller than the spacing of the lights that extended along Taxiway N1. The denser spacing of the taxiway lights illuminated a clear path to Runway 05R; therefore, CM-1 followed the distinct path of green taxiway lights from Taxiway NP onto Runway 05R, as is often the case when aircraft taxi onto Runways.

Research has indicated that human attention is attracted by salient cues in the environment and individuals will tend to neglect non-salient ones[48]. The Safety Council concludes that during the turn from Taxiway NP onto Runway 05R, the green taxiway centerline lights leading into Runway 05R attracted CM-1's attention; therefore, he did not notice the centerline lights that led to Runway 05L and all the runway signage and designation marking in the vicinity of Runway 05R threshold.

As discussed in section 2.3, airport infrastructure, if the ICAO recommended practices had been followed, there should have been 16 lights spaced 7.5 meters apart on the straight portion of Taxiway N1 from the point where the curved portion from Taxiway NP joined N1 onward to Runway 05L. If those recommendations had been followed, the reduced spacing of the centerline lights on Taxiway N1 could assist flight crews to maintain awareness of their position and would reduce the likelihood of taxiing errors.

2.5.7.2.3 Follow the Green Issue

CM-1 was asked how he had made a continuous turn onto Runway 05R from NP when the airport chart clearly showed Taxiway N1 as a straight line of 324 meters from the centerline of Taxiway NP to the centerline of Runway 05L. CM-1 replied that he had followed the green taxiway centerline lights and made a continuous turn from NP through N1 onto Runway 05R, believing it to be Runway 05L.

Changi Airport, the SIA home base, uses the Airfield Lighting Control and Monitoring System (ALCMS) to provide a safe and efficient operating environment on the airfield.[49] Its Taxiway Lighting Control System (TLCS) detects conflicts in multiple selected taxi routes and provides an inter-locking mechanism using taxiway centerline light segments and stop bars to resolve the conflicts at taxiway intersections. For aircraft arriving at or departing from Changi Airport, an air traffic controller will turn on the taxiway centerline lights along their assigned taxi route and instruct pilots to "follow the green." The taxiway centerline lights on other taxi paths will either be turned off, blocked by stop bar lights or other mechanisms, or will be less apparent than the taxiway centerline lights of the assigned taxi path. Therefore, pilots can easily taxi to their assigned gates or departure runways by following the green taxiway centerline lights selected by ATC. CKS Airport does not have this kind of taxiway lighting control system. When aircraft taxi to the gates or taxi out to the active runways at CKS Airport, they need to visually navigate to where they planned to go and were

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[48] Wickens, C. D. 2001. Attention to Safety and the Psychology of Surprise. University of Illinois, Aviation Human Factors Division. Savoy, Illinois.

[49] Koh Ming Sue, 2001. The New Airfield Lighting Control and Monitoring System at Singapore Changi Airport. 2001 International Symposium on Airport Infrastructure Development and Management, April 25-26, Singapore.

cleared to go using airport charts, cockpit instruments, such as the compass and heading indicators, and taxiway lights, signage, and marking.

Research on situation awareness has indicated that individuals develop internal mental models through repetitive experiences and exposures to the environment in which they operate[50]. These mental models can direct limited attention in efficient ways, provide a means of integrating information without loading working memory, and provide a mechanism for generating a projection of future system states. Patterns of critical cues in the environment may be matched to elements in the mental model to achieve situational awareness. In addition, with experience, the pattern-recognition and action-selection sequence can become highly routine and developed to a level of automaticity.[51,52,53] This provides good performance with a low level of attentional demand in certain well-understood environments. In this sense, automaticity can positively impact situational awareness by reducing demands on the human information-processing system; however, situational awareness can also be negatively impacted by automaticity due to a reduction in responsiveness to novel stimuli. Information that is not routine may not be attended to. Situational awareness may suffer when that information is important.

Up until the time of the accident, all three pilots had worked for SIA and flown in and out of Changi Airport for at least five years. They were familiar with that airport's "follow the green" taxiway lighting control system.[54] During interviews, all three pilots stated that the green taxiway centerline lights should take them to the takeoff runway. During the turn from Taxiway NP through N1 onto Runway 05R, CM-1 may have reverted to following the green because of: the salience of the N1 taxiway lights; a possible reversion to a routine action to "follow the green" at a critical point during the taxi where the flight crew's attention was preoccupied by taking off in a strong crosswind, low visibility, and slippery runway conditions.

When the flight crew followed the taxiway centerline lights to Runway 05R and they saw the "piano keys" on the runway, they all apparently believed that they had arrived at the correct departure

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[50] Endsley, Mica R. 1995. Toward a Theory of Situation Awareness in Dynamic Systems. Human Factors, 37(1), 32-64.

[51] Automaticity occurs when routine, familiar, highly practiced skills-based tasks become automatic or habitual with experience. Automaticity enables fast, autonomous, and effortless processing of information (Endsley, 1995; Reason, 1990).

[52] Reason, James. 1990. Human Error. Cambridge UK; Cambridge University Press.

[53] Endsley, Mica R. 1995. Toward a Theory of Situation Awareness in Dynamic Systems. Human Factors, 37(1), 32-64.

[54] MCIT was unable to provide the flight crew's computer flight record for the past three years. However, according to CM-1 and CM-2's flight schedules from Aug. 28, 2000 to Oct. 31, 2000, 44 percent (19 of 43) of the airports that CM-1 operated into and 54 percent (29 of 54) of the airports that CM-2 operated into were equipped with the "follow the green" systems.

runway, Runway 05L. Once the flight crew was convinced that they had reached the takeoff runway, they commenced the takeoff.

2.5.7.2.4 Color of the Centerline Lights

The taxiway centerline lights were green, including the centerline lights on Runway 05R; however, the centerline lights for Runway 05L were white. Interview and CVR data indicated that the flight crew followed the green centerline lights and taxied the aircraft onto Runway 05R. All three pilots reported that they saw the centerline lights running down the runway when the aircraft was lined up on Runway 05R; however, none of them recognized that the color of the runway centerline lights should have been white rather than green if the runway were 05L. During the turn onto the runway, CM-1 saw green taxiway centerline lights along the runway.

Color constancy refers to the invariance of the perceived color of surfaces under changes in illumination; for example, from the green taxiway lights of CKS Airport at night to their illumination during the day. The perception of an object's hue[55] remains constant even when the wavelength distribution of the illumination is changed or altered through atmospheric distortions produced by rain and/or tinted, warped or scratched windshields. Color constancy also means that an individual's perception of hue usually changes very little when the illumination changes.[56,57] When taxiing at night, the scattering of raindrops, marks left by windscreen wipers or other visual noise, will generally have a relatively low contrast and luminance compared to the illuminated taxiway and runway. Previous flight crews had reported no difficulty in determining the color of lights on the CKS surface movement area when rain was present.

The eye is composed of two basic receptors, rods and cones, each of which has its own sensitivity function. At high levels of illumination, the rods and cones both function (photopic vision) and the eye is most sensitive to light wavelengths around 550 nanometers (nm[58]) (green). As illumination levels decrease, the cones cease to function, the rods takeover the role of seeing (scotopic vision) Then, the eye becomes most sensitive to wavelengths around 500 nm (blue-green). This shift in sensitivity from photopic to scotopic vision is called the Purkinje effect. The practical application of this effect is that targets can be made green or blue-green to increase the probability of detection at

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[55] Hue is the experience of a chromatic color such as red, green, yellow and blue.
[56] Foster, D. H., Nascimento, S. M. C., Craven, B. J., Linnell, K. J., Cornelissen, F. W., & Brenner, E. (1997). Four issues concerning color constancy and relational color constancy. *Vision Research*, *37*, 1341-1345.
[57]Goldstein, E. B. (1989). *Sensation and perception* (3rd edition). Belmont, CA: Wadsworth Publishing.
[58] Nanometer =nm=10^{-7}cm.

night[59]. That is one of the reasons why airfield guidance lighting such as taxiway centerline and/or edge lighting are often green or blue. Consequently, despite the glare of the aircraft's landing lights and the reflected glare from the water droplets when the aircraft lined up on Runway 05R, the green centerline lights of Runway 05R would have been clearly discernible along the runway. The "wash-out" type effect, where the color of the green centerline lights may have appeared less distinct to the crew within the immediate range of the aircraft landing lights was not an issue. CM-2 had identified the color of the centerline lights after the activation of the landing lights during the turn through Taxiway N1 prior to runway line up[60]. Further, the flight crew reported that the runway centerline lights were clearly visible.

When the aircraft taxied into position and held on Runway 05R, the focus of the flight crew's attention was occupied by concern about the degraded visibility and fluctuating but poor weather conditions; the approaching typhoon; the cross wind takeoff; and the anomalous PVD indications. The flight crew did not realize that the runway centerline lights should have been white rather than green if they were on the correct runway.

2.5.7.3 Taxiway Centerline Marking

A 20-meter segment of the straight portion of the taxiway centerline marking on Taxiway N1 that led to Runway 05L was not painted on Taxiway N1. The Safety Council was unable to determine the influence of the lack of taxiway centerline marking on the flight crew's turn onto the incorrect runway. Evidence indicated that the flight crew did not refer to the yellow taxiway centerline marking during the taxi from the parking bay to Runway 05L. The CVR data indicated that the pilots of SQ006 did not mention the taxiway centerline marking during taxi. Under low levels of ambient illumination, the yellow taxi lines were of minimal benefit to the crew during taxi. From an airport infrastructure perspective, the taxiway and runway lighting were some of the more prominent means available to the crew for guidance during taxi at night.

When queried about how they normally navigated to the active runway at night, all three pilots mentioned that they follow the green taxiway centerline lights. None of the pilots mentioned that they routinely relied upon the yellow centerline marking for taxiing at night. Further, when CM-1 started the turn from Taxiway NP to Taxiway N1, CM-1 looked to the right side of the aircraft to ensure the

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[59] Saunders, M. S., & McCormick., E. J. (1992). *Human factors in engineering and design* (7th Edition). Singapore: McGraw-Hill.

[60] CVR 151540 CM-2 Strobes on, landing lights all on
……………………
CVR 151550 CM-2 OK green lights are here

aircraft was positioned on the center of the taxiway. It would have been very difficult for CM-1 to see the non-lit yellow line extending in the distance through CM-2's window in darkness and heavy rain.

Research on human perception indicates that non-illuminated objects are difficult to detect in low light conditions.[61] This limitation of the visual system is the reason why runway lighting is needed. Based on the research, the presence of the yellow taxiway centerline marking would have had minimal, if any, effect on the flight crew's behavior (especially at night). If the yellow taxiway centerline marking were painted on the straight portion of Taxiway N1 on the night of the accident, it probably would not have affected the flight crew's opportunity to notice that there was another taxi route that went straight ahead.

2.5.7.4 Runway Difference Issues

According to the Jeppesen CKS Airport chart and CAA AIP, the runway configurations of Runway 05L and 05R have several differences as follows (Figure 2.5-3):

- Runway 05L is 15 meters wider than Runway 05R (60 meters vs. 45 meters respectively);
- Runway 05L has High Intensity Runway Lights (HIRL), Centerline Lights (CL), Touch Down Zone lights (TDZ), and a four-light PAPI to the left of the runway. Runway 05R has only Runway Lights (RL)[62];
- The centerline lights of Runway 05L are white. There were no runway centerline lights for Runway 05R, however, there were taxiway centerline lights on Runway 05R for the purpose of using Runway 05R as a taxiway. The color of the taxiway centerline lights was green; and
- Runway 05L is a CAT II instrument approach runway. Runway 05R is a visual runway for takeoffs only. The runway touch down zone marking stripes were also different.

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[61] Goldstein, E. B. (1989). *Sensation and perception* (3rd edition). Belmont, CA: Wadsworth Publishing.

[62] The green centerline lights were defined as taxiway centerline lights when Runway 05R was used for taxi.

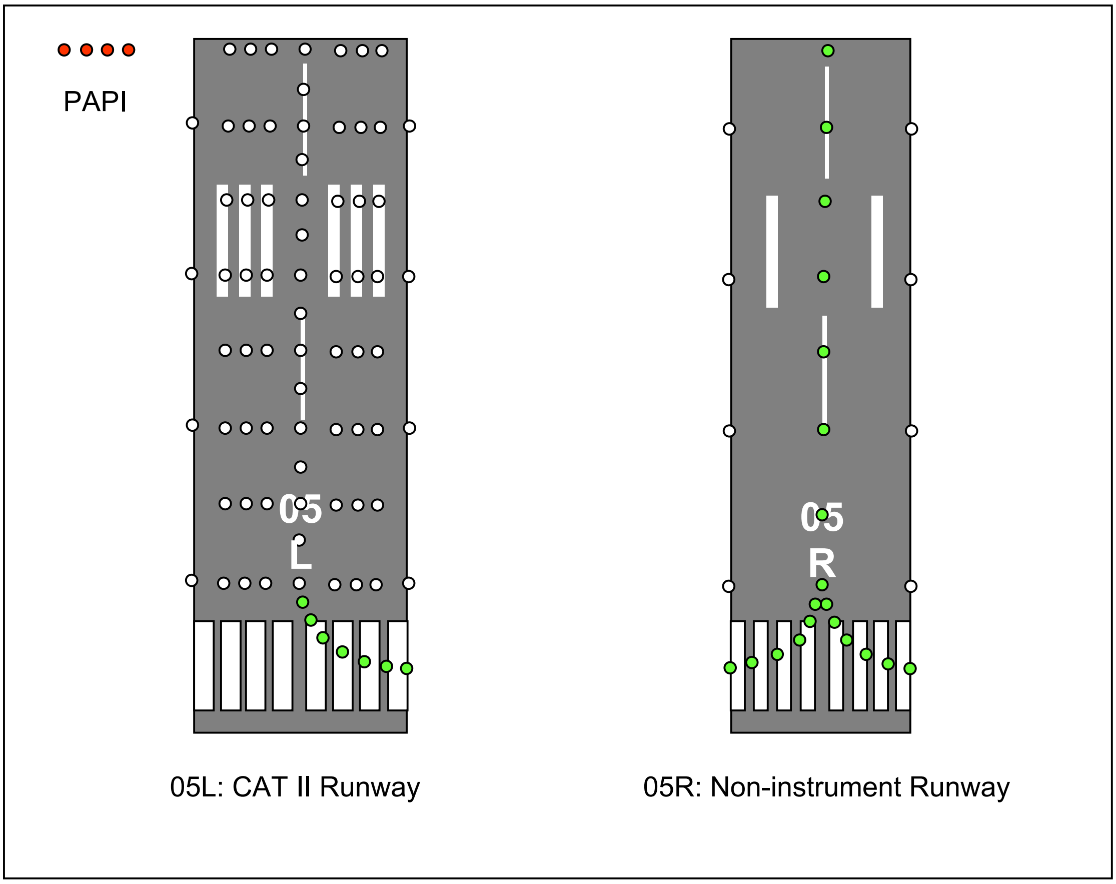

Figure 2.5-3 Configurations of Runway 05L and 05R.

Interview data indicated that SIA flights routinely use Runway 06 at CKS Airport because that runway is closer to the parking bays used by the company (also providing some fuel and time savings during taxi). All three pilots reported that they had not used Runway 05L for approximately 2 to 3 years prior to the occurrence; however, the flight crew was aware that the particular runway view should have included white centerline lights and that there should have been an area of bright TDZ lights on the runway. Evidence for this fact is contained in the CVR transcripts that indicates that the flight crew briefed the use of Runway 05L as a "return alternate" because it was equipped for a CAT II approach. Thus, they should have recognized that their observations of Runway 05R did not match those of a CAT II runway. Further, given the flight crew's experience in night flight operations, they were knowledgeable of taxiway and runway lighting and were aware that taxiway centerline lights are typically green and runway centerline lights are typically white; however, their lack of recent experience with Runway 05L and 05R configurations and the attentional preoccupation with the pre-takeoff tasks and adverse weather may have impeded the crews processing of runway configuration information.

2.5.7.5 Runway 05L Guard Lights

As discussed in section 2.3, the runway guard lights should have been installed on both sides of the Runway 05L holding position at CKS Airport. The runway guard lights (RGL) consist of alternately flashing yellow lights. The lights are used to identify the presence of an active runway and also signify the runway holding position marking. As stated in section 1.10, runway guard lights on both sides of Taxiway N1 and 75 meters from the centerline of Runway 05L would be 249 meters from the centerline of Taxiway NP. Had they been installed, the crew would have had the guard lights in front of them for a taxi distance of 175 meters[63] before the turn from Taxiway N1 onto Runway 05R. About the time of the accident, the visibility was reported to be between 400 and 600 meters. The crew would have had one more indication that the CAT II runway was still ahead of them.

Evidence indicated that when the aircraft approached the threshold of Runway 05R, the flight crew's attention was focused on the weather, before takeoff procedures, PVD information, and following the green lights while taxiing. They did not recall seeing any runway signage, runway designation marking, and lights other than the green lights turning onto Runway 05R in the vicinity of Runway 05R threshold. The Safety Council was unable to determine how the presence of Runway 05L guard lights might have influenced the pilots' situational awareness; however, if runway guard lights had been provided, they would have increased the conspicuity of the Runway 05L holding position and would likely have alerted CM-1 to the location of Runway 05L.

2.5.7.6 Runway 05R Edge Light Status

As stated earlier in section 2.3, after reviewing all available information, the Safety Council was unable to positively determine the on/off status of the Runway 05R edge lights at the time of the accident. Therefore, the Safety Council will discuss both possible situations in the following sections.

2.5.7.6.1 If Runway 05R Edge Lights Were OFF

CVR and interview data indicated that when CM-1 taxied the aircraft onto Runway 05R, he put the windshield wipers on high speed and turned on all the aircraft external lights. The pilots could see the

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[63] The distance from Taxiway NP centerline to the theoretical location of Runway 05L guard lights is 249 meters (324-75). The distance from Runway 05R centerline and Runway 05L centerline is 214 meters (324 - 110). The crew taxied 110 meters along Taxiway N1 as they turned from Taxiway NP onto Runway 05R. The distance between the Runway 05R centerline and theoretical location of Runway 05L guard lights is 139 meters (214 - 75). The intersection of Taxiway N1 turn onto Runway 05R to theoretical location of Runway 05L guard light is about 139 meters + 22.5 meters (half the width of Runway 05R) +13.5 meters (shoulder of Runway 05R) = 175m.

green centerline lights along the runway. In particular, CM-3 stated that he saw a very "bright environment"[64] when he looked up after finishing the crosswind component calculation. The flight crew reported that they could not see any obstacles on the runway in front of them. They all believed that they were on Runway 05L because the runway appeared to be a "normal picture" of a runway.

Research has indicated that people may have certain expectations about what they should see in a particular situation.[65,66] Repeated experience in an environment allows people to develop expectations about future events. On the basis of these expectations, people tend to see what they expect to see.

On the night of the accident, all three pilots believed that the green taxiway centerline lights would take them to the departure runway when they turned from Taxiway NP onto Runway 05R. When CM-1 followed the green taxiway centerline lights and taxied through the runway threshold marking of Runway 05R, all three pilots believed that they were entering a runway, the assigned departure runway, Runway 05L[67].

The Safety Council concludes that the flight crew was convinced that they were on Runway 05L and there was no immediate or salient indication that the runway in front of them was closed for construction work. They saw what they expected to see – a "normal picture" of a runway. Further, the pilots' attention was focused on the PVD information, the visibility along the runway, checklist completion, and how to conduct a visual takeoff in the strong crosswind. They likely did not perceive the absence of runway edge lights, which would indicate that they were on the incorrect runway.

2.5.7.6.2 If Runway 05R Edge Lights Were ON

Runway 05R was 45 meters wide. The width of Runway 05L, Runway 06 at CKS Airport, and also the two runways at Singapore Changi Airport were all 60 meters. If the Runway 05R edge lights were ON on the night of the accident, a comparison with the above runways, which were familiar to the flight crew, would have indicated that Runway 05R was too narrow[68]. This comparative cue may have

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[64] The bright environment might have been due to the refraction of the aircraft's exterior lights on the heavy water droplets.

[65] Jones, D. G. 1977. Self-fulfilling prophecies: Social, psychological and physiological effects of experiences. Hillsdale, NJ: Lawrence Erlbaum Associates.

[66] Endsley, M. R. 2000. Theoretical Underpinnings of Situation Awareness: A Critical Review. In M. R. Endsley; D. J. Garland (Eds.). Situation Awareness Analysis and Measurement: Analysis and Measurement. Mahwah: NJ. Lawrence Erlbaum Assoc.

[67] For example, at time 23:15:50 CM-2 commented that "OK green lights are here" with reference to the curved taxiway lights leading onto Runway 05R. These lights were visible from the right side of the aircraft during the turn, and CM-2's comment was intended to assist CM-1 in lining up the aircraft on the runway.

[68] The Safety Council believes that a line pilot should have a mental model of how a 60 meters wide runway should look from the cockpit. This kind of mental model was built up from day to day flight experience.

alerted the flight crew that they were on the incorrect runway; however, determining such a width difference might have been difficult at night in low visibility conditions. Nonetheless, such a cue had reportedly been used on October 23, 2000, at 2245 by a freighter captain who was conducting a routine flight from CKS Airport. The freighter had been given clearance to taxi for a takeoff on Runway 05L via Taxiway NP. The captain stated that the weather on that evening was rainy with some wind. The visibility was also degraded due to the moderate rain.

The first runway that the captain encountered when he was on Taxiway N1 was Runway 05R. He recalled that he felt compelled to take Runway 05R as the active runway because Runway 05R was brightly lit with centerline and edge lights. He could not see the barriers nor the lights on the barriers further down Runway 05R. He stated that he was able to reject the compelling information because of the following conflicts: Runway 05R was too narrow; there were no touch down zone lights; and he realized that the centerline lights were green on the runway.

The Safety Council concludes that if the runway edge lights were ON at the time SQ006 lined up on Runway 05R, the pilots would have seen the white runway edge lights and green centerline lights on the runway. They did not see any construction signs or equipment on the runway. Under the condition of taking off in the severe weather, and with the expectation that they were on Runway 05L, they might not have been able to perceive that the runway they were on was too narrow to be Runway 05L. In addition, there were no TDZ lights on the runway and the centerline lights of the runway were green, which is the color of the taxiway centerline lights. Nonetheless, the flight crew believed they were on the active Runway 05L and carried out the takeoff.

2.5.7.7 Expectation of Runway Picture

CVR and interview data indicated that while taxiing along Taxiway NP, CM-2 contacted CKS Tower to state that they were ready for takeoff. CKS Tower subsequently issued a clearance to the flight crew to taxi into position and hold on Runway 05L. When the aircraft approached Taxiway N1, the tower controller cleared SQ006 to take off from Runway 05L. CM-2 stated that the timing of the take off clearance gave him an impression that everything was in order. Further, CM-1 stated that the timing of the takeoff clearance gave him an impression that CKS Tower could see them.

All three pilots were convinced that they were on Runway 05L. They were all aware that Runway 05R was closed due to construction between Taxiway N4 and N5, the other sections of Runway 05R were still available for taxi. When queried about their mental pictures of a closed Runway 05R, all three pilots stated that a closed runway should not be illuminated. In addition, CM-1 commented that there should have barricades or crosses after the piano keys. CM-3 commented that there should be obstruction lights and barricades for the work in progress area, and lighted no-entry signs; however, Runway 05R was available for taxi on the night of the occurrence. It was also NOTAMed to that effect.

According to CAA, there was no runway-closed indication in the vicinity of the Runway 05R threshold because this portion of the runway was still being used for taxi on the night of the accident. In addition, given the inbound typhoon, it was not safe to erect mobile runway closure signs, which may have been blown into taxiing aircraft. There were warning lights demarcating the construction area on Runway 05R but the distance from the 05R threshold to the construction area precluded the pilots from seeing those lights.

2.5.7.7.1 Confirmation Bias

Confirmation bias may have affected the crew's decision-making in the SQ006 occurrence. This bias relates to the assumption that individuals will reduce the cognitive effort involved in a decision, either to improve the response latency or manage another task concurrently[69]. This type of bias involves a person or team, such as a flight crew, seeking information to confirm an expectation or assumption and rejecting that information which conflicts. The bias facilitates errors in organizing the search for information. For example, individuals and/or teams may only attend to part of the task information, fail to keep abreast with changes in the environment, or examine details without taking an overall view. Essentially, the crew may only seek information that confirms their present interpretation of the situation.

Procedures and checklists are often used in complex systems such as aviation to overcome these nuances and idiosyncrasies of human behavior. Consequently, the FAA stated in AC 120-74 that "before entering a runway for takeoff, the flight crew should verbally coordinate to ensure correct identification of the runway" in order to provide a safety barrier against confirmation biases, hasty decisions, and loss of situational awareness.

In the case of SQ006, the interview and CVR data indicated that the flight crew sought information that confirmed what they thought, that is, that they were in the correct location. The conflicting instrument indications were not fully considered by the crew. CM-1 also believed the timing of the Air Traffic Control clearances for taxiing into position and hold and the subsequent clearance for takeoff seemed to confirm that he was in the correct location for takeoff. Consequently, CM-1 elected to takeoff because he could see an adequate distance down Runway 05R and, to him, the runway picture looked like an active runway. CM-2 and CM-3 did not express any disagreement with CM-1.

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[69] Bainbridge, L. (1999). Processes underlying human performance. In D.J. Garland, J.A.Wise, & V.D.Hopkin (Eds.), *Handbook of aviation human factors* (pp. 107-172). Mahwah, NJ: Lawrence Erlbaum

In accordance with interview and CVR information, it appeared likely that CM-1 had sought information that allowed him to readily dismiss the aircraft instrument indications. The conflicting information was rejected to confirm the crew's assumptions about their present interpretation of the situation that they were on the correct runway. Further, the crew's attention was focused on taxiing onto the runway when they turned from NP through N1 and onto Runway 05R. Some additional cues that reinforced their perception that they were on the correct runway included the threshold "piano keys" and the distinct taxi path to the runway centerline lights.

2.5.7.8 Summary

Evidence indicated that when the aircraft approached the threshold of Runway 05R, the flight crew's attention was focused on the crosswind component, visibility for takeoff, PVD information, and before takeoff checklist items. The crew did not recall seeing any runway signage or runway designation marking. They saw the green taxiway centerline lights turning onto the runway but did not recall with certainty seeing any other lights in the vicinity of Runway 05R threshold. If runway guard lights or stop bars or densely spaced centerline lighting along Taxiway N1 had been provided, they would have increased the conspicuity of the Runway 05L holding position and would have increased the probability that the crew would have been alerted to the location of Runway 05L.

The flight crew was also aware that the particular runway view should have included white centerline lights and that there should have been an area of bright TDZ lights on the runway. They should have recognized that their observations of Runway 05R did not match those of a CAT II runway. The flight crew was experienced in night operations and was familiar with runway and taxiway lighting. They were aware that taxiway centerline lighting is green and runway lights are white or near white; however, their lack of recent experience with Runway 05L and 05R configurations and along with the attentional preoccupation with the pre-takeoff tasks and adverse weather, may have impeded the crews processing of runway configuration information. When CM-1 decided to takeoff, he could see an adequate distance down the runway, and none of the visual cues prompted him to realize that the aircraft was not on the correct runway. Finally, the contrary cockpit instrument indications were not resolved by the crew.

Additionally, the CM-1 stated that the timing of the ATC instruction for taxiing into position and holding and the takeoff clearance seemed to confirm that they were in the assigned position for takeoff.

2.5.8 Water-affected Runway Issues

The tower controller was not required to provide information to the crew regarding the condition of the runway. The determination of a contaminated runway by ATC is heavily dependent upon pilot reports. Although both pilots and controllers can assess the runway conditions, it is incumbent upon the pilots to be prudent and look for cues to aid them in making the final determination about the runway condition. The statement made by the SIA Chief Pilot indicating that flight crews depend upon ATC to provide runway condition information demonstrated a normative understanding of water-affected runway operations.

Some Asia-Pacific Boeing 747-400 operators have trained their pilots to use contaminated runway performance parameters if the rainfall is heavy. This is a safer and more risk averse policy because it minimizes the guess work in determining if the runway is wet or contaminated. The pilot has no way of visually inspecting the runway before takeoff. For example, one operator's manual stated that "If heavy rain or thunderstorms are forecast, standing water should be expected. The presence of standing water, snow, slush, or ice generally indicates the need for application of contaminated runway performance adjustments." Another operator's manual stated, "when in doubt about the condition of the runway, be conservative" and "very heavy rain on runways which are not grooved…, the runway should be treated as "contaminated" with "poor braking."

Heavy rainfall has been defined as rainfall above 7.6 mm/hr[70]. The European Joint Aviation Administration definition of a contaminated runway was as follows"

A runway is considered to be contaminated when more than 25% of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by the following[71]:

- *Surface water more than 3mm deep, or by slush, or loose snow, equivalent to more than 3mm of water;*
- *Snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow); or*
- *Ice, including wet ice.*

The METAR issued by CAA at 311300Z indicated that the rainfall amount was 13.5 mm/hr. The rainfall in the hour preceding the departure of SQ006 was 22.50 mm (METAR at 1500Z). In addition,

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70 Lankford Terry, 2000 Weather Reports, Forecasts and Flight Planning, McGraw Hills, N.Y..
71 JAA, JAR-OPS 1, Commercial Air Transportation (Aeroplanes), Section 1, Subpart F, 1.480. (Terminology).

the CKS ATIS Tango that pilots received before push back from parking bay indicated heavy rain at the time. SIA has established more conservative criteria for defining a contaminated runway compared to the JAA. In particular, SIA has defined a contaminated runway as "a runway that is partially or entirely covered with standing water of more than 1 mm, slush, snow or ice, or a 'wet' runway with sand or dust;" however, the flight crew assessed the runway condition as "wet." Moreover, the SIA B747-400 Chief Pilot's comment that most runways (unless defective) are designed with adequate drainage to prevent an excessive accumulation of water on the runway surface is not a risk averse assumption to make. A pilot must assess each individual runway because all runways are not the same.

Research has indicated that a smooth, un-grooved runway with a 1.5 percent crown (such as Runway 05L) can become flooded to a depth greater than 3mm in the area 4.5 meters either side of the centerline by a rainfall rate of less than 10mm/hr;[72] therefore, it was likely around the time of the accident that Runway 05L was contaminated. Consequently, the flight crew of SQ006 should have based the aircraft performance calculations on a contaminated runway for departure. The captain of the flight (a Boeing 747-400) who was taxiing for Runway 05L when SQ006 was taking off had based the performance calculations for takeoff on a contaminated runway. The captain of the flight (a Boeing 747-400) who had departed from Runway 05L 16 minutes before SQ006's departure had based the performance calculations for takeoff on a contaminated runway. The captain lined up and held on the runway threshold and waited for the wind conditions to subside below the limits for a cross wind takeoff before departing.

Had the flight crew of SQ006 assessed the intended departure runway as contaminated, they would have realized that the contaminated runway cross wind limit (15 knots) for takeoff in the Boeing 747-400 would have precluded a takeoff, unless the wind had subsided. Given that the weather was worsening with the approaching typhoon, it was possible that the crosswind component would not have reduced to below 15 knots for a sufficient duration to permit a contaminated runway takeoff. Alternatively, had the flight crew assessed the runway as contaminated, they may have had some additional time to assess the position of the aircraft as they waited on the runway threshold for the wind to subside.

[72] Yager, T. T. (1983). Factors influencing aircraft ground handling performance. NASA Technical Memorandum 85652.

2.5.8.1 SIA Crosswind Limitation and Runway Condition Determination Procedure

No procedures for determining a “wet” or “contaminated” runway were provided in the SIA B747-400 Operation Manual, or in any other SIA flight operations publication. Interview data indicated that the SIA B747-400 Chief Pilot and SQ006 CM-1 both believed that it was the responsibility of the airport authority to provide information to the crew on the condition of the runway. They stated that if no information on the runway surface condition or braking action were provided by ATC, then the runway may be considered as a “wet” runway.

Airlines have adopted the aircraft manufacturers’ recommendations on the performance limitations of maximum crosswind component under different runway conditions. The crosswind limitation for a contaminated runway takeoff is always more conservative than the limitations for a wet or dry runway. This is because directional control of the aircraft on a contaminated runway is much more difficult than controlling an aircraft on wet or dry runways. Further, the accelerate-stop performance is degraded. The reduced contaminated runway crosswind limitation provides a larger safety margin for flight operations during severe weather situations, particularly if a critical engine should fail during takeoff.

SIA’s definition of a contaminated runway is much stricter than the European Joint Aviation Administration definition. This shows that SIA was using a higher safety standard for aircraft operating on a water-affected runway. In contrast, when determining if a water-affected runway is to be classified as wet or contaminated, the flight crew of SQ006 and SIA B747-400 Chief Pilot advocated a lower risk management standard; that was, it was reasonable to assume the runway was wet if ATC does not provide standing water information. The Safety Council has concluded that SIA needs to develop procedures to assist its’ pilots to assess the approximate condition of a water-affected runway in heavy rain situations. It was not a risk averse practice to assume that the runway was wet if there was no information provided by ATC, particularly when there had been heavy rain fall (22.50 mm of rain fall) reported in the hour before 1500 UTC.

2.5.9 Crew Coordination

The flight crew’s dismissal of the PVD was the last line of defense in the sequence of events that led to the flight crew not correcting a situation that surfaced during the lined up for takeoff. The CVR indicated that CM-2 questioned the PVD line-up while the aircraft was turning onto Runway 05R. CM-1 and CM-3 then engaged in the following discussion regarding the PVD: CM-1 stated: “Yeah, we gotta line up first.” CM-3 stated: “We need 45 degrees.” CM-1 continued, “Not on yet PVD, never mind, we can see the runway, not so bad.”

After SQ006 lined up on the runway, the 3 pilots did not resolve why the PVD did not unshutter. CM-2 did not continue to address the unshuttered PVD indication nor did CM-1 and CM-3 attempt to support or resolve this anomaly. The opportunity was lost to discover that the aircraft was not on the appropriate runway and was not within the usable signal of the preset localizer.

2.5.9.1 SIA's Crew Resource Management Training Program

Crew Resource Management (CRM) is generally defined as "the effective use of all available resources, that is equipment, procedures and people, to achieve safe and efficient operations"[73]. It is associated with principles such as communication skills, interpersonal skills, stress management, workload management, leadership and team problem solving. These principles have been taught at major airlines since the late 1970s.

CRM training programs generally consist of initial awareness training, recurrent awareness training, knowledge acquisition, skill acquisition, practical training exercises, and the incorporation of CRM elements in normal check and training activities[74]. These courses are pre-dominantly awareness based rather than skill acquisition courses.

The SIA ARM courses are designed to cover concepts that the crews are expected to apply on the flight deck during line operations. During interviews with various SIA Instructor Pilots, the Instructors reported that they informally examine the crewmember's application of CRM principles during checks but the skills are not formally assessed in the same manner as technical skills. The Instructor Pilots reported that they sometimes discuss CRM principles and critique a crewmember's CRM skills during a proficiency check debriefing. Apart from these observations by the Instructors, the company currently has no reliable and valid mechanisms to evaluate if the crew has acquired such skills. At the time of the accident, the ARM courses have not been updated to reflect the advances in CRM and Human Factors research. In summary, the SIA ARM programs did not contain all the elements of what is currently regarded as best practice in this area.

The FAA in the United States has long recognized this problem with traditional CRM training programs. As a result, the FAA has initiated the Advanced Qualification Program (AQP), which requires airlines that adopt the program to demonstrate that flight crews have the ability and skill to utilize effective CRM and decision-making principles during LOFT-type scenarios.

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[73] International Civil Aviation Organization. (1992). Flight crew training: Cockpit resource management (CRM) and Line-Oriented Flight Training (LOFT). (Circular 217-AN/132, Human Factors Digest No. 2). Montreal, Canada: ICAO.

[74] Wiener, E. L., Kanki, B. G., & Helmreich, R. L. (Eds.) (1993). Cockpit resource management. San Diego, CA: Academic Press.

2.5.9.2 SQ006 Crew CRM Performance

The flight crew reported that there were no difficulties in their relationship before or during the flight. They considered that the CRM exhibited during taxi was good. A review of the CVR revealed that relationships between the crew appeared to be cordial. There was an instance where information was not volunteered. An example of sub-optimal CRM was when CM-3 elected not to inform CM-1 about the environmental conditions that he experienced when he conducted a pre-flight check of the aircraft. Although CM-3 mentioned his water-soaked shoes and removed them in the cockpit, no further discussions took place regarding the implications of that fact to the safety of the operation. Open communication is important between crewmembers under all circumstances.

There were also instances of the crew identifying relevant operational issues, such as the PFD wind speed trend vector information, the PVD not unshuttering, and alternates; however, there was no further discussion about the PVD not unshuttering. Interviews with the flight crew of SQ006 and company pilots revealed that alternates are generally not discussed during taxi. Had the crew's pre-flight alternate planning been more comprehensive, they would have had additional attentional resources available for other operationally significant activities rather than spending time discussing alternate options during taxi. Weather related issues were discussed frequently during the taxi as has been previously mentioned.

Because all SQ006 flight crewmembers had not been given comprehensive PVD training that reflected the information contained in the CAAS approved B747-400 AFM PVD supplement, it would be difficult to assume that they would have known fully what the PVD indications were telling them. Nonetheless, there was adequate information available to the crew on the evening of the accident to tell them that they were not in the correct location for takeoff. With reference to navigation during taxi, communicating the severity of weather to all crewmembers, scanning the outside scene, cross-checking position, runway identification, the assessment of the runway conditions, the use of aircraft instruments to verify location during taxi, a higher standard of CRM was possible. CM-3 could have passed the information about the weather conditions he experienced during the external aircraft check to the other flight crewmembers and the crew could have considered the PVD unshuttering further. Such open communications may have enhanced the crew's awareness of runway conditions and the location of the aircraft when it lined up on the runway.

A more extensive company CRM training program may have resulted in a higher standard of CRM during taxi and runway line-up but it was not possible to assess whether this would have prevented the accident.

2.5.9.3 The Role of Relief Crewmembers

The SIA SOP did not assign specific duties to the third flight crewmember, but the captain of SQ006 requested the third pilot to verify crosswind limitations. Management pilots, instructor pilots, and line pilots commented that the level of involvement of relief crewmembers varied in accordance with an aircraft commander's discretion. In general, there was a reluctance to interfere with the two-pilot operational philosophy; therefore, there was a reluctance to assign specific tasks or key operational duties to relief crewmembers during takeoff and landing. Like the other two pilots, CM-3 did not notice that the aircraft had lined up on the incorrect runway. Because SIA B747-400 operations involved variable crew compositions from a two-pilot crew without a relief crewmember up to a two-pilot crew with two additional relief pilots. The relief crew could consist of captains and/or first officers or combinations thereof. SIA relief crews are generally asked to be in the cockpit during takeoff and landing. Nonetheless, the role of relief crewmembers during these critical phases of flight, where transport category accidents occur most often, could be more clearly defined and reinforced during check and training activities. Such initiatives would increase the level of effective involvement of relief crewmembers during these phases.

2.5.10 CAAS Safety Oversight

As noted in section 1.17, the CAAS performs regular safety oversight of the operators to ensure that all flights are operated safely in accordance with ICAO SARPs and Singapore regulatory requirements. The CAAS also assesses the adequacy of the procedures and facilities provided by the operators to enable the crew to perform their duties both in the air and on the ground. In addition, the conduct of the crew training is also observed by the CAAS.

In this report, the Safety Council has identified a number of organizational deficiencies associated with SIA flight operations and training that were not identified by CAAS audits. The deficiencies in the CAAS safety oversight of SIA procedures and training related to the development of the accident included:

- Inadequate CAAS AFM PVD supplement document control, distribution and enactment by operators;
- Inadequate SIA flight crew guidance, procedures and training on the PVD that did not reflect the CAAS approved B747-400 PVD supplement information; and
- Insufficient flight crew training on low visibility taxi procedures and practices.

The Safety Council has concluded that the CAAS has not performed sufficient safety oversight of SIA's low visibility taxi and PVD procedures and training, and the deficiencies in SIA procedures and training were not detected during routine CAAS safety oversight surveillance.

2.6 Survival Factors

2.6.1 SIA Crewmembers' Emergency Evacuation Operations and Training

In this accident, the crewmembers' emergency evacuation performance was affected by the following combined factors: severe impact forces and fuselage breakup; fuel fed post-impact fire; smoke; falling foreign objects; unusual cabin attitude; abnormal slide inflation and extension after door opening; debris on the floor; incapacitation of some of the crewmembers; no PA service; communication difficulties; emergency slide inflation inside the cabin; typhoon weather with heavy rain and dark environment.

During the investigation, the Safety Council found that two cabin crewmembers did not open their designated emergency exits. Most of the cabin crew waited for an evacuation command and did not initiate the evacuation after the accident took place. The Safety Council believes that the importance of, and necessity for, crewmembers' emergency training should be stressed, particularly for critical situations such as was experienced in the aftermath of this accident. The Safety Council considers that in the circumstances of this accident, the crewmembers performance was affected. This is primarily because of the unexpected dynamics of the accident. Further, the Safety Council finds that SIA's ASEP did not clearly state that the crewmembers should use alternate procedures for commanding and directing an emergency evacuation when the PA system failed. A likely consequence of the PA failure was that the cabin crewmembers were hesitant in initiating an emergency evacuation because they expected to hear a PA from the flight deck or CIC commanding an evacuation. Nonetheless, the Safety Council was unable to determine if there were any significant delays in commencing the evacuation as the result of the PA system failure. Consequently, the Safety Council was also unable to determine if the failure of the PA system indirectly impacted upon the post-accident survival rate of the passengers and crew.

Although the SIA emergency evacuation training and procedures were generally in line with existing industry standards, there was no training or exposure to a complex simulated or controlled environment that included adverse weather with fire and smoke. The Safety Council concludes that more complex simulated emergency situations may be necessary as part of cabin safety and emergency procedures training for both flight and cabin crew. This type of training may enhance crewmembers' skills, confidence and resilience to cope with highly traumatic emergency situations.

2.6.2 Emergency Escape Slides

2.6.2.1 Wind Limit of the Slides

The B747-400 slides were manufactured in accordance with FAR 14 CFR 25.810. The specifications of the slides stated that the slides shall be fully inflated in six seconds and can sustain wind speeds of up to 25 knots.

According to the passengers and cabin crew statements, when the UDL door was opened, the slide stayed inside the pack and did not inflate immediately. The slide started to inflate after the cabin crewmember pushed it downward; however, strong wind blew the slide over the top of the fuselage, rendering the slide unusable.

There are a significant number of airline operations around the world that operate during wind conditions exceed the specification limit. Consequently, the risks associated with emergency evacuations during high wind conditions are significantly increased. The Safety Council concludes that the aviation industry and responsible government agencies should consider those risks and develop methods to reduce them.

2.6.2.2 Un-Commanded Inflation of 4R and 5R Slides

According to the information provided by Boeing, the B747-400 slides were designed to sustain 1.5 G lateral acceleration. Normally, the slide would not deployed because of its own weight even if the aircraft rolled 90 degrees. However, if the fuselage sustains a strong impact while it is rotated 90 degrees, the impact, plus the weight of the slide could cause the load to exceed the 1.5G design limit. The un-commanded inflation of slides 4R and 5R inside the cabin was due to lateral impact force exceeding the design limits of these slides.

The un-commanded inflation of the evacuation slides inside the cabin could cause personal injury and potentially block exits. Although there was no personal injury, the cabin crewmember seated next to the 4R and 5R door stated that they almost suffocated as they were momentarily pinned by the inflated slide until they released the seat belts and dropped out of their seats. The Safety Council believes that the risk associated with this hazard should be evaluated by the aviation industry and government authorities.

2.6.3 New Emergency Equipment

Improved emergency equipment involves scientific innovation. Progress in this area is often slow because of financial constraints. History showed that many times safety improvements only come about after disaster strikes. The Safety Council believes that the following concepts should be considered to improve survival in emergency situations.

2.6.3.1 Smoke Protection Devices

According to the survivor statements, during the initial evacuation there was very dense and irritating smoke in the cabin. Surviving passengers stated that just taking one breath of this smoke-filled air caused them to start choking immediately. The toxic gas came from burning fuel, burning cabin equipment, and passengers' belongings.

According to survivor interviews, the upper deck quickly filled with dust and smoke. Because of the "chimney effect," smoke entered the upper deck very quickly. Since passengers could not evacuate all at once, the restricted access to the exits created a life-threatening situation that would require smoke protection devices to survive.

The concept of smoke protection devices is not new and has been studied for many years. The carriage of safety devices, such as smoke hood, protective breathing equipment, fire extinguishers and flashlights, by flight crews and cabin crews is now a standard practice; however, in this particular accident, none of the crewmembers had protective smoke masks available. The Safety Council notes that cabin crews were trained to wear the smoke protection devices only when fighting fires and the flight crews were trained to wear smoke protection devices when there was smoke in the cockpit.

To be effective, smoke protection devices for the passengers would have to be portable, light weight; stowable, provide adequate visibility, variable size, and easy to use.

The Safety Council believes that the aviation industry and government authorities should further evaluate the need for equipping airliners with smoke protection devices for crewmembers and passengers.

2.6.3.2 High Intensity Emergency Exit Light

During an accidents involving post-crash fire, dense smoke and noise adversely affect vision and hearing. It is essential that emergency exits and direction of movement be identified immediately by the survivors.

Some survivors located at the tail section of the aircraft, stated that they did not see the emergency lights at the exit door. Other survivors indicated that they could hardly see the very dim emergency lights. The investigation team determined that most of the cabin emergency lights located in the tail section were operating normally during the accident. The ability to see the emergency lights was impaired by dense smoke and dust, making it more difficult for survivors to find their way out of the aircraft. This indicates that the current system of emergency lights is ineffective when dealing with circumstances of this accident.

2.6.4 Emergency Medical Aid and Rescue Operation of CKS Airport

2.6.4.1 Emergency Medical Procedure and Medical Coordinator

Because of the very strong winds emanating from Typhoon "Xangsane" at the time of the accident, the most of the CKS Airport medical and rescue operations were not able to follow standard procedures and the CCS was unable to be established at the pre-planned location.

The Safety Council found that the CKS Airport authority did not clearly prescribe emergency medical treatment procedures in the "CKS Airport Civil Aircraft Accident Handling Procedures and Regulations" and "CKS Airport Flight Operations Division's Fire Fighting Handling Procedure." as recommended by ICAO AEP section 1.1.9, 1.1.10, 3.6.1 and 9.2.3. Medical treatment and rescue procedures for adverse weather conditions also were not described in CKS handling procedures and regulations.

At the time of the SQ006 accident, it had not been determined which of the on-duty medical personnel from the Ming-Sheng Hospital clinic at CKS Airport would be the designated medical coordinator. Medical personnel arrived at the temporary clearance center near Gate 9 within 15 minutes and provided first aid services immediately, but none of the medical personnel from this hospital had received training in the duties of a medical coordinator.

The Safety Council found that CKS Airport had not provided clear and detailed regulations outlining the required responsibility and training for the position of medical coordinator, or interim coordinator, as recommended by ICAO AEP section3.6.3 and 4.1.6. It is important to provide a clearly written procedures to handle post accident emergency situations.

2.6.4.2 Hospital Information

The "CKS Airport Civil Aircraft Accident Handling Procedures and Regulations," lacked the detail information, such as a neurosurgical treatment facility, to decide which injured passengers should be sent to what kind of special hospital, as recommended by ICAO AEP section 3.7.1.

The contract signed between CKS Airport and the participating hospitals did not indicate what specific type of medical assistance could be provided in the event of an aircraft accident, nor did it specify post accident response procedures clearly. However, this information was found in the handbook used in the fire and rescue drill on July 5, 2000, the Aviation safety Council believes that this information should also be included in the “CKS Airport Civil Aircraft Accident Handling Procedures and Regulations”.

2.6.4.3 Work Designation and Human Resources in Rescue Operations

The “CKS Airport Civil Aircraft Accident Handling Procedures and Regulations” manual did not clearly state who was to be appointed as rescuers, what equipment should be used, how and when to enter the fuselage, and what follow-up procedures would be required. For example, the procedure in the “CKS Airport Flight Operations Division’s fire fighting handling procedure” manual regarding rescue personnel that followed the fire hose operators into the cabin was inconsistent. The statement in the CKS fire fighting handling procedure stated that the medical personnel should board the aircraft with the fire hose operators to rescue people. It is obviously that the procedure regarding the ARFF working designation in CKS Airport is not clear. The Safety Council also found that fire fighters had to perform the dual function of fire fighter and rescuer in the event of an accident. All the above, is inconsistent with the recommendations stated in the ICAO AEP sections 3.3.1 and 3.6.3.

ICAO Emergency Response documents did not state what minimum number of personnel is required in each fire truck or other vehicle; however, operational requirements would suggest that the CKS Airport fire station requires at least 16 people to operate its 8 fire engines; 2 persons to operate one ladder fire engine; 2 persons to operate two water tank vehicles; 2 persons to operate two illumination vehicles; 8 persons to operate 4 ambulances; one person to operate the commander’s vehicle and 2 persons to stay in the fire station to command and communicate. To fully operate the CKS Airport fire station would require 33 people in a major accident.

The number of fire fighters regularly on duty at the fire station at CKS Airport was less than 30 people for each shift per day. The CKS Airport’s human resources policy was restricted by national labor law and employee annual leave. Because of these constraints, the fire-fighting department would be understaffed if a major accident should occur.

The Safety Council believes that the CAA should evaluate the CKS Airport ARFF organization and manpower requirement based on lessons learned from the SQ006 accident.

2.6.5 Coroner’s Inquest

Postmortem examinations of deceased individuals following aircraft accidents are essential to identify not only the causes of death and injuries, but possible corrective actions to reduce future death and injury. In this case, insufficient postmortem examinations were conducted and valuable prevention information may have been lost.

As a result, immediately after the accident, the Safety Council began coordinating with the Ministry of Justice, and Ministry of the Interior, for memoranda of understanding in order to improve postmortem examinations and autopsies if necessary, including reports to the Investigator-in- Charge for future accident investigations.

2.7 Other Safety Issues

2.7.1 CVR Power ON/OFF Logic versus Regulations

The CVR did not record the flight crew's cockpit activities during the pre-departure preparation because the CVR is not activated until one of the engines started. Consequently, valuable operational and human factors information may have been lost.

Based on the system logic for SIA aircraft, other than manual control of the power on/off switch, the power on/off timing is dictated by the timing of engine start and shutdown, when the CVR power switch is in the "AUTO" mode.

According to FAA regulations, the CVR must be operated continuously from the start of the use of the checklist (before starting engines for the purpose of flight), to completion of the final checklist at the termination of the flight.

The FARs and JARs regarding the start of the CVR recording are very similar. Both require that the time the CVR recording shall start when the recorder has a power supply, and during the pre-flight and post-engine shutdown checklist activities.

The Singapore CAAS regulations state clearly that the on-board recorders should be operative from the takeoff run to landing; however, it does not include the taxi operation nor does it cover the pre-engine start phase. The CVR starting time for SQ006 did meet Singapore/CAAS regulations.

Similarly, under the ICAO provisions, the time period that the CVR shall be operational does not include recording the activities during push back prior to the engine start. Thus, as long as the recording starts from the beginning of the taxi operation, the ICAO Standard is met.

Based on this discussion, the SQ006 CVR starting time met the Singapore CAAS regulations and the ICAO Standard, which are different from the FAR and JAR regulations that require an earlier start time; however, when the need for human factors aspects of an investigation are considered, a longer recording period, including the pre-flight phase of the flight crew activities, would certainly add value to the investigation. Further, the logic contained in the SIA maintenance manual to "reduce wear" on the recorder is no longer valid for solid-state recorders that are rapidly replacing magnetic tape recorders. The Singapore CAAS did not meet the ICAO requirements of the flight recorder start time.

Singapore CAAS required that the CVR starting time be from “the beginning of takeoff run,” whereas, the ICAO standard is from “the moment an aircraft first moves under its own power.”

2.7.2 Airport Incident Reporting and Tracking

Only 6 incident reports collected by the Safety Council were related to air traffic services during the factual collection stage: Two of them involved aircraft that taxied onto a closed taxiway after landing, three runway incursions; and the last one was not clearly identified because of insufficient information.

After reviewing these 6 incident reports, neither weather conditions nor similarities were found to the SQ006 accident; however, given the fact that the CKS Airport has been in service for over 22 years, there should be more than 6 reports.

The Safety Council recommends that the CAA establish a reliable incident reporting system, promote this system to user groups, and place higher priority in the use of such a system.

2.7.3 Weather Analysis

The Safety Council checked the Runway 05L RVR sensor after the accident and the accuracy was found to be in conformance with ICAO SARPs. According to the weather observations and the data calculated by the manufacturer, visibility at and before the accident were greater than the takeoff weather minimum (200m).

RVRs are calculated from three parameters: Extinction Coefficient, Runway Light Setting, and Background Light by the AWA and then transmitted to the display stations. Because of the shortage in storage, these three parameters were archived but not the RVRs. Meteorological parameters such as wind, visibility, RVR etc., are important information for air safety investigations. Many airports around the world are able to archive all of the measured and calculated data at a certain sampling rate for future analysis. Although the CKS Weather Station provided airport weather information in accordance with ICAO Annex 3 SARPs, it is insufficient for accident investigation and research. However, a recommendation was made by ASC regarding the hardware improvement to achieve the air safety investigation needs, in an investigation report issued on September, 2001 (ASC-AIR-01-09-001).

2.7.4 SIA Typhoon Procedure

The Safety Council concludes that the SIA typhoon procedure was not well defined and the personnel who were obliged to use the procedures did not fully understand the procedures. In particular, it was unclear, when a typhoon approached Taipei, who was responsible for carrying out the SIA typhoon procedures. Consequently, the typhoon procedures were not followed correctly on the night of the accident.

SIA typhoon warnings were divided up into four categories, or conditions. When typhoon conditions were declared by the FCC, all communications between affected parties were to be followed by telexes addressed URGENT and MUST be acknowledged. Interview data and telex records indicated that after the FCC telexed typhoon Condition I and Condition II information to all relevant personnel and stations, the FCC did not receive a response from any of the stations. The SIA typhoon procedures stipulated that stations are required to acknowledge the telexes when Typhoon Conditions are declared; however, the FCC personnel explained that an acknowledgement or response was not required from a station unless the station is unprepared for the typhoon. The Safety Council was unable to determine why the actual FCC typhoon procedure differed from the written procedures.

In addition, the URGENT telexes pertaining to typhoon information were sent to the stations in off-duty time so it was not possible for personnel such as the SIA B747-400 Chief Pilot to acknowledge the telex because he was not in the office at that time. Consequently, he stated that he was not aware of the typhoon conditions at Taipei on the evening of the SQ006 occurrence. Further, the Chief Pilot reported that there was no requirement for him to talk to the aircraft commander under such conditions. The Chief Pilot stated that SIA Fleet does not interfere with a commander's decision-making. Operational decisions are made by the aircraft commander.

The Safety Council agrees that the aircraft commander should make the final decision and take full responsibility for the aircraft he operates. A well-trained and qualified commander should be able to make a sound decision based on his expertise and judgment when he has received all available information; however, to ensure that the relevant safety information is communicated, the Chief Pilot or SIA Dispatch should make sure the commander has received the information. The Safety Council believes that if SIA had provided a structured decision making process and proactively provided more resources to the commander, it would have helped the commander with his decision making, thereby facilitating an increased probability of developing the best solution to operate the aircraft in typhoon conditions.

According to the SIA Flight Administration Manual, when typhoon Condition II exists at an airport, the responsible agent at the affected airport shall ensure that the Commander of any aircraft on the ground is fully and immediately informed. In order to clarify who is the responsible agent in Taipei, the Safety Council visited the SIA Flight Control Center at Singapore Changi Airport, the SIA Taipei Station at CKS Airport, and the EVA Flight Control Department (FCD) in Nan-Kan, Taoyuan County, Taiwan.

Interview data indicated that the EVA FCD is the ground-handling agent for SIA at CKS Airport to handle SIA flight operations, including the flight dispatch operation. The SIA Taipei Station is part of the SIA marketing division and is responsible for the non-technical aspects of the flight services. On the evening of the accident, the SIA Taipei Station manager believed that it was EVA's responsibility to inform the flight crew about the typhoon status; however, managers of the EVA FCD stated that the responsibilities of EVA on handling SIA's flights are mainly on the flight dispatch and freighter load sheet preparations. They did not believe it was their responsibility to carry out the SIA typhoon procedures. Further, EVA believed that SIA did not require them to carry out any SIA typhoon procedures[75] and they were not aware that SIA had a typhoon procedure. Later, the SIA Senior Manager Flight Control Center clarified that the SIA typhoon procedure is an SIA internal procedure that does not apply to EVA; however, the SIA FCC was unable to clarify who should be responsible for SIA's typhoon procedure in Taipei.

The Safety Council was unable to determine what influence this had on the outcome of the accident. It is unknown what the outcome might have been if the responsible agent in Taipei had been assigned and had carried out SIA's typhoon procedures on the night of the accident; however, this communication break down between the SIA FCC, the SIA Taipei Station, and the EVA FCD would certainly have increased the risk of operating an aircraft under typhoon conditions.

2.7.5 Out Station Dispatch

As previously mentioned, EVA Airways was the handling agent for SIA's flight dispatch operations at CKS Airport. Interview data indicated that the Computer Flight Plan (CFP) for SQ006 was prepared by EVA Airways licensed flight dispatchers at EVA Headquarters located at Nan-Kan, Taoyuan County. The dispatcher obtained the relevant weather information and the SIA Internal INTAM for the flight. The prepared CFP, weather information, and INTAMs were sent via SITA to the EVA Operation Control Services office located at CKS Airport as the meteorology folder. The on-duty EVA Operation Control Service officers then presented the official CAA NOTAM from CKS Flight Information Services, the Scandinavian Airways Systems NOTAM, together with the meteorology folder, to the flight crew at the corridor leading to the holding area of the parking bay.

The licensed flight dispatcher determined that the SQ006 documentation complied with SIA requirements and sent a "dispatch release" to the EVA Operations Officer. The EVA Operations Officer then signed the CFP on behalf of the flight dispatcher, and delivered all the documents to the flight crew. In addition, the EVA Operations Officer highlighted the relevant and important

[75] The contract between SIA and EVA on ground handling services at CKS Airport followed IATA Ground Handling Agreements AHM810.

information of the weather forecast and the official NOTAMs before he handed the documents to the flight crew.

During interviews, the SIA FCC and the SIA Taipei Station Manager believed that the EVA Airways' dispatcher should have provided a full verbal briefing to the SIA flight crew before the flight. Evidence showed that the dispatch briefing provided by EVA to the SIA flight crew was a self-briefing service. EVA Operations Officers provided the dispatch documents to the flight crew without a verbal brief but the dispatcher was available for questioning by the crew if necessary before departure. On the night of the accident, the EVA Operations Officer who presented the flight package to the flight crew of SQ006 was not licensed by CAA as a qualified dispatcher; therefore, any queries pertaining to the completed documentation from the flight crew would have needed to be clarified by the flight dispatcher at the EVA Headquarters office through the company designated VHF frequency or by telephone.

The flight crew had no questions for the EVA dispatcher after their review of the pre-flight briefing package. In addition, the flight crew stated that they were all aware of the weather situation and that Runway 05R was closed due to work in progress.

The Safety Council was unable to determine the influence on the development of the accident if the flight crew had been fully briefed by a licensed dispatcher before departure on the night of the accident. However, the Safety Council has concluded that the potential inconvenience for the flight crew to discuss any relevant concerns with a EVA licensed dispatcher may have increased the risk of a flight crew operating a flight with an incomplete understanding of the documentation provided by dispatch.

2.7.6 Cockpit Surface Guidance and Navigation Technology

As aircraft traffic volume has increased, the airport movement areas have become more and more congested. The increased volume of traffic has led to a need to perform more operations in low visibility conditions and at night. Further, ever-increasing demand for air transport services has led to increasingly complex airport layouts. The traditional procedures and technologies have not been designed to accommodate these situations. The rising trend in runway incursion statistics may be an indirect result of such design limitations.

In the complex airport environment, the key information pilots need to avoid runway incursions includes their precise location and route, the location of other airport traffic and routing constraints as issued by ATC[76]. On July 6, 2000, the NTSB made specific recommendations for reducing runway incursions, including a recommendation that the FAA "require, at all airports with scheduled passenger service, a ground movement safety system that will prevent runway incursions; the system should provide a direct warning capability to flight crews"[77]. There are no specific technologies or systems on board current aircraft to help pilots avoid runway incursions.

The Runway Incursion Joint Safety Advisory Team (JSAT)[78] has determined that moving map technology is highly effective for reducing the threat of accidents caused by runway incursions. The United States National Aeronautics and Space Administration (NASA) and the NTSB also support the addition of this technology into the cockpit for the purpose of runway incursion prevention. The FAA Safe Flight 21 department performed an analysis that estimated that 43 percent of runway incursion incidents could be eliminated using a cockpit surface moving map (with airport diagram)[79].

An additional safety feature of the surface moving map cockpit display is that, in the future, it might provide the basis for a complete ground movement safety system. One upgrade to the system, enabled by data link technology, would add traffic information concerning all other aircraft and surface vehicles at the airport (equipped with a compatible system or transponder). Another upgrade could provide graphical depiction of Notices to Airmen (NOTAM) information, for example, overlaying a different color on part of a runway closed for construction. Such upgrades are currently being developed. However, implementation of a basic surface moving map display as a basis for a ground movement safety system should not be delayed. Many airport ground movement safety problems involve pilots becoming disorientated on the airport, as in the present accident. The current technology display, with GPS location of own aircraft, have immediate safety benefits in that they do not have to wait for an enabling technology or widespread user implementation. Such systems can help pilots avoid airport "hot spots" and closed runways and facilitate accurate taxiing in poor visibility conditions induced by poor weather and/or low levels of celestial illumination.

A surface moving map cockpit display may have prevented the SQ006 accident by providing the flight crew with a source of precise information on the position of their aircraft with respect to the airport maneuvering areas. A surface guidance and navigation cockpit display may have ensured that

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[76] Young, S., and Jones, D. "Flight Testing of an Airport Surface Movement Guidance, Navigation, and Control System." In *Proceedings of the Institute of Navigation National Technical Meetin*g. Long Beach, California, United States, January 21-23, 1998.

[77] National Transportation Safety Board, *Safety Recommendation Letter to the FAA Administrato*r, A-00-66, July 6, 2000.

[78] As part of the FAA's "Safer Skies" agenda, the Commercial Aviation Safety Team (CAST) formed the runway incursion Joint Safety Analysis Team (JSAT) in October 1998.

[79] Bergman, Charles K. 2001. At the Breaking Point: The Ever-increasing Risk Associated With Runway Incursions in the Rapidly Expanding Global Aviation Environment. Proceedings of the FSF 54th annual International Conference. P. 215-220. Athens, Greece.

the flight crew navigated to the correct runway. Moreover, it could have provided a direct and timely warning to the flight crew that they were entering the incorrect runway for take-off. Furthermore, a surface movement guidance system could have compensated for the absence of a control tower radar system such as the Airport Surface Detection Equipment (ASDE). The use of ASDE may require more time for the controller to detect and positively identify a safety problem on the airport maneuvering area compared to a cockpit-based surface guidance display. The time delay for instituting recovery action using ASDE may be further exacerbated by establishing radio contact with the crew in addition to waiting for the flight crew to react and take evasive action in accordance with ATC information. Finally, a cockpit surface moving map could have provided more complete, accessible, and effective navigation information to the flight crew of SQ006 compared to the use of progressive taxi instructions by ATC.

2.7.7 Independent Investigation Authority

Singapore does not have an independent aviation investigation authority according to the “best practices” followed by many States, and currently being adopted by other States. The MCIT is responsible for the safety regulation and safety oversight of Singapore civil aviation (performed by the CAAS), as well as investigations of accidents and serious incidents involving Singapore civil aircraft within and outside of Singapore. Thus, following an accident or serous incident, the MCIT is put in the position of “investigating itself.”

Experience in many countries has shown that an accident investigation authority that is not independent of the regulatory authority may not be as objective or thorough as necessary in identify safety deficiencies and recommending changes. A properly conducted accident (and serious incident) investigation often requires an in-depth assessment of the regulations, policies, practices, and procedures of the responsible regulatory authority and its possible role in the circumstances of the accident or incident. Because the results of such an assessment may necessitate conclusions and recommendations that are critical of, or adverse to, the regulatory authority or its officials, many countries have concluded that no accident investigation entity could fully perform such a function (“investigate itself”), unless it is was separate and independent from the regulatory authority.

Thus, many countries have taken legislative actions to ensure that investigations are conducted by an entity that is functionally independent of the authority responsible for regulation and oversight of the aviation system. This concept is embraced by the ICAO guidance materials. The Safety Council believes that the Singapore government should seriously consider establishing an independent aviation accident/incident investigation authority consistent with the “best practices” of many other countries in the world.

3 Conclusions

In this Chapter, the Safety Council presents the findings derived from the factual information gathered during the investigation and the analysis of the SQ006 accident. The findings are presented in three major categories: **findings related to probable causes, findings related to risk, and other findings.**

The **findings related to probable causes** identify elements that have been shown to have operated in the accident, or almost certainly operated in the accident. These findings are associated with unsafe acts, unsafe conditions, or safety deficiencies associated with safety significant events that played a major role in the circumstances leading to the accident.

The **findings related to risk** identify elements of risk that have the potential to degrade aviation safety. Some of the findings in this category identify unsafe acts, unsafe conditions, and safety deficiencies, including organizational and systemic risks, that made this accident more likely; however, they cannot be clearly shown to have operated in the accident alone. Further, some of the findings in this category identify risks that are unrelated to this accident, but nonetheless were safety deficiencies that may warrant future safety actions.

Other findings identify elements that have the potential to enhance aviation safety, resolve an issue of controversy, or clarify an issue of unresolved ambiguity. Some of these findings are of general interests that are often included in the ICAO format accident reports for informational, safety awareness, education, and improvement purposes.

3.1 Findings Related to Probable Causes

1. At the time of the accident, heavy rain and strong winds from typhoon “Xangsane” prevailed. At 2312:02 Taipei local time, the flight crewmembers of SQ006 received Runway Visual Range (RVR) 450 meters on Runway 05L from Automatic Terminal Information Service (ATIS)

"*Uniform*". At 2315:22 Taipei local time, they received wind direction 020 degrees with a magnitude of 28 knots, gusting to 50 knots, together with the takeoff clearance issued by the local controller. (1.1; 1.7)

2. On August 31, 2000, CAA of ROC issued a Notice to Airmen (NOTAM) A0606 indicating that a portion of the Runway 05R between Taxiway N4 and N5 was closed due to work in progress from September 13 to November 22, 2000. The flight crew of SQ006 was aware of the fact that a portion of Runway 05R was closed, and that Runway 05R was only available for taxi. (1.18.2.6; 2.5.2.1; 2.5.3)
3. The aircraft did not completely pass the Runway 05R threshold marking area and continue to taxi towards Runway 05L for the scheduled takeoff. Instead, it entered Runway 05R and CM-1 commenced the takeoff roll. CM-2 and CM-3 did not question CM-1's decision to take off. (1.1; 1.18.1.1)
4. The flight crew did not review the taxi route in a manner sufficient to ensure they all understood that the route to Runway 05L included the need for the aircraft to pass Runway 05R, before taxiing onto Runway 05L. (1.18.1.1; 2.5.3)
5. The flight crew had CKS Airport charts available when taxing from the parking bay to the departure runway; however, when the aircraft was turning from Taxiway NP to Taxiway N1 and continued turning onto Runway 05R, none of the flight crewmembers verified the taxi route. As shown on the Jeppesen "20-9" CKS Airport chart, the taxi route to Runway 05L required that the aircraft make a 90-degree right turn from Taxiway NP and then taxi straight ahead on Taxiway N1, rather than making a continuous 180-degree turn onto Runway 05R. Further, none of the flight crewmembers confirmed orally which runway they had entered. (1.18.1.1; 2.5.2.2; 2.5.4.3)
6. CM-1's expectation that he was approaching the departure runway coupled with the saliency of the lights leading onto Runway 05R resulted in CM-1 allocating most of his attention to these centerline lights. He followed the green taxiway centerline lights and taxied onto Runway 05R. (1.18.1.1; 2.5.7)
7. The moderate time pressure to take off before the inbound typhoon closed in around CKS Airport, and the condition of taking off in a strong crosswind, low visibility, and slippery runway subtly influenced the flight crew's decision-making ability and the ability to maintain situational awareness. (1.18.1.1; 2.5.6; 2.5.7)
8. On the night of the accident, the information available to the flight crew regarding the orientation of the aircraft on the airport was:

    - CKS Airport navigation chart
    - Aircraft heading references
    - Runway and Taxiway signage and marking
    - Taxiway N1 centerline lights leading to Runway 05L
    - Color of the centerline lights (green) on Runway 05R
    - Runway 05R edge lights most likely not on

- Width difference between Runway 05L and Runway 05R
- Lighting configuration differences between Runway 05L and Runway 05R
- Para-Visual Display (PVD) showing aircraft not properly aligned with the Runway 05L localizer
- Primary Flight Display (PFD) information

The flight crew lost situational awareness and commenced takeoff from the wrong runway. (1.1; 1.18.1; 2.5)

3.2 Findings Related to Risk

1. Based on the current ICAO Annex 14 Standards and Recommended Practices (SARPs), the CKS Airport should have placed runway closure markings adjacent to the construction area on Runway 05R; however, there was no requirement to place runway closure markings near the threshold of Runway 05R. (1.10.4.2; 2.3.3)
2. There is ambiguity in ICAO Annex 14 SARPs regarding a temporarily closed runway because the term "short term" is not defined. (1.10.4.2; 2.3.3)
3. ICAO Annex 14 SARPs, regarding a temporarily closed runway that is still used as a taxiway, do not provide adequate information with respect to warning flight crews that the runway is closed for other than taxi operations. (1.10.4.2; 2.3.3)
4. Although there are no clear ICAO regulations for placement of warnings on temporarily closed runways that are also used for taxi operations, the lack of adequate warnings at the entrance to Runway 05R did not provide a potential last defense, from an airport infrastructure perspective, to prevent the flight crew of SQ006 from mistakenly entering Runway 05R. (1.10.4.2; 2.3.3)
5. Based on ICAO SARPs, the barriers placed around the construction area on Runway 05R should have been frangible. (1.10.4.2; 2.3.3)
6. At the time of the accident, there were a number of items of CKS Airport infrastructure that did not meet the level of internationally accepted standards and recommended practices. Appropriate attention given to these items could have enhanced the situational awareness of the flight crew while taxiing to Runway 05L; however, the absence of these enhancements was not deemed sufficient to have caused the loss of situational awareness of the flight crew. Among these items were:

   - Four days after the accident, the investigation team found that a green centerline light immediately after the Runway 05R entry point along Taxiway N1 leading to Runway 05L was un-serviceable and the following light was dim. It could not be determined what the status of those lights was on the night of the accident. (1.10.3.2.4; 2.3.1.2.3)
   - The green centerline lights leading from Taxiway NP onto Runway 05R were more visible than the Taxiway N1 centerline lights leading toward Runway 05L because they were more

densely spaced. There should have been 16 centerline lights spaced 7.5 meters apart along the straight segment of Taxiway N1 where the curved Taxiway centerline marking from Taxiway NP meets Taxiway N1 up to the Runway 05L holding position, rather than 4 centerline lights spaced at 30 meters, 55 meters, 116 meters, and 138 meters. (1.10.3.2.4; 2.3.1.2.2)

- Segments of the straight portion of the taxiway centerline marking on Taxiway N1 did not extend all the way down to the Runway 05L threshold marking with interruption stops beginning 12 meters before the Runway 05R threshold marking and ending 12 meters after the Runway 05R threshold marking. (1.10.3.1.2; 2.3.1.1)
- Runway guard lights and stop bars were not provided at CKS Airport. (1.10.3.2.2; 1.10.3.2.3; 2.3.2)
- Alternate green/yellow taxiway centerline lights to demarcate the limits of the ILS sensitive area were not installed. (1.10.3.2.4)
- The mandatory guidance signs installed on the left and right sides of Taxiway N1 were located after the holding position for Runway 05L and not collocated with the runway holding position marking. (1.10.3.1)
- There was no interlocking system installed at CKS Airport to preclude the possibility of simultaneous operation of the runway lighting and the taxiway centerline lighting. (1.10.5.1.1; 2.3.1.2.1)
- The serviceability monitoring mechanism of the CKS airfield lighting system was accomplished both electronically and manually. However, there was a lack of a continuous monitoring feature of individual lights, or percentage of unserviceable lamps, for any circuit of CKS Airport lighting. (1.10.5.1.2)

7. Airport Surface Detection Equipment (ASDE) is designed to reduce the risk of airport ground operations in low visibility, but there is no ICAO SARPs requiring the installation of ASDE at airports. The Safety Council was not able to determine whether ASDE would have provided information to the Air Traffic Controllers (ATC) about SQ006 taxiing onto the incorrect runway, because signal attenuation from heavy precipitation diminishes the effectiveness of the radar presentation. (1.18.2.4; 2.4.2)
8. There was a lack of a safety oversight mechanism within CAA that could have provided an independent audit/assessment of CKS Airport to ensure that its facilities met internationally accepted safety standards and practices. (1.17.9; 2.3.5.2.1; 2.3.5.3.2; 2.3.6)
9. There was a lack of a specified safety regulation monitoring organization and mechanism within the CAA that resulted in the absence of a mechanism to highlight conditions at CKS Airport for taxiways and runways lighting, marking, and signage that did not meet internationally accepted safety standards and practices. (1.17.9; 2.3.6)

10. The CAA had not formed a working group for the derivation of a complete Surface Movement Guidance and Control System (SMGCS) plan according to guidance provided by ICAO Annex 14. (1.10.5.2)
11. Being a non-contracting State, the CAA of ROC does not have the opportunity to participate in ICAO activities in developing its airport safety enhancement programs to correspond with international safety standards and recommended practices. (1.17.10; 2.3.5.2.2)
12. The local controller did not issue progressive taxi/ground movement instructions and did not use the low visibility taxi phraseology to inform the flight crew to slow down during taxi. (1.18.2.3; 2.4.1)
13. The flight crew did not request progressive taxi instructions from Air Traffic Controller (ATC). (1.1; Appendix 3)
14. Reduced visibility in darkness and heavy rain diminished, but did not preclude, the flight crew's ability to see the taxiway and runway lighting, marking, and signage. (1.18.1.1; 2.5.7.1)
15. The SIA crosswind limitation for a "wet" runway was 30 knots and for a "contaminated" runway was 15 knots. CM-1 assessed that the runway condition was "wet" at the time he prepared for takeoff and determined that the crosswind was within company limitations. The lack of SIA and ATC procedures for quantitatively determining a "wet" versus "contaminated" runway creates ambiguity for flight crews when evaluating takeoff crosswind limitations. (1.18.4; 2.5.8)
16. There was no procedure described in the SIA B747-400 Operations Manual for low visibility taxi operations. (1.17.4.5; 2.5.4)
17. There was no formal training provided to SIA B747-400 pilots for low visibility taxi techniques. (1.18.1.1.1)
18. SIA did not have a procedure for the pilots to use the PVD as a tool for confirming whether the aircraft is in a position for takeoff in low visibility conditions such as existed for the operation of SQ006 on the night of the accident. (1.18.5.1; 2.5.6.3.3)
19. SIA procedures and training documentation did not reflect the CAAS approved B-747-400 AFM supplement regarding use of the PVD for confirming the correct aircraft takeoff position. (1.18.5.3; 2.5.6.3.3)
20. CAAS oversight of SIA operations and training did not ensure that the approved B747-400 AFM supplement regarding use of the PVD for determining whether the aircraft is in a correct position for takeoff was incorporated into the SIA documentation and operational practices. (1.18.5.3; 2.5.10)
21. At the time of the accident, SIA's Aircraft Operations Manual did not include "confirm active runway check" as a before takeoff procedure. (1.18.1.1; 2.5.5)
22. The SIA training and procedures for low visibility taxi operations did not ensure that the flight crew possessed the appropriate level of knowledge and skills to accurately navigate the aircraft on the ground. (1.17.4.5; 2.5.4.5)

23. CAAS had not performed sufficient safety oversight of SIA's procedures and training and the deficiencies in SIA procedures and training were not discovered during routine CAAS safety oversight. (1.17.1; 2.5.10)
24. The SIA typhoon procedure was not well defined and the personnel who were obliged to use the procedure did not fully understand the procedure and their responsibilities. (1.17.7; 2.7.4)
25. The severe impact forces and rapidly spreading fire and smoke rendered much of the existing emergency evacuation training, hardware, and procedures ineffective. (1.15.1.2, 1.15.1.3; 1.15.1.4, 2.6.1)
26. CM-1 did not order cabin crewmembers and passengers to initiate the emergency evacuation when the Passenger Address (PA) system was found inoperative. (1.15.1.2; 2.6.1)
27. During the annual recurrent emergency evacuation training, which was integrated with the cabin crew, the flight crew played the role of passengers. The SIA procedures did not require the flight crew to give the evacuation command. (1.15.1.1)
28. A majority of the cabin crewmembers' performance was affected because of the unexpected dynamics of the accident. (1.15.1; 2.6.1)
29. The dense smoke made breathing difficult and the emergency lights less visible for the survivors during the evacuation. (1.15.1; 2.6.3.1; 2.6.3.2)
30. During the evacuation in dark conditions, only CM-3, CM-2, and 5L crewmembers carried flashlights. The 5L cabin crewmember used the flashlight to assist during the passenger evacuation. (1.15.1.6)
31. CKS Airport did not prescribe in detail the emergency medical treatment procedures and the responsibilities of a medical coordinator or the interim coordinator in accordance with the ICAO recommendations. (1.15.3.6; 2.6.4.1)
32. CKS Airport did not provide contingency procedures for medical treatment and rescue in adverse weather conditions in accordance with the ICAO recommendations. (1.15.3.6; 2.6.4.1)
33. The "CKS Airport Civil Aircraft Accident Handling Procedures and Regulations" contained incomplete features of the surrounding hospitals (such as neurosurgical ability) as suggested in the ICAO recommendations. (1.15.3.5; 2.6.4.2)
34. The manufacturer of the emergency evacuation slides did not provide information on the effects of high wind in the operator's manual. (1.15.1.3; 1.12.2.3.2; 2.6.2.1)
35. The high lateral G forces associated with the accident produced an unexpected self-inflation of the 4R and 5R slides in the cabin. (1.15.1.5; 2.6.2.2)
36. The fire-fighting department was understaffed in handling a major accident. (1.14.1.2; 1.15.3.2; 2.6.4.3)

3.3 Other Findings

1. The flight crew was properly certificated and qualified in accordance with the applicable CAAS regulations and SIA Company requirements, and ICAO SARPs. (1.5; 2.1)

2. The flight crew was provided with appropriate and complete dispatch documents, including weather, weight and balance information, NOTAMs and SIA INTAMs, in accordance with the established procedures. (1.18.1.1; 2.1)
3. The cabin crew was qualified in accordance with the SIA training program. (1.5; 2.1)
4. Crew duty time, flight time, rest time, and off duty activity patterns did not indicate influence of pre-existing medical, behavioral, or physiological factors of the flight crew's performance on the day of the accident. (1.5; 2.1)
5. The air traffic controllers involved with the control of SQ006 were properly certificated, and qualified to perform their duties. Their duty time, rest time and off duty time activities were not considered to have influenced their performance on the day of the accident. (1.5.5; 1.5.6; 1.5.7; 1.5.8; 2.1)
6. The aircraft was certificated, equipped, and maintained in accordance with CAAS regulations and approved procedures, and ICAO SARPs. There was no evidence of pre-existing mechanical malfunctions or other failures of the aircraft structure, flight control systems, or power plants that could have contributed to the accident. The accident aircraft was considered airworthy before the accident. (1.6; 2.1)
7. There was no evidence to indicate that there was any undue organizational pressure from SIA placed upon the flight crew to take off on the evening of the accident. (1.17.8; 1.18.1.1; 2.1)
8. The Jeppesen charts used by the flight crew were current at the time of the accident. (1.18.3; 2.5.2.2)
9. The taxi check and procedures used by the flight crew were in accordance with the SIA B747-400 Operations Manual. (1.18.1.1; 2.5.4.4)
10. It was appropriate for the flight crew to consider Runway 05L for takeoff on the evening of the accident. (1.18.1.1; 2.5.3)
11. The SIA SOP did not assign specific duties for the third flight crewmember, although CM-1 requested CM-3 to verify crosswind limitations during taxi. (1.17.4.2; 1.18.1.1; 2.5.9.3)
12. ATC taxi instructions and the takeoff clearance did not mislead the flight crew to take off from the partially closed Runway 05R. SQ006 was cleared for takeoff on Runway 05L and the flight crew confirmed the clearance before takeoff. (1.1; 2.1; Appendix 2, 3)
13. The preponderance of evidence indicates that the Runway 05R edge lights were most likely not illuminated during the attempted takeoff of SQ006. (1.12.5; 1.16.5; 2.3.4)
14. The fatality rate of this accident was 46 percent. The serious injury rate was 22 percent. The minor injury rate was 18 percent. The no-injury rate was 14 percent. (1.2)
15. The main deck mid cabin from rows 31 to 48 was not survivable in this accident because of the fuel-fed fire. Sixty four out of seventy six passengers died in this area. All passengers in the tail section survived where there was less fire. (1.2)
16. No slides were fully functional for survivors' evacuation in this accident because of impact forces, fire, and strong wind. (1.12.2.2; 1.16.3; 2.6.2)

17. The Department of Forensic Pathology conducted a total of 7 autopsies. Of the 7 autopsies conducted, 6 died from severe burns and one died from impact injuries. (1.13.2; 2.6.5)
18. Airport Rescue and Fire Fighting (ARFF) personnel arrived at the accident site in approximately 3 minutes and began fire fighting and rescue efforts. A small fire at the tail section was put out immediately. In conditions of severe weather, the fire at the forward and mid-sections of the fuselage were suppressed in 15 minutes and positively controlled in 40 minutes. (1.14.1.1; 1.14.1.2)
19. All fire and medical personnel used the same frequency to communicate in this accident. (1.15.3.1)
20. The majority of the CKS Airport medical and rescue operations were not able to function in accordance with CKS Airport procedures because of strong wind and heavy rain emanating from approaching typhoon "Xangsane." (1.15.3.2; 2.6.4)
21. The first 10 survivors were transported to the hospital in airport ambulances without proper triage procedures. (1.15.3.2; 2.6.4)
22. There was no alcohol and drug testing of the three flight crewmembers of SQ006 and four tower controllers on duty after the accident and there was no evidence to suggest that alcohol or drugs were factors in the accident. (1.13.3)
23. The Ministry of Transportation and Communications (MOTC) staff was not proactive in supporting CAA's requests for the installation of ASDE at CKS Airport. (1.18.2.4; 2.4.2)
24. All new CAA regulations are subject to lengthy formalities in the approval process by the MOTC. (1.17.10; 2.4.2)
25. Although the SQ006 CVR power-on and power-off times were in compliance with ICAO SARPs and CAAS regulations, the Federal Aviation Regulations (FARs) and Joint Aviation Requirements (JARs) require an earlier power-on and later power-off times. An earlier power-on time and later power-off time would be desirable for the examination of operational and human factors safety issues following accidents and incidents. (1.11.1.1; 2.7.1)
26. Only six incident reports collected by ASC were related to air traffic services, the number of reports involving airport facilities at CKS Airport, which has been in service over 22 years, should be more than six. (1.18.2.5; 2.4.3)
27. An airport surface guidance and navigation cockpit display could reduce the risk of incidents and accidents during taxi, take-off and landing operations. (1.18.8; 2.7.6)
28. Singapore does not have an independent aviation accident investigation authority charged with making objective investigations, conclusions, and recommendations. International experience has shown that an independent investigation authority is a benefit to aviation safety, and many States have taken actions to ensure that investigations are conducted by a government agency that is functionally independent from the authority responsible for regulation and oversight of the aviation system. (1.17.2; 2.7.7)

4 Safety Recommendations

In this chapter, safety recommendations derived as the result of this investigation are listed in section 4.1. Safety actions taken. Safety actions that have been accomplished, or are currently being accomplished are listed in section 4.2. It should be noted that the safety actions listed in section 4.2 have not been verified by the Safety Council.

4.1 Recommendations

Interim Flight Safety Bulletin

In November 2000, the Safety Council issued the following Interim Flight Bulletins to the CAA of ROC, MCIT of Singapore, NTSB and ATSB:

1. The Safety Council recommends that the flight crew should be briefed with conditions regarding airport surface maintenance prior to their departure.
2. The Safety Council recommends that the flight crew under Instrument Flight Rules Conditions should make sure the correct use of departure runway by cockpit standard callout.
3. The Safety Council recommends that civil aviation authority should require all airline operators to include abovementioned recommendations in their standard operating procedures.

To Singapore Airlines (SIA)

The Safety Council recommends that SIA:

1. Develop and implement a comprehensive surface-movement training program that reflects the current practice in this area, such as the recommendations contained in the FAA's National Blueprint for Runway Safety and FAA Advisory Circular No. 120-74. (3.1-[3~8]; 3.2-[16, 17, 22])-ASC-ASR-02-04-01

2. Ensure that procedures for low visibility taxi operations include the need for requesting progressive taxi instructions to aid in correct airport surface movement. (3.2-[13]) -ASC-ASR-02-04-02
3. Review the adequacy of current SIA PVD training and procedures and ensure that SIA documentation and operational practices reflect the CAAS approved B747-400 AFM PVD supplement, which included the use of the PVD to indicate whether the aircraft is in a correct position for takeoff. (3.2-[18, 19]) -ASC-ASR-02-04-03
4. Develop and implement a clear policy that ensures that flight crews consider the implications of the relevant instrument indications, such as the PFD and PVD, whenever the instruments are activated, particularly before commencing takeoff in reduced visibility conditions. (3.1-[8])- -ASC-ASR-02-04-04
5. Include in all company pre-takeoff checklists an item formally requiring positive visual identification and confirmation of the correct takeoff runway. (3.1-[8], 3.2-[21]) -ASC-ASR-02-04-05
6. Implement an Advanced Crew Resource Management program to reflect current practices in this area, and ensure that such programs are regularly revised to reflect new developments in CRM. (3.1-[3, 4]) -ASC-ASR-02-04-06
7. Review the adequacy of current runway condition determination procedures and practices for determining a water-affected runway to "wet" or "contaminated" in heavy rain situations, by providing objective criteria for such determinations. (3.2-[15]) -ASC-ASR-02-04-07
8. Conduct a procedural audit to eliminate existing conflicts in the guidance and procedures between the company manuals, the managers' expectations, and the actual practices, such as those contained in the Typhoon Procedures and dispatch briefing policy. (3.2-[24]) -ASC-ASR-02-04-08
9. Modify the emergency procedures to establish an alternate method for initiating the emergency evacuation command in the event of a PA system malfunction. (3.2-[26]) -ASC-ASR-02-04-09
10. Review its procedures and training for the flight and cabin crewmembers to effectively handle diversified emergency situations. (3.2-[25, 26, 27, 28]) -ASC-ASR-02-04-10

To Civil Aviation Authority of Singapore (CAAS)

The Safety Council recommends that the CAAS:

1. Require SIA to develop and implement a comprehensive surface-movement training program, to include a procedure to request progressive taxi instructions during low visibility ground operations. (3.1-[3~8]; 3.2-[13, 16, 17, 22]) -ASC-ASR-02-04-11
2. Review the adequacy of current SIA PVD training and practices and require that SIA revise, if necessary, procedural and training documentation and operational practices to reflect the CAAS approved B747-400 AFM PVD supplement. (3.2-[18, 19, 20]) -ASC-ASR-02-04-12

3. Review the current system of managing AFM supplement document approval, control, distribution, and enactment policies and procedures for operators and make appropriate changes as necessary to ensure that revisions to airline AFMs are adequately managed. (3.2-[20]) -ASC-ASR-02-04-13
4. Ensure that all Singaporean commercial airline operators under its regulatory responsibility implement Advanced Crew Resource Management programs to reflect current practices and ensure that such programs are regularly monitored and revised to reflect new developments in CRM. (3.1-[3, 4]) -ASC-ASR-02-04-14
5. Evaluate and support appropriate research to develop technologies and methods for enhancing flight crews' abilities for objectively determining a water-affected runway condition in heavy rain situations. (3.2-[15]) -ASC-ASR-02-04-15
6. Amend the CAAS Air Navigation Order paragraph 37 (3) to require an earlier power-on and later power-off times for CVRs. (3.3-[25]) -ASC-ASR-02-04-16

To Singapore Government

The Safety Council recommends that the Singapore Government establish an independent aviation accident/incident investigation organization consistent with many other countries in the world. (3.3-[28]) -ASC-ASR-02-04-17

To Civil Aeronautics Administration, ROC (CAA)

The Safety Council recommends that the CAA:

1. Require that the control tower chiefs re-emphasize the concept, training and the use of progressive taxi/ground movement instructions during low visibility ground operations. (3.2-[12]) -ASC-ASR-02-04-18
2. Place priority on budgetary processes and expedite the procurement and installation of ASDE at airports with high traffic volume. (3.2-[7]) -ASC-ASR-02-04-19
3. Clearly redefine its Divisions' job functions to stipulate each individual unit and personnel responsibilities. (3.2-[8, 9]) -ASC-ASR-02-04-20
4. Specifically appoint an organization within the CAA for the development, modification, and issuance of civil aviation regulations. (3.2-[8]) -ASC-ASR-02-04-21
5. Organize a program to continuously monitor ICAO SARPs and industry best practices for safety improvement and distribute them to the relevant organizations for applicable review and necessary action and oversight of their progress. (3.2-[6]) -ASC-ASR-02-04-22
6. Establish an integrated risk assessment and management program, and oversight mechanism to supervise all plans and implementations. (3.2-[6, 7, 8, 9, 10]) -ASC-ASR-02-04-23

7. Evaluate and support appropriate research to develop technologies and methods in providing objective information to pilots regarding water-affected runway conditions (wet versus contaminated) in heavy rain situations. (3.2-[15]) -ASC-ASR-02-04-24
8. Immediately implement all items, or acceptable alternative standards, at CKS and other ROC airports, that are not in compliance with ICAO SARPs and applicable documents, such as the SMGCS plan, the emergency medical procedure, etc. (3.2-[6, 10, 31, 32, 33]) -ASC-ASR-02-04-25
9. Ensure that the ARFF have the necessary manpower to perform their assigned tasks, as compared to similar level 9 international airports. (3.2-[36]) -ASC-ASR-02-04-26
10. Review the communication system at Taiwan airports to develop an integrated plan for improved communications between all agencies involved during emergency fire and rescue operations. (3.3-[19]) -ASC-ASR-02-04-27
11. Establish a reliable incident reporting system, promote the system to the users' groups, and place higher priority to the use of such system. (3.3-[26]) -ASC-ASR-02-04-28
12. Review FAA National Blueprint for Runway Safety and relevant Advisory Circulars with a view toward implementation. (3.2-[4, 5, 6, 7, 8, 9, 10]) -ASC-ASR-02-04-29
13. Ensure that appropriate surface movement technology enabling infrastructure, such as airport and terrain databases, is developed for ROC airports. (3.3-[27]) -ASC-ASR-02-04-30
14. Issue the necessary regulations to support the installation of cockpit-based surface guidance and navigation technologies, such as electronic moving map display, in ROC-registered aircraft engaged in regular public transport for use during airport surface movements. (3.3-[27]) -ASC-ASR-02-04-31

To Ministry of Transportation and Communications, ROC (MOTC)

The Safety Council recommends that the MOTC:

4. Establish professional oversight capabilities for CAA's safety improvement actions and programs for promoting flight safety. (3.3-[23, 24]) -ASC-ASR-02-04-32
5. Proactively provide support to the CAA's safety action plans, such as the ASDE procurement process. (3.2-[10]; 3.3-[23]) -ASC-ASR-02-04-33
6. Grant full authorization to the CAA to avoid lengthy waiting periods for improving and implementing technical safety regulations. (3.3-[24]) -ASC-ASR-02-04-34

To the Boeing Company

The Safety Council recommends that the Boeing Company:

1. Provide airline operators with appropriate guidance information, including cautions to be observed, when required to operate emergency evacuation slides in wind gusts that exceed the certified limit. (3.2-[34]) -ASC-ASR-02-04-35
2. Review the effectiveness of cabin emergency lights to ensure that maximum conspicuity is achieved in dense smoke following survivable accidents. (3.2-[29]) -ASC-ASR-02-04-36
3. Consider incorporating cockpit surface guidance and navigation technologies, such as electronic moving map display, into all proposed and newly certified aircraft. (3.3-[27]) -ASC-ASR-02-04-37
4. Develop and issue the necessary technical support to airline customers to aid in the installation of cockpit surface guidance and navigation technologies, such as electronic moving map display, for use during airport surface movements. (3.3-[27]) -ASC-ASR-02-04-38
5. Develop a mean to reduce failure of PA systems during survivable accidents and provide modified systems to operators. (3.2-[26]) -ASC-ASR-02-04-39

To International Civil Aviation Organization (ICAO)

The Safety Council recommends that ICAO:

1. Develop Standards that would require ASDE or comparable equipment as standard equipment at civil airports with high traffic volume. (3.2-[7]) -ASC-ASR-02-04-40
2. Amend Annex 14 to include clear Standards for defining and protecting a partially closed runway that may be used for taxi purposes. (3.2-[3]) -ASC-ASR-02-04-41
3. Consider accepting ROC to participate in various ICAO activities as an observer, for the purpose of safety improvement, even though ROC is not a contracting State. (3.2-[11]) -ASC-ASR-02-04-42
4. Support the establishment of a government/industry program involving Flight Safety Foundation, IFALPA, Airport Operations Association, and IATA to develop objective methods to assist pilots in assessing whether a runway is “wet” or “contaminated” due to the presence of water. (3.2-[15]) -ASC-ASR-02-04-43
5. Encourage and support the establishment of research by governments and industry to improve passenger smoke protection and improve emergency evacuation slide performance in heavy winds and post-accident fire. (3.2-[29, 35]) -ASC-ASR-02-04-44
6. Develop and issue the necessary SARPs to ICAO Member States’ regulatory authorities to encourage them to adopt the necessary regulations to support the installation and use of cockpit-based surface guidance and navigation technologies, such as electronic moving map display. (3.3-[27]) -ASC-ASR-02-04-45
7. Encourage all ICAO Member States to consider the installation of cockpit surface guidance and navigation technologies, such as electronic moving map display, in commercial airliners for use during airport surface movements. (3.3-[27]) -ASC-ASR-02-04-46

8. Encourage all ICAO Member States' regulatory authorities to ensure that appropriate surface movement technology enabling infrastructure, such as airport and terrain databases, is developed. (3.3-[27]) -ASC-ASR-02-04-47

To International Air Transport Association (IATA)

The Safety Council recommends that IATA:

1. Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death following an aircraft accident. (3.2-[25]) -ASC-ASR-02-04-48
2. Provide member airlines with appropriate guidance information, including cautions to be observed, when required to operate emergency evacuation slides in wind gusts that exceed the certified limits. (3.2-[34]) -ASC-ASR-02-04-49
3. For safety assurance and risk management purposes, urge its member airlines to work with their prospective regulatory agencies to ensure that airports into which they operate meet the Standards and Recommended Practices of ICAO Annex 14; and urge its member airlines to work with their prospective regulatory agencies to develop procedures for evaluating the airport infrastructure as part of their out-station audits. (3.2-[6]) -ASC-ASR-02-04-50
4. Encourage member airlines to consider equipping their aircraft with cockpit surface guidance and navigation technologies, such as electronic moving map display, for use during airport surface movements. (3.3-[27]) -ASC-ASR-02-04-51

To the Federal Aviation Administration (FAA) of the U.S.

The Safety Council recommends that FAA:

1. Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death following an aircraft accident. (3.2-[25]) -ASC-ASR-02-04-52
2. Review emergency slide design to reduce the potential for uncommanded inflation resulting from lateral impact forces. (3.2-[35]) -ASC-ASR-02-04-53
3. Review the effectiveness of cabin emergency lights to ensure that maximum conspicuity is achieved in dense smoke following survivable accidents. (3.2-[29]) -ASC-ASR-02-04-54

4. Initiate rulemaking actions to require the installation, on Boeing aircraft, of public address systems that continue to function following survivable accidents[80]. (3.2-[26]) -ASC-ASR-02-04-55

To the Joint Airworthiness Authorities (JAA)

The Safety Council recommends that JAA:

1. Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death following an aircraft accident. (3.2-[25]) -ASC-ASR-02-04-56
2. Review emergency slide design to reduce the potential for uncommanded inflation resulting from lateral impact forces. (3.2-[35]) -ASC-ASR-02-04-57
3. Review the effectiveness of cabin emergency lights to ensure that maximum conspicuity is achieved in dense smoke following survivable accidents. (3.2-[29]) -ASC-ASR-02-04-58
4. Initiate rulemaking actions to require the installation, on Boeing aircraft, of public address systems that continue to function following survivable accidents[80]. (3.2-[26]) -ASC-ASR-02-04-59

4.2 Safety Actions Accomplished or Being Accomplished[81]

According to the Ministry of Communications and Information Technology (MCIT)

SIA:

1. A new CRM training programme for pilots has been developed and implemented, which includes situational awareness and error management training as separate modules.

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[80] In April 2001 the Australian Transport Safety Bureau issued Recommendation R20000231, which stated: The ATSB recommends that the FAA and JAA review the design requirements for high capacity aircraft to ensure the integrity of the cabin interphone and passenger address systems, particularly with respect to cabin/flight deck communications, in the event of runway overruns and other relatively common types of events, which result in landing gear and lower fuselage damage.

[81] Aviation Safety Council does not have oversight authority in the implementation of the recommendations issued, nor it has the appropriate resource to verify the status of the safety actions taken or being taken. The oversight authority belongs to the Research and Evaluation Council, which is an organization under the Executive Yuan of the ROC government.

2. Human factors and accident prevention training for inclusion in the pilot command training programme is being planned by SIA Flight Crew Training Centre.
3. A risk assessment tool to enable crew to manage risk in their operations has been developed and is being evaluated.
4. Redesign of the female cabin crew's footwear had been initiated in December 1999. New footwear has been introduced.
5. Checklists have been amended to require all crew in the cockpit to visually confirm the correct runway designation before commencing the take-off run.
6. The Flight Crew Operating Manual has been amended to formally require the pilot taxiing the aircraft to refer to signage and markings. It also requires the other pilot to confirm the correct taxi route is being used with reference to airport charts.
7. The Flight Crew Training Manual has been amended to formally document procedures, instructions and the training curriculum for ground operations in poor visibility conditions.
8. The Cross Wind Limitation Policy has been revised and the Flight Crew Operating Manual has been amended accordingly. The revision has a more conservative limit for 'wet' runway conditions.
9. An airport specific operational information gathering process has been implemented to provide additional information with regard to operational procedures and facilities specific to the airport not routinely included in Jeppesen route manuals.
10. Boeing's GPS based "Take-off Runway Disagree Alerting Function" has been accepted by the company for installation on B777 and B747-400 aircraft.
11. An Electronic Moving Map system which provides a pictorial depiction of airport movement areas is being evaluated for installation in SIA aircraft.
12. The FAA Advisory Circular on Runway Safety (FAA AC 120-74) has been reviewed with the objective of identifying useful points for incorporation in the SIA low visibility operations, training and procedures.

CAAS:

1. Singapore operators have been required to review their 'before take-off' checklists.
2. Singapore operators have been required to update their CRM training programmes in keeping with current industry best practice.
3. Singapore operators have been required to review the FAA Advisory Circular (AC120-74) to assess its suitability to enhance their low visibility operations, training programmes and procedures.
4. A proposal to amend the current regulations to require earlier CVR power-on and later power-off times has been submitted to the Ministry of Transport.

According to the Civil Aeronautics Administration, ROC (CAA)

1. Enhancements to CAA Regulations and Procedures

- Reviewed all ICAO Annexes, including collection of information and revising local laws and regulations to meet such requirement as well as to establish a mechanism for such need.
  - A total of 18 items concerning the ICAO Annexes has been tasked to relevant units to look after, and be reviewed and consolidated by appropriate organizations
  - Organizations are required to review and update CAA laws and regulations as required
- Reviewed Airport Certification Standards and Procedures
  - Based on FAA [Airport Certification Program Handbook] and invited expatriate advisors, the CAA will establish an auditing program for Certification Standards.
  - Revise CAA regulations and specifications based on Annex14 and related articles.
- Developed Airport Design and Operations Regulations
  - Established Runway and Taxiway Specifications in 2000
  - Assigned a consultant on Domestic Airport Design Spec study in 2000
  - Established Lighting Specifications
  - Airport Selection and Master Plan Spec and Airport and Related Facility Design Spec to be completed in 2002
- Improved Airport Facility Management
  - Established Airport facility and NAVAID inspection team
  - Established Inspection Plan that requires a two-stage inspection program to improve those areas not meeting requirements
- Developed CAA Monitoring System for Airport Self-inspection
  - FAA specialist will conduct training on Airport Inspection (FAR Part 139) in March 2002
  - Planning to establish Airport Inspector System to perform relevant airport inspections
  - Conducted Ground Handling Management-level Seminar and held a panel discussion to execute a plan for resolving issues in February 2001

2. Airport Monitor and Management System

- Developed Airport Self-inspection and Crisis Management System
  - Airports are to set up safety inspection team
  - Developed an Airport Self-audit and Risk Management program in a self-audit handbook, including flight safety, ground safety, NAVAID facility and airport facility, and etc.

- Developed a Safety Inspection Team schedule to call upon relevant CAA organizations to review/revise the self-audit handbook.

- Invited FAA Advisor to review CKS Airport and KHH Airport and provide general assessment for further improvement
- Developed a team of related units to conduct daily inspections of facilities and make effective corrections as required
- Demanded that contractors strictly adhere to the ICAO and FAA's safety working procedures

3. CKS Airport Facility Improvement

- Painted new runway and taxiway marking
  - For South section of airport, new marking was completed on July 6, 2001, in accordance with the ICAO standards,
  - North Section construction was completed on November 27, 2001.
  - Taxiway centerline marking was completed January 31, 2002, in accordance with the ICAO Standards.
- Airport Lighting
  - Taxiway centerline lighting installation from N1 was completed January31, 2002.
  - Renew sign boards for runway 05/23 were completed January 31, 2002; and the sign boards for 06/24 were completed March 1, 2002.
  - Installation of Runway Guard Lights for runway 05/23 was completed January 31, 2002.
  - Installation of yellow-green taxiway centerline lights in Runway 05/23 was completed on January 31, 2002.
  - Installing Stop Bar on Runway 05/23 and will be completed by December 31, 2003
- Airport Pavement
  - Installed signs at the intersections of all service roads and taxiways, and was completed on July 31, 2001
  - Taxiway S1-S2 indicating boards base adjustment was completed July 31, 2001.
  - Appropriate sections of Runway 06/24 and related taxiway resurfacing was completed July 31, 2001.
  - Appropriate sections of Runway 05/23 and related taxiway resurfacing was completed January 31, 2002.
  - completed repainting and repositioning of "hold" lines on N1 through N11 taxiways with pattern "A" on January 31, 2002.

4. Improvement of CKS Fire Fighting Facilities and Equipment

- Developed Watch Room Center which was opened on September 26, 2001
- Revised and enhanced Airport Emergency Plan in accordance with the ICAO standards.
  - CKS International Airport All Emergencies Handling Procedures and the Civil Aircraft Accident Handling Procedures were amended. The CKS International Airport Aircraft Emergency Landing Procedures were established on June 26, 2000, and the CKS International Airport Emergency Rescue Procedures were established on October 11, 2001
  - The CAA organized an Emergencies Procedure Project Team in August 2001 based on the ICAO specification to revise the Aircraft Accident Handling Plan
- As of June 2001, the fire staff will conduct, during their respective shifts, three different missions: fire fighting, rescue and medical services respectively.
- The Airport Emergency Medical Treatment Procedures are being redrafted with the recently contracted Lee-Shin Hospital who will take over the remaining duties. These procedures are anticipated to be implemented by April 30, 2002.
- Redefining the Emergency Radio Communication Channels as follows: CH1 for on-site command, CH2 for medical rescue Services, CH3 for executive and logistical support, CH5 for emergency rescue operations, and CH6 for firefighting. This will take effect in April 2002

5. Improvement to Air Traffic Control System

- Enhanced air traffic control operations monitoring system in June, July, August and September 2001
- Conducted refresher training to air traffic controllers in April and May 2001
- Established new "Low Visibility procedures, AIP A002C003/02, effective February 1, 2002, for operations at the Taipei/CKS international Airport

6. Improvement to CKS Emergency Communications

To respond to the potential emergency situations, CKS Airport has redefined the use for radio communication channels as thus:

- CH1 for on-site command operations (459.2MHZ).
- CH3 for executive and logistical supports. (467.15MHZ)
- CH6 for fire fighting and rescue operations. (462.75MHZ).

Appendices

Appendix- 1 NOTAM A0606

NOTAM SUMMARY	**REPUBLIC OF CHINA**
	1ST OCT 2000

NOTAM Summaries: The following NOTAMs are still in force at 0001 UTC 1st OCT 2000

TAIPEI AND VICINITY

TAIPEI/C.K.S. INTL

A0605------31 AUG '00
0009130100/0011220100
TWY NP (FROM BAY A1 TO A3) CLSD DUE TO WIP
RMK/TWY N4, N5 AND E REMAIN AVBL

A0606------31 AUG '00
0009130100/0011220100
PORTION OF RWY 05R/23L(BTN TWY N4 AND N5) CLSD DUE TO WIP
RMK/TWY N4 AND N5 REMAIN AVBL

A0621------05 SEP '00
0009060100/0010050100
RWY 24 LLZ 'ICJN' FREQ 111.9MHZ WITHDRAWN FOR INSTALLATION OF NEW SYSTEM

KAOHSIUNG AND VICINITY

RCKH/KAOHSIUNG

A0130------14 MAR '00
WIE/UFN
OBST ELEV 171FT AT 223434N 1202233E APRX PSN AT 96 DEG MAG/0.6NM OF THR RWY 27R OBST LIGHTED

A0533------10 AUG '00
GUN FIRING WILL TAKE PLACE AS FLWS:
1. AREA: 2225N, 2255N, 11925E, 11945E
2. EFF: 2300-2400 DLY ON 14, 15 AUG, 19, 20, 26, 27 SEP, 3, 4, 17, 18, 24, 25 OCT
0000-0400, 0600-0900 DLY ON 15, 16 AUG, 20, 21, 27, 28 SEP, 4, 5, 18, 19, 25, 26 OCT
3. ALT: SFC UP TO 2000FT
4. RMK: AIRSPACE BLOCKED

Appendix- 2 TRANSCRIPT OF AIR-GROUND COMMUNICATIONS OF TAIPEI CLEARANCE DELIVERY

FREQUENCY： 121.8 MHz

DATE：OCTOBER 31, 2000

MAGNETIC TAPE NO.：89 – 7537；TRACK NO.：30

UTC TIME	SOURCE	CONTENTS
	CX 2043	DELIVERY, CX 2043 FL390 TO HONG KONG, 5 MINUTES RECEIVED “SIERRA.”
14:53:26	SQ 006	TAIPEI DELIVERY, GOOD EVENING, SQ 006.
14:53:35	SQ 006	TAIPEI, GOOD EVENING, SQ 006.
14:53:38	ATC	GO AHEAD, PLEASE.
14:53:40	SQ 006	SQ 006, POB IS 179, B-5, 5 MINUTES BEFORE TO START FOR LOS ANGELES, REQUESTING FL330.
14:53:47	ATC	SQ 006, ROGER, CLEARANCE ON REQUEST.
14:55:46	ATC	SQ 006, DELIVERY.
	SQ 006	SQ 006, GO AHEAD.
14:55:51	ATC	SQ 006, FOR YOUR INFORMATION, FL330 AIRBORNE TIME AFTER 21 NEXT HOUR, TIME NOW 56, FL290 AVAILABLE, SAY INTENTION.
14:56:03	SQ 006	SQ 006 CAN ACCEPT FL290.
14:56:06	ATC	STAND BY.
14:56:38	ATC	SQ 006, COPY CLEARANCE FOR FL290.
14:56:43	SQ 006	SQ 006, GO AHEAD.
14:56:45	ATC	SQ 006, CLEARED TO LOS ANGELES AIRPORT, VIA ANPU-3 DEPARTURE, KIKIT TRANSITION, A1, CROSS BULAN AT FL290, MAINTAIN FL290, SQUAWK 2657.
14:57:03	SQ 006	CLEARED TO LOS ANGELES AP-3 DEPARTURE, KIKIT TRANSITION, A1CROSSBULAN AT 290, MAINTAIN 290, SQUAWK 2657, SQ 006.
14:57:16	ATC	SQ 006, CLEARANCE READ BACK CORRECT, CONTACT GROUND 121.7.
14:57:19	SQ 006	121.7, GOOD DAY, SIR, SQ 006.

Appendix- 3 CVR TRANSCRIPT

Legends for SQ006 CVR Transcript

CM-1 PF	Channel 3 (Occupied left hand seat, Captain) Pilot flying
CM-2 PNF	Channel 2 (Occupied right hand seat, First Officer) Pilot non-flying
CM-3 OBS	Channel 1 (Occupied first observer seat, Relief Pilot) Observer
CAM	Channel 4 (Cockpit area microphone on P6 panel)
RDO-2	Radio transmission from CM-2 PNF
MAINT	Ground Maintenance interphone
TWR	Radio transmission from CKS Tower
GND	Radio transmission from CKS Ground Control
CI 004	Call sign of China Airlines flight CI 004 (Dynasty zero zero four)
CX 2043	Call sign of Cathay Pacific Airlines flight CX 2043 (Cathay two zero four three)
----	Unintelligible
△	Conversations between Ground/Tower and CI 004/CX 2043 that relate to ATC clearances
****	Expletives

ATC UTC	SOURCE	CONTENTS
15:00:53	CM-1 PF	Light up
15:00:54	CM-2 PNF	Check
15:01:12	CAM	(Sound similar to that of starter switch in)
15:01:12	CM-1 PF	Fifty percent N two
15:01:14	CM-2 PNF	Valve closed
15:01:16	CM-1 PF	Starting Engine two

ATC UTC	SOURCE	CONTENTS
15:01:18	MAINT	Roger, start two
15:01:18	CM-2 PNF	OK Starting two
15:01:19	CM-1 PF	See if you can get…what's the latest weather. Can you write it down What's the latest... ATIS eh
15:01:23	CM-3 OBS	OK yah
15:01:25	ATIS	Taipei international Airport information Tango one four five four Zulu runway zero five left is in use. Runway zero six for departure only expect ILS runway zero five left category two approach wind zero two zero at three six gust five two visibility five hundred meters, runway zero five left RVR four hundred fifty meters runway zero six five hundred meters with heavy rain cloud broken two hundred feet overcast five hundred feet temperature two one dew point two zero QNH one zero zero one Hectopascal departure frequency one two five point one caution wind shear on runway zero five left final due to radio interference tower frequency change to one two nine point three caution Taxiway November Sierra has been remarked aircraft using November Sierra advise taxi slowly with caution. Taxiway November Papa behind Alpha one and Alpha three closed, runway zero five right between November four and November five closed due to work in progress, Taxiway November four and November five still available. Inform Taipei approach or tower initial contact you have tango.
15:01:29	CM-1 PF	Write up… write behind here
15:01:29	CAM	Write up
15:01:30	CM-3 OBS	I got it.
15:01:33	CAM	(Clicking sound -similar to the sound of chronometer resetting)
15:01:38	MAINT	Number two N one rotation
15:01:40	CM-1 PF	Thank you
15:01:41	CM-2 PNF	Oil pressure number two
15:01:43	CX 2043	Ground Cathay two zero four three request the wind and RVR of runway zero six
15:01:49	CM-1 PF	Light up

ATC UTC	SOURCE	CONTENTS
15:01:49	CM-2 PNF	Check
15:01:51	GND	Cathay two zero four three runway zero six RVR five hundred fifty meters and wind zero two zero at three eight gust five one
15:02:04	CM-1 PF	Ok lah, this is better still, Fifty percent N two
15:02:04	CAM	(Sound similar to that of starter switch in)
15:02:06	CX 2043	Cathay two zero four three
15:02:07	CM-2 PNF	Valve closed
15:02:09	CM-1 PF	Ok starting three
15:02:11	MAINT	Roger start three
15:02:12	CM-1 PF	Zero two zero better for us
15:02:13	CM-2 PNF	Ya
15:02:14	CM-1 PF	Starting three please
15:02:16	CM-1 PF	So resolved already it become less
15:02:21	CAM	(Clicking sound -similar to the sound of chronometer resetting)
15:02:31	CM-2 PNF	Oil pressure number three
15:02:31	CAM	(Clicking sound -similar to the sound of chronometer resetting)
15:02:33	CM-1 PF	Roger N one
15:02:38	MAINT	Number three N one rotation and set the brake
15:02:42	CM-1 PF	Confirm set parking brakes
15:02:44	MAINT	Yes
15:02:46	CAM	(Sound similar to that of parking brake being set)
15:02:47	CM-1 PF	OK light up
15:02:48	CM-1 PF	Check, parking brake set
15:02:49	MAINT	Roger
15:03:01	CAM	(Sound similar to that of starter switch in)
15:03:01	CM-1 PF	Fifty percent N two
15:03:03	CM-2 PNF	Valve closed
15:03:04	CM-1 PF	Ya

ATC UTC	SOURCE	CONTENTS
15:03:05	CM-1 PF	Starting four
15:03:08	MAINT	Roger, starting four
15:03:09	CM-1 PF	Ok start first, four
15:03:24	CAM	(Clicking sound -similar to the sound of chronometer resetting)
15:03:27	CM-2 PNF	N one and oil pressure
15:03:30	CM-1 PF	Fuel on
15:03:34	MAINT	Number four N one rotation
15:03:35	CM-1 PF	Thank you
15:03:37	CM-1 PF	Light up
15:03:38	CM-2 PNF	Check
15:03:55	CM-1 PF	Zero two zero is better
15:03:55	CAM	(Sound similar to that of starter switch in)
15:03:56	CM-1 PF	Fifty percent N two
15:03:58	CM-2 PNF	Valve closed
15:04:00	CI 004	(Dynasty Zero zero four conversation with ground control)△
15:04:04	GND	(Ground control conversation with Dynasty zero zero four)△
15:04:06	CI 004	(Dynasty zero zero four conversation with Ground control)△
15:04:14	GND	(Ground control conversation with Dynasty zero zero four)△
15:04:17	CI 004	(Dynasty zero zero four conversation with Ground control)△
15:04:18	CAM	(Clicking sound similar to that of chronometer resetting)
15:04:21	CAM	(Sound similar to that of seat motor)
15:04:26	CM-1 PF	Today can put on
15:04:33	CM-1 PF	Wait first huh
15:04:34	CM-2 PNF	Ok
15:04:35	CM-1 PF	Ok cockpit to ground we normal start, remove ground equipment hand signal thank you bye bye
15:04:39	MAINT	Roger all equipment removed standby left bye bye
15:04:42	CM-1 PF	Ok

ATC UTC	SOURCE	CONTENTS
15:04:43	CM-1 PF	What's the trim you got there, seven point…
15:04:45	CM-2 PNF	Seven point six…
15:04:48	CAM	(Unknown click sound)
15:04:51	CM-1 PF	Seven point..., Waa pretty high huh today
15:04:54	CM-2 PNF	Point six
15:04:56	CM-1 PF	Ok thanks
15:04:57	CM-1 PF	What's the.. ok.. ok
15:04:58	CM-3 OBS	……this is the latest zero two zero three six gust fifty two lah still within limit
15:05:02	CM-1 PF	Yah, zero two zero better
15:05:02	CM-3 OBS	Yah
15:05:02	CM-1 PF	More, more on head wind side
15:05:03	CM-3 OBS	The rest no significant change
15:05:03	CM-1 PF	Ok,
15:05:07	GND	(Cathay two zero four three conversation with ground control)△
15:05:08	CM-3 OBS	Visibility and RVR still the same four fifty meters
15:05:09	GND	(Ground control conversation with Cathay 2043)△
15:05:12	CX 2043	(Cathay 2043 conversation with ground control)△
15:05:15	GND	(Ground control conversation with Cathay 2043)△
15:05:21	CM-1 PF	Ha ha Ok
15:05:22	CM-1 PF	Ok after start check list
15:05:24	CM-2 PNF	After start check, APU
15:05:25	CM-1 PF	Off
15:05:26	CM-2 PNF	Number four demand pump
15:05:27	CM-1 PF	Auto
15:05:28	CM-2 PNF	Anti-ice
15:05:29	CM-1 PF	Off
15:05:29	CX 2043	(Cathay 2043 conversation with ground control)△

ATC UTC	SOURCE	CONTENTS
15:05:30	CM-2 PNF	Aft cargo heat
15:05:31	CM-1 PF	On
15:05:32	CM-2 PNF	Packs
15:05:32	CM-1 PF	Normal
15:05:33	CM-2 PNF	Recall check huh
15:05:34	CM-1 PF	Check
15:05:34	CM-2 PNF	Check
15:05:35	CM-2 PNF	Trims
15:05:36	CM-1 PF	So we got seven point eight, err seven point six units, zero zero set.
15:05:42	CM-2 PNF	Auto brake
15:05:43	CM-1 PF	Ok RTO
15:05:44	CM-2 PNF	Ground equipment
15:05:45	CM-1 PF	Ok, your side gone already ah
15:05:47	CM-1 PF	Is he there, ok alright ok huh gone away
15:05:48	CM-2 PNF	This guy that guy out this side on the right side
15:05:50	CM-1 PF	Ok huh
15:05:50	CM-2 PNF	Ok, wah "terok" (terrible) man
15:05:51	CM-1 PF	Ok lights cabin going off
15:05:52	CAM	(Click)
15:05:53	CM-2 PNF	Ok
15:05:55	RDO-2	Singapore six request taxi.
15:05:57	GND	Singapore six taxi to runway zero six via taxiway.., correction runway zero five left via taxi way Sierra Sierra, West Cross and November Papa.
15:06:08	CM-2 PNF	I missed that man, what is it
15:06:09	CM-1 PF	Sierra Sierra West Cross and November Papa
15:06:12	RDO-2	Taxi via Sierra Sierra
15:06:14	CM-1 PF	West Cross

ATC UTC	SOURCE	CONTENTS
15:06:14	RDO-2	West Cross
15:06:15	CM-1 PF	And November Papa
15:06:15	RDO-2	And November Papa for runway zero five left Singapore six
15:06:21	CM-2 PNF	Sierra Sierra West Cross November Papa
15:06:25	CM-1 PF	Yah, so you go straight down.
15:06:26	CM-2 PNF	Roger that
15:06:26	CM-1 PF	Hit West Cross, go across the West Cross then November Papa all the way down ok
15:06:26	CM-2 PNF	Ok
15:06:29	CM-2 PNF	Then come down further south ah
15:06:29	CM-1 PF	Ok, alright
15:06:30	CM-2 PNF	Ok, yes sir zero five..-----
15:06:34	GND	(Ground conversation with Dynasty Zero zero four)△
15:06:35	CI 004	(Dynasty Zero zero four conversation with Ground)△
15:06:36	GND	(Ground conversation with Dynasty Zero zero four)△
15:06:36	CM-1 PF	Ok, left is clear ah
15:06:38	CM-2 PNF	Ok right side is.. clear, except for this vehicle-lah down here
15:06:42	CM-1 PF	Ok
15:06:49	CI 004	(Dynasty Zero zero four conversation with Ground)△
15:07:00	GND	(Ground conversation with Dynasty Zero zero four)△
15:07:05	CM-1 PF	Taxi slowly
15:07:10	CAM	(Sound similar to that of parking brake release)
15:07:10	CI 004	Taipei ground from Dynasty Zero zero four, can we check out your wind and RVR please.
15:07:13	CM-1 PF	OK turn left skidding right passing heading about zero two four zero now
15:07:13	CM-2 PNF	Checked
15:07:16	GND	Dynasty Zero zero four runway zero five left RVR is four hundred fifty meters and wind zero two zero at two five and gust four one

ATC UTC	SOURCE	CONTENTS
15:07:21	CM-3 OBS	Actually we have to nominate a return alternate because below landing minimum
15:07:25	CM-1 PF	Landing mim…
15:07:25	CM-2 PNF	Below landing minimum
15:07:27	CM-1 PF	Ah, because er Kaohsiung CAT two we still can go CAT two, no problem.
15:07:28	CM-2 PNF	CAT two lah, CAT two…
15:07:33	CI 004	(Dynasty zero zero four conversation with Ground)△
15:07:38	CM-2 PNF	Still ok lah, CAT two
15:07:40	CM-1 PF	CAT two yah, you can look yah...five left huh
15:07:40	GND	(Ground conversation with Dynasty zero zero four)△
15:07:43	CI 004	(Dynasty zero zero four conversation with Ground)△
15:07:47	CM-1 PF	Can still take Kaohsiung you see
15:07:49	CM-2 PNF	Kaohsiung is closed...the airport
15:07:49	CM-1 PF	Kaohsiung I think, is closed is it
15:07:52	CM-2 PNF	We can take Naha or, yah I think CAT two...
15:07:53	CM-1 PF	But we are CAT two, we can still come back, we can still come back
15:07:55	CM-2 PNF	Yah, yah
15:07:56	CM-1 PF	Ok, flaps twenty please.
15:07:56	CAM	(Sound similar to that of flap lever through the detent positions)
15:08:04	CM-1 PF	Ok checking rudder er
15:08:06	CM-1 PF	Full left
15:08:07	CM-2 PNF	Full left
15:08:08	CM-1 PF	Center
15:08:09	CM-2 PNF	Center
15:08:10	CM-1 PF	Ok full right
15:08:11	CM-2 PNF	Full right
15:08:12	CM-1 PF	Center

ATC UTC	SOURCE	CONTENTS
15:08:13	CM-2 PNF	Center
15:08:14	CM-2 PNF	My controls checks ah
15:08:24	CM-1 PF	Hongkong is closed man, ha ha... worse
15:08:27	CM-3 OBS	Hongkong closed ah
15:08:27	CM-1 PF	That's what he said not accepting any
15:08:29	CM-2 PNF	I see
15:08:30	CM-1 PF	I think some people might have diverted there lah I think
15:08:40	CM-2 PNF	Ok column coming back
15:08:47	CM-1 PF	If the RVR five left was two hundred right just now we checked
15:08:50	CM-3 OBS	RVR yah two hundred
15:08:50	CM-1 PF	Correct, yah two hundred meters ah, ok lah
15:08:54	CAM	(Sound similar to that of seat motor)
15:08:55	CM-1 PF	Ok man before takeoff checklist
15:08:56	CM-2 PNF	Roger sir
15:08:58	CM-2 PNF	Before..takeoff checks, flaps
15:09:02	CM-1 PF	Twenty green
15:09:03	CM-2 PNF	Twenty green
15:09:06	CM-2 PNF	Flight control
15:09:07	CM-1 PF	Check
15:09:07	CM-2 PNF	Check
15:09:08	CM-2 PNF	EPR and speeds
15:09:09	CM-1 PF	Ok, EPR one point five two ah, Vee one, one forty two, Vee R one five six and Vee two, one six nine set
15:09:15	CM-2 PNF	EPR one point five two ah, Vee one, one forty two, rotate one five six and Vee two, one six nine
15:09:19	CX 2043	(Cathay two zero four three conversation with ground control)△
15:09:22	CM-2 PNF	Speed set
15:09:24	CM-2 PNF	Departure routing

ATC UTC	SOURCE	CONTENTS
15:09:25	CM-1 PF	Ok ah Taipei runway zero six left huh
15:09:27	CM-2 PNF	Zero five left
15:09:28	GND	(Ground control conversation with Cathay two zero four three)△
15:09:29	CM-1 PF	Zero five left
15:09:29	CM-3 OBS	Zero five left
15:09:31	CM-1 PF	And er we got Anpu three departure Kikit transition huh
15:09:32	CX 2043	(Cathay 2043 conversation with ground control)△
15:09:34	GND	(Ground control conversation with Cathay 2043)△
15:09:35	CX 2043	(Cathay 2043 conversation with ground control)△
15:09:38	CM-1 PF	Looks like I got to go..
15:09:40	CM-2 PNF	Next one got to go right is it
15:09:41	CM-1 PF	Yah, go right turn right here, all the way to West Cross lah right turn here
15:09:46	CM-2 PNF	Runway is zero five left. Kikit transition initially two hundred ah level alpha one squawk two six five seven, will be two nine zero by Bulan
15:09:58	CM-1 PF	A lot of rudder work man here.. really ah
15:10:01	CM-3 OBS	Cross wind ah..
15:10:02	CM-1 PF	Yah
15:10:03	CM-2 PNF	Transponder TA RA, set, checks down to the line
15:10:06	CM-1 PF	Ok, thanks.
15:10:08	CM-2 PNF	West Cross correct, Sierra Sierra West Cross
15:10:14	CM-1 PF	Everybody waiting for each other for takeoff you see haha
15:10:18	CM-1 PF	The bugger heard us…er going…that fellow also
15:10:21	CM-3 OBS	Yah, it is coming in ah, the longer they delay the worse it is lah
15:10:23	CM-1 PF	Yah, worse if we are going to get out, if don't take off ah…. I am going to go very slow here, ok, because you going get skid
15:10:24	CM-2 PNF	Ok nine knots
15:10:33	CM-3 OBS	Ok, to catch the wind
15:10:35	CM-2 PNF	That's all the moisture

ATC UTC	SOURCE	CONTENTS
15:10:41	CM-2 PNF	Turning left skidding er turning right err skidding left two seven zero
15:10:42	CM-3 OBS	The weather radar will be all red ha ha
15:10:43	CM-1 PF	Ok, passing ah two eight zero now, ah needles tracking and turn right skidding left now ah, past heading of about two.. three hundred now ah
15:10:45	CM-2 PNF	Yah that's right ah
15:10:56	CAM	(Sound of clicks)
15:11:00	CM-2 PNF	My speed excursion is more than the left side, because the wind is coming from here
15:11:03	CM-1 PF	Ah, yah
15:11:03	CM-3 OBS	Your pitot on the other side ah …just pick up
15:11:10	CM-2 PNF	Roger that
15:11:12	CM-1 PF	For the takeoff use autopilot better
15:11:22	CM-1 PF	Typhoon man, ok tomorrow the guys coming in will be "terok" (terrible) man
15:11:28	CM-3 OBS	Yah, tomorrow morning Singapore five
15:11:29	GND	(Ground control conversation with Cathay two zero four three)△
15:11:36	CX 2043	(Cathay two zero four three conversation with ground control)△
15:11:38	GND	(Ground control conversation with Cathay two zero four three)△
15:11:42	CX 2043	(Cathay two zero four three conversation with ground control)△
15:11:47	CX 2043	(Cathay two zero four three conversation with ground control)△
15:11:49	CM-1 PF	The five left also imp..imp.. improve already the visibility to five hundred fifty meters
15:11:52	GND	(Ground control conversation with Cathay two zero four three)△
15:11:54	CX 2043	(Cathay two zero four three conversation with ground control)△
15:11:55	CM-3 OBS	Five left..wait ah
15:11:56	CM-1 PF	Ya, the guys said improved already went up
15:11:59	CM-3 OBS	Now is four fifty
15:12:00	CM-1 PF	Just now the guys ask him over the tower

ATC UTC	SOURCE	CONTENTS
15:12:01	CM-2 PNF	Yah
15:12:02	ATIS	Taipei Chiang Kai Shek International Airport information uniform one five zero zero zulu runway zero six for departure only runway zero five left for category two approach and departure wind zero two zero at three six gust five six visibility six hundred meters runway zero five RVR four hundred fifty meters downward runway zero six RVR five hundred fifty meters downward with heavy rain cloud broken two hundred feet overcast five hundred feet temperature two one dew point two zero QNH one zero zero one Hectopascal
15:12:06	CM-2 PNF	Coming up er.. November Papa eh..
15:12:07	CM-1 PF	Ok, all the way down left turn all the way down
15:12:10	CM-2 PNF	Left ah
15:12:10	CM-1 PF	Yah
15:12:17	CM-2 PNF	One two five one departure
15:12:20	GND	(Ground control conversation with Cathay 2043)△
15:12:21	CAM	(Sound similar to that of radio frequency selection)
15:12:22	CM-1 PF	Ok, first left
15:12:23	CX 2043	(Cathay 2043 conversation with ground control)△
15:12:23	CM-2 PNF	Affirm first left
15:12:24	CM-1 PF	Left
15:12:25	CM-2 PNF	Left
15:12:26	GND	(Ground control conversation with Cathay 2043)△
15:12:33	CAM	(Sound similar to that of seat motor)
15:12:38	CX 2043	(Cathay 2043 conversation with ground control)△
15:12:41	CAM	(Sound similar to that of nose gear scrubbing)
15:12:47	CAM	(Sound similar to that of nose gear scrubbing)
15:12:47	GND	(Ground control conversation with Cathay 2043)△
15:12:56	CM-3 OBS	The latest QNH is one zero zero one
15:12:56	CM-2 PNF	Clearing that huh
15:12:58	GND	Singapore six contact tower one two nine point three, good day.

ATC UTC	SOURCE	CONTENTS
15:13:02	RDO-2	One two nine point three good day sir, Singapore six.
15:13:13	CM-2 PNF	One zero zero one one two nine point.. one two nine point three ah…..ok ah
15:13:25	RDO-2	Taipei Tower, good evening, Singapore six.
15:13:28	TWR	Singapore six, good evening, Taipei Tower hold short runway zero five left.
15:13:33	RDO-2	Hold short runway zero five left, Singapore six.
15:13:38	TWR	Singapore six, for information now surface wind zero two zero at two four, gust four three, say intention.
15:13:44	CM-1 PF	Gusting four three ah
15:13:46	RDO-2	Thank you sir, Singapore six.
15:13:47	CM-1 PF	Ok, ok better less
15:13:48	CM-3 OBS	Less, less gust already
15:13:54	CM-1 PF	Zero two zero it's from left lah
15:13:56	CM-3 OBS	Two four gust four three
15:14:05	CM-2 PNF	Zero two zero
15:14:08	CM-1 PF	Ok this one will be here ah
15:14:18	CM-1 PF	Zero two zero
15:14:20	CM-3 OBS	Ya, left lah
15:14:21	CM-1 PF	Go right to the end of the runway, end of the runway then turn, ok.
15:14:31	CM-3 OBS	Quite a bit of aileron for the takeoff
15:14:35	CM-2 PNF	OK
15:14:40	CM-2 PNF	The next one
15:14:41	CM-2 PNF	Next one is November one
15:14:42	CM-1 PF	Ok second right
15:14:44	CM-2 PNF	Second right, that’s right
15:14:47	CM-1 PF	In Australia, to them, next one is this, first one you know
15:14:50	CM-2 PNF	Next one this one
15:14:51	CM-1 PF	Yah..ha ha

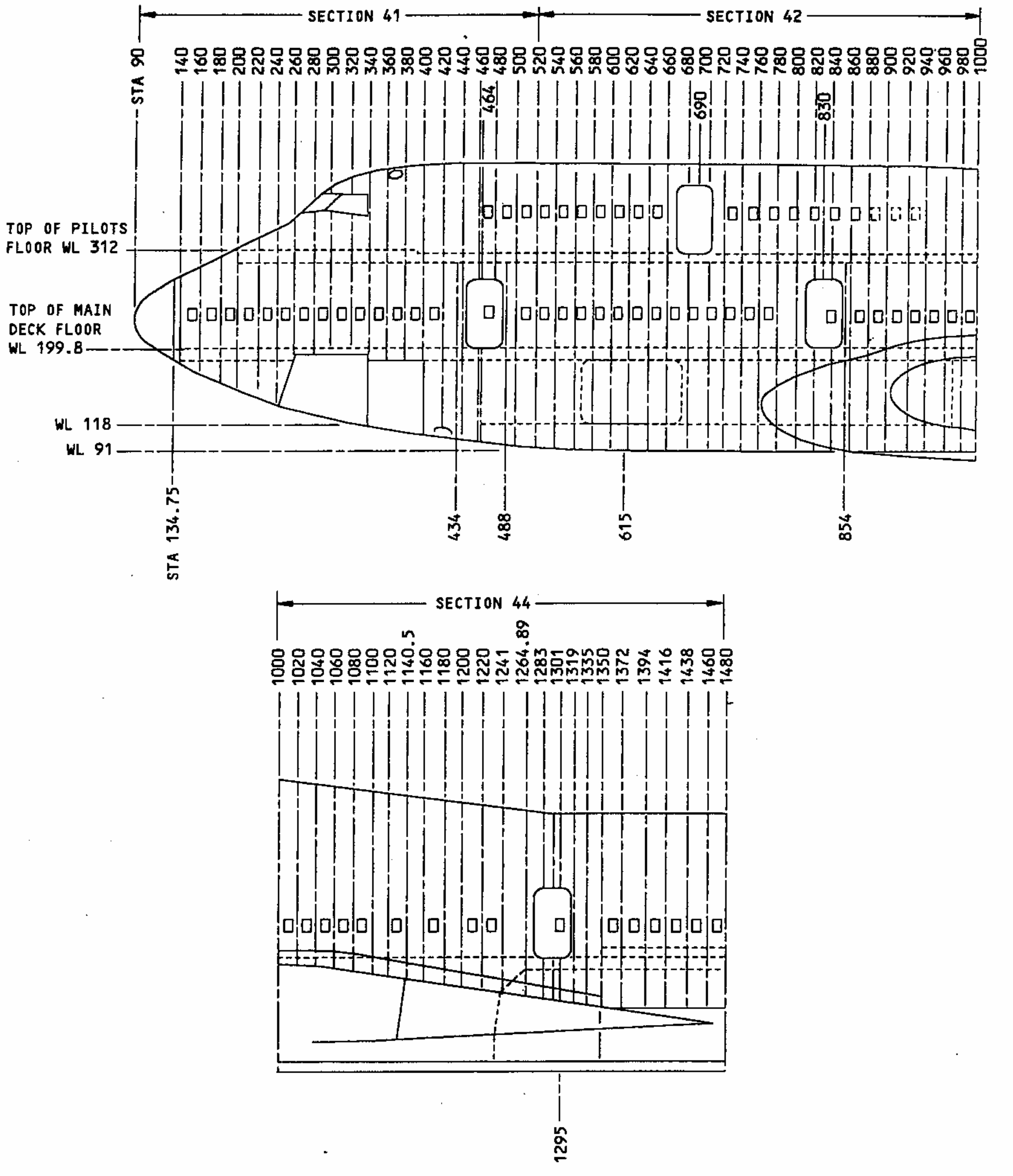
ATC UTC	SOURCE	CONTENTS
15:14:52	CM-1 PF	Australian
15:14:53	CM-1 PF	I think the best is to say second right ah first right second right ah
15:14:55	CM-2 PNF	Clearing that Satvoice
15:14:58	CM-1 PF	Tell them we are ready lah
15:15:02	RDO-2	Singapore six ready.
15:15:04	TWR	Singapore six roger, runway zero five left, taxi into position and hold.
15:15:08	RDO-2	Taxi into position and hold, Singapore six
15:15:12	CM-2 PNF	I get them seated ah
15:15:12	CM-1 PF	Ok below the line please …yah
15:15:15	CM-2 PNF	Cabin crew to your takeoff station thanks
15:15:20	CAM	(Sound similar to that of door closing)
15:15:21	CAM	(Sound of chime)
15:15:22	TWR	Singapore six, runway zero five left, wind zero two zero at two eight, gust to five zero, cleared for takeoff.
15:15:30	RDO-2	Cleared for takeoff, Runway zero five left Singapore six.
15:15:31	CM-1 PF	OK man
15:15:34	CM-2 PNF	OK checks below the line, cabin announcement complete
15:15:37	CM-2 PNF	Packs
15:15:38	CM-1 PF	Ok norm eh
15:15:39	CM-2 PNF	Norm
15:15:40	CM-2 PNF	Strobes on, landing lights all on
15:15:44	CM-2 PNF	Takeoff clearance
15:15:45	CM-1 PF	Obtained hah
15:15:46	CM-2 PNF	Obtained sir
15:15:47	CM-1 PF	OK thanks
15:15:48	CM-2 PNF	Before takeoff checklist completed
15:15:50	CAM	(Sound of click)
15:15:50	CM-2 PNF	OK green lights are here

ATC UTC	SOURCE	CONTENTS
15:15:52	CM-1 PF	It going to be very slippery I am going to slow down a bit, slow turn here
15:15:53	CM-2 PNF	Turning that
15:16:07	CM-2 PNF	And the PVD hasn't lined up ah
15:16:10	CM-1 PF	Yeah we gotta line up first
15:16:12	CM-3 OBS	We need forty five degrees
15:16:15	CM-2 PNF	I see, excellent man
15:16:16	CM-1 PF	Yah
15:16:23	CM-1 PF	Not on yet er PVD huh never mind we can see the runway, not so bad. Ok, I am going to put it to high first. OK ready eh, so zero one zero is from the left lah Ok
15:16:27	CM-2 PNF	Ok
15:16:30	CAM	(Sound similar to that of wipers going to high speed)
15:16:31	CM-2 PNF	Ready sir zero two zero check ok
15:16:33	CM-1 PF	Left wing into aileron, left aileron into wind. Huh OK Cabin reported eh.
15:16:37	CM-3 OBS	Yah cabin is ready.
15:16:37	CM-1 PF	Ok thanks
15:16:37	CM-2 PNF	Yup thanks
15:16:43	CM-3 OBS	Ok –thrust ref toga toga
15:16:43	CM-2 PNF	Thrust ref toga toga
15:16:44	CM-1 PF	Ok –thrust ref toga toga
15:16:44	CAM	(Sound similar to that of engines spooling up)
15:16:54	CM-3 OBS	Hold
15:16:54	CM-2 PNF	Hold
15:16:54	CM-1 PF	Roger
15:16:55	CM-3 OBS	Eighty knots
15:16:55	CM-2 PNF	Eighty knots
15:16:56	CM-1 PF	Ok my control

ATC UTC	SOURCE	CONTENTS
15:17:13	CM-2 PNF	Vee one
15:17:13	CM-3 OBS	Vee one
15:17:16	CM-1 PF	**** something there
15:17:17	CAM	Sound of the first impact
15:17:18	CAM	****waaah****
15:17:18	CAM	Sound of a series of impacts
15:17:22		End of Recording

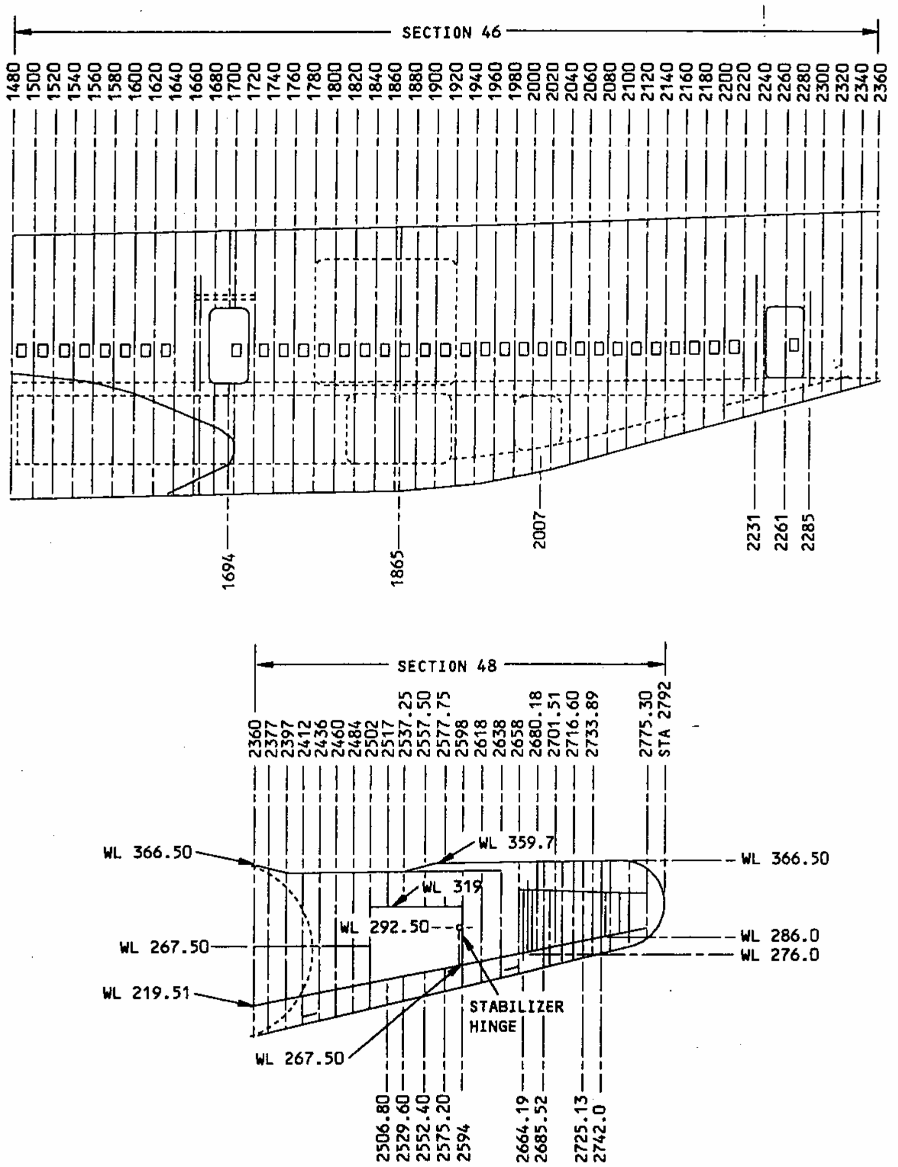
Appendix- 4 SECTION AND STATION DIAGRAMS OF BOEING 747-400

REF DWG
65B00004



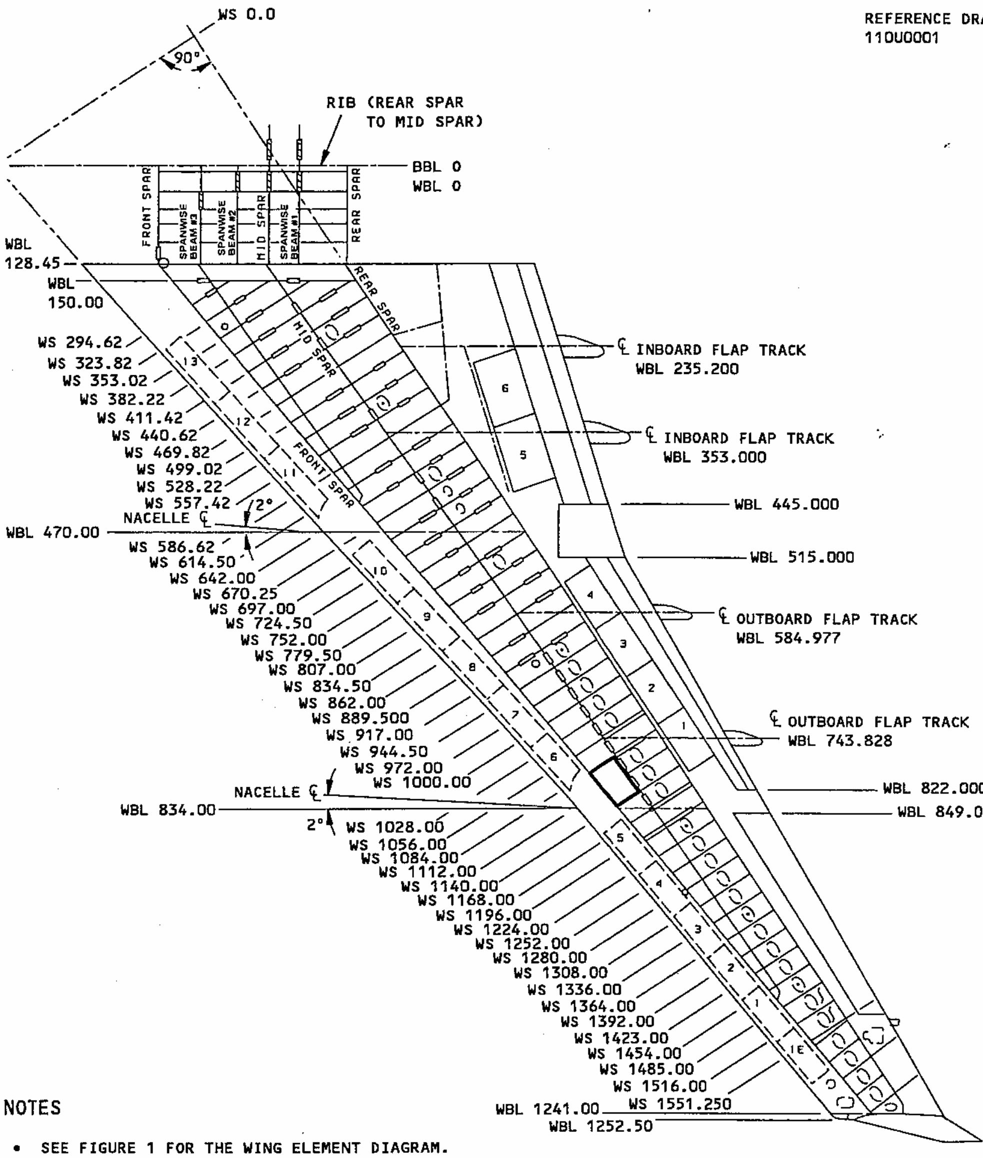
Fuselage Station Diagram
Figure 1 (Sheet 1)

REF DWG
65B00004



Fuselage Station Diagram
Figure 1 (Sheet 2)

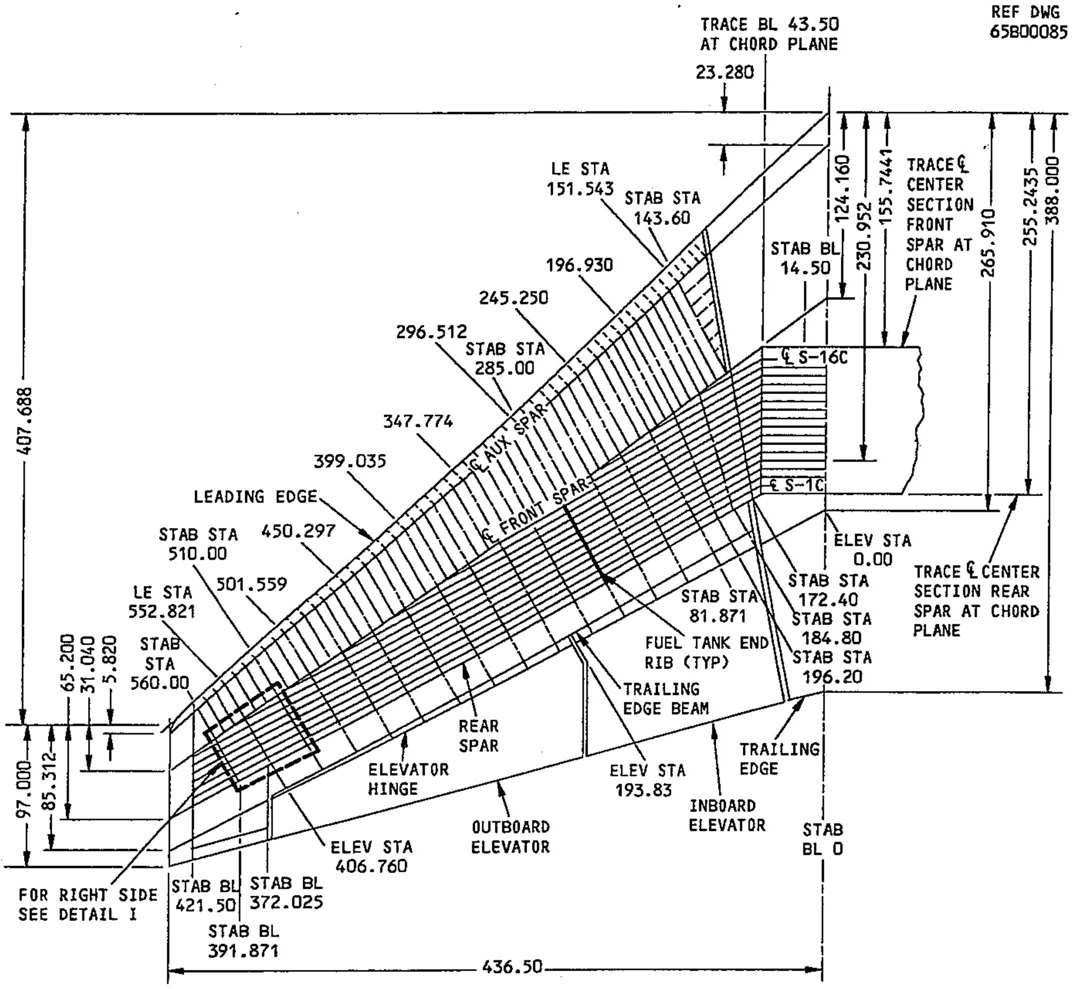
REFERENCE DRAWING
110U0001



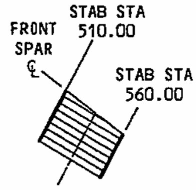
NOTES

- SEE FIGURE 1 FOR THE WING ELEMENT DIAGRAM.
- SEE FIGURE 3 FOR THE WING CENTERLINE DIAGRAM.
- SEE FIGURES 4, 5, AND 6 FOR AIRPLANES THAT DO NOT HAVE WINGLETS.

Wing Station Diagram - Airplane with Winglets
Figure 2



LEFT SIDE SHOWN
RIGHT SIDE OPPOSITE EXCEPT AS NOTED



SURGE TANK END RIBS
DETAIL I

Horizontal Stabilizer Station Diagram
Figure 1 (Sheet 1)

Appendix- 5 INCIDENT REPORTS AT CKS AIRPORT SINCE MARCH 1998

March 27, 1998

A Cathay Pacific B747 aircraft (CX006) was cleared for takeoff on Runway 05L while another aircraft was taxiing on the runway. CX006 held on the runway until the other aircraft was clear.

July 6, 1998

A Cathay Pacific aircraft (CX420) entered a closed taxiway. Pilot's view of the incident was that it was a misunderstanding arising from usage of language. He also observed that although the taxiway had been NOTAMed as closed, there had been no obstruction lighting to mark the limit of the work area.

March 24, 1999

A Cathay Pacific aircraft (CX421) was directed by ATC onto a closed taxiway (no additional details available).

March 5, 2000

A China Airlines B747-400 (CI065) aircraft took off on Runway 05L while another aircraft, a B747-100 (UP7846), was turning onto the runway.

March 23, 2000

A CM922 flight (B737) was cleared for takeoff on Runway 05L while another aircraft, a MD11 (BR671), was still on the runway. CM922's takeoff clearance was cancelled when BR671 alerted the tower that it was still on the runway.

October 22, 2000

A Singapore Airline flight SQ7693 initiated a go-around at decision height (DH) on Runway 05L as the flight crew could not make visual contact with the runway. During the go-around, the PIC of the flight noted that the runway and approach lights had not been switched on. The controller later apologized for forgetting to switch the lights on.

Appendix- 6 PVD SUPPLEMENT TO BOEING 747-400 AFM

SECTION 3 - NORMAL AND ABNORMAL PROCEDURES

Procedures contained in Section 3 of the basic manual are supplemented by the following:

PARA VISUAL DISPLAY (P V D)

The runway lighting is the primary means of guidance during takeoff. The PVD system can be used as a reversionary source of guidance to the localizer centerline during periods of reduced visibility. The direction of the streaming display is the direction to steer to acquire and maintain the localizer centerline.

The flight crew should confirm that when the PVD is selected ON, the display streams right, left and then stops momentarily. The display will then either provide guidance to the localizer centerline or will shutter dependent upon whether the airplane is in a position for takeoff or not.

The PVD system monitoring will not unshutter the display and provide guidance unless sufficient equipment is available. The minimum requirement for PVD operations is an active display for the flying pilot.

Appendix- 7 COMMENTS ON ASC'S FINAL DRAFT REPORT

7.1 Summary of Acceptance

The summary of comments from NTSB, ATSB, MCIT and CAA of ROC on ASC's Final Draft Report is presented in the following table:

LEGEND:
A- Accepted
R- Rejected
PA-Partially accepted
AC-Acknowledged

NTSB			
	1	**Section 4 New Recommendations**	**A**
ATSB			
	1	**Section 3.1 Finding 7, Point 9**	**A**
	2	**Section 3.2 Finding 8**	**A**
	3	**Section 3.3 Finding 15**	**A**
	4	**Section 4.1 Recommendation to SIA, Point 3**	**A**
	5	**Section 4.1 Recommendation to SIA, Point 10**	**A**
	6	**Section 1.10.3.1.2**	**A**
	7	**Section 1.17.4.1 Para 4**	**A**
	8	**Sections 1.18.1.3.1 through to 1.18.1.3.4**	**A**
	9	**Section 1.18.7**	**A**
	10	**Section 1.18.8.2**	**A**
	11	**Section 2.5.6.4 Para 1**	**A**
	12	**Section 2.5.7.1 Last para**	**PA**
	13	**Section 2.5.7.2.3 Para 3**	**R**
	14	**Section 2.5.7.5**	**A**
	15	**Section 2.5.8.4**	**A**
	16	**Section 2.5.9**	**A**
	17	**Section 3.2 Finding 8**	**A**
	18	**Section 4 Recommendations**	**PA**

MCIT/SINGAPORE			
PART 2	1	**Section 3.1 Finding 1**	**R**
	2	**Section 3.1 Finding 2**	**R**
	3	**Section 3.1 Finding 3**	**R**
	4	**Section 3.1 Finding 4**	**R**
	5	**Section 3.1 Finding 5**	**R**
	6	**Section 3.1 Finding 6**	**PA**
	7	**Section 3.1 Finding 7**	**PA**
PART 3	8	**Section 3.2 Finding 1**	**R**
	9	**Section 3.2 Finding 2**	**R**
	10	**Section 3.2 Finding 3**	**R**
	11	**Section 3.2 Finding 4**	**R**
	12	**Section 3.2 Finding 5**	**R**
	13	**Section 3.2 Finding 6**	**R**
	14	**Section 3.2 Finding 7**	**A**
	15	**Section 3.2 Finding 8**	**A**
	16	**Section 3.2 Finding 9**	**PA**
	17	**Section 3.2 Finding 10**	**PA**
	18	**Section 3.2 Finding 11**	**R**
	19	**Section 3.2 Finding 12**	**AC**
	20	**Section 3.2 Finding 13**	**R**
	21	**Section 3.2 Finding 14**	**R**
	22	**Section 3.2 Finding 15**	**R**
	23	**Section 3.2 Finding 16**	**R**
	24	**Section 3.2 Finding 17**	**R**
	25	**Section 3.2 Finding 18**	**R**
	26	**Section 3.2 Finding 19**	**R**
	27	**Section 3.2 Finding 21**	**R**
	28	**Section 3.2 Finding 22**	**R**
	29	**Section 3.2 Finding 25**	**R**
	30	**Section 3.2 Finding 26**	**R**
	31	**Section 3.2 Finding 27**	**R**
	32	**Section 3.2 Finding 28**	**A**
	33	**Section 3.2 Finding 29**	**R**
	34	**Section 3.2 Finding 30**	**R**

	35	**Section 3.3 Finding 2**	**AC**
	36	**Section 3.3 Finding 5**	**R**
	37	**Section 3.3 Finding 10**	**AC**
	38	**Section 3.3 Finding 15**	**A**
	39	**Section 3.3 Finding 23**	**R**
PART 4	40	**Section 4.1 Recommendation to SIA, Point 1**	**AC**
	41	**Section 4.1 Recommendation to SIA, Point 2**	**AC**
	42	**Section 4.1 Recommendation to SIA, Point 3**	**R**
	43	**Section 4.1 Recommendation to SIA, Point 4**	**AC**
	44	**Section 4.1 Recommendation to SIA, Point 5**	**A**
	45	**Section 4.1 Recommendation to SIA, Point 6**	**AC**
	46	**Section 4.1 Recommendation to SIA, Point 7**	**R**
	47	**Section 4.1 Recommendation to SIA, Point 8**	**AC**
	48	**Section 4.1 Recommendation to SIA, Point 9**	**R**
	49	**Section 4.1 Recommendation to SIA, Point 10**	**AC**
	50	**Section 4.1 Recommendation to SIA, Point 11**	**A**
	51	**Section 4.1 Recommendation to CAAS, Point 1**	**R**
	52	**Section 4.1 Recommendation to CAAS, Point 2**	**R**
	53	**Section 4.1 Recommendation to CAAS, Point 3**	**R**
	54	**Section 4.1 Recommendation to CAAS, Point 4**	**AC**
	55	**Section 4.1 Recommendation to CAAS, Point 5**	**AC**
	56	**Section 4.1 Recommendation to CAAS, Point 6**	**AC**
	57	**Section 4.1 Recommendation to Singapore Government**	**R**
	58	**Section 4.1 Recommendation to CAA, Point 1**	**A**
	59	**Section 4.1 Recommendation to CAA, Point 7**	**AC**
	60	**Section 4.1 Recommendation to CAA, Point 9**	**R**
	61	**Section 4.1 Recommendation to CAA, Point 10**	**PA**
	62	**Section 4.1 Recommendation to CAA, Point 11**	**AC**
	63	**Section 4.1 Recommendation to Boeing, Point 1**	**A**
PART 5	64	**Section 2.6.1**	**AC**
	65	**Section 2.6.4**	**R**
	66	**Section 1.12.2.3.2 (3 issues)**	**R**
	67	**Section 1.15.1.1, Para 3**	**A**
	68	**Section 1.15.1.1, Para 6**	**PA**
	69	**Section 1.15.1.1, Para 7**	**PA**

	70	**Section 1.15.1.1, Para 3**	**R**
	71	**Section 1.15.1.1, Para 4**	**R**
	72	**Section 1.15.1.3, Para 2**	**PA**
	73	**Section 1.15.1.6, Para 1**	**R**
	74	**Section 1.15.1.6, Para 2**	**R**
PART 6	75	**Section 2, Para 2**	**A**
	76	**Section 2.1, Para 3**	**R**
	77	**Section 2.3.1.1 Para 2**	**R**
	78	**Section 2.3.1.1 Para 4**	**R**
	79	**Section 2.3.1.2.2 Para 4**	**R**
	80	**Section 2.3.1.2.3 Para 1**	**R**
	81	**Section 2.3.1.2.3 Para 2**	**R**
	82	**Section 2.3.2 Para 1**	**A**
	83	**Section 2.3.2 Para 3**	**A**
	84	**Section 2.3.3 Para 1**	**R**
	85	**Section 2.3.3 Para 2**	**R**
	86	**Section 2.3.4.1 Para 2**	**A**
	87	**Section 2.3.4.1 Para 3**	**R**
	88	**Section 2.3.4.1 Para 3**	**R**
	89	**Section 2.3.4.1 Para 8**	**R**
	90	**Section 2.3.4.1 Para 9**	**R**
	91	**Section 2.3.4.1 Para 10**	**R**
	92	**Section 2.3.4.1 Para 11**	**R**
	93	**Section 2.3.4.2 Para 2**	**R**
	94	**Section 2.3.5.2.2 Para 1**	**AC**
	95	**Section 2.3.6 Para 4**	**R**
	96	**Section 2.4.1 Para 4**	**R**
	97	**Section 2.4.1 Para 6**	**R**
	98	**Section 2.4.2 Para 2**	**PA**
	99	**Section 2.5.4 Para 1**	**R**
	100	**Section 2.5.4.1 Para 1**	**A**
	101	**Section 2.5.4.2 Para 1**	**AC**
	102	**Section 2.5.4.2 Para 2**	**A**
	103	**Section 2.5.4.3 Para 2**	**R**
	104	**Section 2.5.4.4 Para 1**	**R**

	105	**Section 2.5.4.4 Para 2**	**R**
	106	**Section 2.5.4.5 Para 1**	**R**
	107	**Section 2.5.4.5 Para 11**	**PA**
	108	**Section 2.5.4.6 Para 1**	**R**
	109	**Section 2.5.5 Para 1**	**R**
	110	**Section 2.5.6.2 Para 1**	**R**
	111	**Section 2.5.6.3.1 Para 2**	**PA**
	112	**Section 2.5.6.3.1 Para 5**	**PA**
	113	**Section 2.5.6.3.1 Para 6**	**R**
	114	**Section 2.5.3.6.2 Para 5**	**PA**
	115	**Section 2.5.6.3.3 Para 11**	**A**
	116	**Section 2.5.6.3.3 Para 12**	**A**
	117	**Section 2.5.6.3.3 Para 13**	**R**
	118	**Section 2.5.6.4 Para 3**	**R**
	119	**Section 2.5.7.1 Para 2**	**R**
	120	**Section 2.5.7.1 Para 7**	**A**
	121	**Section 2.5.7.1 Para 10**	**R**
	122	**Section 2.5.7.1 Para 11**	**R**
	123	**Section 2.5.7.1 Para 12**	**R**
	124	**Section 2.5.7.2.1 Para 2**	**R**
	125	**Section 2.5.7.2.2 Para 1**	**A**
	126	**Section 2.5.7.2.2 Para 3**	**R**
	127	**Section 2.5.7.2.3 Para 1**	**R**
	128	**Section 2.5.7.2.3 Para 3**	**R**
	129	**Section 2.5.7.2.3 Para 4**	**R**
	130	**Section 2.5.7.4 Para 2**	**AC**
	131	**Section 2.5.7.4 Para 4**	**R**
	132	**Section 2.5.7.4 Para 4**	**A**
	133	**Section 2.5.7.6 Para 1**	**A**
	134	**Section 2.5.7.6.1.1 Para 4**	**R**
	135	**Section 2.5.7.6.1.2 Para 1**	**R**
	136	**Section 2.5.7.6.1.2 Para 2**	**R**
	137	**Section 2.5.7.6.1.2 Para 3**	**R**
	138	**Section 2.5.7.7 Para 3**	**R**
	139	**Section 2.5.7.8 Para 1**	**R**

	140	**Section 2.5.7.8 Para 2**	**PA**
	141	**Section 2.5.8.1 Para 1**	**R**
	142	**Section 2.5.8.2 Para 3**	**A**
	143	**Section 2.5.8.2 Para 5**	**R**
	144	**Section 2.5.8.2 Para 6**	**R**
	145	**Section 2.5.8.2 Para 10**	**A**
	146	**Section 2.5.8.3 Para 1**	**A**
	147	**Section 2.5.8.4 Para 2**	**R**
	148	**Section 2.5.8.4 Para 4**	**R**
	149	**Section 2.5.8.5 Para 3**	**A**
	150	**Section 2.5.9 Para 1**	**AC**
	151	**Section 2.5.9 Para 9**	**R**
	152	**Section 2.5.9.1 Para 3**	**R**
	153	**Section 2.5.10 Para 1**	**AC**
	154	**Section 2.5.10.1 Para 3**	**R**
	155	**Section 2.5.10.1 Para 1**	**R**
	156	**Section 2.5.10.1 Para 3**	**R**
	157	**Section 2.5.10.3 Para 1**	**AC**
	158	**Section 2.5.11 Para 6**	**R**
	159	**Section 2.6.1 Para 1**	**A**
	160	**Section 2.6.1 Para 2**	**R**
	161	**Section 2.6.3.1 Para 2**	**R**
	162	**Section 2.6.3.1 Para 3**	**AC**
	163	**Section 2.6.5 Para 3**	**PA**
	164	**Section 2.7.3 Para 1**	**A**
	165	**Section 2.7.4 Para 3**	**AC**
	166	**Section 2.7.4 Para 4**	**PA**
	167	**Section 2.7.4 Para 6**	**R**
	168	**Section 2.7.4 Para 7**	**R**
	169	**Section 2.7.5 Para 4**	**A**
CAA/ROC			
	1	**Section 1.1**	**R**
	2	**Section 1.3**	**PA**
	3	**Section 1.4**	**R**
	4	**Section 1.5.1**	**A**

	5	**Section 1.5.2**	**A**
	6	**Section 1.5.3**	**A**
	7	**Section 1.7.2 issue 1**	**R**
	8	**Section 1.7.2 issue 2**	**R**
	9	**Section 1.10.1**	**R**
	10	**Section 1.10.2.1 issue 1**	**A**
	11	**Section 1.10.2.1 issue 2**	**A**
	12	**Section 1.10.3.2.2**	**A**
	13	**Section 1.10.3.2.3**	**A**
	14	**Section 1.10.3.2.4**	**A**
	15	**Section 1.10.5.1.2**	**PA**
	16	**Section 1.13**	**A**
	17	**Section 1.16.6**	**R**
	18	**Section 1.17.3.2**	**R**
	19	**Section 1.17.4.4**	**R**
	20	**Section 1.17.4.5**	**R**
	21	**Section 1.17.4.6**	**R**
	22	**Section 1.17.5**	**R**
	23	**Section 1.17.6**	**R**
	24	**Section 1.17.8**	**R**
	25	**Section 1.17.9**	**R**
	26	**Section 1.17.11**	**A**
	27	**Section 1.18.1.1 issue 1**	**A**
	28	**Section 1.18.1.1 issue 2**	**A**
	29	**Section 1.18.1.3.4**	**R**
	30	**Section 1.18.1.5**	**R**
	31	**Section 1.18.2.3 issue 1**	**PA**
	32	**Section 1.18.2.3 issue 2**	**PA**
	33	**Section 1.18.2.4 issue 1**	**A**
	34	**Section 1.18.2.4 issue 2**	**R**
	35	**Section 1.18.2.4 issue 3**	**R**
	36	**Part 2 Analysis**	**AC**
	37	**Section 2.2**	**R**
	38	**Section 2.3**	**R**
	39	**Section 2.3.1.1 issue 1**	**R**

	40	**Section 2.3.1.1 issue 2**	**PA**
	41	**Section 2.3.1.2.1**	**R**
	42	**Section 2.3.1.2.2 issue 1**	**R**
	43	**Section 2.3.1.2.2 issue 2**	**PA**
	44	**Section 2.3.1.2**	**R**
	45	**Section 2.3.2**	**R**
	46	**Section 2.3.3**	**R**
	47	**Section 2.3.5.2.1**	**A**
	48	**Section 2.3.6 issue 1**	**R**
	49	**Section 2.3.6 issue 2**	**PA**
	50	**Section 2.4.1 issue 1**	**PA**
	51	**Section 2.4.1 issue 2**	**R**
	52	**Section 2.4.1 issue 3**	**A**
	53	**Section 2.4.2 issue 1**	**R**
	54	**Section 2.4.2 issue 2**	**R**
	55	**Section 2.5.2.1**	**R**
	56	**Section 2.5.4.1**	**PA**
	57	**Section 2.5.4.2**	**A**
	58	**Section 2.5.4.3**	**A**
	59	**Section 2.5.4.5**	**R**
	60	**Section 2.5.5**	**R**
	61	**Section 2.5.6.1**	**A**
	62	**Section 2.5.6.3.3**	**R**
	63	**Section 2.5.7.1 issue 1**	**A**
	64	**Section 2.5.7.1 issue 2**	**A**
	65	**Section 2.5.7.2.1**	**PA**
	66	**Section 2.5.7.2.2 issue 1**	**PA**
	67	**Section 2.5.7.2.2 issue 2**	**R**
	68	**Section 2.5.7.2.3 issue 1**	**PA**
	69	**Section 2.5.7.4 issue 1**	**A**
	70	**Section 2.5.7.4 issue 2**	**PA**
	71	**Section 2.5.7.5**	**R**
	72	**Section 2.5.7.6.1**	**R**
	73	**Section 2.5.7.6.1.1**	**R**
	74	**Section 2.5.7.6.1.2 issue 1**	**R**

	75	**Section 2.5.7.6.1.2 issue 2**	**PA**
	76	**Section 2.5.7.7 issue 1**	**R**
	77	**Section 2.5.7.7 issue 2**	**PA**
	78	**Section 2.5.7.7.1 issue 1**	**A**
	79	**Section 2.5.7.7.1 issue 2**	**PA**
	80	**Section 2.5.7.8 issue 1**	**A**
	81	**Section 2.5.7.8 issue 2**	**PA**
	82	**Section 2.5.8**	**A**
	83	**Section 2.5.8.1**	**A**
	84	**Section 2.5.8.2 issue 1**	**A**
	85	**Section 2.5.8.2 issue 2**	**R**
	86	**Section 2.5.8.3**	**A**
	87	**Section 2.5.8.4**	**PA**
	88	**Section 2.5.9**	**R**
	89	**Section 2.5.9.1**	**R**
	90	**Section 2.5.10**	**PA**
	91	**Section 2.6.1**	**A**
	92	**Section 2.6.4.3**	**R**
	93	**Section 2.7.2**	**R**
	94	**Section 3**	**R**
	95	**Section 3.1 Finding 1**	**R**
	96	**Section 3.1 Finding 4**	**R**
	97	**Section 3.1 Finding 5**	**A**
	98	**Section 3.1 Finding 6**	**PA**
	99	**Section 3.1 Finding 7 issue 1**	**PA**
	100	**Section 3.1 Finding 7 issue 2**	**PA**
	101	**Section 3.2 Findings 1 & 2 issue 1**	**R**
	102	**Section 3.2 Findings 1 & 2 issue 2**	**R**
	103	**Section 3.2 Finding 4**	**R**
	104	**Section 3.2 Finding 5**	**R**
	105	**Section 3.2 Finding 8**	**A**
	106	**Section 3.2 Finding 9**	**R**
	107	**Section 3.2 Finding 11**	**R**
	108	**Section 3.2 Finding 13 issue 1**	**PA**
	109	**Section 3.2 Finding 13 issue 2**	**PA**

	110	**Section 3.2 Finding 14**	**A**
	111	**Section 3.2 Finding 16**	**R**
	112	**Section 3.2 Finding 18**	**A**
	113	**Section 3.2 Finding 23**	**A**
	114	**Section 3.2 Finding 25**	**A**
	115	**Section 3.2 Finding 31**	**R**
	116	**Section 3.2 Finding 32**	**R**
	117	**Section 3.2 Finding 33**	**R**
	118	**Section 3.2 Finding 36**	**R**
	119	**Section 3.3 Finding 12**	**R**
	120	**Section 3.3 Finding 18**	**PA**
	121	**Section 3.3 General**	**AC**
	122	**Section 4 Recommendation to CAA Point 2**	**R**
	123	**Section 4 Recommendation to CAA Point 7**	**A**
	124	**Section 4 Recommendation to CAA Point 11**	**A**
	125	**Section 4 Recommendation to ICAO Point 1**	**R**
	126	**Section 4.2**	**A**
	127	**Section 4.2 Point 3**	**A**
	128	**Section 4.2 Point 5**	**A**
	129	**Section 4.2 New Item 6**	**A**

7.2 Comments from NTSB

National Transportation Safety Board
Washington, D.C. 20594

Office of Aviation Safety

25 March 2002

Dr. Kay Yong
Managing Director
Aviation Safety Council
16th Floor, 99 Hsing North Road
Taipei, 105
Taiwan R.O.C.

Dear Kay,

Enclosed please find the U.S. team's comments to the "Final Draft" of the investigation of SQ006, the Singapore Airline Boeing 747-400 that crashed on takeoff from CKS Airport, Taoyuan, Taiwan on October 31, 2000.

A National Transportation Safety Board (NTSB) Accredited Representative and staff participated in the investigation and two follow-up meetings as the state of manufacture of the accident airplane, a Boeing 747-400, SQ006, that was involved in the scenario of the accident. Advisors from the Federal Aviation Administration (FAA), the Boeing Company, and Pratt & Whitney (the engine manufacturer) also participated. We wish to express our appreciation for the level of participation afforded to our team. We also wish to congratulate the Aviation Safety Council (ASC) for the excellent job of conducting the investigation and the ample consideration given to all the parties involved.

NTSB staff that participated in the investigation has reviewed the complete draft report. In addition, Boeing personnel that participated in the investigation have submitted comments to the U.S. Accredited Representative.

The report makes a determined effort to examine all unsafe acts, unsafe conditions, and safety deficiencies that were likely to have operated in the accident. It seems especially appropriate that the report explored issues related to both flight crew and airport, since both include significant factors likely to have contributed to the overall system deficiencies.

From a human performance viewpoint, the Taiwan Aviation Safety Council (ASC) may wish to consider an additional area of recommendations: the implementation of cockpit surface moving map displays. Current technology makes such displays possible and, for several reasons, they may represent the single most effective method of preventing a recurrence of this accident.

A cockpit surface moving map display is a navigation aid that would display in the cockpit the airplane's exact position (determined by Global Positioning System (GPS) satellite navigation) superimposed on a map of airport surface features including all runway, taxiway, and terminal areas. The airplane depiction would move as the flight navigated along taxiways and runways on the airport surface, portraying visually information that is now provided in a less complete format in such resources as paper charts and progressive taxi instructions. The human value of a moving map display is that it integrates a variety of complex data into a clear, precise, and intuitive representation of aircraft position with reference to a pre-planned course, allowing the pilot to maintain a mental picture, especially in low visibility conditions.

Such moving map displays have been used with great success and industry acceptance to depict airborne navigation information. One authority on automation has suggested, with regard to cockpit moving map displays already implemented, that "...no single feature has mitigated flight crew cognitive workload as much as these new displays, and it is probable that no technological advance has done as much to make the modern airplane more error-resistant than its predecessor." Research confirms that an electronic map display, if extended to navigation on the airport surface, can significantly decrease navigational errors such as wrong turns in low visibility conditions.

An additional safety feature of the cockpit surface moving map display is that, in the future, it might provide the basis for a complete ground movement safety system. One upgrade to the system, enabled by data link technology, would add traffic information concerning all other aircraft and surface vehicles at the airport (equipped with a compatible system or transponder). Another upgrade would provide graphical depiction of Notices to Airmen (NOTAM) information, for example overlaying a different color on part of a runway closed for construction. Such upgrades are being currently developed. However, implementation of a basic surface moving map display as a basis for a ground movement safety system should not be delayed. Many airport ground movement safety problems involve pilots becoming lost on the airport, as in the present accident. The current technology displays, with GPS location of own aircraft, have immediate safety benefits in that they do not have to wait for an enabling technology or widespread user implementation and can help pilots avoid airport "hot spots" and closed runways and taxi in bad weather.

A cockpit surface moving map display may have prevented the present accident, giving the flight crew a source of precise, current location information to build a mental picture of their route to an unfamiliar runway. It would have provided a direct, timely warning to the flight crew that would not have been available with a control tower radar system such as the Airport Surface Detection Equipment (ASDE), which would require significant time for the controller to detect and identify the safety problem, determine the necessary action, and establish radio contact with the crew as well as for the flight crew to react and take evasive action. It would have provided more complete and accessible navigation information, regardless of visibility conditions, than progressive taxi instructions.

Therefore, from a human performance perspective, the ASC may wish to consider recommendations such as the following:

To the Boeing and Airbus Companies:

1. Incorporate cockpit surface moving map displays into all newly-certified aircraft;
2. Develop retrofit installation options for cockpit surface moving map displays in all previously certified aircraft.

To International Civil Aviation Organization (ICAO):

1. Encourage all member states to survey major airport environments to develop a suitable database for display on a moving map multifunction display;

To the airline industry:

1. Equip all company aircraft with cockpit surface moving map displays

Specific comments from the Safety Board's operations staff were made to an electronic copy of the 'Final Draft' and therefore to large to send electronically with this letter. They have been included on a disk and printed out and sent under separate cover with this letter.

Comments from the Boeing Company have also been included as an attachment to the electronic version and sent under separate cover with the letter.

Pratt and Whitney had no comments to make regarding the 'Final Draft'.

Thank you again for inviting the safety board to present these comments before your staff and board members and we are sorry that we cannot be there for the formal presentation. We all realize how important this investigation is to the ASC and to aviation safety throughout the world.

With best regards,

Alfred W. Dickinson
Accredited Representative, NTSB, USA

17398.pdf

Attachment: Boeing comments

7.3 Comments from ATSB

ATSB
Australian Transport Safety Bureau

Australian Transport Safety Bureau
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Dr Kay Yong
Managing Director
Aviation Safety Council
16th Floor, 99 Fu-Hsing North Road
Taipei 105
Taiwan, R.O.C.

Dear Dr Yong,

SINGAPORE AIRLINES FLIGHT 006, BOEING 747-400, REGISTRATION 9V-SPK, CKS AIRPORT, TAOYUAN, TAIWAN, 31 OCTOBER 2000

Thank you for your letter and final draft report of the accident involving Singapore Airlines Limited Boeing 747-400, registration 9V-SPK, which collided with construction equipment on Runway 05R at Chiang Kai-Shek International Airport, Taiwan, on October 31, 2000.

As the Australian accredited representative, my advisers and I have reviewed the draft final report of the accident in accordance with the provisions of paragraphs 6.3 and 6.4 to Annex 13 (Ninth edition, July 2001) of the Convention on International Civil Aviation. We find the report thorough and the conclusions fully supported by the factual content. We also note that you have proposed recommendations aimed at preventing similar accidents in the future. Our detailed comments are noted below.

With respect to the following paragraphs of the report, we suggest that the paragraphs be amended as follows to ensure the meaning of the statements is correct:

- Executive Summary and Part 3
  Findings related to probable causes

  ATSB suggests that finding 7, bullet point 9, be altered from the incorrect term Parallel Visual Display (PVD) to the correct term Para-Visual Display (PVD).

- Executive Summary and Part 3
  Findings related to risk

  ATSB suggests that finding 8 be deleted for the reasons cited in comments associated with section 2.5.8.4 - Taxiway Lighting Issues. (See comments page 6)

- Executive Summary and Part 3
  Findings related to risk

  ATSB suggests that ASC rewrite finding 16, dot point 7 to form a stand alone finding with respect to runway closed warning/alert markings/indicators, and review the significance of the finding to ensure that it is given appropriate status with respect to findings related to probable causes and findings related to risk.

- Executive Summary, Part 1 and Part 3
  Other findings

  ATSB suggests that other finding 15 and the text in section 1.13.3 from which it is drawn, indicate that while there was no alcohol or drug testing of the three flight crewmembers of SQ006 after the accident, there was no evidence to suggest that alcohol or drugs were factors in the accident.

- Executive Summary and Part 4
  Recommendation 3 to Singapore Airlines

  ATSB suggests that recommendation 3 be amended to state:

  Review the adequacy of current SIA PVD training and procedures and ensure that SIA documentation and operational practices reflect the CAAS approved B747-400 AFM PVD supplement, which stated that the PVD "will shutter dependent upon whether the airplane is in a position for takeoff or not". (3.2-[9, 10]).

- Executive Summary and Part 4
  Recommendation 10 to Singapore Airlines

  ATSB suggests that recommendation 10 be amended to state:

  Review its procedures and training for the crew to effectively handle diversified emergency situations. (3.2-[24, 25, 26, 27]).

- Part 1
  Section 1.10.3.1.2 Taxiway centerline marking

  The picture/diagram Figure 1.10-6 is missing.

- Part 1
  Section 1.17.4.1 Crew Resource Management

  Paragraph 4, line 4:

  They sometimes discuss the ATC principles and critique the crews on the CRM issues during flight or simulator checks debriefings.

  ATSB suggests that the term *ATC principles* be clarified.

- Part 1
  Sections 1.18.1.3.1 through to 1.18.1.3.4

  ATSB suggests that a clear summary statement of the evidence, which indicates whether the Runway 05L approach lights, touchdown zone lights, runway edge and centerline lights, and PAPI were on for SQ006's departure is needed. On the evening of the accident, other flight crews had reported that all Runway 05L approach and runway lighting was illuminated for their departure but the controllers statements indicate uncertainty about the status of the Runway 05L CAT II approach lighting for SQ006's departure.

The RVR printout of the Runway 05L lighting system status revealed that the lights were powered on about 2313 LT (about 4 minutes before the accident). There are implications for analysis section 2.5.5 (Before take-off check) and section 2.5.7.4 (Runway difference issues). The factual is not clear on whether all Cat II lighting for Runway 05L had been illuminated before SQ006 turned from taxiway NP through taxiway N1 onto Runway 05R.

- Part 1
  Section 1.18.7 Navigation Display (ND)

  ATSB suggests that a concluding statement be added as follows:

  The investigation team was unable to determine what range had been set on the Navigation Display prior to or on runway line-up.

- Part 1
  Section 1.18.8.2 Videotapes provided by CKS Airport Office

  ATSB suggests that a concluding statement be added as follows:

  No Runway 05R lights were visible from either CKS airport camera 77 or camera 92.

- Part 2
  Section 2.5.6.4 Heading Indicators

  For accuracy, ATSB suggests the following amendment to replace paragraph 1 text commencing at line 5 (sentence 3):

  When the aircraft completed the turn from Taxiway NP onto Taxiway N1, the flight crew needed to maintain a heading of about 320 degrees magnetic for about 270 meters to reach the turn lead-in for Runway 05L. Instead of making a 90 degree turn from NP onto N1 as the airport chart indicated, CM-1 turned the aircraft through 180 degrees as it traversed from a heading of about 230 degrees magnetic to a heading of about 050 degrees magnetic onto Runway 05R.

- Part 2
  Section 2.5.7.1 Markings and signage

  ATSB suggests that the last paragraph be amended after the word *position*, line 2, to state:

  Based on the above evidence, the Safety Council has concluded that if the flight crew had looked for the runway markings and signage to locate their position, **they would normally have been able to see that information to help them to navigate the aircraft to the correct runway. On the other hand, if the flight crew was not able to clearly see runway markings and signage because of the degraded visibility during the last phase of the taxi from NP through N1 onto Runway 05R, they could have considered alternatives. For example, the crew could have requested some assistance from ATC to verify their position.**

- Part 2
  Section 2.5.7.5. Runway 05L Guard Lights

  ATSB suggests that the report should explain in detail how the figure of 175 meters was derived in the following statement: *The crew would have had the guard lights in front of them for a taxi distance of 175 meters before the turn from Taxiway N1 onto Runway 05R.* Suggested text could include:

  The distance from NP centerline to the theoretical location of 05L runway guard lights is 249 meters (324-75). The distance from runway 05R centerline and 05L centerline is 214 meters (324 - 110). The crew taxied 110 meters along N1 as they turned from NP onto 05R. The distance between the 05R centerline and theoretical location of 05L runway guard lights is 139 meters (214 - 75). The intersection of N1 turn onto Runway 05R to theoretical location of 05L guard light is about 139 meters + 22.5 meters (half the width of Runway 05R) +13.5 meters (shoulder of 05R) = 175m.

Part 2
Section 2.5.8.4 Taxiway Lighting Issues

CM-1 was asked how he had made a continuous turn onto Runway 05R from NP when the airport chart clearly showed Taxiway N1 as a straight line of 214 meters to Runway 05L.

ATSB suggests that the report be amended to reflect the correct distances as in the suggested amendment for 2.5.7.5 above:

The distance between the NP centerline and the Runway 05L centerline is 324 meters as per Figure 1.10-2. The distance from the Runway 05R centerline and 05L centerline is 214 meters.

Additional ATSB comment on the 'follow the green' hypothesis:

However, at CKS airport if the crew had followed the green, the failure would have been safe. They would either have followed the green lights down Runway 05R until they realized their error, or they would have approached the lighted barriers at low speed. In this case, once the crew was convinced they had reached the take-off runway they commenced the takeoff. Whether the 'follow the green' *habit* was triggered during the turn from NP onto 05R cannot be determined with complete confidence. The crew reported following the green during the turn from NP through taxiway N1 onto Runway 05R. There are sufficient alternative explanatory mechanisms discussed in the report with respect to such an action.

- Part 2
  Section 2.5.9 Water-affected Runway issues

Last sentence of paragraph 4 is not correct. It should read:

A pilot must assess all runways since all runways are *not* the same.

6

- Part 3
  Section 3.2 Findings related to risk

  ATSB suggests that finding 8 be deleted for the reasons cited in comments associated with section 2.5.8.4 - Taxiway Lighting Issues.

- Part 4
  Recommendations

  ATSB suggests that the following additional recommendations be made at Part 4 of the report and included in the Executive Summary.

  The Safety Council recommends that IATA:

  - **for safety assurance and risk management purposes, urge its member airlines to work with their respective regulatory agencies to ensure that airports into which they operate meet the Standards and Recommended Practices of ICAO Annex 14; and**

  - **urge its member airlines to work with their respective regulatory agencies to develop procedures for evaluating the airport infrastructure as part of their out station audits.**

Thank you again for providing us the opportunity to review your report. We look forward to receiving the final version of the report so that we can make it available to others in the Australian aviation community for information and accident prevention purposes. We have appreciated the opportunity to assist you with this investigation and the professional manner with which the process has been managed.

Yours sincerely,

Alan L Stray
Deputy Director - Air Safety Investigation
Australian Transport Safety Bureau
12 March 2002

7.4 Comments from MCIT/SINGAPORE

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Our ref: MCIT/CA/SQ006

Your ref:

29 March 2002

Dr Kay Yong
Investigator-in-Charge
SQ 006 Accident Investigation
Aviation Safety Council
16th Floor, 99 Fu-Hsing North Road
Taipei 105
Taiwan

Dear Dr Yong,

SQ 006 INVESTIGATION

Thank you for the draft Final Report of the SQ 006 accident investigation, upon which you sought Singapore's comments by 31 March 2002.

2 The Singapore Ministry of Transport (MOT) team comprising its investigators, advisers, and consultants appointed through ICAO, Dr Rob Lee and Captain Richard McKinlay, has carefully studied and reviewed the ASC draft Final Report.

3 The sole purpose of the Singapore team's comments is to provide constructive feedback to the ASC on the draft Final Report. Our aim is to achieve a Final Report of the highest possible quality, and one that will make a significant contribution to the enhancement of international aviation safety.

4 Thank you very much for taking in some of the comments that the Singapore team provided earlier.

5 However, many of the key issues raised by the Singapore team in its comments to the ASC on the preliminary Draft Report have not been included in the draft Final Report.

MCIT 6/2001

The ASC draft Final Report

6 The Singapore team considers that:

a) The ASC draft Final Report presents an unbalanced account of the SQ 006 accident. It minimises the significance of the many systemic factors which contributed to the accident, such as the deficiencies in the runway lighting, signage and markings at CKS Airport.

b) The ASC draft Final Report does not adequately address the fundamental systemic error management and risk analysis issues raised by the investigation. These include the absence of warning signs, lights or markings which would have alerted the crew to their mistake, and the lack of physical barriers to prevent aircraft from entering, lining up and taking off on the closed Runway 05R.

c) The ASC draft Final Report contains factual inaccuracies, internal contradictions, and hypothetical statements that are not supported by empirical evidence.

d) The ASC draft Final Report does not highlight the very valuable systemic runway safety lessons from the SQ 006 accident investigation that will benefit the global aviation community.

7 The improvement of runway safety is a major challenge confronting the world aviation industry. The SQ 006 accident was a tragic manifestation of this international systemic safety problem, and therefore it should be considered in that context.

8 The potential safety benefits of the SQ 006 accident investigation will extend well beyond Taiwan and Singapore.

Guiding Principles of the Singapore team's review of the ASC draft Final Report

9 As with the preliminary Draft Report, the primary guidance material against which we have reviewed the ASC draft Final Report is Annex 13 to the Convention on International Civil Aviation. In accordance with the principles and spirit of Annex 13, our aim is to ensure that the Final Report of the SQ 006 investigation is accurate, objective and balanced, and does not apportion blame or liability.

10 We have also considered areas of the ASC draft Final Report in the context of other documents published by ICAO, the guidelines of major regulatory authorities, and where appropriate, industry best practice.

11 In accordance with ICAO guidelines, the Singapore team views the SQ 006 accident as a failure of the aviation system, and not as the failure of a person, or of people. We recognize the fact that human error is inevitable, and that systems must therefore be designed and operated to be error tolerant.

12 We have considered the ASC draft Final Report in the light of established and proven air safety investigation methodology. We have considered whether all of the relevant factual material gathered in the investigation has been included in the ASC draft Final Report. We have also assessed the degree to which the analysis and conclusions are based upon sound investigation procedures and factual evidence.

13 In considering the individual human factors involved in the accident, we have assessed the performance of pilots, cabin crew, air traffic controllers, and fire-fighting and rescue personnel, in terms of what could be realistically expected of such line personnel, especially in the aftermath of a catastrophic accident such as SQ 006.

14 Where errors have occurred, our aim has been to understand the reasons why those errors occurred.

15 In addition, we have considered the equally important broader systems safety issues, such as how the probability of human errors may be reduced, and measures which would prevent such errors, if they do occur, from resulting in accidents.

Singapore Team's Comments

16 The detailed Singapore team's comments are contained in the attachments to this letter. However, we would also like you to refer to the earlier comments that we have submitted on the ASC preliminary Draft Report, and to our written analysis.

17 As per my emails of 15, 18 and 25 March 2002 to you, I would like to request that the Singapore team's comments be appended in full to the ASC Final Report, and that they be published and distributed simultaneously with all copies of the ASC Final Report. We also reiterate our earlier request that the Singapore team be provided with an advance copy of the ASC Final Report, in accordance with established international practice.

Conclusion

18 Finally, may I again express the Singapore team's regret that it has not been permitted to participate in the analysis process, in accordance with its entitlements under Annex 13.

19 If the Singapore team had been able to take part and contribute to the analysis, the accident investigation process would have more efficient, effective, and complete.

20 Both Singapore and Taiwan share the common goal of pursuing excellence in aviation safety. Notwithstanding the difficulties that have been encountered, I hope that the valuable lessons learned by both Singapore and Taiwan from the experience of the SQ 006 investigation will help facilitate greater cooperation and communication in any future air safety investigations.

Thank you

Yours sincerely,

HO SEE HAI
ACCREDITED REPRESENTATIVE, SINGAPORE

cc Mr Chua Kheng Hwa
MOT

Part 1

Comments by the Singapore Ministry of Transport Investigation Team on the ASC Draft Final Report of the Investigation into the Accident to Singapore Airlines Boeing 747 – 400 at Taipei on 31 October 2000

EXECUTIVE SUMMARY

Introduction

1 The Singapore Ministry of Transport (MOT) finds the ASC draft Final Report incomplete, and does not present a full account of the SQ006 accident.

2 The ASC draft Final Report lists seven "findings related to probable causes .. that have been *shown to have operated … or almost certainly operated* in the accident". Six of these refer to the SQ006 flight crew, the seventh refers to the weather. Other significant contributing factors, arising from the major deficiencies in the CKS Airport design, layout and facilities are played down, and categorised only as "findings related to risk … that *cannot be clearly shown to have operated* in the accident". However, the Singapore team believes that the major deficiencies at CKS Airport played a critical role in the accident.

3 As a result, many valuable lessons which could have been learnt from the SQ006 accident have not been explored in the analysis, and clarified in the findings. In fact, the CKS Airport itself has taken measures after the accident to remedy some of these deficiencies. The rapid initiation of these major changes by the Taiwanese authorities is an acknowledgement that many of the deficiencies which have been, or are being, rectified were major causal factors in the accident, yet none appear in the ASC 'findings related to probable causes'.

4 An air safety investigation of an accident or incident should seek to:

- understand why mistakes and errors were made by people in the aviation system;
- recommend measures to reduce the likelihood of such errors; and,
- identify means to prevent such errors, when they do occur, from resulting in accidents.

5 In accordance with paragraph 6.3 of Annex 13 to the Convention on International Civil Aviation (Chicago Convention), Singapore desires that these comments be appended in full to the ASC Final Report.

The accident

6 At night, in inclement weather, believing that they were on the correct runway, the crew of SQ006 mistakenly attempted to take off on a runway (Runway 05R), which was adjacent and parallel to the runway on which they intended to take off (Runway 05L). Just over one kilometre along Runway 05R, and out of sight of the crew at the position from which they commenced their take-off, a section had been closed due to works in progress. During its take-off run, SQ006 collided with heavy construction equipment on the closed portion of Runway 05R.

7 There were no visual warnings or physical barriers to prevent aircraft from lining up and attempting to take off from Runway 05R.

8 If these preventative measures had been in place, in accordance with ICAO Standards and Recommended Practices, and with prudent safety practice, the accident would not have occurred.

9 The runway and taxiway lighting, signage and markings at CKS Airport did not conform to international standards, as set out in ICAO Annex 14. In particular, some critical taxiway signs, markings, and guidance lights in the vicinity of the take-off runway were either missing or not working. As a consequence, there was only a single line of taxiway centreline lights which the crew followed onto Runway 05R. There was no visible alternative path leading to Runway 05L.

10 Although Runway 05R was closed to be permanently redesignated as a taxiway, none of the runway markings had been removed as they should have been. For example, the white runway threshold markings, or 'piano keys' were still present.

11 There were some cues in the cockpit which provided indications that SQ006 had not lined up on the intended take-off runway, Runway 05L. However, due to the powerful visual cues of an operational runway ahead of them, this information was missed by the crew.

12 The SQ006 tragedy was a classic example of an accident occurring on the ground at an airport, involving a complex interaction of many factors, including actions by flight crews and air traffic controllers, the design and layout of the airport, airport facilities, and weather conditions.

Runway safety – a global problem

13 The SQ006 accident should not be seen as an isolated event specific to CKS Airport. Rather, it should be seen as a symptom of the global problem of runway safety.

14 Accidents and incidents involving the confusion of runways and taxiways are an increasingly serious problem facing the world's airline industry. The extent of this problem is graphically illustrated by events which have occurred since the SQ006 accident, such as the collision on the runway at Milan Linate Airport on 8 October 2001. This accident resulted in the loss of an MD87 and a Cessna Citation, with 122 fatalities.

15 The US FAA has specified runway safety as one of its top five priorities, which reflects the serious nature of this world-wide problem.

The ASC Investigation

16 Although Taiwan is not a Contracting State of ICAO, it undertook to investigate the accident in accordance with the provisions of Annex 13 to the Chicago Convention. The ASC of Taiwan was the agency responsible for carrying out the investigation.

17 Under the provisions of Annex 13, aircraft accident investigation is a team effort, pursued in the interests of aviation safety. Annex 13 states that:

> *The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.* (Annex 13, paragraph 3.1)

18 Under the Annex, the State of Singapore was entitled to appoint an accredited representative to participate in all aspects of the investigation. (Annex 13, paragraphs 5.18, 5.25)

19 Contrary to the provisions of paragraphs 5.18 and 5.25 (h) of Annex 13, the ASC did not permit the Singapore accredited representative and his advisers to participate in the 'deliberations related to analysis, findings, causes and safety recommendations'.

20 The ASC has adopted a format for the Conclusions section which does not conform to Annex 13, or to the format used by other major accident investigation bodies. Annex 13 states that the investigation report should list 'the findings and causes established in the investigation. The list of causes should include both the immediate and the deeper systemic causes' (APP-2, 3).

21 Instead of listing the findings established, immediate causes and deeper systemic causes, the ASC draft Final Report lists only findings, and under three major categories:

(1) "findings related to probable causes" which identify elements that have been shown to operate or almost certainly have operated in the accident;
(2) "findings related to risk" which cannot be clearly shown to have operated in the accident; and
(3) "other findings" that have the potential to enhance aviation safety, resolve an issue of controversy or clarify an issue of unresolved ambiguity.

22 Systemic factors which contributed to the accident, such as deficiencies in the design and layout of the airport, defective or inadequate runway lighting, signage and markings and their non-conformance with ICAO Standards and Recommended Practices, are listed as “findings related to risk” (ie cannot be clearly shown to have operated in the accident) while the Singapore team feels that these factors clearly played a major role in the accident. They should rightfully be categorised as “findings related to probable causes”.

Singapore’s response to the accident

23 Following the accident, the then Singapore Ministry of Communications and Information Technology (MCIT) assembled a team to participate in the investigation, and immediately despatched it to Taipei to assist the ASC.

24 In accordance with Annex 13, the Singapore investigation team members were appointed by the Minister for the then MCIT. On 23 August 2001, the MCIT became the Ministry of Transport (MOT).

25 The Singapore MOT Investigation Team (Singapore Team), comprised investigators and advisers from different organisations, including Civil Aviation Authority of Singapore (CAAS), the Ministry of Defence, Singapore Airlines, and universities. Subsequently, Singapore requested that ICAO provide specialist consultants to assist the MOT Team.

26 Dr Rob Lee, former Director of the Australian Bureau of Air Safety Investigation, and Capt. Richard McKinlay, Deputy Chief Inspector of the UK Air Accidents Investigation Branch were appointed by ICAO, and commenced duty in April, 2001.

27 The Singapore Team is an independent body, which reports directly to the Minister.

The Singapore Team’s approach to the investigation

28 In accordance with the philosophy of Annex 13, the Singapore Team regards the SQ006 accident as a failure of the aviation system, rather than a failure of a person, or people.

29 As stated by Captain Dan Maurino, Co-ordinator of the ICAO Flight Safety and Human Factors Study Programme:

> *To achieve progress in air safety investigation, every accident and incident, no matter how minor, must be considered as a failure of the system and not simply as the failure of a person, or people.*

30 The Singapore Team's analysis of the accident adopts this systemic approach. It is a fact that the crew of SQ006 took off on the wrong runway. The Singapore Team seeks to understand the reasons why this mistake was made by an experienced airline crew, and why it resulted in the accident. The objective is to develop and implement measures to reduce the likelihood of such errors, and, if they do occur, to prevent them resulting in catastrophic accidents.

Cooperation with the ASC

31 From the outset, the Singapore Team cooperated with the ASC, and endeavoured to make a full contribution as a member of the ASC team. For example, Singapore provided a Boeing 747-400 to carry out taxi simulation trials at CKS Airport.

32 The Singapore Team has provided documents and personal presentations to the ASC in Taipei. The Singapore Team also advised the ASC of new factual data as it became available, such as the results of metallurgical tests concerning the runway lighting. These tests were carried out by scientists from the National University of Singapore and the Singapore Defence Science Organisation.

33 During the investigation the Singapore Team provided detailed inputs to the ASC team on many key issues. These included human factors, systems safety, error management, operational procedures, training, documentation, airport issues, air traffic control procedures, and investigation methodology. However, many significant matters raised by the Singapore Team were not accepted by the ASC.

Singapore Team's Inputs to the ASC investigation

34 On 4-5 July 2001 the Singapore Team presented its preliminary analysis of the accident to the ASC. This was followed by a written analysis, sent to the ASC on 17 September 2001.

35 On 28 September 2001, the Singapore Team received the ASC's preliminary draft report on the accident. Following a comprehensive review of the ASC preliminary draft report, the Singapore Team advised the ASC on 1 November 2001 of a number of significant omissions, inaccuracies, contradictions, and statements which were not supported by empirical evidence.

36 While some of the points raised by the Singapore Team were considered by the ASC, and had been included in the draft Final Report, areas of fundamental disagreement remain concerning the interpretation and analysis of the factual evidence. This is particularly the case with regard to the measures which could have been taken at CKS Airport to prevent mistakes in runway identification by pilots from resulting in accidents, such as the provision of warning lights, signage and physical barriers to stop aircraft from entering closed runways.

37 If the Singapore Team had been allowed by the ASC to participate in the analysis process, as it was entitled to do under Annex 13, the present differences might have been avoided, through open two-way discussion, and ongoing communication at all levels of the investigation.

Overall Review of the ASC Draft Final Report

38 A number of areas of the ASC analysis are not supported by factual evidence. In some instances, judgements are made, hypotheses are put forward, and opinions are expressed which are not based upon either factual evidence or research data.

39 For example, the ASC concludes that *"if the flight crew had looked for the runway markings and signage to locate their position by scanning the outside scene, they would have been able to see that information and consequently navigate the aircraft to the correct runway."* (Section 2.5.7.1 of ASC's draft Final Report.) This conclusion is not based on any objective evidence, simulator tests or research, that replicate the rapidly changing low visibility conditions on the night of the accident. Without any supporting data, this statement in the ASC draft Final Report can only be an opinion, and therefore its validity is questionable.

40 Another example is the ASC's conclusion that *"it was possible that CM-1 (the commander) reverted to the most dominant previously formed mental model under high workload to follow the green taxiway centreline lights."* However, there is no factual evidence to support this "dominant mental model" hypothesis.

41 Approximately ninety percent of the airports to which SIA crews operate do not have a "follow the green" taxiway light guidance system. Consequently, the factual evidence contradicts the ASC conclusion.

42 Several important safety issues relevant to the understanding of the SQ006 accident are not discussed in the analysis section of the ASC draft Final Report.

43 For example, the provision of runway closure markers and barriers are described in the factual information section of the ASC report. However, the significance of these markers and barriers has been down-played in the draft Final Report. By concentrating primarily on the flight crew, the ASC analysis does not consider the accident as a systemic failure, and therefore does not objectively address the combination of factors which contributed to the accident.

44 Some safety recommendations derived from the analysis are not supported by evidence in the draft Final Report. For example, recommendation 4.1.3 states that the CAAS approved B747-400 AFM PVD supplement includes "the use of the PVD to verify the correct departure runway."

45 The AFM PVD supplement does not refer to 'the use of the PVD to verify the correct departure runway'. (See Section 2.5.6.3.1 of ASC's draft Final Report).

46 The ASC draft Final Report describes numerous significant measures which have been taken by the Taiwanese aviation authorities to enhance safety following the accident to SQ006. Some of these measures were put in place immediately after the accident, and others are in the process of being implemented. The rapid initiation of these major changes by the Taiwanese authorities is an acknowledgement that many of the deficiencies which have been, or are being, rectified were major causal factors in the accident, yet none appear in the ASC 'findings related to probable causes'

47 Examples of deficiencies at CKS Airport which have been rectified include:

- painting the missing segment of the Taxiway N1 centreline marking leading to Runway 05L
- removing the Runway 05R threshold markings
- removing the Runway 05R designator marking
- disconnecting the Runway 05R runway edge lights
- adding to taxiway centreline lights from Taxiway N1

48 The Singapore Team commends the actions of Taiwanese aviation authorities to rectify these deficiencies and improve their aviation system. However, these systemic deficiencies, all of which existed at the time of the accident, should have been included in the 'findings related to probable causes' of the accident in the ASC draft Final Report. (Section 3.1 of ASC's draft Final Report.)

Summary

49 The Singapore Team considers that the ASC draft Final Report is deficient in many critical aspects.

50 As noted above, it is a fact that the pilots mistakenly turned onto the wrong runway. However, they took off firm in their belief that they were on the correct runway. Contributing factors and major deficiencies at CKS airport that either led to, and reinforced, their wrong belief, are not included in this probable cause category.

51 The outcome of the human factors analysis of the performance of the flight crew of SQ006 does not provide an understanding of why an experienced and professional airline crew mistakenly commenced take-off on the wrong runway.

52 As in all aviation accidents, deeper systemic factors play a major role in their causation. However, the ASC draft Final Report lists no such factors in its 'findings related to probable causes'.

53 As a result, the potential value of the ASC investigation in contributing to global aviation safety will not be realised.

Documents containing earlier and detailed comments by the Singapore Team on the ASC Draft Final Report

54 The Singapore Team provided earlier comments on the ASC's preliminary draft Report in November 2001, including the submission of a complete separate analysis. The substance of those comments remains essentially valid, and the Singapore Team requests that the ASC refer to these earlier documents, as well as to the comments on the draft Final Report which follow.

55 A separate analysis of the SQ006 accident by the Singapore Team is not included with the comments on the draft Final Report, as the Singapore Team has been advised by the ASC that it would not be prepared to append such an analysis to its Final Report.

56 The Singapore MOT team's comments are presented in the following documents:

- Part 1 – Comments by the Singapore Ministry of Transport Investigation Team on the ASC Draft Final Report of the Investigation into the Accident to Singapore Airlines Boeing 747-400 at Taipei on 31 October 2000.

- Appendix to Part 1 – Singapore Ministry of Transport Investigation Team's submission relating to Safety Actions and Safety Recommendations.

- Part 2 – Comments by the Singapore Ministry of Transport Investigation Team on Overall Format of the Conclusions Section of the ASC draft Final Report and on Section 3.1 relating to 'Findings Related to Probable Causes'.

- Part 3 – Comments by the Singapore Ministry of Transport Investigation Team on Sections 3.2 and 3.3 of ASC draft Final Report 'Findings Related to Risk' and 'Other Finding'.

- Part 4 – Comments by the Singapore Ministry of Transport Investigation Team on Section 4 'Safety Recommendations' of the ASC draft Final Report.

- Part 5 – Comments by the Singapore Ministry of Transport Investigation Team on the 'Survival Aspects' of the ASC Draft Final Report.

- Part 6 – Comments by the Singapore Ministry of Transport Investigation Team on Section 2 of the ASC draft Final Report 'Analysis'.

- Additional document : 'MCIT Investigation Team's Comments on Salient Issues in the ASC preliminary draft Report on the SQ 006 Accident Investigation' (originally submitted on 1 November 2001)

Appendix to Part 1

Singapore Ministry of Transport Investigation Team's Submission Relating to Safety Actions and Safety Recommendations

SAFETY ACTIONS

1 CKS Airport

CKS Airport has advised that since the accident, the following actions have been taken:

a) Efforts have been initiated to set up safety inspection teams and self audit programmes.

b) Runway 05R was decommissioned with effect from 1 February 2001 and has since been reopened as a taxiway.

c) The take-off minima for Runway 05L has been changed to 350m Runway Visual Range (RVR).

d) The Airport Emergency Handling Procedures, Civil Aircraft Accident Handling procedures, and the Emergency Airport Rescue Procedures have been revised.

e) CKS Airport is expediting the installation of Surface Movement Radar (SMR) at the airport.

2 CAA Taiwan

CAA Taiwan has advised that the following actions have been taken since the accident:

a) A review of ICAO Annexes and documents has been carried out, and a mechanism has been set up for follow-up action.

b) Expatriate advisors on airport standards have recently been appointed.

3 Singapore Airlines

SIA has advised that the following actions have been taken since the accident to SQ006:

a) A new CRM training programme for pilots has been developed and implemented, which includes situational awareness and error management training as separate modules.

b) Human factors and accident prevention training for inclusion in the pilot command training programme is being planned by SIA Flight Crew Training Centre.

c) A risk assessment tool to enable crew to manage risk in their operations has been developed and is being evaluated.

d) Redesign of the female cabin crew's footwear had been initiated in December 1999. New footwear has been introduced.

e) Checklists have been amended to require all crew in the cockpit to visually confirm the correct runway designation before commencing the take-off run.

f) The Flight Crew Operating Manual has been amended to formally require the pilot taxiing the aircraft to refer to signage and markings. It also requires the other pilot to confirm the correct taxi route is being used with reference to airport charts.

g) The Flight Crew Training Manual has been amended to formally document procedures, instructions and the training curriculum for ground operations in poor visibility conditions.

h) The Cross Wind Limitation Policy has been revised and the Flight Crew Operating Manual has been amended accordingly. The revision has a more conservative limit for 'wet' runway conditions.

i) An airport specific operational information gathering process has been implemented to provide additional information with regard to operational procedures and facilities specific to the airport not routinely included in Jeppesen route manuals.

j) Boeing's GPS based "Take-off Runway Disagree Alerting Function" has been accepted by the company for installation on B777 and B747-400 aircraft.

k) An Electronic Moving Map system which provides a pictorial depiction of airport movement areas is being evaluated for installation in SIA aircraft.

l) The FAA Advisory Circular on Runway Safety (FAA AC 120-74) has been reviewed with the objective of identifying useful points for incorporation in the SIA low visibility operations, training and procedures.

4 CAAS

CAAS has advised that the following actions have been taken since the accident:

a) Singapore operators have been required to review their 'before take-off' checklists.

b) Singapore operators have been required to update their CRM training programmes in keeping with current industry best practice.

c) Singapore operators have been required to review the FAA Advisory Circular (AC120-74) to assess its suitability to enhance their low visibility operations, training programmes and procedures.

d) A proposal to amend the current regulations to require earlier CVR power-on and later power-off times has been submitted to the Ministry of Transport.

SAFETY RECOMMENDATIONS

1. CKS Airport should ensure that, whenever runways or taxiways are closed to aircraft operations, be it partially or fully, suitable barriers are provided at locations that would physically prevent aircraft from entering such closed movement areas. The relevant ICAO standards and recommended practices (SARPs) concerning runway/taxiway closure markings should be adhered to.

2. A formal mechanism among international airlines needs to be developed by means of which operators can actively seek out and exchange local 'intelligence' on potential safety hazards, and ensure that such information is made available to crews. SIA should initiate coordination with other major airlines to better utilise the present "informal" and "ad hoc" exchange of local knowledge regarding operational safety hazards at airports.

3. SIA should review its emergency safety training programme to determine whether it is possible, and practical, to incorporate more realism, and to inculcate more awareness of the potential difficulties flight and cabin crew may encounter in catastrophic aircraft emergencies.

4. CKS Airport should ensure that its Air Traffic Controllers adhere to their Standard Operating Procedures. In particular, when aircraft cannot be seen from the control tower, controllers should advise pilots of this situation, and that they should taxi with caution.

5. CKS Airport should set up an integrated safety management system, so that systematic safety reviews, hazard analyses, and risk assessments are undertaken before implementing any airside work or changes that could affect aircraft operations.

6. CAA Taiwan and CKS Airport management should establish a joint task force to review the US FAA National Blueprint for Runway Safety (details at: www.faa.gov/runwaysafety), and wherever appropriate, adopt the safety philosophy and operational recommendations of that programme, so as to improve operational safety.

7. CKS Airport should ensure that the contents of all NOTAMs and AIP Supplements pertaining to airfield work contain clear and current information on the actual status of the taxiways/runways, and the configuration of the markings, signage and lighting. This will also facilitate the issuance of supplementary information by airport chart providers.

8. CKS Airport should utilise frangible barriers to demarcate work areas on the airfield.

9. The aviation industry should establish a working group, involving the airport authorities, airlines, regulators, ICAO, Flight Safety Foundation, IFALPA, Airports Council International and the IATA Safety Committee to develop a system to objectively determine whether a runway is “wet” or “contaminated” due to the presence of water. At present, there is no objective method by means of which this can be determined.

10. CKS Airport should formulate a written Surface Movement Guidance and Control System (SMGCS) plan to ensure the safety of aircraft movements on the ground.

11. CKS Airport should clearly define the operational responsibilities and safety accountabilities of the departments involved in the airside operations of the airport, so as to ensure that timely implementation of safety measures and improvements are not delayed due to ambiguities in areas of responsibility.

12. CAA Taiwan, in cooperation with the ASC, should establish and promote a more effective air safety incident reporting programme as part of an overall integrated safety management system. Such an

incident reporting programme would provide a wide range of safety information, including data on airport safety issues.

13. CKS Airport should review its ARFF procedures to ensure that its personnel are able to carry out rescue operations inside aircraft using breathing apparatus.

14. ASC should coordinate with the relevant authorities to ensure that autopsies of all aircraft accident fatalities are performed to determine the survivability aspects of the accident.

15. ASC should ensure that blood toxicology tests are carried out on all relevant personnel such as pilots, air traffic controllers and apron controllers immediately after an accident.

16. ICAO should establish a study group to investigate the parameters affecting the functionality of aircraft escape slides in high wind conditions, with a view to determining a revised basis for the certification of these slides.

17. Aircraft manufacturers should review the design of public address systems so that these systems can continue to function largely independently of airframe or engine system condition in the event of an accident.

Part 2

Comments by the Singapore Ministry of Transport Investigation Team on Overall Format of the Conclusions Section of the ASC draft Final Report and on Section 3.1 relating to 'Findings related to probable causes'

Overall format of the Conclusions section of the ASC draft Final Report

1 Annex 13 to the Chicago Convention (page APP-2 of Appendix) states that the Conclusions section of the Final Report should 'list the findings and causes established in the investigation. The list of causes should include both the immediate and the deeper systemic causes'. The ASC daft Final Report does not conform to this format. Instead of listing the findings established, immediate causes and deeper systemic causes, the ASC draft Final Report lists only "findings" and under three major categories:

(4) "findings related to probable causes" which identify elements that have been shown to operate or almost certainly have operated in the accident;

(5) "findings related to risk" which cannot be clearly shown to have operated in the accident; and

(6) "other findings" that have the potential to enhance aviation safety, resolve an issue of controversy or clarify an issue of unresolved ambiguity.

2 An aircraft accident is a failure of the aviation system, and is always the result of a combination of many contributing factors and causes.

3 From the perspective of flight safety, all these contributing factors and causes must be addressed and appropriately categorised. When arbitrary classification of factors and causes is made, it can direct the focus of attention disproportionately towards particular factors, while downgrading the importance of the other factors that had played a significant part in the accident.

4 This is what has happened in the ASC draft Final Report. Six of the seven 'findings related to probable causes' are in relation to the aircrew; none refer to the major deficiencies in the runway lighting, signage and markings at CKS airport. The result, whether intended or otherwise, is that the flight crew of SQ 006 are effectively 'blamed' for the accident.

5 The format of the Conclusions section in the ASC Draft Final Report therefore results in an unbalanced analysis of why the accident occurred, and is a major defect if it is used again in the Final Report.

6 Consequently, the Singapore Team does not accept the format of the Conclusions used in the ASC Draft Final Report.

Section 3.1 : 'Findings related to probable causes'

7 It is clear from the factual evidence that warning markings and barriers if located at the threshold of the closed runway would have stopped the crew of SQ 006 from commencing to take off, and thus would have prevented the accident.

8 However, the lack of these systemic safety measures is not mentioned in the ASC 'probable causes' findings. This critical factor is relegated to a sub-paragraph of one of the thirty six 'findings related to risk' i.e. factors that "have the potential to degrade safety" but "which cannot be clearly shown to have operated in the accident".

9 The following paragraphs address each of the ASC "probable cause" findings. The remaining findings, and other issues, are addressed elsewhere in the Singapore Team's comments.

10 **<u>ASC Finding 1:</u>** *At the time of the accident, heavy rain and strong winds from typhoon "Xangsane" prevailed and the wind direction was 020 degrees with a magnitude of 36 knots, gusting to 56 knots. RVR was 450 meters on Runway 05L.*

> **Singapore Team's Comment:** It is not clear how this finding relates to a 'probable cause' of the accident. The weather conditions on the night of the accident were a factor in the environment in which the accident occurred. They did not 'cause' the accident.
>
> Furthermore, the winds quoted in this ASC finding are not correct. These were not the wind speeds "at the time of the accident". The accident occurred at 15:17:17. The wind speeds and directions shown in the ASC finding were those which were broadcast on the ATIS at 15:12:02, four minutes 41 sec before the commencement of the takeoff.
>
> There were two further wind speed updates given to the crew of SQ 006 by ATC. The last wind direction and speed given to the crew when they were cleared for takeoff at 15:15:22 were 020 degrees with a magnitude of 28kts, gusting to 50kts. The crew based their decision to take off on the latest advice given to them by ATC. Table 1.7-1, of the ASC draft Final Report shows the wind directions and speeds recorded by the automated weather observation system for CKS Airport. At 23:15 (15:15 UTC) the wind was 029 degrees at 29.6 knots, at 23:16 (15:16 UTC) it was 013 degrees at 29.3kts, and at 23:17 (15:17 UTC) it was 360 degrees at 20.5kts. The ASC finding does not refer to this information, which indicates that very close to the time of the accident the winds were rapidly changing direction and in fact decreasing in strength.

Despite the fact they were varying, the weather conditions at the time of the accident were within the operational limits of the aircraft.

11 **<u>ASC Finding 2:</u>** *On August 31, 2000, CAA of ROC issued a Notice to Airman (NOTAM) A0606 indicating that a portion of the Runway 05R between Taxiway N4 and N5 was closed due to work in progress from September 13 to November 22, 2000. The flight crew of SQ 006 was aware of the fact that a portion of Runway 05R was closed, and that Runway 05R was only available for taxi.*

Singapore Team's Comment: It is not clear how his finding can be considered a 'probable cause'.

This ASC finding omits to mention the INTAM and the other NOTAM that were also provided to the crew of SQ 006 on the night of the accident. These documents gave no clear indication of the actual status of the runway markings, lighting and signage on runway 05R - for example, whether or not any work had been done in removing the runway markings from runway 05R (as stated in the INTAM) before the postponement of the redesignation of runway 05R to a taxiway, as *stated in NOTAM 0740*.

12 **<u>ASC Finding 3:</u>** *The aircraft did not completely pass the Runway 05R threshold marking area and continue to taxi towards Runway 05L for the scheduled takeoff. Instead, it entered Runway 05R and CM-1 commenced the takeoff roll. CM-2 and CM-3 agreed with CM-1's decision to take off.*

Singapore Team's Comment: This finding is misleading because it provides no information as to the context in which the crew made the turn onto, and commenced take-off on Runway 05R. The evidence shows that the crew of SQ 006 followed the continuous line of green taxiway centreline lights leading from Taxiway N1 onto Runway 05R. On lining up, they were presented with a picture of a brightly lit active runway.

In the absence of any indications at the Runway 05R threshold that the runway was closed, the crew of SQ 006 entered Runway 05R and commenced the take-off roll.

This finding also implies that a verbal statement of 'agreement' from CM-2 and CM-3 was required before take off. This was not the case. In accordance with established airline practices, if any member of the crew had not been comfortable with the take off decision, he would have spoken up, as the crew members indicated in their evidence to the investigation.

13 **<u>ASC Finding 4</u>***: The flight crew had CKS Airport charts available when taxiing from the parking bay to the departure runway. However, when the aircraft was turning from Taxiway NP to Taxiway N1 and continued turning onto Runway 05R, none of the flight crew verified their taxi route in*

accordance with the airport chart, which would have shown the need to make a 90 degree turn from Taxiway NP and then taxi straight ahead on Taxiway N1, rather than to make a continuous 180 degree turn onto Runway 05R. Further, none of the flight crewmembers confirmed orally whether the runway they entered was Runway 05L.

Singapore Team's Comment: This finding is misleading because it ignores the context in which the crew's actions took place.

The evidence shows that the crew of SQ 006 had navigated their way accurately to the end of taxiway NP using their Jeppesen airport charts. Having reached this point, and having received the take off clearance from ATC, the final stages of the taxi were carried out using the external visual cues offered by the taxiway and runway lighting. This manner of operation was in accordance with normal airline practice.

Foremost among these visual cues was the single continuous clear line of green lights that provided taxiway guidance. These green centreline lights formed a continuous pathway onto the runway. There was no alternative continuous line of lights to Runway 05L, as there would have been if CKS Airport had conformed to ICAO Annex 14 standards and recommended practices.

14 **ASC Finding 5:** *The flight crew did not build a mental picture of the taxi route to Runway 05L that included the need for the aircraft to pass Runway 05R before taxiing onto Runway 05L.*

Singapore Team's Comment: The existence or otherwise of an internalised 'mental model' is at best only a hypothesis. It therefore cannot be an unequivocal 'finding related to probable cause'. At best, such a hypothesis is a statement of probability.

This 'finding' is not supported by empirical evidence.

15 **ASC Finding 6:** *The moderate time pressure to take off before the inbound typhoon closed in around CKS Airport, and the high workload of taking off in a strong crosswind, low visibility, and slippery runway conditions subtly influenced the flight crew's decision-making and ability to maintain situational awareness.*

Singapore Team's comment: This finding is not supported by the evidence. In his evidence CM-1 reported that he 'felt no time pressure on the evening of the accident'. In addition CM-1 stated that '…if the winds had exceeded the company operating limits, he would have postponed the take-off''. It should be noted that the ASC draft Final Report also stated that the captain instructed the crew to 'take their time and to be careful with the checklists and procedures.'

In view of such evidence, this finding can neither be substantiated nor cited as a 'probable cause'.

The finding refers to the crew of SQ 006 being under ‘high workload’. This assertion is not supported by the evidence. The B747-400 is designed and certified to be operated by a two-man crew. The presence of CM-3 on the flight deck of SQ 006 provided an additional resource to the normal crew complement. By allocating the tasks of monitoring the weather and calculating the crosswind component during the taxi to CM-3, CM-1 was able to reduce the workload on CM-2 and himself.

16 **ASC Finding 7**: *On the night of the accident, the information available to the flight crew regarding the position of the aircraft was:*

- *CKS Airport navigation chart*
- *Aircraft heading indicators*
- *Runway and Taxiway signage and marking*
- *Taxiway N1 centreline lights leading to Runway 05L*
- *Colour of the centreline lights (green) on Runway 05R*
- *Runway 05R edge lights most probably not on*
- *Width difference between Runway 05L and Runway 05R, if the Runway 05R edge lights were on*
- *Lighting configuration differences between Runway 05L and Runway 05R*
- *Parallel Visual Display (PVD) showing aircraft not properly aligned with the Runway 05L localizer*
- *Primary Flight Display (PFD) information*

The flight crew did not comprehend the available information. They lost situational awareness and commenced takeoff from the wrong runway.

Singapore Team’s Comment: This finding presents a distorted picture of the situation in which the crew of SQ 006 were operating. This ‘probable cause’ finding only specifies sources of information which were available to the crew. It ignores the significant deficiencies in the information available to the crew of SQ 006.

The ASC draft Final Report identifies and provides a detailed description of these deficiencies at CKS Airport that did not meet the level of internationally accepted standards and recommended practices.

There were also no runway closed markings in the area where SQ 006 entered Runway 05R.

If these external visual warnings had been present, together with physical barriers to prevent aircraft entering Runway 05R from Taxiway N1, the crew would have had the requisite situational awareness to realise that they were on the wrong runway and the accident to SQ 006 would not have occurred.

Warning signs, markings, lights and physical barriers are defences to prevent human errors resulting in accidents. If such defences had been in place as they should have on the night of the accident, the crew of SQ 006 would have been alerted that they were entering the wrong runway. In addition, physical barriers would have made it impossible for the aircraft to commence its take-off on Runway 05R.

The absence of these essential warning signs, markings and physical barriers was the single most important factor which contributed to the accident. If the 'probable causes' format is to be retained in the ASC draft Final Report, these deficiencies should be highlighted as the major causal factor in the SQ 006 accident.

Detailed comments on ASC Finding 7 are as follows:

(a) CKS Airport navigation chart: The crew had the Jeppesen chart for the airport. However, there was no yellow page supplement which would have provided additional information on the works in progress on Runway 05R. The lack of such a supplement is not mentioned in the finding.

(b) Aircraft heading indicators: This information was available to, and used by the crew in accordance with normal procedures at the time of the accident. The crew's evidence states that: 'The aircraft heading was around 050 degrees on line-up, which was the expected direction for take-off…' (p. 143 of ASC draft Final Report). In other words, the crew of SQ 006 were aware that their heading was correct when they lined up.

It should be noted that the crew of SQ 006 navigated their aircraft accurately to the end of Taxiway NP. Beyond this final point of the taxi, the primary means of guidance from the taxiway onto the take-off runway were the external visual cues provided by the then runway and taxiway lighting, signage and markings. Using these cues, the aircraft lined up on the correct take-off heading, without realising that they were on the wrong runway.

(c) Runway and Taxiway signage and marking: The deficiencies associated with the runway and taxiway lighting, signage and marking are covered above. The central issue here is that, while these were a source of information to the crew, the ASC finding did not mention that they did not conform to international standards, and as a result, were seriously deficient – as described in ASC's 'findings related to risk'.

(d) Taxiway N1 centreline lights leading to Runway 05L: This finding does not mention the deficiencies in these lights. These are well described in ASC's "findings related to risk", which states: 'There should have been sixteen centreline lights spaced 7.5m apart along the straight segment of Taxiway N1 where the curved taxiway centreline markings from Taxiway NP meets Taxiway N1 up to the Runway 05L holding position, rather than the four centreline lights spaced at 30m, 55m, 116m and 138m.' The fact that there were only four lights, not all of which were serviceable, meant that there was no alternative line of lights to those leading onto Runway 05R. There was only one visible path – there was no 'fork in the road', as there had been earlier in the taxi.

(e) Colour of the centreline lights (green) on Runway 05R: Even though these lights were green, the factual evidence shows that the crew perceived them as just 'centreline lights'. This perception confirmed their expectation that they were lined up on an active runway.

To illustrate, CM-1 stated in his evidence that 'as the aircraft was lining up the image before him was that of a runway. He reported that he could see the centreline light running down the runway.' In his evidence, CM-2 said: 'The runway picture was correct. He recalled seeing lights down the middle of the runway and they were very bright.... He further stated that the visual cues indicated that the aircraft was on an active runway.'

(f) Runway 05R edge lights most probably not on: This finding is not supported by the factual evidence. The evidence of CM-1, together with the analysis of recorded ATC communications, as well as data from the metallurgical tests carried out on runway edge light wires, indicate that the Runway 05R edge lights probably were illuminated at the time of the accident.

(g) Width difference between Runway 05L and Runway 05R, if the Runway 05R edge lights were on: Pilots do not have an expectation of runway width as a primary visual cue to identify runways, as they operate to airports world wide which have runways of differing widths. Of more critical importance is that if the Runway 05R edge lights were on, a possibility which is acknowledged in this ASC finding, and which is supported by the factual evidence, it would have indicated an active runway, as noted in the Singapore Team's comments above.

(h) Lighting configuration differences between Runway 05L and Runway 05R: Both Runway 05R and 05L had centreline lights. The captain selected Runway 05L because it was a Cat II runway. Cat II runways have centreline lights, so he would have been expecting to line up on a runway with centreline lights, as opposed to Runway 06, which was the normal runway used by SIA. Runway 06 has no centreline lights. On lining up on Runway 05R, the bright centreline lights confirmed his belief that the aircraft had lined up on the correct runway.

(i) Para-Visual Display (PVD) showing aircraft not properly aligned with the Runway 05L localizer: This statement is misleading as it implies that the PVD will at all times 'show' aircraft alignment with the runway localiser. This is not the case.

In the case of SQ 006, the PVD remained shuttered. Consequently, there was no display showing a displacement from the localiser. This could have been a possible cue to the crew regarding the position of the aircraft.

However, as the aircraft lined up on Runway 05R, the crew saw an active runway ahead of the aircraft, as they had expected. Airline pilots are trained to always regard external visual cues as their primary source of information for takeoff. Consequently, this compelling external visual cue of the runway took priority in the captain's decision to commence the take-off. This is shown by the CVR evidence.

(j) Primary Flight Display (PFD) information: As stated in the ASC draft Final Report, 'pilots routinely use the ILS localiser indicator and the rising runway symbol on the PFD as a runway alignment reference during landing. This could have been a cue to the crew regarding the position of the aircraft. However, there were no procedural requirements for the flight crew to check these indications before take-off.'

17 **<u>ASC statement below its Finding 7</u>** *"The flight crew did not comprehend the available information. They lost situational awareness and commenced takeoff from the wrong runway."*

This statement, appearing as a summary statement at the end of the section on findings related to probable causes, implies that the pilots were totally to blame for the accident. The finding specifies the various sources of information available to the pilots, but omits to also point out that these sources of information were for the most part deficient.

Maintenance of situational awareness by flight crew is dependent upon the quality of information on which it is based. Good quality information is the foundation of accurate situational awareness – what has been termed the 'first level' of situational awareness (Endsley, 1995). If this information is not available, or is difficult to detect or perceive, or if it is misperceived, the situational awareness of a crew may not correspond to their actual situation.

In the case of SQ 006 the primary information upon which the crew was relying for situational awareness was defective – for example, the runway lighting, signage and markings. On lining up on Runway 05R, they firmly believed they were on Runway 05L. The CVR confirms this.

The statement by the ASC that *"The flight crew did not comprehend the available information. They lost situational awareness and commenced takeoff from the wrong runway."* is not correct. The evidence shows that the crew of SQ 006 did comprehend the information available to them, and based their situational awareness on this information. Unfortunately, the information available to them was flawed resulting in their comprehension being flawed without their knowledge.

The summary statement of this particular finding implies blame, contrary to the provisions of Annex 13.

Summary comments on the ASC "findings related to probable causes"

18 The ASC draft Final Report does not portray the accident as a failure of the aviation system, rather it is being portrayed as a failure of the crew. In its executive summary, the ASC states that '…the purpose of the investigation report is to enhance aviation safety and not to apportion blame and responsibility…'

19 However, the overall format of the Conclusions section and the content of the ASC 'findings related to probable causes' are so flawed that this objective has not been achieved.

<u>Part 3</u>

Comments by the Singapore Ministry of Transport Investigation Team on Sections 3.2 and 3.3 of ASC draft Final Report entitled ‘Findings Related to Risk’ and ‘Other Finding’

ASC draft Final Report	Singapore Team's Comments
3.2 Findings Related to Risk 1. The local controller did not issue progressive taxi/ground movement instructions and did not use the low visibility taxi phraseology to inform the flight crew to slow down during taxi.	Should amend as follows: "The local controller did not issue progressive taxi/ground movement instructions *"in accordance with CKS ATC SOPs",* and did not use the low visibility taxi phraseology to inform the flight crew to slow down during taxi.
2. The flight crew did not request progressive taxi movement instructions from Air Traffic Controller (ATC).	The flight crew did not make such a request as they are not required to do so by any international standards. The only time a flight crew would make such a request is when they are uncertain of their position. This was not the case in the SQ 006 accident. At all times the crew believed that they knew where they were. At the end of Taxiway NP they were misled by the external visual cues before them, and entered the wrong runway. This finding should be deleted.
3. Reduced visibility in darkness and heavy rain diminished, but did not preclude, the flight crew's ability to see the taxiway and runway lighting, markings, and signage.	The phrase "did not preclude" is superfluous and should be deleted. In addition, the finding should also point out that the lighting, signage and markings did not conform to international standards. Notwithstanding this fact, this finding is speculative and not supported by any factual or empirical evidence and should be deleted.
4. The SIA crosswind limitation for a "wet" runway was 30 knots and for a "contaminated" runway was 15 knots. CM-1 assessed that the runway condition was "wet" at the time he prepared for takeoff and determined that the crosswind was within company limitations. The lack of SIA and ATC procedures for quantitatively determining a "wet" versus "contaminated" runway creates ambiguity for flight crew when evaluating takeoff crosswind limitations.	There was no evidence from the crew interviews or the CVR that the crew had any ambiguity about the condition of the runway. This finding is irrelevant to the accident and should be deleted. The correct criteria for determining whether a runway is "wet" or "contaminated" is an industry wide issue and should be addressed through the appropriate forum such as ICAO or IATA.

ASC Draft Final Report	Singapore Team's Comments
5. There was no procedure described in the SIA B747-400 Operations Manual for low visibility taxi operations.	Guidance information on low visibility taxi operations is provided in the SIA Flight Crew Training Manual, which is a part of the SIA B747-400 Operations Manual. This finding should be deleted.
6. There was no formal training provided to SIA B747-400 pilots for low visibility taxi techniques.	There is no evidence that this was a 'risk factor' in the accident. This finding is based on incorrect understanding of airline training. A captain who is qualified and current in Cat III operations would have received training in low visibility taxiing techniques as part of his training package. Taxiing the aircraft in low visibility is part and parcel of the overall training package for low visibility operations. However, taxiing in low visibility conditions was, and continues to be, a normal part of an SIA pilot's introduction to training in low visibility operations. The CVR evidence shows that the crew was taxiing the aircraft in a manner appropriate to the visibility conditions.
7. The SIA SOP did not assign specific duties to the third flight crewmember, although CM-1 requested the third pilot to verify crosswind limitations during taxi.	This finding is unrelated to risk. The B747 is designed and certified for operation by two pilots. If a third crew member is present, it is for the captain to decide what duties may be allocated to the third crew member according to the operational circumstances at the time.
8. It was possible that CM-1 inadvertently reverted to the most dominant previously formed mental model under high workload to follow the green taxiway centerline lights, which generally takes him to where he is supposed to go, and he reverted to this habit while turning from NP onto Runway 05R.	There is no evidence to support this dominant 'mental model' hypothesis. Unless there is such evidence, this 'finding' is only an opinion and is speculative. In the absence of empirical evidence, it should therefore be withdrawn. In the context of the ASC draft Final Report, the "dominant previously formed mental model … to follow the green centerline lights" refers to the "follow the greens (i.e. green taxiway centreline lights)" system at Singapore Changi Airport.

ASC Draft Final Report	Singapore Team's Comments
	Reference to SIA crew rosters shows that the majority of take-offs conducted by SIA B747 pilots takes place at airports other than Singapore Changi Airport. Of these other airports, only approximately 10% of them has a 'follow the greens' system similar to Singapore Changi Airport. Consequently, SIA pilots do not taxi using a 'follow the greens' taxiway lighting system with sufficient frequency for it to become a 'dominant' mental model.
9. SIA did not have a procedure for the pilots to use the PVD as a tool for confirming the correct runway for takeoff in low visibility conditions such as existed for the operation of SQ 006 on the night of the accident.	The PVD was not designed to be a device for identifying runways or the runway threshold. The PVD is used primarily as a reversionary aid to assist pilots to maintain the runway centerline when they conduct take-offs. The PVD will un-shutter anywhere along the runway within the capture zone of the ILS localizer. It will therefore operate at any point along the runway. For this reason it cannot be used to positively identify the position of the runway threshold. This finding is invalid, as any procedure for the pilots to use the PVD as a tool for confirming the correct runway for take off in low visibility conditions would be contrary to the design and approval of the PVD system. This finding should be deleted.
10. SIA procedures and training documentation did not reflect the Civil Aviation Authority of Singapore (CAAS) approved B-747-400 AFM supplement regarding use of the PVD for correct runway identification.	The CAAS did not approve the use of the PVD as a means of runway identification. This is outside the scope for which the PVD system was designed by the system manufacturer or as flight tested by the airframe manufacturer. From a safety standpoint, it would be improper for any regulator to insist on procedures and training documentation which are outside the scope of system design and approvals. Furthermore, the AFM supplement regarding the PVD does not contain the words "correct runway identification". This finding is based on an incorrect interpretation of the AFM supplement. This finding should be deleted.
11. CAAS oversight of SIA operations and training did not ensure	The PVD is not a mandatory instrument, and is not designed

ASC Draft Final Report	Singapore Team's Comments
that the approved B747-400 AFM supplement regarding use of the PVD for correct runway identification was incorporated into the SIA documentation and operational practices.	for runway identification. Many airlines do not equip their aircraft with PVD. It is designed and certified to aid runway centreline steering and is only to be used for takeoff on a Cat III runway. Accordingly, the approved B747-400 Airplane Flight Manual (AFM) supplement contains instructions on PVD use for runway centreline steering and does not deal with PVD use for runway identification. The primary means for runway identification are the pilots' normal visual cues. The approved B747-400 AFM supplement is incorporated into the SIA documentation and operational practices. Since the PVD is not for runway identification, the issue of CAAS safety oversight of SIA's PVD operations and training on the use of the PVD for runway identification does not arise and is irrelevant. This finding is based on a misinterpretation of the purpose of the PVD and the provisions of the approved B747-400 AFM supplement on the PVD. Accordingly, this finding should be deleted.
12. At the time of the accident, SIA's Aircraft Operations Manual did not include "confirm active runway check" as a before takeoff procedure.	Singapore agrees with this finding, however it needs to be amplified to place it in the correct context. With the benefit of hindsight, subsequent to this accident, it is clearly good practice to have a procedure for positive runway identification. At the time of the accident to SQ 006, the fact that this was not common practice within the aviation industry should be noted in the finding.
13. The deficiencies in SIA training and procedures for low visibility taxi operations precluded the flight crew from possessing the appropriate level of knowledge and skills to accurately navigate the aircraft on the ground.	There is no empirical evidence to indicate such systemic deficiencies. Such evidence could only be obtained by determining whether SIA had any history of air safety incidents connected with low visibility operations. Unless there is valid evidence to sustain this finding, it must be withdrawn and deleted.
14. CAAS had not performed sufficient safety oversight of SIA's procedures and training. Therefore, the deficiencies in SIA	The Singapore Team disagrees with the finding. This is sweeping statement and not based on empirical evidence.

ASC Draft Final Report	Singapore Team's Comments
procedures and training were not discovered during routine CAAS safety oversight.	In referring to section 2.5.11 of the draft Final Report, it would appear that this finding is referring to "inadequate SIA flight crew procedures and training on the PVD that did not reflect the CAAS approved B747-400 PVD supplement and insufficient flight crew training in low visibility taxi procedures and practices." Regarding the PVD procedures and training, as mentioned in the Singapore Team's comments on Finding No. 11 above, the PVD is not for runway identification and the CAAS approved B747-400 PVD supplement therefore does not deal with runway identification. Hence, it was not a deficiency that SIA's PVD procedures and training did not include the use of the PVD for runway identification. It would have been improper for CAAS to approve procedures and training for use of equipment which is outside the scope of the equipment design. Regarding training in low visibility taxiing, as noted in MOT's earlier response to the ASC's preliminary draft report, MOT has explained that there is no specific formal training for taxiing in low visibility. Taxiing is part of basic airmanship. Throughout their career, flight crews undergo various training courses and taxiing is part and parcel of such training. Taxiing skills are further reinforced in the course of their flying experience when they operate to different airports in all sorts of weather conditions. There are no International Civil Aviation Organisation Standards and Recommended Practices (ICAO SARPs) or internationally agreed norms on the level and amount of flight crew training in low visibility taxi procedures and practices. There is no basis to conclude that there were deficiencies on SIA's flight crew training and procedures on the use of the PVD and low visibility taxiing.

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	Consequently, the finding that deficiencies in SIA's procedures and training were not discovered during routine CAAS safety oversight is incorrect and this finding should be removed.
15. The preponderance of evidence indicates that the Runway 05R edge lights were most probably not illuminated during the attempted takeoff of SQ 006.	This finding is not valid as it cannot be determined conclusively whether the Runway 05R edge lights were on or off. This finding should be deleted.
16. At the time of the accident, there were a number of items of CKS Airport infrastructure that did not meet the level of internationally accepted standards and recommended practices. Appropriate attention given to these items would have enhanced the situation awareness of the SQ 006 flight crew while taxiing to Runway 05L for takeoff. However, the absence of these enhancements was not deemed sufficient to have caused the loss of situational awareness of the flight crew. Among these items were:	The manner in which the airport deficiencies are listed as bullet points within a single finding diminishes the critical importance of these factors. These CKS Airport factors are so critical to the accident that they should be listed separately as individual findings in the 'findings related to probable causes'. (However, please note Singapore Team's comments regarding classification of findings. These are at Part 2 of the Singapore Team's comments on the ASC draft Final Report). The lack of any barriers at the threshold to prevent take-off, which on its own would have been sufficient to prevent the accident, is not even mentioned in the findings. These "infrastructure deficiencies" cannot be relegated to the level of mere "enhancements". They are the ICAO standard requirements for international airports. The crew did not perceive that they had lost situational awareness when entering Taxiway N1. Their situational awareness from this point was based upon the information available to them, and this information was flawed. It was only at this stage that the crew's situational awareness did not correspond to their actual situation.
• Four days after the accident, the investigation team found the green centerline light immediately after the Runway 05R entry point along Taxiway N1 leading to Runway 05L un-serviceable and the following light was	This should be a 'finding related to probable cause'. It is highly improbable that these two lights only became dim or unserviceable in the short span of time between the time of the accident and the evening of 4 November 2000. For most of this

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dim. It could not be determined what the status of those lights was on the night of the accident.	period of time the lights were switched off. Comment: --The fact that these lights were not inspected by the investigation team until four days after the accident is a serious deficiency in the investigation process. It was clear soon after the accident that the aircraft had commenced take-off on Runway 05R. Consequently, the determination of the visual cues available to the pilots should have been a top priority in the investigation. A four-day delay in obtaining such critical information is unacceptable in a major investigation.
• The green centerline lights leading from Taxiway NP onto Runway 05R were more visible than the Taxiway N1 centerline lights leading toward Runway 05L because they were more densely spaced. There should have been 16 centerline lights spaced 7.5m apart along the straight segment of Taxiway N1 where the curved Taxiway centerline markings from Taxiway NP meets Taxiway N1 up to the Runway 05L holding position, rather than the 4 centerline lights spaced at 30m, 55m, 116m, and 138m.	The absence of a visible line of lights leading to Runway 05L is a fundamental reason why the crew turned on to Runway 05R. Therefore, this finding should be highlighted as a "finding related to probable cause".
• Segments of the straight portion of the taxiway centerline marking on Taxiway N1 did not extend all the way down to the Runway 05L threshold markings with interruption stops 12 meters to and from the Runway 05R threshold markings.	The taxiway centerline markings were not compliant with ICAO Standards and Recommended Practices (SARPs). This non-compliance should be stated as an individual finding, rather than as a bullet point within a finding. It should be listed as a 'finding related to probable cause'.
• Runway guard lights and stop bars were not provided at CKS Airport.	The lack of runway guard lights and stop bars lights meant that CKS Airport did not comply with ICAO SARPs. This non-compliance should be stated as an individual finding, rather than as a bullet point within a finding. It should be listed as a 'finding related to probable cause'.
• Alternate green/yellow taxiway centerline lights to demarcate the limits of the ILS sensitive area were not installed.	This situation was not compliant with ICAO SARPs. This non-compliance should be stated as an individual finding, rather than as a bullet point within a finding. It should be listed

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	as a 'finding related to probable cause'.
• The mandatory guidance signs installed on the left and right sides of Taxiway N1 were located after the holding position for Runway 05L and not collocated with runway holding position marking.	This situation was not compliant with ICAO SARPs. This non compliance should be stated as an individual finding, rather than as a bullet point within a finding. It should be listed as a 'finding related to probable cause'.
• Although the flight crew was aware that Runway 05R was closed, there were no runway-closed markings in the area where SQ 006 entered Runway 05R. • Although the construction equipment located on the closed portion of Runway 05R was protected by barriers and marked with lights, the lights were not visible from the takeoff threshold of Runway 05R.	Both of these findings are fundamental to an understanding of the accident. As the crew lined up on Runway 05R, there was nothing to indicate to them that they were on the wrong runway, or to physically prevent them from commencing taking off. Runway-closed markings and lights warning of obstacles on the runway would have been among the critical defences which could have on their own prevented the accident. Their absence contributed to the accident. They fall into the category of deeper systemic causes. These two findings should be listed separately in the 'findings related to probable causes'.
• There was no interlocking system installed at CKS Airport to preclude the possibility of simultaneous operation of the runway lighting and the taxiway centerline lighting.	
• There was a lack of a monitoring feature of individual lights, or percentage of unserviceable lamps, for any circuit for CKS Airport lighting.	
• ASDE is designed to reduce the risk of airport ground operations in low visibility. There is no requirement for installation of Airport Surface Detection Equipment (ASDE) at CKS Airport. The Safety Council was not able to determine whether ASDE would have provided information to the ATC controllers about SQ 006 taxiing onto the incorrect runway because of attenuation of the signal from heavy precipitation that diminishes the	

ASC Draft Final Report	Singapore Team's Comments
effectiveness of the radar presentation.	
17. There is ambiguity in ICAO Annex 14 Standards and Recommended Practices (SARPs) regarding a temporarily closed runway because the term "short term" is not defined.	This finding is not relevant to the accident, because Runway 05R was to be permanently re-designated as a taxiway. There was no intention ever to re-open it as a runway. Further, whether the closure was temporary or permanent was irrelevant because markings and barriers should have been present to indicate that Runway 05R was closed and to physically prevent aircraft attempting to use it for take-off.
18. There was a lack of a specified safety regulation monitoring organization and mechanism within CAA that permitted conditions to exist at CKS Airport for taxiways and runways lightings, markings, and signage that did not meet internationally accepted safety standards and practices.	That the taxiway and runway lightings, markings, and signage did not meet internationally accepted safety standards and practices were deeper systemic factors which contributed to this accident. This should be a finding related to probable cause.
19. There was a lack of a safety oversight mechanism within CAA that could have provided an independent audit/assessment of CKS Airport to ensure that its facilities met internationally accepted safety standards and practices.	That the CKS Airport facilities did not meet internationally accepted safety standards and practices were deeper systemic factors which contributed to this accident. This should be a finding related to probable cause.
20. CAA had not formed a working group for the derivation of a complete Surface Movement Guidance and Control System (SMGCS) plan according to guidance provided by ICAO Annex 14.	
21. Being a non-contracting State, the CAA of ROC does not have the opportunity to join ICAO and participate in the activities in developing its airport safety enhancement programs to correspond with international safety standards and recommended practices.	Non-participation in ICAO activities does not preclude any airport operator from complying with and implementing ICAO Standards and Recommended Practices or to put in place airport safety enhancement programmes to correspond with international safety standards and recommended practices. ICAO documentation is catalogued on its website. It is readily available to any interested party.
22. The SIA typhoon procedure was not well defined and the personnel who were obliged to use the procedures did not fully understand the procedures and their responsibilities.	The aircraft did not take off in typhoon conditions. The SIA typhoon procedures were irrelevant to the accident. This finding should be deleted.
23. The main deck mid cabin from row 31 to 48 was not	

ASC Draft Final Report	Singapore Team's Comments
survivable during this accident due to fuel tank fire and explosion. Sixty-four out of 76 passengers died in this area. All passengers in tail section survived due to much less fire damage.	
24. The circumstances of the SQ 006 accident, involving severe impact forces induced damage and rapidly spreading fire and smoke, rendered much of the existing emergency evacuation training, hardware, and procedures ineffective.	
25. The crewmembers did not use alternative methods to order the emergency evacuation when Public Announcement (PA) system was found inoperative.	The accident was catastrophic, and in this situation the cabin crew were required to use their initiative, as prescribed in the SIA Aircraft Safety and Equipment Procedures manual. When the cabin crew did not hear an evacuation command from the Captain, they used the alternative method of initiating evacuation by shouting to passengers to evacuate, in accordance with the ASEP.
26. During evacuation training, the flight crew did not play their role as a commander to initiate the evacuation.	This has no relevance to the accident. It should not be a finding and should be removed.
27. Some of the crewmembers did not execute SIA's evacuation procedures during the evacuation.	The accident was catastrophic. The SQ 006 crew executed those ASEP procedures that were possible in the extreme circumstances of the accident. In this situation the cabin crew were required to use their initiative, as prescribed in the SIA Aircraft Safety and Equipment Procedures manual, which they did.
28. An Upper Deck Left (UDL) cabin crewmember was hampered in her movement during the emergency evacuation because she lost her sandals.	There is no evidence that the cabin crew member who lost her sandals was hampered in her movement during the emergency evacuation. This finding should be removed.
29. During the evacuation in dark conditions, only CM-3, CM-2, and 5L crewmembers carried flashlights. The 5L cabin crewmember used the flashlight to assist during the passenger evacuation. No megaphone was used.	It is not clear why this is a "finding related to risk". In the immediate aftermath of an accident such as this, when the aircraft came to rest, broken in two and on fire, it is not surprising that some crew members were unable to locate their safety equipment. The fact that some crew members were able to do so suggests that their training and the procedures were effective. Furthermore, there is no direct evidence that

ASC Draft Final Report	Singapore Team’s Comments
	this caused any delay in the evacuation. This finding should be deleted.
30. The dense smoke made breathing difficult and the emergency lights less visible for the survivors during the evacuation.	This finding should be expanded to include the non-use of breathing apparatus by the ARFF.
31. CKS Airport did not prescribe in detail the emergency medical treatment procedures and the responsibilities of a medical coordinator or the interim coordinator in accordance with the ICAO recommendations.	
32. CKS Airport did not provide contingency procedures for medical treatment and rescue in adverse weather conditions in accordance with the ICAO recommendations.	
33. The “CKS Airport Civil Aircraft Accident Handling Procedures and Regulations” contained no specific features such as neurosurgical ability or burn treatment of hospitals in accordance with the ICAO recommendations.	
34. There was no information of high wind effect to the slide operation in relevant manual from the manufacturer for the operators’ reference to prepare for a suitable response during high wind operation.	
35. The lateral G forces associated with the accident produced an unexpected self-inflation of the 4R and 5R slides in cabin.	
36. The fire-fighting department was understaffed in handling a major accident.	

ASC Draft Final Report	MOT Comments
3.3 Other Findings 1. The flight crew were properly certificated and qualified in accordance with the applicable CAAS regulations and SIA Company requirements, and ICAO SARPs.	
2. The flight crew were provided with appropriate and complete dispatch documents, including weather, weight and balance information, NOTAMs and SIA INTAMs in accordance with the established procedures.	As no yellow Jeppesen airport plan had been issued, CKS Airport should have provided an airport plan suitably annotated showing works in progress so that crews would be fully briefed on the airfield situation.
3. The cabin crew was qualified in accordance with the SIA training program.	
4. Crew duty time, flight time, rest time, and off duty activity patterns did not indicate influence of pre-existing medical, behavioral, or physiological factors of flight crew's performance on the day of the accident.	
5. The air traffic controllers involved with the control of SQ 006 were properly certificated, and qualified to perform their duties.	This finding does not accord with the factual information. However, the Singapore Team acknowledges that the lack of a current medical certificate for a controller was not causal to the accident.
6. The aircraft was certificated, equipped, and maintained in accordance with CAAS regulations and approved procedures, and ICAO SARPs. There was no evidence of pre-existing mechanical malfunctions or other failures of the aircraft structure, flight control systems, or power plants that could have contributed to the accident. The accident aircraft was considered airworthy before the accident.	
7. There was no evidence to indicate that there was any undue organizational pressure from SIA placed upon the flight crew to take off the evening of the accident.	
8. The Jeppesen charts used by the flight crew were current at the time of the accident.	
9. The taxi check and procedures used by the SQ 006 flight crew were in accordance with the SIA B747-400 Operations Manual.	

ASC Draft Final Report	MOT Comments
10. ATC taxi instructions and the takeoff clearance did not mislead the flight crew to take off from the partially closed Runway 05R. SQ 006 was cleared for takeoff on Runway 05L and the flight crew confirmed the clearance before takeoff.	Agreed, however the ATC taxi instructions did not include reference to Taxiway N1 and the crossing of Runway 05R. The timing of the clearance could have given the crew the impression that the next active runway was 05L.
11. It was appropriate for the flight crew to consider Runway 05L for takeoff the evening of the accident.	
12. The fatality rate of this accident was 46%. The serious injury rate was 22%. The minor injury rate was 18%. The no injury rate was 14%.	
13. No slides were fully functional for survivors' evacuation in this accident because of impact forces, fire, and strong wind effects.	
14. The Department of Forensic Pathology conducted a total of 7 autopsies. Out of the 7 autopsies conducted, 6 died from severe burns and one died from impact injuries.	
15. There was no alcohol and drug testing of the three flight crewmembers of SQ 006 after the accident.	ATC personnel were also not tested for alcohol and drugs. The finding should include that ATC personnel were also not tested.
16. Airport Rescue and Fire Fighting (ARFF) personnel arrived at the accident site approximately in 3 minutes and began its fire fighting and rescue efforts. A small fire at tail section was put out immediately. In conditions of severe weather, the fire at forward and mid-section fuselage was suppressed in 15 minutes and positively controlled in 40 minutes.	
17. All fire and medical people used the same frequency to communicate in this accident.	
18. The majority of the CKS Airport medical and rescue operations were not able to function in accordance with CAA regulations and procedures because of very strong wind and heavy rain emanating from approaching typhoon "Xangsane".	
19. The first 10 survivors were sent to hospital by airport's ambulances directly without proper triage procedure.	

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20. The Ministry of Transportation and Communications (MOTC) staff was not proactive in supporting CAA's requests for the installation of ASDE at CKS Airport.	
21. All new regulations of CAA are subject to lengthy formalities of legitimating approval by MOTC.	
22. Although the SQ 006 CVR power-on and power-off times were in compliance with ICAO SARPs and CAAS regulations, the Federal Aviation Regulations (FARs) and Joint Aviation Regulations (JARs) require an earlier power-on and later power-off times. An earlier power-on time and later power-off time would be desirable for examination of operational and human factors safety issues following accidents and incidents.	
23. Singapore does not have an independent aviation accident investigation authority charged with making objective investigations, conclusions, and recommendations. International experience has shown that an independent investigation authority is a benefit to aviation safety, and many States have taken actions to ensure that investigations are conducted by a government agency that is functionally independent of the authority responsible for regulation and oversight of the aviation system.	The recommendation is irrelevant and inappropriate, as Singapore is not the State leading the SQ 006 investigation. In any accident investigation, recommendations should be based upon factual evidence gathered during the investigation and the analysis of that evidence. While the recommendation that Singapore should consider establishing an independent accident/incident investigation organisation appears in the ASC draft Final Report, there is no evidence or analysis contained in the draft Final Report to either support or justify the recommendation. For example, there is no evidence that there has been any problem with the present administrative arrangement concerning the participation by Singapore in the SQ 006 investigation. Under these arrangements, the Minister for Transport (previously MCIT) appointed an independent investigation team reporting directly to him. The team is made up of investigators from the CAAS, Ministry of Defence, National University of Singapore, and other organisations. In addition, the Minister appointed three international specialist consultants through the International Civil Aviation

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	Organisation (ICAO). The Singapore Team perates completely independent of the aviation regulatory authority. These arrangements are fully in accordance with the Convention on International Civil Aviation. It should also be noted that not many countries have a fully independent, permanent stand-alone air safety investigation organisation. The recommendation should be withdrawn.

Part 4

Comments by the Singapore Ministry of Transport Investigation Team on Section 4 'Safety Recommendations' of ASC Draft Final Report

General Comment: When action has been taken on a particular issue, this should be described in the Safety Actions section of the Final Report. There is no need to make recommendations if action has been, or is being taken, because the recommendation is then redundant. Examples of this redundancy are recommendations to SIA, numbers 1, 2, 5, 6, 8, 10 and 11. Similar examples can be found concerning recommendations to the CAA ROC.

ASC Draft Final Report	MOT Comments
Safety Recommendations In this chapter, safety recommendations derived as the result of this investigation are listed in 4.1. Safety actions taken, or currently undertaking by both SIA and CAA, ROC are listed in 4.2. It should be noted that those safety actions have not been verified by the Safety Council	
Recommendations **To Singapore Airlines (SIA)** The Safety Council recommends that SIA: 1. Develop and implement a comprehensive surface-movement training program that reflects the current practice in this area, such as the recommendations contained in the FAA's National Blueprint for Runway Safety and FAA Advisory Circular No. 120-74. (3.1-[3~7]; 3.2-[5, 6, 12])	The FAA National Blueprint for Runway Safety was published in October 2000. FAA AC 120-74 was issued in June 2001. SIA is reviewing these documents with a view to incorporating useful practices and procedures into SIA's training programme. This information on SIA's actions should be included in 'Safety Actions' in the Final Report. This recommendation should be withdrawn.

ASC Draft Final Report	MOT Comments
2. Ensure that procedures for low visibility taxi operations include the need for requesting progressive taxi instructions to aid in correct airport surface movement. (3.2-[1, 2])	This recommendation should be withdrawn. Flight crew were not, at the time of the accident, required to request progressive taxi instructions by any international standards. This procedure is currently being reviewed by SIA, and should be included in 'Safety Actions'. See also our comments on recommendations to CAAS number 1.
3. Review the adequacy of current SIA PVD training and procedures and ensure that SIA documentation and operational practices reflect the CAAS approved B747-400 AFM PVD supplement, which included the use of the PVD to verify the correct departure runway. (3.2-[9, 10])	This recommendation is based on a false premise. The approved AFM PVD supplement does not and should not include the use of the PVD to verify the correct departure runway. The PVD is not designed for runway identification, but for runway centreline steering. It is unnecessary to review SIA training and procedures for a use of the PVD that is outside the scope of the PVD design and certification, and for which it would have been improper for CAAS to so certify. This recommendation should be withdrawn.
4. Develop and implement a clear policy that ensures that flight crews consider the implications of the PFD, and PVD indications whenever the instruments are activated, particularly before commencing takeoff in reduced visibility conditions. (3.1-[7])	This recommendation should include reference to all relevant instruments, not only the PFD and PVD.
5. Include in all company pre-takeoff checklists an item formally requiring positive visual identification and confirmation of the correct takeoff runway. (3.1-[7], 3.2-[12])	This has been done by SIA, and should be included in 'Safety Actions'. This action by SIA should be included in the 'Safety Action' section of the Final Report and this recommendation should be withdrawn.
6. Implement an Advanced Crew Resource Management program to reflect current practices in this area, and ensure that such programs are regularly revised to reflect new developments in CRM. (3.2-[7])	This has been done by SIA, and should be included in 'Safety Actions'. This action by SIA should be included in the 'Safety

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	Action' section of the Final Report and this recommendation should be withdrawn.
7. Review the adequacy of current runway condition determination procedures and practices for determining a water-affected runway to "wet" or "contaminated" in heavy rain situations, by providing objective criteria for such determinations. (3.2-[4])	This recommendation addresses a broader industry issue and should be followed up through the appropriate international aviation organisations such as ICAO and IATA, and not through an individual airline.
8. Conduct a procedural audit to eliminate existing conflicts in the guidance and procedures between the company manuals, the managers' expectations, and the actual practices, such as those contained in the Typhoon Procedures and dispatch briefing policy. (3.2-[22])	SIA's Typhoon Procedures had no bearing on the accident. However, they are under review, and consequently this information should be included in 'Safety Actions'. This recommendation should be withdrawn.
9. Modify the emergency procedures to establish an alternate method for initiating the emergency evacuation command in the event of a PA system malfunction. (3.2-[24, 25])	The SIA procedures already allow for alternate methods to initiate the emergency evacuation command in the event of a PA system malfunction. These procedures were used by the crew of SQ006. An issue in the SQ006 accident was the failure of the PA system, something which has occurred in other accidents involving the B747. It is an industry issue and should be addressed through ICAO and IATA.
10. Reevaluate its procedure and training for the crew to effectively handle diversified emergency situations. (3.2-[24, 25, 26, 27])	SIA trains crew to industry standards. However, no training can simulate the extreme conditions faced by the crew of SQ006 following the accident, a point acknowledged by the ASC. There was no evidence that there were deficiencies in SIA training or emergency procedures. Nevertheless following the accident SIA has reviewed its emergency procedures and training to determine what lessons can be learned from the accident. The actions by SIA should be included in the 'Safety

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	Action' section of the Final Report, and the recommendation withdrawn.
11. Redesign the footwear and skirts of the female cabin crew (that were used at the time of the accident) to provide better protection and maneuverability during emergency evacuations. (3.2-[28])	The redesign of the cabin crew footwear was initiated in 1999 and has since been introduced. This information should be included in the 'Safety Actions' section of the Final Report. There is no evidence that the design of the skirts of the female cabin crew restricted the movement of cabin crew during the evacuation. This recommendation should be withdrawn.
To Civil Aviation Authority of Singapore (CAAS) The Safety Council recommends that the CAAS: 1. Require SIA to develop and implement a comprehensive surface-movement training program, to include a procedure to request progressive taxi instructions during low visibility ground operations. (3.1-[3~7]; 3.2-[5, 6, 13])	SIA has an existing training programme in low visibility operations. The SIA FCTM contains the training procedures and provides appropriate guidelines for low visibility operations. Flight crews are not required to request progressive taxi instructions during low visibility ground operations by any international standards. In conditions of low visibility at airports, it is the Air Traffic Controllers who implement progressive taxi instructions. It is not a flight crew responsibility to request progressive taxi instructions, unless the crew are uncertain of their position. (See, for example, para 5g.(4) of FAA AC 120-74 which was issued on 18 June 2001, well after the SQ 006 accident.) In an extreme case, a pilot may request a 'follow me' vehicle to provide guidance. The recommendation states that there should be a procedure that would require all pilots to request progressive taxi instructions in conditions of low visibility

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	at airports. Such a situation would be operationally impractical. For example, the additional reporting requirements would slow down traffic flow and impede radio communications between aircraft and ATC due to frequency congestion. In addition, the recommendation is not supported by factual evidence from the investigation. At no stage were the crew of SQ006 uncertain of their position. There was no necessity for them to request progressive instructions. However, the CKS Airport ATC SOPs did require the implementation of 'progressive taxi/ground movement instructions' whenever the aircraft could not be seen from the control tower. These procedures were not implemented by CKS ATC in the case of SQ006. This recommendation should be withdrawn.
2. Review the adequacy of current SIA PVD training and practices and ensure that SIA procedural and training documentation and operational practices reflect the CAAS approved B747-400 AFM PVD supplement. (3.2-[9, 10])	This recommendation is not supported by factual evidence from the investigation. SIA procedural and training documentation and operational practices do reflect the CAAS approved B747-400 AFM PVD supplement. The PVD is designed and certified to aid runway centreline steering, not to identify a runway. It should be noted that the CAAS approved B747 AFM PVD supplement does not include the use of the PVD as a runway identifier. CAAS has reviewed the SIA PVD training and practices and found them to be adequate. This recommendation should be withdrawn. (See also

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	comments on recommendation to SIA, number 2).
3. Review AFM supplement document approval, control, distribution, and enactment policies and procedures for operators to ensure that revisions to airline AFMs are adequately managed. (3.2-[11])	The recommendation is not supported by any factual evidence that there is a systemic deficiency in this area. This recommendation arises out of Finding Number 11 that the AFM supplement, which deals with PVD use, was not incorporated into SIA's documentation and operational practice. The AFM supplement was properly incorporated into the SIA documentation, training or operational practices as appropriate to the design and certified use of the PVD. The draft Final Report shows no evidence that ASC investigators carried out inspections of Aircraft Flight Manuals carried on a representative sample of other SIA B747 aircraft to determine whether the revisions to airline AFMs are adequately managed. This recommendation should be withdrawn.
4. Ensure that all Singaporean commercial airline operators under its regulatory responsibility implement Advanced Crew Resource Management programs to reflect current practices in this area and ensure that such programs are regularly monitored and revised to reflect new developments in CRM. (3.2-[7])	This recommendation has already been implemented. The information should be included under 'Safety Actions' in the Final Report and the recommendation should be withdrawn.
5. Evaluate and support appropriate research to develop technologies and methods for enhancing flight crew's abilities for objectively determining a water-affected runway condition in heavy rain situations. (3.2-[4])	This recommendation should be withdrawn, as it is not appropriate to address this issue to an individual regulator. Identifying the means to enable the objective determination of a water-affected runway condition is an industry wide issue, and should be addressed through ICAO and IATA.
6. Amend the CAAS Air Navigation Order Paragraph 37 (3) to require an earlier power-on and later power-off times for CVRs.	CAAS is in the process of amending the relevant regulations to require earlier power-on and later power-off

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(3.3-[22])	times for CVRs. This information should be included in the 'Safety Actions' section of the Final Report, and the recommendation should be withdrawn.
To Singapore Government The Safety Council recommends that Singapore Government seriously consider establishing an independent aviation accident/incident investigation organization consistent with many other countries in the world. (3.3-[23])	The recommendation is irrelevant and inappropriate, as Singapore is not the State leading the SQ006 investigation. In any accident investigation, recommendations should be based upon factual evidence gathered during the investigation and the analysis of that evidence. While the recommendation that Singapore should consider establishing an independent accident/incident investigation organisation appears in the ASC draft Final Report, there is no evidence or analysis contained in the draft Final Report to either support or justify the recommendation. For example, there is no evidence that there has been any problem with the present administrative arrangement concerning the participation by Singapore in the SQ 006 investigation. Under these arrangements, the Minister for Transport (previously Minister for Communications and Information Technology) appointed an independent investigation team reporting directly to him. The team is made up of investigators from CAAS, Ministry of Defence, the National University of Singapore, and other organisations. In addition, the Minister appointed three external specialist consultants through the International Civil Aviation Organisation (ICAO).

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	The Singapore SQ006 investigation team operates completely independently of the aviation regulatory authority. These arrangements are fully in accordance with the Convention on International Civil Aviation. It should also be noted that not many countries have a fully independent, permanent stand-alone air safety investigation organisation. The recommendation should be withdrawn.
To Civil Aeronautics Administration, ROC (CAA) The Safety Council recommends that the CAA: **1.** Require that the control tower chiefs re-emphasize the concept, training and the use of progressive taxi/ground movement instructions during low visibility ground operations. (3.2-[1])	General Comments for all the recommendations to CAA ROC: • The recommendations to CAA ROC should include reference to an integrated risk management programme. • The recommendations to CAA ROC should include implementation of FAA National Blueprint for Runway Safety and the relevant advisory circulars.
2. Place priority on budgetary processes and expedite the procurement and installation of ASDE at airports with high traffic volume. (3.2-[16])	
3. Clearly redefine its divisions' job functions to stipulate each individual unit and personnel responsibilities. (3.2-[18])	
4. Specifically appoint an organization within the CAA for the development, modification, and issuance of civil aviation regulations. (3.2-[18])	
5. Organize a program to continuously monitor ICAO SARPs and industry best practices for safety improvement and distribute them to the relevant organizations for applicable review and necessary action and oversight of their progress. (3.2-[18])	
6. Establish an integrated safety assessment and oversight	

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mechanism to supervise all plans and implementations. (3.2-[19])	
7. Evaluate and support appropriate research to develop technologies and methods for enhancing air traffic controllers' abilities in providing objective information regarding water-affected runway conditions (wet versus contaminated) in heavy rain situations to pilots. (3.2-[4])	This is an industry wide issue, and should be addressed through ICAO and IATA. This recommendation should be withdrawn, as it is not appropriate to address this issue to an individual regulator.
8. Immediately implement all items, or acceptable alternative standards, at CKS and other ROC airports, that are not in compliance with ICAO SARPs and applicable documents, such as SMGCS plan, the emergency medical procedure, etc. (3.2-[16, 20, 32])	
9. Ensure that the ARFF at Taiwan airports have the necessary manpower to perform their assigned tasks, as compared to similar level 9 international airports. (3.2-[36])	As well as manpower, this recommendation should also encompass training, equipment and procedures. Reference should be made to equipment, such as a breathing apparatus simulator, and to procedural issues – for example, the need for a contingency plan for effective aircraft disaster management under severe weather conditions.
10. Establish sufficient emergency communication channels for Taiwan airport emergency rescue operations. (3.3-[17])	This recommendation should read as follows: 'Review the communication system at Taiwan airports to develop an integrated plan for improved communications between all agencies involved during emergency rescue operations'.
11. Ensure that its regulations pertaining to post-accident/incident toxicological testing of surviving crewmembers following aircraft accidents in Taiwan is performed for accident/incident prevention purposes. (3.3-[15])	This recommendation should be re-worded for clarification, and should include reference to the testing of air traffic control personnel.
To Ministry of Transportation and Communications, ROC (MOTC) The Safety Council recommends that the MOTC: **1.** Establish professional oversight capabilities for CAA's safety	

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improvement actions and programs for promoting flight safety. (3.2-[20])	
2. Proactively provide support to the CAA's safety action plans, such as the ASDE procurement process. (3.2-[20])	
3. Grant full authorization to the CAA to avoid lengthy waiting periods for improving and implementing technical safety regulations. (3.2-[21])	
To the Boeing Company The Safety Council recommends that the Boeing Company: **1.** Provide information for operators' reference regarding emergency evacuation slide operation in high wind conditions. (3.2-[34])	Recommendation needs to be clarified.
2. Consider redesigning the mechanisms of emergency slide packs for lateral G endurance to avoid uncommanded slide inflation during moderate crash forces. (3.2-[35])	
3. Evaluate means to have better illumination of emergency lights for survivors in dense smoke conditions following survivable impact accidents. (3.2-[30])	
To International Civil Aviation Organization (ICAO) The Safety Council recommends that ICAO: **1.** Develop Standards that would require ASDE or comparable equipment as standard equipment at civil airports with high traffic volume. (3.2-[16])	
2. Amend Annex 14 to include clear Standards for defining and protecting a partially closed runway that may be used for taxi purposes. (3.2-[16])	
3. Consider accepting CAA of ROC to participate in various ICAO activities as an observer, solely for the purpose of safety	

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improvement, even though ROC is not a contracting State. (3.2-[21])	
4. Support the establishment of a government/industry program involving Flight Safety Foundation, IFALPA, Airports Council International, and the IATA Safety Committee to develop objective methods to assist pilots in assessing whether a runway is "wet" or "contaminated" due to the presence of water. (3.2-[4])	
5. Encourage and support the establishment of research by governments and industry into improved passenger smoke protection and improved emergency evacuation slide performance in heavy winds and post-accident fire. (3.2-[30, 34])	
To International Air Transport Association (IATA) Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death. (3.2-[24])	
To the Federal Aviation Administration (FAA) of the US Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death. (3.2-	

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[24])	
To the Joint Airworthiness Authorities (JAA) Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death. (3.2-[24])	
Safety Actions Taken or Underway According to Ministry of Communications and Information Technology (MCIT) **1.** SIA has introduced situation awareness training as separate module in it upgraded CRM training. The new CRM training programme for the flight crew will also take into account on-going global developments in aviation human factors training.	With regard to 'Safety Actions Taken or Underway', see Note above at the beginning of Singapore team's comments on the 'Safety Recommendations' section. See also the Singapore's team's submission on Safety Actions at Appendix 1 to Part 1 of the Singapore team's comments.
2. SIA has initiated redesign of the female cabin crew's footwear in December 1999. New footwear has been introduced after the accident.	
3. SIA has included in all company pre-takeoff checklists an	

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item formally requiring positive visual identification and confirmation of the correct takeoff runway.	
According to Civil Aeronautics Administration, ROC (CAA) 1. Enhancements to CAA Regulations and Procedures • Reviewed all ICAO Annexes, including collection of information and revising local laws and regulations to meet such requirement as well as to establish a mechanism for such need.	
– A total of 18 items concerning the ICAO Annexes has been tasked to relevant units to look after, and be reviewed and consolidated by appropriate organizations	
– Organizations are required to review and update CAA laws and regulation as required	
• Reviewed Airport Certification Standards and Procedures	
– Based on FAA [Airport Certification Program Handbook] and invited expatriate advisors, the CAA will establish an auditing program for Certification Standards.	
– Revise CAA regulation and specification based on Annex14 and related articles.	
• Developed Airport Design and Operations Regulations	
– Established Runway and Taxiway Specification in 2000	
– Assigned consultant on Domestic Airport Design Spec study, in 2000	
– Established Lighting Specification	
– Airport Selection and Master Plan Spec and Airport and Related Facility Design Spec to be completed in 2002	
• Improved Airport Facility Management	
– Established Airport facility and NAVAID inspection	

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team	
– Established Inspection Plan that requires a two-stage inspection program to improve those areas not meeting requirements	
• Developed CAA Monitoring System for Airport Self-inspection	
– FAA specialist will conduct training on Airport Inspection (FAR Part 139) March 2002	
– Planning to establish Airport Inspector System to perform relevant airport inspections	
– Conducted Ground Handling Management-level Seminar and held a panel discussion to execute a plan for resolving issues - February 2001	
2. Airport Monitor and Management System	
• Developed Airport Self-inspection and Crisis Management System	
– Airports are to set up safety inspection team	
– Developed an Airport Self-audit and Risk Management program in a self-audit handbook, including flight safety, ground safety, NAVAID facility and airport facility, and etc.	
– Developed a Safety Inspection Team schedule to call upon relevant CAA organizations to review/revise the self-audit handbook.	
• Invited FAA Advisor to review CKS Airport and KHH Airport and provide general assessment for further improvement	
• Developed a team of related units to conduct daily inspections of facilities and make effective corrections as required	
• Demanded contractors to strictly adhere to the ICA and FAA's safety working procedures	
3. CKS Airport Facility Improvement	

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• Painted new runway and taxiway markings	
– For South section of airport, new markings were completed on July 6, 2001, in accordance with the ICAO standards,	
– North section is under construction and will be completed on November 27, 2001	
– Taxiway centerline marking will be completed March 31, 2002 in accordance with the ICAO standards	
• Airport Lighting	
– Adding to taxiway centerline lights from N1, and will be completed by January 31, 2002	
– Renew sign boards for Runway 05/23 and 06/24, and will be completed by March 1, 2002	
– Installing Runway Guard Lights for Runway 05/23 and will be completed by January 31, 2002	
– Installing yellow-green taxiway centerline lights on Runway 05/23, and will be completed by January 31, 2002	
– Installing Stop Bar on Runway 05/23 and will be completed by December 31, 2003	
• Airport Pavement	
– Taxiway S1-S2 indicating boards base adjustment were completed July 2001	
– Installed signs at the intersections of all service roads and taxiways, and was completed on July 31, 2001	
– Resurfaced Runway 06/24 and related taxiways, and was completed on July 31, 2001	
– Plans to Resurface Runway 05/23 and related taxiways, and will be completed by January 31, 2002	
4. Improvement of CKS Fire Fighting Facilities and Equipment	
• Developed Watch Room Center which was opened on	

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September 26, 2001	
• Revised and enhanced Airport Emergency Plan in accordance with the ICAO standards.	
– CKS International Airport All Emergencies Handling Procedures and the Civil Aircraft Accident Handling Procedures were amended, the CKS International Airport Aircraft Emergency Landing Procedures were established June 26, 2000, and the CKS International Airport Emergency Rescue Procedures were established October 11, 2001	
– CAA organized an Emergencies Procedure Project Team August 2001 based on the ICAO specification to revise Aircraft Accident Handling Plan	
5. Improvement to Air Traffic Control System	
• Enhanced air traffic control operations monitoring system on June, July, August and September 2001	
• Conducted refresher training to air traffic controllers on April and May 2001	

Part 5

Comments by the Singapore Ministry of Transport Investigation Team on the 'Survival Aspects' of the ASC Draft Final Report

Section I

Introduction

1 The ASC has commendably examined the various aspects of the emergency response to the SQ 006 accident. The comments below are intended to assist the ASC to improve these sections of the Final Report.

Comments on Section 2.6.1 of ASC draft Final Report

2 To be more accurate, the analysis of the survival factors in the ASC draft Final Report should acknowledge the extreme circumstances that confronted the crew. Although the SQ 006 accident was a catastrophic accident, the ASC report analyses the actions of the crew in the context of procedures which are primarily applicable to non-catastrophic situations.

3 Additional comments are provided in Section 4 below to highlight certain inaccuracies in the ASC factual information.

Section 2

Emergency Evacuation

4 We suggest that ASC's analysis of the post-accident performance of the crew of SQ 006 (paragraph 2 of 2.6.1 of ASC draft Final Report) should acknowledge the existence of the following statements in the SIA Aircrew Safety Emergency Procedures (ASEP), which apply specifically to extreme circumstances such as those faced by the crew of SQ006:

> *…each emergency is essentially unique, no procedures can include all possible types of accidents or emergencies. The land evacuation procedures should be considered as guidelines for effective and quick action by crew members. These procedures should not preclude the use of initiative in circumstances which dictate a variation from the set procedures.*
>
> *…Neither is it possible to dictate the exact steps to follow in such situations. In an emergency situation, cabin crew should in most circumstances start an emergency procedure only after an order from the captain. However in cases which are clearly catastrophic, individual crew members should be prepared to act immediately on their own initiative.*

5 The severe dynamics of the accident following the initial impact, when the aircraft was rotating, breaking apart and catching fire, were traumatic for both crew and passengers. The factual evidence shows that the crew of SQ 006 carried out their duties to the best of their ability in these catastrophic circumstances.

6 In summary, the analysis and findings of the ASC Final Report with regard to the performance of the SQ 006 crew following the accident should take into consideration the above comments.

<u>Section 3</u>

Comments on Section 2.6.4 of ASC Draft Final Report

7 Evidence shows that the CKS Airport Rescue and Fire Fighting (ARFF) team did not use their breathing apparatus during the rescue operations. The use of breathing apparatus during the rescue operations could have possibly contributed to the rescue of passengers who were trapped in the aircraft. We suggest that appropriate findings and safety recommendations be developed in this area.

<u>Section 4</u>

Comments on ASC Factual Section on Survival Factors

1. Para 1.12.2.3.2 Doors and Evacuation Slide/Rafts (Page 88 of ASC Draft Final Report):

<u>Door 4R</u>

‘Soot and fire burnt damage were found at inlet of aspirators to the inner skin of slide. See Figure 1.12-11’.

The above information was not officially verified by the Survival Factors Group.

2. Para 1.12.2.3.2 Doors and Evacuation Slide/Rafts (Page 88-89):

<u>Door 4L</u>

The word ”close” should be replaced by “ cocked open “

This is based on the Survival Factor Group Report, paragraph 1.3.2.2, Doors and Evacuation Slide/Rafts, which states that: ‘Door 4L was found intact and in a “cocked open” position.’

3. Para 1.12.2.3.2 Doors and Evacuation Slide/Rafts (Page 89):

In the table 1.12-2, under the column 'status' it is indicated that the UDR and UDL doors were opened by the UDR cabin crew.

As there are conflicting testimonies regarding the opening of these doors, it could not be determined who opened the UDR and UDL doors. Therefore, the relevant entry in the column 'Opened By' should be 'unknown'.

4. Para 1.15.1.1 SIA Crewmember's Emergency Evacuation Procedures and Training [Para 3] (Page 97):

'Land evacuation procedure should be conducted quickly and efficiently**. The initiation of an evacuation is the Commander's responsibility. Should a Cabin Crew consider that an evacuation is necessary, he/she should advise the Commander of the situation and await his decision. In cases, where it is obvious that an evacuation is imperative and no contact with the cockpit is possible, the Cabin Crew should initiate the evacuation immediately on his/her own.* ***(Especially for CIC)'.

The first sentence should be quoted separately from the second sentence onwards as they are extracted from different paragraphs of Chapter 4, Section 4 of the ASEP manual.

The last sentence '(Especially for CIC)' should be deleted as it is not in the content of the ASEP manual.

5. Para 1.15.1.1 SIA Crewmember's Emergency Evacuation Procedures and Training [Para 6] (Page 98):

This cabin evacuation trainer is programmed with an automated Captain's PA announcement to cabin crew and passengers to prepare for an evacuation, brace for impact and to evacuate the aircraft.

The fourth sentence in paragraph 1.15.1.1 of the ASC draft Final Report should be corrected, as it has incorrectly stated that 'the CIC declared the emergency evacuation'.

6. Para 1.15.1.1 SIA Crewmember's Emergency Evacuation Procedures and Training [Para 7] (Page 98):

The pilots practise evacuation commands via the PA system in the flight simulator during their regular proficiency checks.

The alternate method of ordering an evacuation in the absence of a pilot's evacuation command is for the cabin crew to initiate the evacuation if contact with the pilot is not possible and an evacuation is imminent. As such, the second and third sentences of this paragraph should be corrected to reflect this.

7. Para 1.15.1.1 SIA Crewmember's Emergency Evacuation Procedures and Training [Para 3] (Page 99):

To reflect accurately the interview report, the phrase in the second last sentence 'since no one took any action to evacuate' should be changed to 'as nobody actually wanted to evacuate'.

8. Para 1.15.1.1 SIA Crewmember's Emergency Evacuation Procedures and Training [Para 4] (Page 99):

'He then turned back and saw the left outside fire starting to diminish and passengers jumping down through the UDL exit. CM-3 did not see CM-1 at that time, but <u>he saw a female cabin crew shaking and weeping near the left side exit</u>. CM-3 instructed this cabin crewmember to jump out.'

The statement: 'he saw a female cabin crew shaking and weeping near the left side exit.' is not in the interview records. It should therefore be deleted.

9. Para 1.15.1.3. Upper Deck Cabin Crew's Emergency Evacuation [Para 2](page 99):

'*The UDL cabin crew saw the UDR crew attempted to open the UDR exit and was forced to move backward because of the fire and smoke from the UDR exit immediately after his opening of this exit. The UDR cabin crew then opened the UDL door. As the UDL door was opened, the slide/raft inflated and the fire burned and deflated this slide/raft immediately.*'

The above statements are incorrect as they are not supported by the evidence of the UDL cabin crew. The UDL crew, in her interview, only stated that she saw the UDR cabin crew attempting to open the UDR door, but he was not successful.

10. Para 1.15.1.6 Emergency Equipment [Para 1] (Page 103):

Not all cabin crew were asked during the interviews by ASC if they carried the torches from their stations during the evacuation. It should be noted that during the breakup of the aircraft, the torches could have dislodged from their place of storage and it would not be possible for cabin crew to locate the torches.

11. Para 1.15.1.6 Emergency Equipment [Para 2] (Page 103):

These statements do not take into consideration the catastrophic circumstances of the accident to SQ 006.

Part 6

Singapore Ministry of Transport Investigation Team comments on Section 2 of ASC draft Final Report 'Analysis'

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Reference : Analysis, para 2, ASC Draft Final Report page 175	
Chapter 2 starts with a general description of the factors we ruled out from the investigation as it is shown in Section 2.1. Section 2.2 provides the necessary structural failure sequence of this accident. Section 2.3 and 2.4 analyze the condition of the airport at the time of the accident, the ATC procedure during the accident sequence, as well as the organizational; and management factors of the CKS Airport and CAA of ROC. Section 2.5 analyzes the crew performance and the related crew training, coordination, the unsafe acts by the crew, and the defenses that we consider to be important to this accident. Section 2.6 provides analysis of the post accident fire, rescue and medical condition, or the survivor factors analysis. And Section 2.7 provides the analysis of the safety issues that are deemed important for the improvement of aviation safety.	In accordance with current usage of the Reason model, the term 'unsafe acts' should be replaced with 'individual or team actions'.
Reference : 2.1 General, para 3, ASC Draft Final Report page176	
The air traffic controllers involved with flight SQ006 were properly certificated. <u>The evidence from CVR, FDR, interviews with ATC controllers and the flight crew indicated that the ATC taxi instructions and takeoff clearance did not mislead the crew to take off from the partially closed Runway 05R.</u> ATC procedures, airport infrastructure	Suggest replacing with: 'The evidence from CVR, FDR, interviews with ATC controllers and the flight crew indicated that the ATC taxi instructions and takeoff clearance were for Runway 05L.'

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issues and the performance of CAA management are discussed later in this chapter.	
Reference : 2.3.1.1 Design of Taxiway N1 Centreline Marking, para 2, ASC Draft Final Report page181-182	
By calculation, the distance between the south edge of the Runway 05R and the tip of the curvature where N1 centerline made a turn into Runway 05R was 32 meters and the distance between the north edge of the Runway 05R and the tip of the curvature where taxiway centerline marking turned away from Runway 05R to join Taxiway N1 was 35 meters. According to the CAA civil engineering specifications (ATP-AE 1000301: 3.8.5.1) as stated earlier, the N1 centerline marking should have a 20-meter extension from the tip of the curvature toward Runway 05R and a 23-meter extension away from Runway 05R toward Runway 05L.	A diagram should be inserted to illustrate the missing segment of taxiway centre line marking and what ought to have been provided on site according to the specifications of CKS ATP-AE 1000301: 3.8.5.1, ICAO Annex 14 and FAA requirements to guide aircraft from Taxiway NP across the threshold of Runway 05R towards Runway 05L.
Reference : 2.3.1.1 Design of Taxiway N1 Centreline Marking, para 4, ASC Draft Final Report page 182	
The FAA Advisory Circular 150/5340-1H indicates that the taxiway centerline marking should stop at the edge of a runway	FAA AC 150/5340-1H also states that taxiway centreline markings **'<u>shall continue across all runway markings</u>'** for those taxiways used for low visibility (RVR below 360m) with the exception of the runway designation markings (Item 1.10.3.1.2, Page 58 of the Factual Section).
Reference : 2.3.1.2.2 Spacing of Taxiway Centerline Lighting para 4, ASC Draft Final Report page 183	
The Safety Council considers that the spacing of the taxiway centerline	Instead of considering this deficiency as 'increased the risk', it

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lights at the time of the accident increased the risk of the safety aircraft operations, as it will further be discussed in section 2.5.	should be classified as a factor related to 'probable cause,' that led the crew to taxi into Runway 05R as elaborated in Section 2.5.7.2.2 below.
Reference : 2.3.1.2.3 Unserviceable Taxiway Centerline Lights para 1, ASC Draft Final Report page 183	
ICAO Annex 14, Vol.1, Paragraph 9.4.23 indicated that two adjacent unserviceable lights were not permitted when the RVR is less than 350 meters. The Safety Council found during the site survey on November 4 (four days after the accident) that the second light after N1 departed from the tip of the taxiway curvature was out of service. In addition, the third light's luminance intensity was substantially degraded. However, there were no reports from the CKS Airport Flight Operations Section, airfield lighting Maintenance Group, or any other flight crew taking off from Runway 05L on the evening of the accident stated that there were two adjacent unserviceable lights along Taxiway N1. Furthermore, flight crews prior to the evening of the accident had submitted no safety concerns or reports about the Taxiway N1 lighting.	It is not a requirement or routine practice for flight crew to report specific unserviceable lights to ATC.
Reference : 2.3.1.2.3 Unserviceable Taxiway Centerline Lights para 2, ASC Draft Final Report page 183-184	
Thus, the Safety Council concluded that although the second Taxiway N1 light was not serviceable and the third light was less intense on the evening of November 4, 2000, the status of these N1 taxiway lights on the night of the accident might or might not be the same as in accordance with the findings of the November 4 inspection.	It is highly improbable that these two lights only became dim or unserviceable in the short span of time between the time of the accident and the evening of 4 November 2000.
Reference : 2.3.2 The Installation of Runway Guard Lights (RGL) **para 1, ASC Draft Final Report page 184**	

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ICAO Annex 14 (third edition-July 1999) Vol. 1, Paragraph 5.3.20.1, stated that a configuration A Runway Guard Light (Figure 2.3-1) shall be provided as a standard. FAA AC 120-57A Paragraph 8b suggests: runway guard lights to be provided when operating below RVR 365 meters. AC 150/5340-28 also mentioned: RGL provides a distinctive warning to anyone approaching the runway holding position that they are about to enter an active runway. CKS Airport didn't install configuration A RGL at the location greater than 75 meters from the 05L/23R runway centerline along Taxiway N1. Therefore, it does not meet the standard stated by ICAO.	This statement gives an impression that CKS Airport installed runway guard lights, but at an incorrect location, when in fact, there were no runway guard lights at all.
Reference : 2.3.2 The Installation of Runway Guard Lights (RGL) **para 3, ASC Draft Final Report page 184**	
If CKS Airport had installed RGL at the location on both the left and right sides of Taxiway N1 as required by the ICAO standard, that is, 75 meters from the centerline of Runway 05L, the distance from that location to the centerline of Taxiway NP would be 249 meters and the distance to the intersection on Taxiway N1 that turns into Runway 05R is about 175 meters. Since the RVR on the night of the accident was 450 meters, the crew could have had one indication that the CAT II Runway (05L) was still ahead of them, as it will be further discussed in Section 2.5.	This statement gives an impression that CKS Airport installed runway guard lights, but at an incorrect location, when in fact, there were no runway guard lights at all.
Reference : 2.3.3 Safety Considerations for Temporarily and Partially Closed Runway, para 1, ASC Draft Final Report page 184-185	

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ICAO Annex 14 is the source of the generally accepted safety standards for the marking of temporary closures of aerodrome maneuvering surfaces. There can be no question that those operating aircraft and other vehicles on aerodromes need clear indications of temporarily closed maneuvering areas. It is obvious that such indications should provide warning during all operating conditions. One way to do this is through the publishing of NOTAMs and broadcasting on the ATIS. That was done at CKS around the time of the accident. The other form of warning is the physical outlining of the temporarily closed area. Where the area can be marked without disrupting traffic and the approach is generally simple. Where, as at CKS, there would be a major disruption through the closure of the entire length of the runway and the problem was much more complex. In this instance, the problem was not in closing the runway, as a runway, but in closing it in its virtually exclusive use as a main taxiway.	It is possible to provide visual warnings on the temporary closure of Runway 05R-23L and the unserviceable area, without any significant impact on the efficiency of operations. This could have been achieved by closing Runway 05R-23L for taxiing operations between Taxiways N1 and N2.
Reference : 2.3.3 Safety Considerations for Temporarily and Partially Closed Runway, para 2, ASC Draft Final Report page 185	
When an area is temporarily closed, it is preferable to use frangible markers. The lighted Jersey blocks were not frangible. An attempt was made by the airport authority to mark the construction area and maintain operations at a reasonable level at the same time. The efforts of the airport and the knowledge of the crew of the closed area in combination did not prevent the aircraft from attempting to depart into the closed area. The Safety Council believes, in addition to enhance crew training, the airport has an obligation to seek a more compelling form of indicating closed areas.	Earlier NOTAMs and AIP Supplements indicated that the CKS Airport had intended to permanently close Runway 05R/23L and re-open it as Taxiway NC after repair works had been completed. As such, the runway markings should have been removed, the runway lights decommissioned, and more importantly, closure markers should have been strategically placed to prevent crew from entering and taking off from the closed runway.

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	Had these steps been taken, the accident could have been prevented.
Reference : 2.3.4.1 Evidence Regarding Status of Runway 05R Edge Lights, para 2, ASC Draft Final Report page 185	
Although videotapes from airport security and a passenger aboard CI004 recorded events in the general location of Runway 05R about the time of the accident, including the landing lights of SQ006 during its takeoff roll and the initial explosion and subsequent fire, Runway 05R edge lights were not perceptible at the time immediately before, or after, the accident. It was stated in 1.18 that the exterior lights of SQ006 were visible on airport security camera no. 77, if the Runway 05R edge lights were on, they should have been visible on the video as well. Although the quality of the videos in the prevailing weather conditions precludes a definite conclusion regarding the status of the edge lights, this evidence strongly suggests that the Runway 05R edge lights were not on during takeoff roll.	*The status of the 05R runway edge lights could not be conclusively determined.*
Reference : 2.3.4.1 Evidence Regarding Status of Runway 05R Edge Lights, para 3, ASC Draft Final Report page 185	
The absence of an interlocking system to prevent simultaneous operation of the edge lights for Runways 05R and its centerline lights made it possible for both to be powered at the time of the accident, if an error was made in the tower. However, statements from the ATC controllers indicated that none of them had turned on the Runway 05R edge lights. Although this evidence is not conclusive that the lights	The presence of an interlocking system would have prevented the possibility of such human errors on switching of the lights. There had been past reports of mistakes involving the switching on or off of airfield lights.

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were off, it is plausible because there was no need for the edge lights on Runway 05R to be illuminated at the time of the accident.	
Reference : 2.3.4.1 Evidence Regarding Status of Runway 05R Edge Lights, para 3, ASC Draft Final Report page 185	
Two Captains operating near the time of the accident were questioned about their observations of Runway 05R lighting. The Captain of CI004, which was taxiing along Taxiway NP for takeoff on Runway 05L when SQ006 crashed, stated that he first saw SQ006 when his aircraft was abeam A7 gate. He said that SQ006 was already in its takeoff roll. He could see the accident aircraft's landing lights, but could not determine if the aircraft was airborne. He also said that visibility was good, but the rain was heavy at the gate, although it was "on and off." The Captain of CI004 said that he did not see any lights on either Runway 05R or 05L, although he did recall that Taxiway NP taxi lights were on. He stated that SQ006's landing lights were visible as it moved down the runway, but "the rest was pitch dark." Since the landing lights of SQ006 during its takeoff roll were visible to the Captain of CI004, it is very likely that the Runway 05R edge lights were not on or he would have seen them, since they were only about 110 m from Taxiway NP.	The Captain of flight CI004 was focused on the aircraft and its bright lights while taxiing on taxiway NP, and as such peripheral details including the runway edge lights might not have registered with him.
Reference : 2.3.4.1 Evidence Regarding Status of Runway 05R Edge Lights, para 8, ASC Draft Final Report page 186	

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According to ATC recorded transmissions, about 40 minutes after the accident, the CKS SFOO called the CKS tower using his hand-held radio and requested that all runway lights of Runway 05 be turned on (he did not specify 05L or 05R). This statement makes it clear that the edge lights for Runway 05R were off at that time. However, the RVR printout revealed that Runway 05L edge lights were also off at this time and came on shortly after the SFOO requested all runway lights to be turned on. Thus, this evidence does not enable the Safety Council to draw a conclusion regarding the status of the edge lights at the time of the accident.	This statement indicates that the edge lights for Runway 05R were off at the time of SFOO's request. But they may or may not have been on at the time of the accident. The runway edge lights could have been switched off when the runways were closed soon after the accident.
Reference : 2.3.4.1 Evidence Regarding Status of Runway 05R Edge Lights, para 9, ASC Draft Final Report page 186	
The tests and research conducted on the two runway edge light wires from the locations of RE239 and RE240 revealed conflicting evidence. The absence of arcing damage on the wire strands from RE239 suggests strongly that the light was not powered when it was damaged by aircraft debris during the accident, or by AFFR vehicles shortly after the accident. The absence of arcing more likely indicates that the light at the location RE239 was not powered when SQ006 commenced its takeoff.	The absence of arcing damage on the wire strands from RE239 does not necessarily suggest the absence of electrical power at the time when the light fitting was damaged by foreign objects. From test results of arcing experiments conducted by Dr Hsu and Dr Lim of NUS/DSO, the absence of globules when the airfield light wires are separated does not necessarily preclude the possibility of the airfield light being powered on at the time of separation.
Reference : 2.3.4.1 Evidence Regarding Status of Runway 05R Edge Lights, para 10, ASC Draft Final Report page 186-187	
The evidence of arcing on the wire strand ends and along length of the	While the scenario painted is plausible, the arcing damage

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wire from the location of RE240 reveals that, at some point, the wires were connected to a power source and arcing damage occurred. The examinations of RE240 and tests conducted after the accident suggest the possibility for the arcing damage. Assuming that the edge light at location RE240 was on when wreckage or fire and rescue vehicles passed over it, the arcing could have occurred when the wire separated. That scenario could easily explain the arcing noted on the wire strand ends. However, it does not explain the arcing damage along the wire lengths that would have been protected by insulation until the post-accident fire burned the insulation away. The ATSB laboratory report suggests that the fire damage to the wire strands of RE240 involved a “boundary effect” whereby the plug end of the wire was immersed in a liquid, which protected it, while the remainder of the wire insulation burned away. If that were the case, arcing evidence on the wire lengths would have to have occurred sometime after the insulation burned away, possibly after power was re-applied to the lighting system about 40 minutes after the accident. Tests conducted by CSIST revealed that arcing of this nature can occur both along the length of the wire strands, and at the strand ends where globules were found after the wired are separated and subsequently momentarily contact metal to ground with power available.	found at the ends of the wire strand, and those along the sides of the wire, could have been produced as a result of two separate events: the former when the wires were knocked away and pulled apart by the wreckage, and the latter as the result of an after-event.
Reference : 2.3.4.1 Evidence Regarding Status of Runway 05R Edge Lights, para 11, ASC Draft Final Report page 186	
Regarding the arcing damage found on the length of the wires, the Safety Council developed a probable scenario to explain the origin of the damage.	There are other scenarios which are consistent with the evidence, and which indicate that the runway edge lights were on at the time of the accident.

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Reference : 2.3.4.2 Summarized Analysis of the Status of Runway 05R Edge Lights, para 2, ASC Draft Final Report page 187	
In summary, although some of the evidence regarding the status of the Runway 05R edge lights at the time of the takeoff of SQ006 is inconclusive, the Safety Council believes that the preponderance of evidence indicates a high probability that edge lights were off during the SQ006 takeoff.	There is a lack of evidence to determine conclusively whether the lights were on or off at the time of the accident.
Reference : 2.3.5.2.2 Current Status of Modification and Updating of Local Regulations, para 1, ASC Draft Final Report page 190	
On September 3, 1987, the CAA published its "Civilian airport civil engineering design standard and specifications" and "Airfield air navigation lighting specification". The CAA regulations have not been regularly revised to reflect the most recent amendments to ICAO SARPs. Interviews with CAA personnel indicated that an effort to modify domestic regulations to reflect the most recent ICAO SARPs did not begin until 1999. CAA was planning to complete a revision of the civil aviation regulations by the end of 2001. Furthermore, adherence to international standards and recommended practices is an essential component of aviation safety. However, because of political reasons, Taiwan is not an ICAO signatory and receives no direct help or information from ICAO. This isolation from the primary international aviation advisory and standards body has had an adverse bearing on Taiwan's ability to conform to ICAO SARPs.	Although Taiwan is not an ICAO Contracting State, it has stated in the AIP that it is in compliance with ICAO SARPs.
Reference : 2.3.6 Summary of Organization and Management Related Airfield Deficiencies, para 4, ASC Draft Final Report page	

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1. Deficiencies caused by inadequate administrative management: · Safety measures during airfield work in progress; · Process of converting Runway 05R into Taxiway NC; · Fail to revise CAA regulations to reflect updated ICAO SARPs.	Should also include: · Inadequate maintenance and monitoring of airfield lights to keep up with the required standards
Reference : 2.4.1 Low Visibility Taxiing and Ground Movement Instruction, para 4, ASC Draft Final Report page 192	
According to the Chief of CKS Control Tower, the purpose of the ATC low visibility taxi procedure was to prevent aircraft accidentally taxiing into each other. When the CKS Ground Controller issued the taxi clearance to SQ006, SQ006 was the only aircraft taxiing in the area. In addition, the Ground Controller stated that he was able to maintain visual contact with SQ006 until the aircraft was handed off to the Local Controller on Taxiway NP. Therefore, the Ground Controller did not inform the SQ006 crew that part of the airport was invisible from the tower and to slow down the taxi with caution. Furthermore, the Chief of Tower stated that according to the ICAO Procedures for Air Navigation Services (ICAO Doc 4444) and the Manual of Surface Movement Guidance and Control Systems (ICAO Doc 9476), there is no requirement for a Ground Controller to advise pilots that they are not visible from the tower.	The ATP 88 requires air traffic controllers at CKS Airport to advise pilots on the ground when their aircraft are not visible from the tower. However, this was not done on the night of the accident.
Reference : 2.4.1 Low Visibility Taxiing and Ground Movement	

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Instruction, para 6, ASC Draft Final Report page 192-193	
It is apparent that the controller did not issue progressive ground movement instructions and did not use the low visibility taxi phraseology to remind the aircraft to slow down its taxi. Based on the evidence, including the comments made by the flight crew on the CVR about taxi speed, the Safety Council concludes that the taxi speed of SQ006 did not contribute to this accident. However, if the controller had issued progressive taxi instructions to the SQ006 crew, it is likely that this would have significantly enhanced the flight crew's situational awareness.	As stated in the analysis (Item 2.4.1 of page 192/193), had the ATC complied with the CKS Airport's SOPs, 'it is likely that this would have significantly enhanced the flight crew's situational awareness'. This is a significant finding that ought to have been included in the 'findings related to probable causes'.
Reference : 2.4.2 Airport Surface Detection Equipment (ASDE), para 2, ASC Draft Final Report page 193	
In conditions of heavy rain, the presentation of an ASDE display can be diminished considerably by the attenuation of the <u>rain beam.</u> There was extensive precipitation at CKS Airport because of the approaching typhoon weather at the time of accident. Therefore, it is not clear whether the ASDE could have provided useful information to the controllers to prevent the accident. However, during interview, the Controller A believed that ASDE could have prevented this accident. Nonetheless, there is a possibility that had ASDE been installed and used by the controllers, it might have alerted them to the <u>incorrect taxi route of SQ006.</u>	To amend the clause to '… diminished considerably by the attenuation of <u>the radar beam in the rain</u>.' The phrase 'incorrect taxi route of SQ006' is misleading. It should be worded as '… it might have alerted them that SQ006 did not taxi onto the assigned departure runway at the end of its taxi route.'
Reference : 2.4.4 Taxi Navigation Cycle, para 1, ASC Draft Final Report page 196	

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The FAA Advisory Circular (AC) No. 120-74 dated June 2001, provides guidelines for the development and implementation of SOPs for conducting safe aircraft operations during taxiing, focusing on the activities occurring within the cockpit. Sections of the AC provide a useful frame of reference for assessing the low visibility taxiing performance of the crew of SQ006. Flight crew procedures are addressed in Part 5 of the AC. The following paragraphs have examined the performance of the SQ006 crew against relevant criteria outlined in the AC. Measured against the guidelines set out in AC 120-74, the performance of the SQ006 crew revealed some areas in their performance and that of SIA procedures or training that needed improvement. Neither the flight crew nor SIA met the basic benchmarks in their entirety.	This is not correct. The SQ 006 crew met the relevant criteria set out in the FAA AC120-74, as shown by the CVR evidence.
Reference : 2.5.4.1 Taxiing, para 1, ASC Draft Final Report page 196-197	
On the night of the accident, the flight crew followed the taxi checklist and procedures in accordance with the SIA B747-400 Operations Manual and navigated themselves accurately until the aircraft approached the end of Taxiway NP. The flight crew was somewhat distracted by the execution of the before takeoff procedures and tasks, and it was likely that this impacted upon the crew's monitoring of the final phase of the taxi. Interviews with the flight crew indicated that they did not monitor the final phase of taxi (the turn from Taxiway NP onto Runway 05R via N1) in accordance with the airport chart and associated aircraft-heading indications. Furthermore, the crew did not check the taxiway and runway signage and markings to help verify the	There is no evidence to substantiate that the 'crew was somewhat distracted by the execution of the before takeoff procedures and tasks'. Such tasks are not distractions, they are an essential part of normal operations. Instead, they were misled by the prominence of the taxiway single line of taxiway centreline lights leading onto Runway 05R and the absence of runway closure markings on Runway 05R.

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position of the aircraft when the aircraft turned from Taxiway NP onto Runway 05R via Taxiway N1. The pilots' field of view during the critical turn from NP onto Runway 05R will be discussed in Section 2.5.7.1 of the report.	
Reference : 2.5.4.2 Flight Crew Awareness, para 1, ASC Draft Final Report page 197	
FAA AC 120-74 states; "*Flight crews should use a continuous loop process for actively monitoring and updating their progress and location during taxi. This includes knowing the aircraft's present location on the route that will require increased attention. For example, a turn onto another taxiway, an intersecting runway, or any other transition points. As the 'continuous loop' is updated, flight crewmembers should verbally share relevant information with each other.*"	See comments above.
Reference : 2.5.4.2 Flight Crew Awareness, para 3, ASC Draft Final Report page 197	
The taxi route originally briefed by CM-1 prior to push back was changed by ATC during the issuance of the taxi clearance. CM-1 briefed the new taxi route but he did not include the crossing of Runway 05R before reaching Runway 05L. CM-2 or CM-3 did not challenge this omission.	However, it should be noted that the new taxi route did not include a clearance to cross or hold short of R/W 05R. CM-1's briefing of the taxi route was correct, as cleared by ATC. As there was no error in CM-1's briefing, it was unnecessary for the co-pilots to challenge CM-1's briefing.
Reference : 2.5.4.3 Intra-flight Deck/Cockpit Verbal Coordination, para 2, ASC Draft Final Report page 198	
Reference to the CVR shows that, prior to the turn onto Runway 05R,	The crew was certain that they were on Runway 05L as they

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the crew of SQ006 knew where they were. They had verbally coordinated to ensure they all knew that Runway 05L was the takeoff runway, and they had obtained the required ATC clearance to use it. As the aircraft taxied into position for takeoff, the crew were certain that they were on Runway 05L. However, critical information upon which they had to rely to maintain the accuracy of their situational awareness such as aircraft instrumentation and airport lights and signage was not used effectively.	were misled into believing they were on the correct runway by the visual cues presented. It is incorrect to state that 'critical information' was not used effectively. The information was flawed. The veracity of situational awareness depends upon the quality of the information upon which it is based.
Reference : 2.5.4.4 Taxi Procedures, para 1, ASC Draft Final Report page 198	
Analysis of the procedures in the SIA B747-400 Operations Manual, the FDR parameters, and the CVR transcript, indicated that the taxi clearance which the pilots received, taxi path, taxi speed, and cockpit conversation, were generally routine. One exception to the routine was the flight crew discussion of alternates during taxi. The CVR transcript, the audio recorder transcripts from CKS Airport tower, and interviews with the 3 pilots, confirmed that the revised clearance was to taxi after push back to Runway 05L via Taxiway SS, Taxiway WEST CROSS, and Taxiway NP. Taxiway N1 was not specified in the clearance[1]. The taxi checklist and procedures performed by the flight crew were in accordance with the SIA B747-400 Operations Manual with the exception of the period when the aircraft turned from Taxiway NP onto Runway 05R. Furthermore, the flight crew did not request progressive	*There was no regulatory or operational requirement for the crew to request progressive taxi instructions. They taxied their aircraft accurately to the final turn onto Taxiway N1*

[1] CKS Ground Control issued the taxi clearance to SQ006 as "…taxi to Runway 05L by Taxiway SS, West Cross and NP". The controller did not include "cross Runway 05R" in the clearance. According to CAA ATP-88 Chapter 3-7-2 b., when authorizing an aircraft to taxi to an assigned takeoff runway and hold short instructions are not issued, specify the runway preceded by "taxi to," and issue taxi instructions if necessary. This authorizes the aircraft to "cross" all runways/taxiways, which the taxi route intersects except the assigned takeoff runway.

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taxi instructions to augment their navigation accuracy in low visibility conditions.	
Reference : 2.5.4.4 Taxi Procedures, para 2, ASC Draft Final Report page 198	
As stated in section 1.17.4.5, SIA instructs pilots to use the correct taxiway and runway. Such admonishments are typical in complex socio-technical industries but exhorting people to comply with such directives is generally an ineffective accident or incident countermeasure unless specific methods to achieve the objective are provided[2]. The SIA Flight Instructor Manual requests instructors to teach pilots about the "taxi routing and situational and environmental awareness", but there are no detailed guidelines for taxiing in low visibility conditions. There was no specific procedure for low visibility taxi described in the SIA B747-400 Operations Manual. MCIT submissions to the investigation team indicated that taxiing an aircraft is a part of basic airmanship. There is no specific technique to be applied for taxiing in low visibility. Moreover, SIA stated that there were no specific requirements for low visibility taxi training for pilots stipulated in ICAO SARPs, JAR's, FAR's or promulgated by the major manufacturers and that SIA was following industry best practice.	This analysis does not take into account the fact that taxi guidance information in low visibility is provided in the SIA B747-400 FCTM.

[2] Reason, J. (1997). Managing the risk of organizational accidents. Aldershot, UK: Ashgate.

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Reference : 2.5.4.5 SIA Low Visibility Taxi Training, para 1, ASC Draft Final Report page 199	
Although there was no industry benchmark set for low visibility taxi training before the accident, it was found (from the CVR) that the crew of SQ006 did not measure up to the FAA Advisory Circular AC 120-74 guidelines on taxiing practices (p. 8). The SIA Operations Manual did not provide guidelines for operations in low visibility conditions. The SIA Flight Crew Training Manual's (FCTM) low visibility training section instructs flight crew to "…taxi slowly as necessary for safety. Do not hesitate to request from ATC the positions of other taxiing aircraft or to ask for a follow me car." However, CM-1 stated that he did not receive low visibility taxi training.	A captain of CM-1's qualifications and experience in Cat II and Cat III operations has received training in low visibility taxiing operations as an integral part of his training package. This training should have been checked and reviewed by the ASC investigation team.
Reference : 2.5.4.5 SIA Low Visibility Taxi Training, para 11, ASC Draft Final Report page 199	
<u>The flight crew did not possess an appropriate level of knowledge to fully evaluate the effects that weather on the aerodrome might have had on their ability to accurately navigate the aircraft on the ground</u>. It must be emphasized that in any complex system breakdown, there are many factors that contribute to the outcome. The FAA's *National Blueprint for Runway Safety* offers initiatives that address all system elements including flight crew, ATC operations, and airport infrastructure and safety management systems. With reference to flight crew performance, SIA did not have a comprehensive surface	This statement is not supported by any factual evidence, and is contradicted by the crew's qualifications, training and operational flying experience in all weather conditions. Such statements, which have no basis in fact should be deleted from the Final Report.

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movement training program.	In this case, it was not a lack of knowledge that caused the SQ006 crew to mistake the closed Runway 05R for the assigned take off runway 05L. The most significant factor that contributed to this mistake was the deficient visual aids which misled the pilots into taxiing into a closed runway.
Reference : 2.5.4.6 Summary, para 1, ASC Draft Final Report page 200	
Measured against the guidelines set out in FAA AC 120-74, the taxiing performance of the flight crew of SQ006 revealed some areas in their performance and that of SIA procedures and training that needed improvement. Neither the flight crew nor SIA met the FAA AC benchmarks in their entirety. On the basis of the evidence, there were many factors that led to the aircraft lining up on Runway 05R instead of 05L. Some of these factors were related to the performance of the flight crew. <u>In summary, the SIA low visibility taxi training and procedures did not contain all the elements of what is currently regarded as safer and better practice in this area.</u>	This statement is not supported by the factual evidence. See earlier comments.
Reference : 2.5.5 Before Take-Off Check, para 1, ASC Draft Final Report page 200	
The CVR indicated that none of the flight crew orally confirmed whether the runway they entered was Runway 05L. When an aircraft receives a clearance for takeoff, the flight crew's confirmation that they are on the active runway provides an additional measure of safety. On runway line-up, the flight crew did not cross reference their outside picture with the information on the CKS Airport chart.	In normal operations, once a crew has navigated their aircraft to the runway holding position, by reference to their airport charts,, they refer to external visual cues to guide them onto the takeoff runway. The 'confirm active runway check' item was not a regulatory requirement, or an industry standard at the time of the accident.

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	The before takeoff check-list requires confirmation of the takeoff runway as cleared by ATC, and this was done by the crew of SQ 006, as shown by the CVR.
Reference : 2.5.6.2 Navigation Displays, para 1, ASC Draft Final Report page 201	
The navigation information necessary to fly the aircraft (such as track, waypoints and lateral and vertical navigation pointers, wind speed and direction, and other data) was shown on the Navigation Displays (ND) in front of both pilots. When a runway is selected, the ND displays a runway symbol, which appears as two parallel white lines. The position of the aircraft relative to the runway is shown by the aircraft symbol (white triangle) and identifier or label such as 05L. Runway 05L had been selected for departure. With the intended runway centerline being 214m (650ft.) to their left, the aircraft symbol appeared to the right edge of the runway symbol, indicating that the aircraft was possibly not aligned with Runway 05L. The Runway 05L label also remained unchanged.	There are no procedural or operational requirements for the flight crew to check these specific indications at the point of takeoff.
Reference : 2.5.6.3.1 Para-Visual Display (PVD) Information, para 2, ASC Draft Final Report page 202	
The procedure is not specified as related to Category III operations, rather, it is a general procedure for use of the PVD. The CAAS approved AFM supplement indicates that the PVD assists the flight crew in determining whether the aircraft is in the correct position for takeoff.	This statement is factually incorrect. The wording and intent of the CAAS approved AFM supplement has been misinterpreted in this analysis.

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Reference : 2.5.6.3.1 Para-Visual Display (PVD) Information, para 5, ASC Draft Final Report page 202-203	
As part of the investigation, information was obtained from other Asia-Pacific B747-400 operators regarding the use of the PVD (they have been de-identified for commercial reasons). In particular, one operator's B747-400 Operations Manual stated that "Using the runway localizer tuned on the Navigation Radio page, the PVD provides guidance to runway centerline during ground operations." Ground operations include taxiing, takeoff run, and landing roll. The operator's information was consistent with the CAAS approved B747-400 AFM supplement, which indicates that the PVD assists flight crew in determining if they are in the correct position for takeoff.	The PVD system is designed solely to provide steering guidance to the pilot under low visibility conditions. It is **not designed nor is it certified** to assist the crew in determining whether the aircraft is on the correct runway. The wording referred to is also that used in the SIA Operations Manual. The PVD is only designed and intended to be used to provide reversionary visual guidance to the runway centerline during the take off roll. It has no role in other ground operations. This should have been checked with airline operators who use the PVD.
Reference : 2.5.6.3.1 Para-Visual Display (PVD) Information, para 6, ASC Draft Final Report page 203	
SIA was not operating in accordance with the CAAS approved B747-400 AFM PVD supplement. The supplement information was not reflected in SIA procedures and training documentation.	This statement is wrong. The supplement information was reflected in SIA's procedures and training documentation.

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Reference : 2.5.6.3.2 Operational use of PVD, para 5, ASC Draft Final Report page 204	
The Safety Council was unable to determine how well the pilots of SQ006 understood the PVD system. The flight crew did not mention the CAAS approved supplement to the Boeing 747-400 AFM which indicated that the PVD will shutter dependent upon whether the "aircraft is in a position for takeoff or not". In accordance with the CAAS approved Boeing 747-400 AFM PVD supplement information, the Safety Council concluded that the failure of the PVD to unshutter indicated to the flight crew that the aircraft was not at the correct location for takeoff. The routine operational context of PVD usage led the flight crew to discount the unshuttered indication further.	The sole purpose of the PVD is to assist the pilot to maintain centreline tracking during the takeoff run and **not** to identifiy the 'correct location for takeoff'.
Reference : 2.5.6.3.3 PVD Procedures, para 11, ASC Draft Final Report page 205	
Therefore, when an aircraft positions and lines up and holds on the runway and the PVD has not unshuttered, if the ILS frequency is correctly selected and no message appears on the EICAS, the PVD information indicates to the flight crew that the aircraft is not in the correct position for takeoff.	The PVD system is designed solely to provide steering guidance to the pilot under low visibility conditions. It is **not designed nor is it certified** to assist the crew in determining whether the aircraft is on the correct runway.
Reference : 2.5.6.3.3 PVD Procedures, para 12, ASC Draft Final Report page 205	
In this occurrence, the PVD was still shuttered when the aircraft lined up on Runway 05R. The PVD did not unshutter because the PVD was not within the valid localizer region for Runway 05L. The PVD information was a cue indicated to the flight crew that the aircraft was	The PVD system is designed solely to provide steering guidance to the pilot under low visibility conditions. It is **not designed nor is it certified** to assist the crew in determining whether the aircraft is on the correct runway.

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not on the correct runway for takeoff. Although MCIT and CAAS made numerous submissions to the Safety Council investigation team to emphasize that the PVD was not intended to be used as a runway identifier. However, despite this very strong sentiment from Singapore, the language in the CAAS approved PVD supplement clearly stated that the PVD display will "shutter dependent upon whether the airplane is in a position for takeoff or not". The language in the CAAS approved PVD supplement did not reflect the sentiment that the PVD was not to be used as a runway identifier. Rather, the language in the CAAS approved PVD supplement indicated that the PVD will provide the crew with information as to whether the airplane is in a position to takeoff or not.	
Reference : 2.5.6.3.3 PVD Procedures, para 13, ASC Draft Final Report page 205	
Had the information in the CAAS approved PVD supplement been distributed in SIA training and operational documentation and reflected in operational practice, the crew of SQ006 probably would have considered the PVD indications further with a view that the airplane may not have been in a position to takeoff. The assessments and actions of the flight crew on the evening of the accident were indicative of their limited knowledge of what the PVD system was indicating, the operational context of PVD usage, the competing demands for their attention, the high task load, and degraded environmental conditions. A latter section of the analysis will discuss some of the factors that influenced the crew during the taxi from NP to Runway 05R.	Contrary to the report’s assertion, the information in the CAAS approved supplement **is contained and explained** in SIA’s training and operational documentation.

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Reference : 2.5.6.4 Heading Indicators, para 3, ASC Draft Final Report page 206	
Although CM-2 stated that the compass rose can help maintain orientation during taxi, he did not mention the use of the aircraft's heading indicators and/or the compass to verify visual orientation during the critical phase of the taxi when SQ006 turned from Taxiway NP through Taxiway N1 directly onto Runway 05R. During interviews, CM-1 and CM-3 did not mention the use of the aircraft's heading indicators and/or the compass to supplement visual orientation during taxi. The compass and heading indicators were useful aids available to the flight crew to enhance their orientation and navigational accuracy during taxi, especially in the low visibility conditions. It is standard industry practice to utilize the heading indicator and/or compass to assist surface navigation during complex taxi routing and/or degraded visibility.	It has to be noted that CM-2 was not specifically asked during the interview if he had referred to these instruments. It cannot therefore be inferred that his not mentioning these instruments means that he did not use them. Runways 05R and 05L are <u>parallel runways</u>. Thus, the heading indication is of no assistance as far as differentiating the two runways is concerned.
Reference : 2.5.7.1 Markings and Signage, para 2, ASC Draft Final Report page 206	
• A black/red sign marked "N1/5R-23L" was on the southwest side of Taxiway N1; located 54 meters from Runway 05R centerline and 20 meters from the left edge of Taxiway N1;	This sign was oriented obliquely away from the turn from Taxiway NP to Taxiway N1, and this significantly reduced its conspicuity and readability for a pilot making the turn.
Reference : 2.5.7.1 Markings and Signage, para 7, ASC Draft Final Report page 207	
The Boeing field of view study showed that the pilots' field of view outside the cockpit through the areas swept by the windscreen wipers was limited. However, the study found that the following items would	Boeing did not carry out any field-of-view study of the SQ 006 accident. The company has advised that it merely provided a series of diagrams showing possible field of view from the

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have been visible from the cockpit at intervals throughout the turn from Taxiway NP through Taxiway N1 onto Runway 05R: the Taxiway N1 sign and Taxiway N1 centerline lights leading to Runway 05L; the Runway 05R sign; the Runway 05R threshold markings and designation; and the Runway 05L signage. In particular, the study indicated that the “N1/5R-23L” signage was visible from CM-1’s eye reference point through CM-1’s windshield when the aircraft was turning from Taxiway NP onto Taxiway N1 (Figure 2.5-1). The clear areas in the diagram present the visible areas available to CM-1 during taxi. CM-1 stated that he had his eyes out of the cockpit during the turn from Taxiway NP onto the runway because he was taxiing the aircraft with reference to the taxiway lights during the turn.	cockpit of a B747. The ASC analysis fails to take into account all the factors involved at the time SQ 006 turned onto Runway 05R such as limited visibility and restricted field of view.
Reference : 2.5.7.1 Markings and Signage, para 10, ASC Draft Final Report page 208	
In addition, the “N1/5R-23L” signage was internally illuminated. The distance between the signage and the cockpit was about 60 meters when the aircraft was turning. With a RVR of 450 meters, the signage would have been visible from the cockpit when the aircraft was turning from Taxiway NP onto Taxiway N1.	The signage was located such that it only came into the pilot’s view during the turn from Taxiway NP to N1. There could only have been a momentary exposure of the sign to the pilots, at the moment when the pilots were focusing their attention on safely executing the turn and keeping to the taxiway centreline.
Reference : 2.5.7.1 Markings and Signage, para 11, ASC Draft Final Report page 208	
When the aircraft taxied through Taxiway N1 and was just about to turn onto Runway 05R (Figure 2.5-2), the piano keys on Runway 05R and the Taxiway N1 centerline lights leading to Runway 05L were visible from CM-1’s eye reference point through CM-1’s windshield. The runway marking “05” and “R” were also visible from CM-1’s eye	Given the heavy rain and wet pavement surfaces, it would be difficult to discern the runway designation markings on the pavement surface. In addition, the exposure of the runway designation markings to the pilots’ field of view would also have been limited, as the aircraft was making a turn.

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reference point through CM-2's windshield. The distance between the cockpit and the Runway 05R marking, Taxiway N1 centerline lights leading to Runway 05L, and the Runway 05R piano keys were all within 120 meters.	
Reference : 2.5.7.1 Markings and Signage, para 12, ASC Draft Final Report page 208	
Based on the above evidence, the Safety Council has concluded that if the flight crew had looked for the runway markings and signage to locate their position by scanning the outside scene, they would have been able to see that information and consequently navigate the aircraft to the correct runway.	This conclusion by the ASC is not based on any objective evidence, simulator tests or research.
Reference : 2.5.7.2.1 Taxiway Centerline Lights, para 2, ASC Draft Final Report page 210	
As discussed in Section 2.5.8.2, the attention focus of CM-2 and CM-3 was "inside" the cockpit for the checklist and crosswind component calculation during the turn onto Runway 05R. In addition, CM-1 was concentrating on maintaining the minimum taxi speed and following the green lights onto the runway. The use of the crew's attention resources was not optimized to fully process cues and information that would have helped them maintain an awareness of their location during the taxi in challenging conditions. The flight crew's limited attention resources were probably fully occupied by the high workload induced by: checklist and procedural requirements; taxiing accurately in slippery conditions; degraded visibility and fluctuating but poor weather conditions; concerns about the approaching typhoon; cross wind calculations and company requirements; and PVD indications	The CVR evidence indicates they coped well with their duties and worked well as a team. The evidence also shows that they had a heightened awareness of the additional hazards resulting from the prevailing weather conditions, and took extra care to taxi slowly and to keep with the lighted taxi route. See also MOT team's comments on ASC's 'findings related to probable causes' in Part 2 of the Singapore MOT Team's Comments.

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during the turn onto and line up on the runway. Consequently, the flight crew did not comprehend the available information nor did they prioritize the information to ensure such that positive runway identification was achieved prior to takeoff.	
Reference : 2.5.7.2.2 Spacing of the Taxiway Centerline Lights, para 1, ASC Draft Final Report page 210-211	
The spacing difference between the taxiway centerline lights on Taxiway N1 that led to Runway 05L and those that turned right onto Runway 05R were a factor that influenced the flight crew to believe they were lining up on the correct runway. According to site survey data of CKS Airport, the only lighting system installed on Taxiway NP is the green taxiway centerline lights. As the taxiway turns right into Taxiway N1, the spacing of the taxiway centerline lights along the curved section to Runway 05R was 7.5m. However, the spacing of the taxiway centerline lights on Taxiway N1 between Runway 05R and Runway 05L was 4 times wider than the spacing of the taxiway centerline lights turning from Taxiway N1 onto Runway 05R. Therefore, the taxiway centerline lights that diverged onto Runway 05R were more salient than the lights that continued to Runway 05L because the spacing of the turning lights was smaller than the spacing of the lights that extended along Taxiway N1. The denser spacing of the taxiway lights illuminated a clear path to Runway 05R. Therefore, CM-1 followed the distinct path of green taxiway lights from Taxiway NP onto Runway 05R, as is often the case when aircraft taxi onto Runways. During interviews with CM-1, when he was asked how he had made a continuous turn onto Runway 05R when the airport chart showed a straight line on Taxiway N1 for Runway 05L, CM-1 replied that he had just followed the green taxiway centerline lights and made	At the point of tangency to the turn leading to Runway 05R, there was no clear alternative line of lights visible to the pilot leading across Runway 05R towards Runway 05L.

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a continuous turn from NP onto Runway 05R, believing it to be Runway 05L.	
Reference : 2.5.7.2.2 Spacing of the Taxiway Centerline Lights, para 3, ASC Draft Final Report page 211	
Research has indicated that human attention is attracted by salient cues in the environment and individuals will tend to neglect non-salient ones[3]. The Safety Council has concluded that during the turn from Taxiway NP onto Runway 05R, the green taxiway centerline lights leading into Runway 05R attracted CM-1's attention. Therefore, he missed the centerline lights that led to Runway 05L and all the runway signage and designation marking in the vicinity of Runway 05R threshold.	When SQ 006 was turning from Taxiway NP onto Taxiway N1, the green taxiway centreline lights clearly indicated a continuous pathway ahead of the aircraft, and there were no other routes branching from this path.
Reference : 2.5.7.2.3 Color of the Centerline Lights, para 1, ASC Draft Final Report page 211	

[3] Wickens, C. D. 2001. Attention to Safety and the Psychology of Surprise. University of Illinois, Aviation Human Factors Division. Savoy, Illinois.

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The taxiway centerline lights were green, including the centerline lights on Runway 05R. However, the centerline lights for Runway 05L were white. Interview and CVR data indicated that the flight crew followed the green centerline lights and taxied the aircraft onto Runway 05R. All three pilots reported that they saw the centerline lights running down the runway when the aircraft positioned and held on Runway 05R. However, none of them recognized that the color of the runway centerline lights should have been white if the runway was 05L, rather than green. During the turn onto the runway CM-1 had sighted green taxiway centerline lights along the runway.	*The rain on the cockpit windscreen would have further downgraded the resolution of the image. Hence the presence of the centreline lights and not their colour would have been the dominant perception to the pilots.*
Reference : 2.5.7.2.3 Color of the Centerline Lights, para 3, ASC Draft Final Report page 212	
The eye is composed of two basic receptors, rods and cones, each of which has its own sensitivity function. At high levels of illumination, the rods and cones both function (photopic vision) and the eye is most sensitive to light wavelengths around 550 nanometers (nm[4]) (green). As illumination levels decrease, however, the cones cease to function, the rods takeover the role of seeing (scotopic vision), and the eye becomes most sensitive to wavelengths around 500 nm (blue-green). This shift in sensitivity from photopic to scotopic vision is called the Purkinje effect. The practical application of this effect is that targets can be made green or blue-green to increase the probability of detection at night[5]. That is one of the reasons why airfield guidance lighting such as taxiway centerline and/or edge lighting are often green or blue. Consequently, despite the glare of the aircraft's landing lights and the reflected glare from the water droplets when the aircraft lined	*The rain on the cockpit windscreen would have further downgraded the resolution of the image. Hence the presence of the centreline lights and not their colour would have been the dominant perception to the pilots.*

[4] Nanometer =nm=10^{-7}cm.
[5] Saunders, M. S., & McCormick., E. J. (1992). *Human factors in engineering and design* (7th Edition). Singapore: McGraw-Hill.

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up on Runway 05R, the green centerline lights of Runway 05R were clearly discernible along the runway. The "wash-out" type effect, where the color of the green centerline lights may have appeared less distinct to the crew within the immediate range of the aircraft landing lights was not an issue. CM-2 had identified the color of the centerline lights after the activation of the landing lights during the turn through Taxiway N1 prior to runway line up[6]. Moreover, the flight crew reported that the runway centerline lights were clearly visible.	
Reference : 2.5.7.2.3 Color of the Centerline Lights, para 4, ASC Draft Final Report page 212	
As discussed in Section 2.5.8.2, when the aircraft taxied onto and held on Runway 05R for takeoff, the focus of the flight crew were probably fully occupied by the high workload induced by concern about the degraded visibility and fluctuating but poor weather conditions; the approaching typhoon; cross wind takeoff; and PVD indications. Consequently, the flight crew did not comprehend the information that the centerline lights were green.	As mentioned above, the saliency of the runway centerline lights was the dominant attribute in the perception of the lights by the crew, and not their colour.
Reference : 2.5.7.4 Runway Difference Issues, para 2, ASC Draft Final Report page 213	
• Runway 05L is 15 meters wider than Runway 05R (60 meters vs. 45 meters respectively);	*There was nothing unusual about the width of the runway ahead of the SQ 006 crew on lining up as SIA operates to many airports with 45m-wide runways.*

[6] CVR 151540 CM-2 Strobes on, landing lights all on
……………………
CVR 151550 CM-2 OK green lights are here

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Reference : 2.5.7.4 Runway Difference Issues, para 4, ASC Draft Final Report page 214	
• The centerline lights of Runway 05L are white. There was no runway centerline lights for Runway 05R, however, there were taxiway centerline lights on Runway 05R for the purpose of using Runway 05R as a taxiway. The color of the taxiway centerline lights was green; and	See comments on colour above.
Reference : 2.5.7.4 Runway Difference Issues, para 5, ASC Draft Final Report page 214	
• Runway 05L is a CATII instrument approach runway. Runway 05R is a visual runway for takeoff only. The runway touch down zone (TDZ) marking stripes were also different.	Airline crews would be looking for the overall picture of an operational runway.
Reference : 2.5.7.6 Runway 05R Edge Lights, para 1, ASC Draft Final Report page 215-216	
As stated earlier in section 2.3, after reviewing all available information, the Safety Council was unable to positively determine the on/off status of the Runway 05R edge lights at the time of the accident. <u>However, regardless of the status of the Runway 05R edge lights, it was possible that the crew may have still taken off from Runway 05R.</u> Therefore, the Safety Council will discuss both possible situations in the following section.	This statement 'However, regardless… taken off from Runway 05R.' is not supported by evidence. This statement should be deleted.

ASC Draft Final	MOT Comments
Reference : 2.5.7.6.1.1 If Runway 05R Edge Lights Were Off, para 4, ASC Draft Final Report page 216	
The Safety Council has concluded that the flight crew was convinced that they were on Runway 05L and there was no immediate or salient indication that the runway in front of them was closed for construction works. They saw what they expected to see - a "normal picture" of a runway. Furthermore, the pilots' attention was focused on the PVD information, the visibility along the runway, crosswind checklist completion, and how to conduct a visual takeoff in the strong crosswind. They probably did not perceive the absence of runway edge lights and process such information to realize that they were on the incorrect runway.	If they had perceived that the runway edge lights were off, it is unlikely that the crew would have commenced the take-off. The Captain stated that he was quite sure that the runway edge lights were on.
Reference : 2.5.7.6.1.2 If Runway 05R Edge Lights Were ON, para 1, ASC Draft Final Report page 217	

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Runway 05R was 45 meters wide. The width of Runway 05L, Runway 06 at CKS Airport, and also the two runways at Singapore Changi Airport were all 60 meters. If the Runway 05R edge lights were ON on the night of the accident, a comparison with the above runways, which were familiar to the flight crew, would have indicated that Runway 05R was too narrow[7]. This comparative cue may have alerted the flight crew that they were on the incorrect runway; however, determining such a width difference might have been difficult at night in low visibility conditions. Nonetheless, such a cue had reportedly been used on 23rd Oct 2000 at 2245 by a freighter captain who was conducting a routine flight from CKS Airport. The freighter had been given clearance to taxi for a takeoff on Runway 05L via Taxiway NP. The captain stated that the weather on that evening was rainy with some wind. The visibility was also degraded due to the moderate rain.	The critical issue was that Runway 05R looked exactly like an operational runway to the crew. The apparent widening of the pavement as the aircraft turned from Taxiway NP (30m width) into the 45m-wide Runway 05R may also have reinforced their belief that they were on Runway 05L. The ASC's footnote number 9 is not supported by factual or research evidence. Reference to basic aviation physiology and aviation psychology texts, together with accident investigation reports of mid-air collisions, would demonstrate that this belief by the Safety Council is misplaced.
Reference : 2.5.7.6.1.2 If Runway 05R Edge Lights Were ON, para 2, ASC Draft Final Report page 217	
The first runway that the aircraft captain encountered when he was on Taxiway N1 was Runway 05R. He recalled that he felt compelled to take Runway 05R as the active runway because Runway 05R was brightly lit with centerline and edge lights. He could not see the barriers nor the lights on the barriers further down Runway 05R. He stated that he was able to reject the compelling information because he had paused to think and became aware of the following conflicts: Runway 05R was too narrow; there were no touch down zone lights; and he realized that the centerline lights were green on the runway.	The statement by the freighter Captain reinforces the fact that at CKS Airport the Runway 05R taxiway centreline lights and runway edge lights had been switched on at the same time.

[7] The Safety Council believes that a line pilot should have a mental model of how a 60 meters wide runway should look like from the cockpit. This kind of mental model was built up from day to day flight experience. For example, pilots should be able to recognize an A320 or an A300 just by the size of the aircraft. It is not necessary to compare them side-by-side.

ASC Draft Final	MOT Comments
Reference : 2.5.7.6.1.2 If Runway 05R Edge Lights Were ON, para 3, ASC Draft Final Report page 217	
The Safety Council has concluded that if the runway edge lights were ON at the time when SQ006 lined up on Runway 05R, the pilots would have seen the white runway edge lights and green centerline lights on the runway. They did not see any construction signs or equipment on the runway. Under the high workload of taking off in the severe weather conditions, and with the expectation that they were on Runway 05L, they might not have been able to perceive that the runway they were on was too narrow to be Runway 05L. In addition, there were no TDZ lights on the runway and the centerline lights of the runway were green, which is the color of the taxiway centerline lights. Nonetheless, the flight crew believed they were on the active Runway 05L and carried out the takeoff.	Touchdown zone lights are not required to be switched on for an aircraft taking-off.
Reference : 2.5.7.7 Expectation of Runway Picture, para 3, ASC Draft Final Report page 218	
According to CAA, there was no runway-closed indication in the vicinity of the Runway 05R threshold because this portion of the runway was still being used for taxi on the night of the accident. In addition, given the inbound typhoon, it was not safe to erect mobile runway closure signs, which may have been blown into taxiing aircraft. There were warning lights demarcating the construction area on Runway 05R but the distance from the 05R threshold to the	The use of the runway as a taxiway does not preclude the provision of appropriate closure markings to indicate that Runway 05R was closed as a runway. In this case, there were no visual warnings at all at the threshold of Runway 05R to indicate that it was closed. The section of Runway 05R between Taxiways N1 and N2 could have been closed and appropriately marked and lit

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construction area restricted the pilots from seeing those lights.	without any significant impact on taxiing operations at the airport. The painting of runway closure markings on Runway 05R would have addressed any concern about runway closure signs or marker boards being blown away. Alternatively, the runway threshold and designation markings could have been removed to prevent pilots from mistaking it for an operational runway.
Reference : 2.5.7.8 Summary, para 1, ASC Draft Final Report page 219	
Evidence indicated that when the aircraft approached the threshold of Runway 05R, the flight crew's attention was focused on the crosswind component, visibility for takeoff, PVD information, and before takeoff checklist items. The crew did not recall seeing any runway signage and the runway designation marking. They saw the green taxiway centerline lights turning onto the runway but did not recall seeing any other signage or markings (except the piano keys that are not unique to a particular runway) in the vicinity of Runway 05R threshold. If runway guard lights or stop bars or a densely spaced centerline light along Taxiway N1 had been provided, they would have increased the conspicuity of the Runway 05L holding position and would likely have alerted CM-1 to the location of Runway 05L.	More importantly, had edge lights of the closed Runway 05R been disconnected, and the green taxiway center line lights leading from Taxiway N1 into the closed runway been disabled, and had Runway 05R been marked as a closed runway at the threshold, the pilots would not have taken off from the closed runway.

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Reference : 2.5.7.8 Summary, para 2, ASC Draft Final Report page 219-220	
The flight crew was also aware that the particular runway view should have included white centerline lights and that there should have been an area of bright TDZ lights on the runway. Thus, they should have recognized that their observations of Runway 05R did not match those of a CATII runway. In addition, given the flight crew's experience in night flight operations, they were knowledgeable of taxiway and runway lighting and were aware that taxiway lights are typically green and runway lights are typically white. However, their lack of recent experience with Runway 05L and 05R configurations and high workload may have impeded the crews processing of runway configuration information. Furthermore, CM-1 elected to takeoff because he could see an adequate distance down Runway 05R to takeoff and the runway picture accorded with his mental model of an active runway. Finally, the conflicting instrument indications were not fully considered by the crew. The crew also believed the timing of the Air Traffic Control clearances for taxiing into position and holding and takeoff seemed to confirm that they were in the correct location for takeoff.	The word 'elected' should be changed to 'decided'. The 'instrument indications' mentioned in the second last sentence of this paragraph were not referred to by the crew during the take-off phase as it was not a requirement to do so under normal company operating procedures.
Reference : 2.5.8.1 Time Pressure to Take Off Before Typhoon Was Closing, para 1, ASC Draft Final Report page 220	

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At the time of the occurrence, typhoon “Xangsane” was approximately 360 kilometers south of CKS Airport and moving NNE at 12 knots. CKS Airport was experiencing heavy rain, low visibility, and strong wind. The conditions were expected to worsen when the typhoon got closer to the airport in several hours. CVR and interview data indicated that during taxi, the pilots were discussing the typhoon status[8] and they were aware that the weather conditions were going to deteriorate. Moreover, CM-1 stated that he was concerned that the typhoon was closing in and the weather would only deteriorate further if he delayed the flight. CM-3 had expressed similar concerns. The crews concerns about the typhoon and their desire to avoid it could enticed them to hasten their departure without appropriate attention checks to correctly identify and confirm the correct runway prior to takeoff. This could have occurred despite the CM-1’s instructions for the crew to take their time and to be careful with checklists and other procedures.	This assertion that the SQ 006 crew were under time pressure to depart is not supported by the CVR evidence. This shows that the crew were not in a hurry, and had carried out their duties appropriate to the operational situation. Evidence from the DFDR also shows that the aircraft taxi speed was appropriate to the prevailing conditions.
Reference : 2.5.8.2 Attention Allocation, Workload, and Situation Awareness, para 3, ASC Draft Final Report page 221	
CM-2 was focused on the before takeoff checklist when the aircraft was turning onto Runway 05R. When CM-2 completed the checklist, the aircraft was half way through the turn and lining up on the runway. He had commented to CM-1 that the PVD had not unshuttered. CM-2	

[8] CVR 15:10:21, CM-3 said “Yah, it【typhoon】is coming in ah, the longer they delay the worse it is lah”. CM-1 replied “Yah, worse if we are going to get out, if don’t take off ah …..”

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stated that his attention was focused on the PVD. The focus of CM-2's attention inside the cockpit reduced CM-2's opportunity to scan outside the aircraft. Furthermore, he did not notice any runway marking or runway signs. However, he recalled seeing lights leading onto the runway and CM-1 following the lights onto the runway. CM-2 stated that he saw bright lights in the middle of the runway and that it was the "correct picture" for him.	The report is wrong in stating that CM-2 did not notice any runway marking. The factual evidence shows that CM-2 saw the runway piano keys and remembered that they appeared 'scratchy'.
Reference : 2.5.8.2 Attention Allocation, Workload, and Situation Awareness, para 5, ASC Draft Final Report page 221	
It is clear that all three pilots were not aware of the position of the aircraft when CM-1 turned onto Runway 05R. The attention focus of CM-2 and CM-3 was "inside" the cockpit for the checklist and crosswind component calculation. CM-1 was concentrating on maintaining the minimum taxi speed and following the green lights onto the runway. The crew essentially lost awareness of their location during the taxi. None of the three pilots had allocated their attention to the runway markings and signs during the turn.	The factual evidence shows that the crew believed that they were on the correct runway. There is no evidence that they were uncertain of their location. The taxiway marking and lights led the crew into Runway 05R, and the presence of the markings of an operational runway reinforced their perception that they were on Runway 05L.
Reference : 2.5.8.2 Attention Allocation, Workload, and Situation Awareness, para 6, ASC Draft Final Report page 221-221	
A loss of situation awareness can be due to a failure to attend to and perceive the information that is necessary for people to understand a given situation. The acquisition and maintenance of situation awareness is particularly important for individuals in complex, dynamic, socio-technical industries such as aviation. Research has	A loss of situational awareness could also result from misleading cues provided by deficient visual aids. In the case of SQ 006, the pilots navigated the aircraft during the final part of the taxi onto the take-off runway according to the cues provided by the runway and taxiway signage, markings and lighting. The

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indicated that humans have limited working memory and attention resources[9]. Therefore, increased attention to some elements (such as crosswind component, low visibility, slippery runway, following the green lights, checklist), the less attention to other elements (such as runway signs and markings, Taxiway N1 centerline lights leading to Runway 05L). Therefore, a loss of situation awareness occurs once the information-processing limit is reached or attention saturation occurs due to high concurrent task load and environmental stressors.	combination of these external visual cues guided them onto what they believed was the correct runway. The crew did not lose situational awareness in the sense that they became unsure or uncertain of their position. The CVR shows that at all times they believed that they knew the position of their aircraft, and this belief was correct until the very final stage of the taxi onto the take-off runway. It was only during this last segment of the taxi that the crew's situational awareness did not correspond to the actual situation of their aircraft.
Reference : 2.5.8.2 Attention Allocation, Workload, and Situation Awareness, para 10, ASC Draft Final Report page 223	
The Safety Council has concluded that under the high workloads experienced by the crew, the flight crews' attention had overly narrowed and focused on the weather information to the detriment of other critical operational information. Therefore, the crew could have missed the airport infrastructure information that may have been able to indicate their position on the airfield and that they were taxiing onto the incorrect runway for takeoff.	This proposition is based on the assumption that the crew were under high workload. However, there is no evidence that the crew of SQ 006 were under abnormally high workload. The B747-400 is designed to be operated by a two-pilot crew. In the case of SQ 006, the presence of the third pilot enabled the Captain to delegate some duties which would normally have been performed by the standard two-pilot crew prior to take-off. In the light of these facts, the 'high workload' argument is not

[9] Endsley, Mica. 1996. Situation awareness in aircraft. In Brent J. Hayward and Andrew R. Lowe (Eds.), Applied aviation psychology: achievement, change, and challenge: proceedings of the Third Australian Aviation Psychology Symposium. P403-417. Aldershot; Brookfield, Vt: Avebury.

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	valid.
Reference : 2.5.8.3 Pattern Matching, para 1, ASC Draft Final Report page 223	
Pattern matching problems are relatively common during high workloads. This is because the individual's mental model accepts as a match for the required object something that looks similar, is in a similar location, or does a similar job[10]. In particular, the flight crew believed that Runway 05R was Runway 05L because their mental pictures lead them to believe that Runway 05R was a normal runway at night. CM-1 and other crewmembers may not have had the required attention resources to conduct a precise matching process because they were captured by: • CM-1 taxiing the aircraft in poor visibility and over relying upon the green taxiway lights for guidance onto the runway; • CM-2 completing the pre-takeoff checklist; and • CM-3 regularly re-calculating the crosswind component for takeoff to ensure it was within company limits.	See comments above. This analysis is predicated on the validity of the assumption that the SQ 006 crew were under high workload. However, as discussed above, the situation was that of a two-pilot aircraft being operated by a three-pilot crew. Consequently the workload was not abnormally high.
Reference : 2.5.8.4 Taxi Lighting Issues, para 2, ASC Draft Final Report page 224	
Changi Airport, the SIA home base, uses the "Airfield Lighting Control	The clause ', or be less apparent than the taxiway centreline

[10] Reason, James. 1990. Human Error. Cambridge UK; Cambridge University Press.

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and Monitoring System (ALCMS)" to provide a safe and efficient operating environment in the airfield[11]. Its "Taxiway Lighting Control System (TLCS)" detects conflicts in multiple selected taxi routes and provides an inter-locking mechanism using taxiway centerline light segments and stop bars to resolve the conflicts at taxiway junctions. For aircraft arriving at or departing from Changi Airport, an air traffic controller will turn on the taxiway centerline lights along their assigned taxi route and tell pilots to "follow the green". The taxiway centerline lights on other taxi paths will either be turned off, blocked by stop bar lights or other mechanisms, or be less apparent than the taxiway centerline lights of the assigned taxi path. Therefore, pilots can easily taxi to their assigned gates or departure runways by following the green taxiway centerline lights selected by ATC. However, CKS Airport does not have this kind of taxiway lighting control system. When pilots taxi in to the gates or taxi out to the active runway at CKS Airport, they need to visually navigate to where they planned and were cleared to go using airport charts, cockpit instruments such as the compass and heading indicators, and taxiway lights, signage, and markings.	lights of the assigned taxi path.' should be deleted.
Reference : 2.5.8.4 Taxi Lighting Issues, para 4, ASC Draft Final Report page 225	
Up until the occurrence, all three pilots had worked for SIA and flown in and out of Singapore Changi Airport for at least five years. They	Most of the airports which SIA operates to do not have the 'follow the green' system. In fact, only the minority of these

[11] Koh Ming Sue, 2001. The New Airfield Lighting Control and Monitoring System at Singapore Changi Airport. 2001 International Symposium on Airport Infrastructure Development and Management, April 25-26, Singapore.

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were familiar with that airport's "follow the green" taxiway lighting control system[12]. During interviews, all three pilots stated that the green lights should take them to the takeoff runway. Under the time pressure to take off before the inbound typhoon closed in around CKS Airport, and the high workload of taking off in a strong crosswind, low visibility, and slippery runway conditions, it is possible that CM-1 inadvertently reverted to the most dominant previously formed mental model under high workload to follow the green taxiway centerline lights, which generally takes him to where he is supposed to go, and he reverted to this habit while turning from NP onto Runway 05R.	airports have such a system. Thus, the 'dominant mental model' hypothesis cannot be supported. With regard to the ASC footnote number 14, on 21 December 2001, the MOT team had provided to the ASC records of the airports the SQ 006 pilots had operated to in the 12 months preceding the accident. These records show that only about a small number of the airports they operated to were equipped with a 'follow the green' taxiway lighting system.
Reference : 2.5.8.5 Airport Layout, para 3, ASC Draft Final Report page 226	
Interview data indicated that during the preflight briefing, CM-1 briefed his intended taxi route to CM-2 and CM-3. Instead of taking the simple taxi route to Runway 05L - from Taxiway SS southbound to Taxiway WEST CROSS, to Taxiway NP, right turn on Taxiway N1 and onto Runway 05L, CM-1 originally anticipated to taxi to Runway 05L via eastwards on Taxiway SS to Taxiway EAST CROSS, proceed on Taxiway EAST CROSS until Runway 05R and backtrack on Runway 05R, exit left onto Taxiway N7, then onto Taxiway NP[13], pass Taxiway N2 and right turn Taxiway N1 to the threshold of intended departure Runway 05L. This planned taxi route matches the taxi route at Changi Airport when an aircraft taxies out from T1 East and T2 North Apron.	This hypothetical and speculative discussion is irrelevant to the investigation. The evidence shows that the crew of SQ 006 navigated their aircraft as briefed. The CVR shows that they made the appropriate decisions as to the route on their way to the take-off runway. They were well aware that they were at CKS Airport. In addition, the majority of take-offs and landings

[12] MCIT was unable to provide the flight crew's computer flight record for the past three years. However, according to CM-1 and CM-2's flight schedules from Aug. 28, 2000 to Oct. 31, 2000, 44% (19 of 43) of the airports that CM-1 operated into and 54% (29 of 54) of the airports that CM-2 operated into were equipped with the "follow the green" systems.

[13] Due to construction on north apron, aircraft was unable to left turn onto Taxiway NP from taxiway EAST CROSS.

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According to the AIP published by CAAS (Figure 2.5-7), when an aircraft parks at T1 East and T2 North aprons and is going to use Runway 02L for takeoff, the normal taxi route will be to take Taxiway A6 northbound to Taxiway NORTH CROSS, left turn onto Taxiway NORTH CROSS to Taxiway WP, then left turn onto Taxiway WP taxi southbound, pass Taxiway W7, right turn onto Taxiway W8 and continues right onto Runway 02L.	by SIA pilots on SIA's international routes are at airports other than Singapore Changi Airport.
Reference : 2.5.9 Water-affected Runway Issues, para1, ASC Draft Final Report page 229	
The ATC controller was not required to provide information to the crew regarding the condition of the runway. The determination of a contaminated runway by ATC is heavily dependent upon pilot reports. Although both pilots and controllers can assess the runway conditions, it is incumbent upon the pilots to be prudent and look for cues to aid them in making the final determination about the runway condition. The statement made by the SIA Chief Pilot indicating that the flight crews depend upon ATC to provide runway condition information demonstrated a normative understanding of water-affected runway operations.	This statement is not correct. ICAO Doc 4444, para 7.4.3 states that 'Essential information on aerodrome conditions shall be given to every aircraft, except when it is known that the aircraft already has received all or part of the information from other sources…' In para 7.4.2 of Doc 4444, essential information includes: a) construction or maintenance work on, or immediately adjacent to the movement area; b) rough or broken surfaces on a runway, a taxiway or an apron, whether marked or not marked; c) water on a runway, a taxiway or on apron …' It is extremely difficult for pilots to judge the depth of water on a runway from the cockpit. They depend on information from ATC. There is no means by which the pilot can determine the exact depth of water on a runway. The crew of SQ 006 were not

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	advised by ATC that Runway 05L was contaminated.
Reference : 2.5.9 Water-affected Runway Issues, para 9, ASC Draft Final Report page 231	
Had the crew of SQ006 assesses the intended departure runway as probably contaminated, they would have realized that the contaminated runway cross wind limit (15 knots) for takeoff in the Boeing 747-400 would have precluded a takeoff unless the wind had subsided long enough to attempt a takeoff. Given that the weather was worsening in accordance with the approaching typhoon, it was possible that the crosswind component would not have reduced to below 15 knots for sufficient duration to permit a contaminated runway takeoff. Alternatively, had the flight crew assessed the runway as contaminated, they may have had some additional time to assess the position of the aircraft as they waited on the runway threshold for the wind to subside for a contaminated runway takeoff as the flight 16 minutes before SQ006 had done.	This discussion is speculative and unnecessary. The accident to SQ 006 resulted from a take-off on the incorrect runway. The assessment of the runway surface as contaminated or wet had no bearing on the crew's mistake in taxiing onto Runway 05R instead of Runway 05L.
Reference : 2.5.9.1 SIA Crosswind Limitation and Runway Condition Determination Procedure, para 3, ASC Draft Final Report page 231	
The SIA's definition of a contaminated runway is much stricter than the	In the absence of notification by ATC, the SQ 006 crew

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European Joint Aviation Administration contaminated runway definition. This shows that SIA was using a higher safety standard for aircraft operating on a water-affected runway. In contrast, when determining if a water-affected runway is to be classified as a wet or a contaminated one, SIA pilots use a lower risk management standard; they assume the runway is wet if ATC does not provide standing water information. The Safety Council has concluded that SIA should provide procedures to assist pilots to assess the condition of the water-affected runway in heavy rain situation. It was not a risk averse practice to assume that the runway was wet if there was no information provided by ATC, particularly when there had been heavy rain fall (22.50 mm of rain fall) reported in the hour before 1500 UTC.	assessed the runway condition as 'wet'. This was in accordance with normal operational practice. SIA's runway contamination procedures are similar to those of other airlines. It is an industry-wide issue that there is no objective means for ATC or flight crew to determine the level of water on a runway from the cockpit or the control tower. In any case, this discussion is irrelevant to the underlying contributory factors in the case of the SQ 006 accident.
Reference : 2.5.10 Crew coordination, para 1, ASC Draft Final Report page 232	
As discussed earlier in the report, the flight crew's dismissal of the PVD was the last line of defense in the sequence of events that led to the flight crew not correcting a situation that surfaced during the critical stage of lining up for takeoff. The CVR indicated that CM-2 questioned the PVD line-up while the aircraft was turning onto Runway 05R. CM-1 and CM-3 then engaged in the following discussion regarding the PVD: CM-1 stated: "Yeah, we gotta line up first". CM-3 stated: "We need 45 degrees". CM-1 continued, "Not on yet PVD, never mind, we can see the runway, not so bad". After SQ006 lined up on the runway, the 3 pilots did not resolve why the PVD did not unshutter. CM-2 did not continue to resolve the unshuttered PVD indication nor did CM-1 and CM-3 attempt to support or resolve this issue. This indicated the flight crew failed to apply basic CRM principles in resolving a critical operational problem. The opportunity was lost to discover that the	The PVD was designed as a defence against pilots deviating from the runway centerline during the take-off roll in low visibility conditions. It was not designed, and nor was it intended, to be a defence against incorrect runway selection by pilots. Contrary to the ASC statement, evidence from the CVR and the linguistic discourse analysis shows that the SQ 006 crew did practice good CRM principles. The reasons for the crew not 'trouble-shooting' the unshuttered PVD have been fully explained elsewhere in the MOT comments.

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aircraft was not on the appropriate runway within the preset localizer.	
Reference : 2.5.10.1 SIA's Crew Resource Management Training Program, para 3, ASC Draft Final Report page 232	
The SIA ARM courses are designed to cover concepts that the crews are expected to apply on the flight deck during line operations. During the interviews with various SIA Instructor Pilots, the Instructors reported that they informally examine the crewmember's application of CRM principles during checks but the skills are not formally assessed in the same manner as technical skills. The Instructor Pilots reported that they sometimes discuss CRM principles and critique a crewmember's CRM skills during a proficiency check debriefing. Apart from these observations by the Instructors, the company currently has no reliable and valid mechanisms to evaluate if the crew has acquired such skills. Furthermore, the ARM courses have not been updated to reflect the advances in CRM and Human Factors research. In summary, the SIA ARM programs did not contain all the elements of what is currently regarded as best practice in this area.	The SIA ARM training programme has been updated and enhanced since its original introduction in 1984. SIA crew are required to attend three ARM modules that cover CRM principles. A further update of the ARM programme, incorporating the latest CRM principles, was being considered before the accident. The new program was launched in 2001.

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Reference : 2.5.10.1SQ006 Crew CRM Performance, para 1, ASC Draft Final Report page 233	
The flight crew reported that there were no difficulties in their relationship before or during the flight, and they considered, from their recollection and after listening to the CVR, that the CRM exhibited during taxi was good. A review of the CVR revealed that relationships between the crew appeared to be cordial. There was an instance where information was not volunteered. An example of sub-optimal CRM was when CM-3 elected not to inform CM-1 about the environmental conditions that he experienced when he conducted a pre-flight check of the aircraft. Although CM-3 mentioned his water-soaked shoes and removed them in the cockpit, no further discussions took place regarding the implications of that fact to the safety of the operation. Open communication is important between crewmembers under all circumstances.	There is ample evidence that the crew had practised good CRM principles. For example, the crew's decision to use Runway 05L was evidence that they were fully aware of the environmental conditions. The content of the CVR and the linguistic discourse analysis showed that the SQ 006 crew were operating well as a team and that the communication between the crew members was open and consultative. This analysis of the SQ 006 CRM does not reflect an understanding of the reality of modern airline operations. The discussion is not in keeping with the standard to be expected in a high quality accident investigation report.
Reference : 2.5.10.1SQ006 Crew CRM Performance, para 3, ASC Draft Final Report page 233-234	
Because all SQ006 crewmembers had not been given comprehensive PVD training that reflected the information contained in the CAAS approved B747-400 AFM PVD supplement, it would be difficult to assume that they would have known fully what the PVD indications were telling them. Nonetheless, there was adequate information available to the crew on the evening of the accident to tell them that they were not in the correct location for takeoff. With reference to navigation during taxi, communicating the severity of weather to all crewmembers, scanning the outside scene, cross-checking position,	See comments above.

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runway identification, the assessment of the runway conditions, the use of aircraft instruments to verify location during taxi, a higher standard of CRM was possible. CM-3 could have passed the information on the weather conditions experienced during his external aircraft check to the other crew and the crew could have considered the PVD unshuttering further. Such open communications may have enhanced the crew's awareness of runway conditions and the location of the aircraft when it lined up on the runway.	
Reference : 2.5.10.3 The Role of Relief Crewmembers, para 1, ASC Draft Final Report page 234	
The SIA SOP did not assign specific duties to the third flight crewmember, although the captain of SQ006 requested the third pilot to verify crosswind limitations. Management pilots, instructor pilots, and line pilots commented that the level of involvement of relief crewmembers varied in accordance with an aircraft commander's discretion. In general, there was a reluctance to interfere with the two-pilot operational philosophy, and therefore a reluctance to assign specific tasks or key operational duties to relief crewmembers during takeoff and landing. Like the other two pilots, CM-3 did not notice that the aircraft had lined up on the incorrect runway. Because SIA B747-400 operations involve variable crew compositions from two-pilot without relief crew up to two additional relief pilots who may be either captains and/or first officers or combinations thereof, it is difficult to assign specific duties to relief crewmembers during takeoff and landing. SIA relief crews are generally asked to be in the cockpit during takeoff and landing. Nonetheless, the role of relief crewmembers during these critical phases of flight, where transport category accidents occur most often, could be more clearly defined	The B747-400 is certified for two-pilot operations. Consequently, no duties are specifically assigned to a third pilot. For reasons of operational flexibility, the allocation of duties to a third pilot are left up to the Captain and vary in accordance with the operational requirements of a particular flight.

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and reinforced during check and training activities. Such initiatives would increase the level of effective involvement of relief crewmembers during these phases.	
Reference : 2.5.11 CAAS Safety Oversight, para 6, ASC Draft Final Report page 235	
The Safety Council has concluded that CAAS has not performed sufficient safety oversight of SIA's low visibility taxi and PVD procedures and training, and the deficiencies in SIA procedures and training were not detected during routine CAAS safety oversight surveillance.	The investigation has found no evidence of systemic deficiencies in SIA's low visibility taxi and PVD procedures and training. Consequently, there is no factual basis for this statement.
Reference : 2.6.1 SIA Crewmember's Emergency Evacuation Operations and Training , para 1, ASC Draft Final Report page 235	

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In this accident, the crewmember's emergency evacuation performance were affected by the following combined factors: severe impact and fuselage breakup, fuel tank explosion, post crash fire in the cabin and outside, smoke, falling foreign objects, unusual cabin attitude, abnormal slide inflation and extension after door opening, debris on the floor, incapacitation of some of the crew, no PA service, difficult for crew to communicate, emergency slides inflated in cabin, typhoon weather with heavy rain, dark environment, and panic reaction because of the accident.	From the interview report, there was no evidence to suggest panic reaction on the part of the crew.
Reference : 2.6.1 SIA Crewmember's Emergency Evacuation Operations and Training , para 2, ASC Draft Final Report page 235	
The Safety Council believed that under the situation such as the SQ006 accident, where severe impact damage to the aircraft and fire spreading was obvious, currently existed emergency declaration method/ hardware/ procedure was ineffective. The Safety Council believes that under the circumstances of this type of accident, it would be very difficult to follow all of the procedures described in the ASEP. This was primarily because of the unexpected dynamics of the accident. However, the preparation to encounter an emergency situation during takeoff and landing was essential for the professional crew to avoid any incapacitation from shock. For instance, the crewmembers did not use any other proper method to declare emergency evacuation.	The current existing emergency declaration methods and procedures are effective. The procedures stated that where it is obvious that an evacuation is imperative and no contact with the cockpit crew is possible, the cabin crew should initiate the evacuation. In this instance the crew initiated and evacuated passengers from the cabin successfully. Cabin crew are trained to make a 30-second silent review of their emergency procedures prior to every takeoff and landing. Under the circumstances, the crew used words appropriate to the situation to instruct passengers to evacuate such as "Open seat belt", "Come this way" and "Jump".
Although the SIA emergency evacuation training and procedures were generally in line with existing industry standards, there is no training in a complex environment of simulated adverse weather with fire and	SIA's crew are trained to handle complex emergency situations in a cabin evacuation trainer with sound, motion and smoke effects. The trainer is capable of simulating adverse cabin

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smoke. The Safety Council believed more complex emergency situations may be necessary as part of the training syllabus in cabin safety training courses.	attitude and smoke scenario. SIA's training is consistent with industry best practice. There is no evidence from the investigation that the cabin crew's performance reflected deficiencies in their training. Consequently, there is no factual evidence upon which to base this statement.
Reference : 2.6.3.1 Smoke Protection Devices, para 2, ASC Draft Final Report page 237	
According to the interview of the survivors; the fuel-fed post crash fire in the main deck burned its way through to the upper deck in a very short period. In fact there was virtually no time delay as the chimney effect for the smoke to go to the upper deck. Since passengers could not evacuate all at once, a queuing situation arose and this delay in a life-threatening situation would require the smoke protection devices.	Provision of smoke hood for passenger evacuation is not legally required and no commercial airline provides them as acknowledged by Safety Council.
Reference : 2.6.3.1 Smoke Protection Devices, para 3, ASC Draft Final Report page 237	
The concept of smoke protection devices is not new and has been studied for many years. The carriage of safety devices, such as fire extinguishers and flashlights, by flight crew and cabin crew at each station is a standard practice. However, in this particular accident, none of the crew has smoke masks available for protection. The Safety Council noticed those cabin crews were trained to wear the smoke protection devices only during the fire fighting and the cockpit crew were trained to wear the smoke protection devices during cockpit smoke.	Smoke hoods are provided at crew stations for in-flight fire fighting purposes only as per TSO C116. Provision of smoke hood for crew evacuation is also not legally required and no commercial airline provides them, as acknowledged by Safety Council. The issue of smoke hoods has been debated in the aviation industry for many years and to-date no clear policy has been formulated with regard to their provision for passengers. The

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	debate is on-going and is kept under regular review by the industry.
Reference : 2.6.5 Coroner's Inquest, para 3, ASC Draft Final Report page 240	
Though there was no sufficient autopsy report for the cause of the death for occupants seated between Row 31 to 48, we suspect that the smoke was one of the main reasons of fatality.	Para 5.9 of ICAO Annex 13 provides for autopsies to be carried out on fatally injured crew and passengers after an accident. In the case of SQ006, only seven autopsies were carried out. This small number of autopsy reports prevented a comprehensive analysis of the survival factors of the accident.
Reference : 2.7.3 Weather Analysis, para 1, ASC Draft Final Report page 242	
The Safety Council checked the Runway 05L RVR sensor after the accident and the accuracy was found to be in conformance with ICAO SARPs. According to the weather observations and the data calculated by the manufacturer of the RVR, the visibilities at and before the accident were greater than the takeoff weather minimum (350m).	The take-off visibility minima for Runway 05L was promulgated as Runway Visual Range (RVR) of 200m at the time of the accident.
Reference : 2.7.4 SIA Typhoon Procedure, para 3, ASC Draft Final Report page 242-243	
In addition, the URGENT telexes pertaining to typhoon information were sent to the stations in off-duty time so it was not possible for personnel such as the Chief Pilot of SIA B747-400 to acknowledge the telex because he was not in the office at that time. Consequently, he	

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was not aware of the typhoon conditions at Taipei on the evening of the SQ006 occurrence. Moreover, the Chief Pilots reported that there was no requirement for him to talk to the aircraft commander under such conditions. The Chief Pilot stated that Fleet does not interfere with a commander's decision-making. He defers operational decisions to the aircraft commander.	
Reference : 2.7.4 SIA Typhoon Procedure, para 4, ASC Draft Final Report page 243	
The Safety Council agrees that the aircraft commander should make the final decision and take full responsibility for the aircraft he operates. A well-trained and qualified commander should be able to make a sound decision based on his expertise and judgment when he has received all available information. However, to ensure relevant safety information is communicated, the Chief Pilot should inform the commander to improve his awareness but leave the decision to the commander. The Safety Council believes that if SIA had provided a structured decision making process and proactively provided more resources to the commander, it would have helped the commander with his decision making, thereby facilitating an increased probability of developing the best solution to operate the aircraft in typhoon conditions.	There is no need for the Chief Pilot himself to inform an aircraft commander of a typhoon condition, because the commander would have the latest weather update from the station concerned. The commander would base his decisions on the operational policy and the aircraft performance limits. SIA commanders undergo training and courses in structured decision making processes. For situations such as typhoon conditions, tactical day-to-day decisions are best left to the commander, as he would have the most current information and be in the best position to make operational decisions. It should be noted that the crew of SQ 006 were fully aware of the approaching typhoon. The SIA typhoon procedures were not a contributory factor in the accident. Once again, this ASC discussion does not reflect an understanding of modern airline operations.

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Reference : 2.7.4 SIA Typhoon Procedure, para 6, ASC Draft Final Report page 243	
Interview data indicated that EVA FCD is the ground-handling agent for SIA at CKS Airport to handle SIA flight operations including the flight dispatch operation. SIA Taipei Station is part of the SIA marketing division and is responsible for the non-technical aspects of the flight services. On the evening of the occurrence, the SIA Taipei Station manager believed that it was EVA's responsibility to inform the crew about the typhoon status. However, managers of EVA FCD stated that the responsibilities of EVA on handling SIA's flights are mainly on the flight dispatch and freighter load sheet preparations. They did not believe it was their responsibility to carry out the SIA typhoon procedures. Moreover, EVA believed that SIA did not require them to carry out any SIA typhoon procedures[14] and they were not aware that SIA has a typhoon procedure. Later, the SIA Senior Manager Flight Control Center clarified that the SIA typhoon procedure is an SIA internal procedure that does not apply to EVA. However, SIA FCC was unable to clarify who should be responsible for SIA's typhoon procedure in Taipei.	To clarify the statements by ASC, it should be noted that - SIA's handling agent at CKS Airport, EVA, was procedurally required to inform the SIA Flight Control Centre (FCC) of an approaching typhoon. EVA did this on the day of the SQ 006 accident. - SIA's FCC, through the SIA Taipei Station, would inform the commander of any SIA aircraft on the ground of the need to evacuate or tie down his aircraft should it be necessary.

[14] The contract between SIA and EVA on ground handling services at CKS Airport was followed IATA Ground Handling Agreements AHM810.

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Reference : 2.7.4 SIA Typhoon Procedure, para 7, ASC Draft Final Report page 244	
The Safety Council was unable to determine the influence of this situation on the outcome of the accident. It is unknown what the outcome might have been if the responsible agent in Taipei had been assigned and had carried out SIA's typhoon procedures on the night of the accident. However, this communication break down between SIA FCC, SIA Taipei Station, and EVA FCD would certainly increase the risk of operating an aircraft under typhoon conditions.	It should be noted that Typhoon Procedures are applicable for flights to an affected station and not for a departing aircraft. As such, SIA's Typhoon Procedures had no relevance to the departing SQ 006 flight.
Reference : 2.7.5 Out Station Dispatch, para 4, ASC Draft Final Report page 244-245	
The Safety Council was unable to determine the influence on the development of the accident if the flight crew had been fully briefed by a licensed dispatcher before departure on the night of the accident. However, the Safety Council has concluded that the inconvenience for the flight crew to discuss with a licensed dispatcher would have increasd the risk of operating a flight in adverse weather situations.	There is no basis to conclude that the 'inconvenience for the flight crew to discuss with a licensed dispatcher' increased the risk of operating a flight in adverse weather conditions. SIA crew are trained to self-brief, and its operations are not predicated on the need for a briefing by a licensed dispatcher. There is therefore no risk associated with the non-availability of a licensed dispatcher for briefing in adverse weather conditions. This is a common industry practice.

7.5 Comments from CAA/ROC

Singapore Airlines

Boeing 747 Accident, October 31, 2000

At

Chiang Kai-Shek Airport, taoyuan, Taiwan, Republic Of China

Representations on the draft final report

By the

Civil aeronautics administration Republic of china

Submitted March 2002

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Part 1

An Overview of the Representations from the CAA to the ASC on the Confidential Draft Final Investigation Report Concerning the SIA Boeing 747-400 Accident at CKS Airport, 31 October 2000

In addition to summarizing the CAA's submission, some liberty has again been taken to provide readers with a degree of explanation and comment on the content of the representations made by the CAA. This was done only to increase the clarity of the summary.

The ASC has declared that the aviation accident report on Singapore Airlines flight SQ006 is to be used solely in the prevention of accidents and incidents. The ASC further states that its investigation was not for the purpose of apportioning blame or liability. The CAA's representations on the draft final investigation report have been made only to increase the fairness, clarity and accuracy of the ASC's report. The CAA's representations are intended for the advancement of aviation safety, and are not to be used for any other purpose. They are particularly not intended for use in litigation that may be related to the accident. We have been unguarded and forthcoming in the interests of safety, which is quite different from being truthful but protecting our own interests as we would with comments intended to be used in disciplinary or court processes. This we believe is in line with your preface to the draft report.

The representations are much less numerous than on the preliminary draft. There are still a significant number of observations, but it is a modest number in light of the complexity and importance of the report.

In technically complex, well managed, and carefully operated systems, such as civil aviation, there are occasional safety failures. It is almost inevitable that in an objective analysis of one of those failures, such as is represented by this ASC investigation, all involved are able to learn that there are improvements that can be made to eliminate, or at least reduce, risks within the system. Generally, some of the risks are inherent, some were there but were simply not identified and removed when the system was developed, and others are introduced as components of the system develop and change. The draft final report prepared by the ASC has demonstrated that there were safety risks in the system and all involved have work to do to minimize those risks both on their own and in concert with others. The ASC was clearly open to the representations made on the preliminary draft and the report has been extensively revised, clarified and significantly strengthened.

On the night of the accident the weather was adverse with heavy rain, a low ceiling, and strong gusty crosswinds related to the approach of typhoon “Xangsane”. However, during the entire time that the crew was in the aircraft the visibility was in the order of a half kilometer. The visibility was certainly not good but it was within the range where modern commercial aircraft can operate safely. During the latter part of the taxiing and the turn onto Runway 05R, the crew did not respond to the numerous indications that they had not reached the assigned takeoff runway. When the crew lined up the aircraft on partially closed Runway 05R instead of the intended Runway 05L they noticed an anomaly in the Para Visual Display but discounted it and elected to take off. With the cloud base at 200 feet the crew would have had to make a transition from visual to instrumental flight within a few seconds after lift-off. The key information necessary to fly the aircraft; such things as track, heading, altitude, rate of climb, airspeed and other vital data are shown on the Primary Flight Displays (PFD) in front of both pilots. With the intended runway centerline being 214m (650ft.) to their left, the Instrument Landing System azimuth (localizer) indication showed a left-turn command with the indicator fully deflected. Similarly, the runway symbol and the required track, instead of being in the center of their displays, were deflected to the left. Generally, there is a takeoff briefing by the captain shortly before the aircraft moves into position on the runway. Such a briefing confirms the departure procedure and actions in the event of an emergency such as an engine failure. This was not done. An experienced crew of three that was rated from average to above average, flying a modern aircraft, designed to be operated by a crew of two, with no noted unserviceable items, missed the last possible indication that they were not on the assigned runway. It was clear from the Primary Flight Display that they were not on the takeoff runway. The PFD was the display that they would have had to rely upon to fly the aircraft from a few seconds after lift-off, but apparently they did not look at it, or if they did, they did not appreciate what it was telling them. How this could have happened was clearly the object of the investigation. The investigation was comprehensive and looked at the accident and the circumstances surrounding it.

The draft final report follows the ICAO format with the three basic sections of factual information, analysis, and conclusions. The factual information covers a wide range of activities, systems, and data. It was carefully gathered but it is inevitable that there were some imperfections in communications, and there was new information that came to light after interviews were completed and documents were gathered. Often those supplying the information cannot see the gaps and errors until the preliminary confidential draft is prepared with all the information in context. The recognition of the need for change, where new or confirming information came to light following the confidential preliminary draft has resulted in a stronger and clearer draft final report.

In that light the CAA has reviewed the Factual section of the draft final report and has offered corrections to the information that it provided earlier, and corrections to the impressions that it left with those who were conducting the investigation

The review of the Analysis section brought forth comments on the information in the section and on the way it was treated. In the analyses of the draft final report, the CAA found there were more conjectural statements remaining than we believe is supportable in an excellent aviation accident investigation report. There were also still places where significant amounts of new factual information appeared in the analysis. The human factors analysis was detailed, as one might expect in this sort of accident. In a few places the CAA has noted disagreement with the views expressed in the ASC report on some of the human factors issues.

The total revision to the Conclusions section of the report has resulted in a major strengthening of the report. The number of findings and recommendations in the draft final report remains large. It is the view of the CAA that some very strong and important findings and recommendations lose some of their impact when set among some that are much less important. The CAA urges the ASC to review the findings and recommendations with a view to eliminating the less important among them in order to give greater impact to the more important ones. The individual recommendations, we believe, would be more compelling if they were supported by more rationale in the recommendations section. That approach was adopted and improved the acceptance of recommendations in accident investigation reports produced by United States and by Canada.

While there are some deficiencies in the CAA's organization and operations, both in the headquarters and at CKS airport, one must remember that in January 2000 the CAA Headquarters earned and received an ISO 9002 Warranty Certificate and the affiliated airport offices, Air Navigation & Weather Services and the Aviation Training Institute received the same award prior to April 2000. Also in January 2000 the CAA made public a civil aviation "White Paper" setting forth the direction of the ROC's civil aviation policy. Such central direction will encourage a new degree of coherence in civil aviation matters. Finally, in 2000 there was a review of air transport management to judge objectively how national air carriers were performing. The assessment included the review of the three major items of flight safety management, passenger service and policy adaptation.

In aviation safety the draft final report emphasizes that the ROC faces an inherent difficulty that is associated with being neither a member state of, nor an observer at, ICAO activities. Most ICAO documents can be obtained, although not directly, in a fairly timely manner but there is no opportunity to take part in the deliberations that result in new standards and recommended practices. Being excluded from ICAO, there is not the good notice of developing standards that permits the planning for their implementation and there is no forum for the ROC to bring its unique requirements to the international civil aviation community.

We noted there was still some information that was interesting but not really relevant to the accident or to safety deficiencies uncovered in the investigation. This tends to make a long report a little longer than necessary and a little more difficult to understand than is necessary.

To the extent practicable, we have noted our differences with the draft report, given reasons for the differences and suggested changes to the wording that can be ‘pasted’ into the report.

The CAA understands that the ASC will advise on the degree to which it accepts the representations made on the final draft report. The CAA will then decide whether to ask to have its representations appended to the public report.

Part 2

Representations on Section 1, Factual Information

✈ Section 1.1 History of Flight

Ref: Second to last Paragraph of the section, ending with "end of the recording."

CAA Issues and Discussion

To enhance the factual information, it is important to include the fact that the jersey barriers were equipped with lights at the time SQ006 collided with them.

CAA Proposed Changes

The CAA proposes that the word "lighted" be inserted in the following paragraph:

"Approximately 33 seconds after the takeoff roll commenced, the aircraft collided with several lighted concrete "jersey" barriers, 2 excavators, 2 vibrating rollers, a bulldozer, an air compressor cart, and a pile of metal reinforcing bars on Runway 05R, between Taxiways N4 and N5. The FDR recorded airspeed about 158 knots and ground speed about 131 knots at the end of the recording."

✈ Section 1.3 Damage to Aircraft

Ref: General to the one Para section, which ends with "vertical drip patterns."

CAA Issues and Discussion

Section 1.3 Damage to Aircraft, is a general description of the aircraft damage, and it would benefit from a brief discussion of the overall damage to the aircraft and the monetary amount of the hull loss. (i.e. The airplane was destroyed by impact and fire damage. According to the insurance company the airplane was valued at $??? million dollars (U.S.). The information currently presented is better suited for discussion in Section 1.12.

CAA Proposed Changes

The airplane was destroyed by impact forces and by a post-accident fire. According to insurance company records the airplane was valued at $??? million dollars (U.S.).

✈ Section 1.4 Other Damage

Ref: Last portion of section ending with the words “in the various pits.”

CAA Issues and Discussion

Other Damage is a general description of the overall damage to the construction equipment and any other airport property that was damaged or destroyed in the accident. This description should include a monetary value estimated to be in the thousands or million of dollars for both equipment and cleanup.

CAA Proposed Changes

Airplane wreckage and the post-crash fire either destroyed or significantly damaged two excavators (Figures 1.4-1), two vibrating rollers (Figures 1.4-2), one small bulldozer (Figure 1.4-3) and one air compressor. The total equipment damage (not including airplane) and clean up of construction site were estimated at $740,000 dollars (U.S.).

✈ Section 1.5.1 The Captain (CM-1)

Ref: Paragraph 3, ending with “initial and recurrent training.”

CAA Issues and Discussion

The report states that the CM-1 was qualified for CAT III operations and that he had received both initial and recurrent PVD training. The report does not state when he received his CAT III qualification, or the initial and recurrent PVD training.

Also, in Section 2.5.4.5, SIA Low Visibility Taxi Training, the ASC report states “…CM-1 stated that he did not receive low visibility taxi training.” It is apparent that this statement could be contradictory to the information for CAT III qualifications because a portion of this training (Crew Training Manual (CTM)) addresses “Taxiing in Poor Visibility,” and the SIA Flight Instructor Manual requests instructors to teach pilots about, “taxi routing and situational and environmental awareness.” Further, although the video portion of this training does not address low visibility taxi operations, and the written materials and instructor training may not have been complete or as detailed as necessary to provide a good foundation, the SIA training program did provide some information and recommended practices in the CTM.

CAA Proposed Changes

The CAA suggests that the dates of CM-1 CAT III qualification and the PVD be included to complete the factual record.

✈ Section 1.5.2 The First Officer (CM-2)

Ref: Paragraph 2, which ends with “in February 2000.”

CAA Issues and Discussion

The report states that the CM-2 was qualified for CAT III operations and that he had received both initial and recurrent PVD training. The report does not state when he received his CAT III qualification.

Also, based on the discussion that occurred with the CM-2 and the other crewmembers about the PVD and its operation (CM-3 explaining the 45 degree alignment), it is important to know why the CM-2 may not have known this fact about its operation since he had just completed PVD recurrent training on September 24, 2000, one month prior to the accident.

CAA Proposed Changes

The CAA suggests that the date(s) of CM-2 CAT III qualification be included to complete the factual record.

✈ Section 1.5.3 The Relief Pilot (CM-3)

Ref: Paragraph 3, which ends with “initial and recurrent training.”

CAA Issues and Discussion

The report states that the CM-3 was qualified for CAT III operations and that he had received both initial and recurrent PVD training. The report does not state when he received his CAT III qualification or his initial and recurrent PVD training.

CAA Proposed Changes

The CAA suggests that the date(s) of CM-3 CAT III qualification and initial and recurrent PVD training be included to complete the factual record.

✈ Section 1.7.2 Surface Weather Observations [2 issues]

Issue 1:
Ref. table 1.7-1

CAA Issues and Discussion

This wind direction and magnitude in this table are currently presented in meters per second although the column headings indicate “degrees/knots.” The numbers presented in bold font are the corrected “knots” values. Also, the table contains information derived from both the automated weather observation system for CKS Airport called Airport Weather Advisor (AWA) and the runway crosswind magnitude calculated by the

ASC. As currently presented, the chart could be misunderstood because there is no explanation of the source of the values used.

Additionally, the text that is currently presented after the chart should be revised and placed ahead of the chart to provide the reader with an explanation of where the automated system records the wind values. Also, the calculated crosswind magnitudes need to be explained so that the reader will understand the method used in their determination.

CAA Proposed Changes

Table 1.7-1 Weather Condition of CKS Runway should be re-titled to reflect accurately that the values in the Table are not weather conditions but recorded AWA wind and visibility readings. The chart should be edited so that the Crosswind magnitude is removed and discussed separately, or a footnote should be added to tell the reader that these values do not come from the AWA but were calculated by the ASC using some specific method (airline table, National Weather Service program, etc.)

Also, the description of the AWA (see example) should include information that there are three sensors along runway 5L (approach-end, mid-field and departure-end) and the values presented in the chart are from the 05L approach end sensor. Also it needs to be noted that the wind magnitude and direction recorded by the AWA for the time periods listed in the chart are the "average" of the wind reading recorded over a one minute period and not the actual wind value at the beginning of that minute. These values also incorporate any peak gusts during that period.

Example text: "The automated weather observation system for CKS Airport is called Airport Weather Advisor (AWA). The AWA is comprised of anemometers, forward scatter sensors (RVR sensors), ceilometers, barometers and temperature/dew point sensors. The anemometers are located at the approach-end, mid-point and departure-ends of runways 05, 23, 06, 24; and the RVR sensors are located in the vicinity of each anemometer with the exception of the mid-point of Runway 06/24. The AWA records the "average" wind direction and magnitude over a rolling "1-minute" period. Thus, the values presented in the Table 1.7-1 for the one-minute periods beginning at 2312 through 2317 are averages and not the actual wind condition at the particular time.

Additionally, the wind value provided by the air traffic controller to the flight crews is based on a 2 minute rolling average recorded by the AWA at the runway 5L threshold."

Issue 2

CAA Issues and Discussion

The information presented in Finding No. 1 (Findings Related To Probable Cause) can be confusing because it states the wind condition at the time of the accident was from 020 degrees with a magnitude of 36 knots, gusting to 56 knots, and the values are not attributed to a specific location on the airport. However, Table 1.7-1 indicates the wind condition at 2317 for Runway 05 was 360 degrees at 41 knots with a crosswind magnitude of 31 knots. Further, the Table does not represent the instantaneous wind gusts that occurred during that period that would have had to be factored into the flight crew's determination of headwind and crosswind limitations for the "wet" runway.

The variance in these values is significant because the reduced steady-state wind conditions are "more acceptable" and within the SIA operating limits. However, as CM-3 has stated in his interview, he was concerned the wind condition (by his calculation 28.5 knots) was at a value close to the SIA maximum limit when they began their takeoff.

CAA Proposed Changes

Table 1.7-1 Recorded AWA Wind and Visibility Readings

Time	Runway 05 Wind Direction and Magnitude (degree/knots)	Runway 05 Cross Wind Magnitude from Left Hand Side (knots)	Runway 05 Visibility[1] (meters)	Mid-Point 05/23 Visibility (meters)
2312	358/**29**	**23**	518	475
2313	023/**86**	**38**	504	604
2314	018/**56**	**29**	923	420
2315	029/**59**	**20**	450	236
2316	013/**59**	**34**	360	168
2317	360**/41**	**31**	444	192

✈ Section 1.10.1 General

Ref: Paragraphs 1 & 2, which end with "CKS Airport was commissioned."

CAA Issues and Discussion

The Ralph M. Parsons Company designed the CKS Airport in 1973 according to FAA specifications.

The main purpose of Runway 05R/23L was always for taxiing.

CAA Proposed Changes

The following corrected text will enhance the clarity of this section:

[1] The visibilities were calculated by the manufacturer.

The Ralph M. Parsons Company of the United States designed the CKS Airport in 1973, according to FAA specifications; and construction was completed in February 1979. CKS Airport diagram is shown in Figure 1.10-1.

The original design of the airport did not include Runway 05R/23L, but rather included a parallel taxiway (identified as Taxiway A). It was determined during construction that an additional runway was necessary in the event that the primary runway, 05L/23R, was closed. Hence, Taxiway A was re-engineered and designated Runway 05R/23L when CKS Airport was commissioned. However, the intended purpose of Runway 05R/23L was always for taxi operations.

In 1987 the CAA created its own airport construction specifications, incorporating information from both the FAA Airport Specifications and ICAO Standards and Recommended Practices (SARPs).

In November 1971 the ICAO ceased to recognize the Republic of China (ROC) as a member State. Although the CKS Airport had been constructed in accordance with FAA Specifications and ICAO SARP's, the CAA of the ROC was no longer able either to receive directly the ICAO SARP's information or participate in working groups.

✈ Section 1.10.2.1 Runway Configuration and Specifications

Ref: Paragraph 3, which ends "or 17 knots "wet runway.""

CAA Issues and Discussion

The information presented is complete. Minor editorial change and the addition of a key word would make the factual record complete.

CAA Proposed Changes

The following words are suggested for inclusion in the ASC paragraph:

"Runway 05R/23L was 45 meters wide and 2752 meters long and was designated as a "non-instrument" runway. It was equipped with green centerline lights for taxi operations and white edge lights for takeoff operations. The runway was not available for landing but pilots were able to request its use for takeoff. Pilots were required to obtain prior approval from both the CKS Airport and the Air Traffic Controller for the use of the runway. Typically, approval would not be granted when there were large aircraft on Apron 501-515 because of the lack of sufficient safety zone clearance. Further, the simultaneous use of Runway 05R/23L and the parallel Taxiway "NP" was prohibited if the crosswind component exceeded 22 knots (dry runway) or 17 knots (wet runway)."

Issue 2:

CAA Issues and Discussion

Figure 1.10-6, identified as the Taxiway centerline markings near the threshold areas of runway 05R is " missing."

CAA Proposed Changes

Include Figure 1.10-6

✈ Section 1.10.3.2.2 Runway Guard Lights

Ref: End of section, which ends with "guard lights installed."

CAA Issues and Discussion

This section should reflect the statement found in Section 1.10.3.2.3 regard the SMGCS program to provide continuity.

CAA Proposed Changes

The CAA suggests the inclusion of the following sentence at the end of this section:

"At the time of the accident, CKS Airport did not have a SMGCS program and the runways were not equipped with guard lights."

✈ Section 1.10.3.2.3 Stop Bar Lights

Ref: 2nd paragraph beginning with, "The stop bar lights are also one component…."

CAA Issues and Discussion

The stop bar lights don't necessarily enhance taxiing capability in low visibility conditions. In fact, the stop bar identifies the intersection of a runway and a taxiway and provides an indication of proximity to a runway in low visibility conditions.

CAA Proposed Changes

It is suggested that the paragraph be modified as follows:

The stop bar lights are also one component of the SMGCS that is used to identify the intersection of a runway and taxiway in low visibility conditions. The stop bar lights, in conjunction with the other components of the SMGCS are also intended to enhance the pilot's awareness of his proximity to a runway.

✈ Section 1.10.3.2.4 Taxiway Centerline Lights

Ref: Paragraph titled "ICAO Annex 14, Volume 1, Paragraph 5.3.15.7 (Standard):"

CAA Issues and Discussion

The section would benefit and be more complete with information from ICAO Annex 14, Volume 1, Paragraph 5.3.15.10

CAA Proposed changes

Insert: According to ICAO Annex 14, Volume 1, Paragraph 5.3.15.10,

> *"Recommendation – Taxiway center line lights should normally be located on the taxiway center line marking, except that they may be offset by not more than 30 cm where it is not practicable to locate them on the marking."*

✈ Section 1.10.5.1.2 Circuit Monitoring

Ref: Last paragraph which ends with, "selected at intensity level 3."

CAA Issues and Discussion

In the spirit of addressing those issues that are either causal or contributing to the accident, the information provided in Section 1.10.5.1.2, Circuit Monitoring, is not pertinent to the accident because, 1) SQ006 was assigned runway 05L for takeoff not 05R, 2) the appropriate taxiway centerline lights were operational on runway 05R the night of the accident and 3) the crew of SQ006 was aware of the operational status of this runway by NOTAM. Therefore it is recommended that this section be deleted.

CAA Proposed Changes

If the ASC believes the information should remain in the report, the CAA suggests the following text change for the third paragraph to complete the factual record and provide clarity:

"The airfield lighting system is monitored both electronically and by personnel from the Air Navigation and Weather Services (ANWS) section at CKS Airport. This unit is comprised of ten persons, six supervisors and four artisans; and they are scheduled on shifts round the clock. ANWS maintenance staffers inspect the airfield lights twice a day, once in the morning (0900 – 1100 hours) and once in the afternoon (1300 – 1500 hours). They coordinate this activity with the Control Tower for an available time slot to enter the taxiway/runway and conduct necessary repairs. Typically, any faults recorded in the morning are rectified in the afternoon on the same day. In addition to the daily checks, ANWS has weekly and monthly checks for airfield lights that require greater attention."

✈ Section 1.13 Medical and Pathological Information

CAA Issues and Discussion

The information presented in this section regarding the "Alcohol and Drug Test on the Flightcrew" needs to be expanded to provide an explanation of the regulations governing these tests and why they were not conducted. Article 6 of the ASC regulations explains the authority of the ASC regarding toxicological tests for deceased crew members – but there is ambiguity for surviving crew.

CAA Proposed Changes

Provide additional information regarding the authority of the ASC, the CAA and "Prosecutor" regarding the ordering of these tests.

✈ Section 1.16.6 Cockpit Field of View Study

Ref: End of section, which reads "range of the human eye."

CAA Issues and Discussion

The conclusions that can be drawn from this study are extremely limited. The study was based on the assumption that pilots only look straight ahead. The study does not take into account [continuous] head and shoulder movements of the pilots. Therefore, figure 1.16-8 provides an extremely conservative and misleading depiction of the pilots' field of view. CM-1 even stated in his interview (1.18.1.1.1) that the "wiper cleaned most of the windscreen and he could see through almost the whole windscreen." CM-1 also reported that he "felt that his visibility was not impaired by the rain, even in the areas not swept by the wipers." Because of the limited nature of this study, it also produces results that are inconsistent with the Taxi Route Simulation (1.16.1) that showed that most signs, markings, and lights were visible from the cockpit. To be performed correctly, this field of view study should have calculated the field of view for different degrees of head rotation from both the left and right of pilots' forward views. These overlapping fields should then have been plotted in figure 1.16-8 to illustrate a more realistic range of ground visibility. Simply stating in the text that "the actual field of view will be slightly better when the pilot moves his head" (p. 118), is inappropriate.

CAA Proposed Changes

Either the study should be expanded to identify the overlapping fields of views from different rotation angles of the pilots' heads, or the above paragraph should be inserted in the text to notify the reader of the extreme limitations of the study and subsequent conclusion that can be drawn from it.

✈ Section 1.17.3.2 Training Department

Ref: Sub-section on Low Visibility Training, which ends with "approved level 2 simulator."

CAA Issues and Discussion

The issue of training discussed in Section 1.17.3.2, especially the low visibility training, should be explored with more depth. The CM-1 made a statement that he did not receive low visibility taxi training yet he is CAT III and PVD qualified. Furthermore, both the CM-2 and CM-3 were CAT III and PVD qualified. If the CM-1 did not receive "any" training regarding low visibility taxiing operations, then it is likely that CM-2 and CM-3 were also at a disadvantage. However, neither the CM-2 nor CM-3 indicated this training deficiency in their interview statements. Further, the CAT II & III training video that crewmembers are required to view does not address low visibility taxi operations. Consequently, it is apparent that the low visibility training focuses only on the takeoff and approach portions of flight operation, as has been implied by the CM-1. Based on the lack of training and detailed training materials available to educate the crew members as to the hazards associated with this type of operation, it can be concluded that this flight crew was not fully trained by SIA and was at a disadvantage on the evening of the accident.

In addition, the deficiency in the training extend beyond a lack of information in SIA B-747-400 Operations Manual and "no formal training" for low visibility taxi as stated in Findings No. 6 and No. 13 under Findings Related to Risk. SIA, in not providing such training, resulted in the flight crew not being equipped with the knowledge and tools necessary to conduct such an operation. Thus, Finding No. 6 and No. 13 could be combined to reflect the seriousness of SIA's deficiency and the implications it had on the accident flight crew.

CAA Proposed Changes

It is suggested that the description of the Low Visibility training conducted for both CAT III operations and the PVD be expanded to include the exact information that is provided to crewmembers in the flight and training manuals, the classroom, the simulator and in the videotape. This would provide a clear picture to the extent of the low visibility training especially on taxiing operations. Also, it would serve to demonstrate exactly where the deficiencies are in the training program and provide the basis for a more definitive Safety Recommendation.

✈ Section 1.17.4.4 Aircraft Documentation

Ref: The entire section which ends with, "of Runway 05R and 05L."

CAA Issues and Discussion

The information provided in Section 1.17.4.4 is interesting information but it is not relevant to the accident nor is it referenced in the analysis.

CAA Proposed Changes

It is proposed that section 1.17.4.4 be deleted from the report. However, if the ASC believes it should remain in the report, it could be moved to Section 1.17.3.4 since it relates to a function of the SIA FCC.

✈ Section 1.17.4.5 SIA Taxi Procedures

Ref: End of section which reads "B747-400 Operations Manual."

CAA Issues and Discussion

There are several sections of this report that should be rearranged to improve its clarity. One such section is 1.17.4.5 because it is training related. Thus, for report continuity, the information should be moved in sequence with Section 1.17.3.2.

CAA Proposed Changes

It is suggested that 1.17.4.5 be moved in sequence with Section 1.17.3.2.

✈ Section 1.17.4.6 Out-Station Audits

Ref: Entire section, which ends with "audit on May 31, 2000."

CAA Issues and Discussion

Section 1.17.4.6 is related to the FCC and out station services. For report continuity, the information should be moved in sequence with Section 1.17.3.4.

CAA Proposed Changes

It is suggested that 1.17.4.6 be moved in sequence with Section 1.17.3.4.

✈ Section 1.17.5 EVA Airways Flight Control Department

Ref: Entire section, which ends with "typhoon condition II at 2155."

CAA Issues and Discussion

Section 1.17.5 is related to the FCC and out station services. For report continuity, the information should be moved in sequence with Section 1.17.3.4.

CAA Proposed Changes

It is suggested that 1.17.5 be moved in sequence with Section 1.17.3.4.

✈ Section 1.17.6 SIA Taipei Station

Ref: Entire section, which ends with "crew of the typhoon status."

CAA Issues and Discussion

Section 1.17.5 is related to the FCC and out station services. For report continuity, the information should be moved in sequence with Section 1.17.3.4.

CAA Proposed Changes

It is suggested that 1.17.5 be moved in sequence with Section 1.17.3.4.

✈ Section 1.17.8 Voyage Record

Ref: Entire section, which ends with "satisfactory reasons are provided."

CAA Issues and Discussion

Section 1.17.8 is interesting factual information but its relationship to the accident is unclear and is not referenced in the analysis nor used to support a Safety Recommendation.

CAA Proposed Changes

It is suggested that 1.17.8 be deleted from the report.

✈ Section 1.17.9 Organization of CAA

Ref: Organization chart.

CAA Issues and Discussion

The CAA has a new organizational chart that should be included in the report to provide the most accurate data. Also, the current positioning of the chart in the report is confusing because there is no introduction.

CAA Proposed Changes

Insert most current Organizational Chart and move the chart to the end of the 1st paragraph.

✈ Section 1.17.11 The Aerodrome Engineering Division

Ref. Entire section, which ends with “ the airport master plan.”

<u>CAA Issues and Discussion</u>

The correct name of the division is the ‘Aerodrome Division (AD).’

<u>CAA Proposed Changes</u>

Change all references in this section and other sections (e.g. 1.17.13) to eliminate the word ‘engineering’ and the related abbreviation ‘E’ wherever it is used.

✈ Section 1.18.1.1 The Captain CM-1 [2 issues]

Issue 1:

Ref: <u>Points to note by CM-1</u>, first paragraph of the subsection, which ends with “and this was the trap.”

<u>CAA Issues and Discussion</u>

Under the subsection of “Points to note by CM-1,” the statement, “and this was the trap” should be in quotation marks if this is what the captain actually said. If it is not what he actually said, then the statement is biased and should be removed from the document.

<u>CAA Proposed Changes</u>

Remove the statement if it is not what the pilot actually said or enclose the statement in quotation marks if it does reflect the exact words of the pilot.

Issue 2:

Ref. Final paragraph of section, which ends “in low visibility conditions.”

<u>CAA Issues and Discussion</u>

Unlike CM-2 and CM-3, CM-1 was apparently never asked what his mental picture of a closed runway would look like. However, in the analysis section 2.5.7.7, it is implied that he was asked this question. Also, none of the flight crew was asked to describe a mental picture of what a CAT II runway should look like. This seems like a very important oversight, since a great deal of the analysis is based on the idea of “confirmation bias” or that the pilots “saw” what they expected to see.

<u>CAA Proposed Changes</u>

Some of the analyses of flight crew comments should be re-evaluated in light of these apparent oversights during the interview process. These issues have been addressed within relevant sections of the document.

✈ Section 1.18.1.3.4 Interviews with Controller D

Ref: Entire section, which ends with “there was no arrival traffic.”

CAA Issues and Discussion

Sections 1.18.1.3 is related to Section 1.18.2. Thus, for report continuity, either section should be moved as appropriate to be in sequence with each other.

CAA Proposed Changes

It is suggested that 1.18.1.3 be moved in sequence with Section 1.18.2.

✈ Section 1.18.1.5 Other Interviews

Ref: 5th paragraph, which ends with “broken clouds at 30,000 feet, no rain.”

CAA Issues and Discussion

The inclusion of the interview with the freighter captain of the MD-11 is questionable. The captain did not contact Singapore MCIT until two months after the accident and the first interview did not take place until 4 months after the accident. It also appears that the first interview was not done with all parties to the investigation being present. The second “official” interview took place almost 9 months after the accident. The freighter captain had obviously been exposed to reports of the accident and possible runway issues. His recollection could also have been biased by questions asked during the first interview. Furthermore, the statements in the document do not indicate from which interview they came (1st or 2nd).

CAA Proposed Changes

The statements derived from the interview are dubious and unsubstantiated, and should be deleted from the report.

✈ Section 1.18.2.3 ATC Procedures [2 Issues]

Issue 1:

Ref: Following point 3 there is a line that reads, “The progressive taxi instruction was not issued to SQ006.”

CAA Issues and Discussion

Insert an additional sentence in place of the referenced sentence.

CAA Proposed Changes

The replacement sentence should read:

"SQ006 was the only traffic in the maneuvering area. The controller provided precise taxi instructions to the crew of SQ006 which they accepted without a request for progressive taxi instructions."

Issue 2:
Ref: Paragraph beginning with, "During interviews with the Chief of the Tower…"

CAA Issues and Discussion

The following sentences are not factually correct:

1st sentence: "In particular, ATC tries to ensure that the aircraft are expedited from the active runway after landing and that taxiing aircraft do not enter the active runway until cleared" is not factually correct because of the context in which the words "expedite" and cleared are used.

2nd sentence "If there are no other aircraft on the airfield during taxi, ATC does not have specific procedures or practices to assist flight crew's navigating." This is not factually correct because ATC does have specific procedures and practices to assist flightcrew taxiing around the airport. The controller provided the crew of SQ006 with a detailed taxi plan. It was accepted by the crew. If the crew believed they would not be able to safely navigate to the runway it would have been incumbent upon the pilot to request progressive taxi instructions. Further, it is evident that the need for progressive taxi instructions was not necessary since the crew was able to taxi from the terminal apron to runway 5R

CAA Proposed Changes

To enhance the factual record, the following replacement sentences are suggested where appropriate:

1st sentence: "In particular, ATC must ensure that the aircraft are clear of the active runway after landing and that taxiing aircraft do not enter an active runway until authorized by ATC."

2nd sentence: "ATC does have specific procedures and practices to assist flightcrew taxiing around the airport but they are not normally exercised unless requested by the pilot."

✈ Section 1.18.2.4 Airport Surface Detection Equipment [3 issues]

Issue 1:
Ref. Opening sentence, which ends “duties at any time.”

CAA Issues and Discussion

The first part of the opening sentence is inaccurate. The controller is not ‘required to use ASDE’ but has the discretion to use it or not use it to augment visual observations of aircraft or vehicles.

CAA Proposed Changes

The opening words of the sentence should read: “ATP-88 states that the controller can use Airport Surface Detection . . .”

Issue 2:
Ref: 2nd paragraph, first sentence, which ends with “control instructions by aircraft and vehicles.”

CAA Issues and Discussion

First sentence is redundant (see previous paragraph) and should be deleted.

CAA Proposed Changes

Delete the first sentence of the paragraph.

Issue 3:
Ref: 3rd paragraph beginning with, “During interviews, the duty controller stated that…”

CAA Issues and Discussion

The statement is an opinion and does not represent the CAA’s position.

CAA Proposed Changes

It is suggested that the statement be deleted. However, if the ASC believes the statement should remain, there should be a clarifying statement that this is a personal opinion and does not represent the CAA’s position.

Part 3

Representations on Section 2, Analysis

Changes Proposed to the 'ANALYSIS' section of the ASC Draft Final Investigation Report.

✈ Part 2 Analysis

Ref: The final paragraph that ends "utility of air safety investigation data."

CAA Issues and Discussion

The classification of the findings as 'cause related', 'risk related' and 'other' is very progressive and serves safety purposes better than the more traditional and slightly different classifications often seen in accident investigation reports. The addition of 'safety deficiencies' identified in the course of the investigation, whether related to cause or not is also very constructive.

CAA Proposed Changes

The clarity and the strength of the report could be further improved by consolidating some of the findings and by eliminating those of less importance.

✈ Section 2.2 Structural Failure Sequence

Ref: Entire Section

CAA Issues and Discussion

This information is factual with no conclusions being drawn and is not the basis for Safety Recommendation support.

CAA Proposed Changes

The information could be edited and moved to the Section 1.12 Wreckage Information to enhance the description of the accident site and damage to the airplane.

✈ Section 2.3 CKS Airport at the time of SQ006 Accident

Ref: Entire section

CAA Issues and Discussion

The information presented in this section is factual information and is discussed in Section 1.10, Airport Information.

CAA Proposed Changes

To eliminate redundancy, it is suggested that this Section be deleted.

✈ Section 2.3.1.1 Design of Taxiway N1 Centerline Marking [2 issues]

Issue 1:
Ref: Paragraph 2 – which ends with "from Runway 05R toward Runway 05L."

CAA Issues and Discussion

The CAA civil engineering specifications (ATP-AE 1000301: 3.8.5.1) did not state how to calculate the distance between the south edge of the Runway 05R and the tip of the curvature where N1 centerline made a turn into Runway 05R, and the distance between the north edge of the Runway 05R and the tip of the curvature where taxiway centerline marking turned away from Runway 05R to join Taxiway N1.

CAA Proposed Changes

CAA recommends that this reference be deleted.

Issue 2:
Ref: Paragraph 5 [final paragraph], which ends with "safety oversight mechanism by the CAA."

CAA Issues and Discussion

There is no question that there were deficiencies in the marking of Taxiway N1. The significance of those deficiencies appears to be very slight in light of the extensive time that they went unnoticed by the airport operator, the carriers and the States that conducted inspections prior to authorizing their carriers to operate out of CKS airport. While the ASC believes that the lack of a safety specialist and the lack of a safety supervision mechanism were responsible for the oversight there are additional plausible considerations. Even with a specialist and an oversight organization, there is no guarantee that their observations would be acted upon. There could be an assessment that the standard was not important, there could be an absolute shortage of money to implement the changes and there could be other more important safety items that used the available funding year after year.

CAA Proposed Changes

It is suggested that the final sentence be revised to read:

"The Safety Council was not able to determine the reason for the discrepancy. Certainly the absences of a safety specialist and a safety oversight mechanism increased the probability of the discrepancy remaining unnoticed. However, air carriers operating at CKS and ICAO member States that conducted inspections of the CKS Airport did not identify these discrepancies. Further, the Safety Council is concerned that other factors such as the availability of funding and other safety priorities may have also played a role."

✈ Section 2.3.1.2.1 Taxiway Lighting System Interlock with Runway 05R Lighting Systems

Ref. Para 2 – which ends with "to update the local regulations."

CAA Issues and Discussion

According to ICAO Annex 14, Volume 1, Paragraph 5.2.1.3 and the FAA Advisory Circular 150/5340-1H, Taxiway N1 centerline marking of CKS Airport meet ICAO standard and FAA AC**.**

CAA Proposed Changes

CAA recommends that this paragraph be deleted.

✈ Section 2.3.1.2.2 Spacing of Taxiway Centerline Lighting [2 issues]

Issue 1:
Ref: Paragraph 2, which begins with "The curved radius from Taxiway NP…"

CAA Issues and Discussion

The CAA offers clearer wording**.**

CAA Proposed Changes

It is suggested that the following text be inserted beginning at the second sentence:

"Therefore, in order to meet the most recent ICAO recommendation (issued in 1999), there should be 16 centerline lights spaced 7.5 meters apart along the straight segment of taxiway N1 where the curved portion of taxiway NP intersects with taxiway N1, up to the runway 05L holding position. . ."

Issue 2:
Ref: Paragraph 3, which begins with "The distance of Taxiway N1 centerline lights . . ." and ends with, "… did not meet ICAO SARPs."

CAA issues and Discussion

It has been recognized that the 200 meter RVR that was in print at the time of the accident was the result of the misinterpretation of the ICAO standard. Although this is factual information and should be addressed along with the change that was made after the accident to 350 meters, the analysis of this issue, as it relates to the SQ006 accident, should be based on the fact that the RVR at the time of the accident was in excess of 350 meters. Further, although the standards call for a certain number of centerline lights to be installed for use during "low visibility" operations, on the night of the accident the RVR was well in excess of both the 200 meter and 350 meter RVR minimums. Therefore, to focus the issue, the discussion should address the fact that there was a misinterpretation of standards resulting in the wrong RVR minimum

CAA Proposed Changes

The text should discuss the requirements for 350 meter RVR, which was the intent and was the practice at CKS until the error was introduced. Further, the 350 meter limit was restored when the error was realized.

In addition it is suggested that the following sentence be inserted as the conclusion to this section:

"The Safety Council considers that a reduced spacing of the centerline lights on the curves should assist crews to maintain awareness of their position and would reduce the likelihood of taxiing errors."

✈ Section 2.3.1.2. Unserviceable Taxiway Centerline Lights

Ref: 2nd paragraph which ends "of the November 4 inspection."

CAA Issues and Discussion

The information in the section moves the balance of probabilities toward the lights being normal at the time of the accident.

CAA Proposed Changes

In the last full line of the second paragraph change "might or might not . . ." to "were unlikely to . . ."

✈ Section 2.3.2 The Installation of Runway Guard Lights

Ref: Paragraph 2 which begins, "If CKS Airport had installed RGL…"

CAA Issues and Discussion

The text, as written, draws a conclusion that can not be supported by fact. The installation of runway guard lights would have increased the conspicuity of the taxiway and runway intersection, however, it is not known what effect the RGL would have had since the flightcrew believed they were on the correct runway. Further, the flight crew did not identify other visual cues that would have alerted them to fact they were not on the assigned runway

CAA Proposed Changes

It is suggested that the concluding paragraph be revised to summarize the fact that the RGL, in combination with the stop bars and other taxiway/runway markings typically used for low visibility operation were not installed. Further, the installation of this equipment would reduce the probability of such an event.

✈ Section 2.3.3 Safety Considerations for Temporarily and Partially Closed Runway

Ref: Paragraph 1 – which ends with "exclusive use as a main taxiway."

CAA Issues and Discussion

The problem is greater than noted. Instead of the normal situation of having traffic separated by direction, there would be the need to handle opposing traffic on a single taxiway.

CAA Proposed Changes

Add the sentence:

"The closure would put the combined traffic of Runway (Taxiway) 05R and Taxiway NP onto Taxiway NP. There would be the loss of the ability to provide directional separation and an increase in the risk of ground collisions."

✈ Section 2.3.5.2.1 Making Revising and Updating of Civil Aviation Regulations

Ref: Paragraph 1, which ends with " rules and regulations in time."

CAA Issues and Discussion

It is not clear why the specialist division staff should have any legal background. One often finds those with the technical background state the operational requirement and legal experts draft the language for the regulations.

CAA Proposed Changes

Restate the first paragraph as follows:

"Each individual division of the CAA was responsible for making the regulations within its jurisdiction; however, most of the staff members of the divisions had no legal background. That resulted in delays occasioned by a requirement to coordinate the operational requirements with the process of legalization. In addition, CAA's access to certain civil aviation resources is impaired by its absence from participation in major international organizations, including ICAO. This also causes some timeliness problems in the modifications of some rules and regulations."

✈ Section 2.3.6 Summary of Organization and Management Related Airfield Deficiencies [2 issues]

Issue 1:
Ref: Item 1,2 & 3 in paragraph 1

CAA Issues and Discussion

There are inaccuracies in each of the items.

CAA Proposed Changes

1. Relevant facilities met the ICAO standards at the time of design but did not correspond to subsequent revisions:

- Runway and taxiway lighting systems interlock mechanism;
- Installation of stop bar lights;
- Installation of runway guard light.

2. Relevant facilities did not meet ICAO SARPs at the time of design and were not identified during the construction specification review, acceptance at work completion or in routine maintenance and operations.
   - Mandatory Instruction Signs;
   - Taxiway centerline marking and lighting.

3. Inadequate administrative management:
   - Safety measures during airfield work in progress;
   - Process of converting Runway 05R into Taxiway NC;
   - Fail to revise CAA regulations to reflect updated ICAO SARPs.

Issue 2:
Ref: Paragraph 2 that ends with "caused those deficiencies to exist."

CAA Issues and Discussion

It is difficult to see how the above conclusion can be the only one. Regardless of the organizational structure, the denial of participation in ICAO working groups is an impediment to learning about developing standards and an impediment to inserting ROC requirements into those standards. Similarly, the availability of funding and other safety priorities would have to be considered and could easily affect the scheduling of dealing with any deficiencies.

CAA Proposed Changes

It is suggested that the final sentence be revised to read:

"The Safety Council concludes that the inadequacy of the CAA organizational structure and the exclusion of the ROC from ICAO increased the probability of the deficiencies remaining unattended. It was not determined how the availability of funding and the existence of other safety priorities affected the scheduling of dealing with the deficiencies."

✈ Section 2.4.1 Low Visibility Taxiing and Ground Movement Instruction [2 issues]

Issue 1:
Ref: Paragraph 1, which begins, "Air Traffic Control Procedures (ATP-88)…."

CAA Issues and Discussion

The primary purpose of the ATC system is to prevent a collision between aircraft. In accordance with ATP-88, during periods of reduced visibility, or when the taxi route is not visible from the tower, the controller is not required to issue progressive taxi instructions, but has the option, based on his or her judgment, to issue such instructions. SQ006 was the only aircraft operating on the airport at the time the taxi clearance was issued. The controller provided a precise taxi route, which was accepted by the pilot of SQ006 without a request for progressive taxi instructions.

Further, it is evident that the crew was able to navigate to the runway environment without difficulty using the taxi clearance they received.

CAA Proposed Changes

It is suggested that the last sentence be revised as follows:

The primary purpose of the ATC system is to prevent a collision between aircraft, both on the ground and in-flight. The controller provided the flightcrew of SQ006 with a precise taxi route from the terminal apron to runway 05L. Although the visibility was reduced due to weather and SQ006 was the only aircraft moving on the airport, the guidance provided in ATP-88 only requires the controller to issue progressive taxi instruction if requested by the pilot. ATP-88 also indicates that if the pilot does not request progressive taxi instruction, the controller, at his or her option may issue progressive taxi instructions

Issue 2:

Ref: Paragraph 4 – which ends with "been more alert about the aircraft location."

CAA Issues and Discussion

It would have taken very little alertness on the part of CM-1 to realize that the tower controller could not see 2,000 meters in about 600 meters visibility. The CM-2 noted that he did not expect the tower to see the aircraft as it approached the departure runway. Information from the tower controller about not seeing the aircraft may have increased the probability of pilot remaining alert to his position, however, it must be noted that the CM-1 was not alerted by much more compelling information.

CAA Proposed Changes

Replace the last two sentences with:

"However, the Safety Council believes that if the CKS ground controller had told the pilots that they were not be able to see the aircraft from the tower, there is an increased likelihood that CM-1 may have been more alert to his position."

Issue 3:

Ref: Paragraph 5, beginning with, "It is apparent that the controller did not issue…"

CAA Issues and Discussion

There is nothing in the factual or analysis to support the assertion " . . . it is likely that this would have significantly enhanced the flight crew's situational awareness." Refer to discussion in Issue 1 of this section.

CAA Proposed Changes

It is suggested that the last sentence be replaced with the following:

"The effects of issuing progressive taxi instructions to the accident aircraft are not known. However, if the controller had issued progressive taxi instructions to the SQ006 crew, there would have been one more indication to the crew of their position and there is a possibility that the crew may have remained conscious of their position beyond Taxiway NP."

✈ Section 2.4.2 Airport Surface Detection Equipment (ASDE) [2 issues]

Ref: Paragraph 3, which ends with "traffic and occasional poor visibility."

CAA Issues and Discussion

The Safety Council proposal appears to be advocating ASDE without ensuring that it is considered in the light of all other safety priorities at airports with high traffic volume.

CAA Proposed Changes

It is suggested that the last two sentences be replaced with:

"Therefore, the Safety Council concludes that the CAA should conduct a risk analysis of its safety related requirements to ensure that expenditures are matched with the highest risks. The Safety Council also recommends that ASDE or an equivalent be considered among the safety requirements assessed, on the basis of a risk analysis, at civil airports."

Issue 2:
Ref: Paragraph 4, which ends with "CAA's safety enhancement project"

CAA Issues and Discussion

There is nothing in the factual section to support the assertion that the MOTC did not understand the significance of such an installation, or that there was a lack of professional knowledge or motivation. The discussion in Section 1.18.2.4 indicates that in 1996, the ANWS and CAA agreed on the need for ASDE and began the procurement process. The process did continue from 1996 with final approval from the MOTC in August 2001**.**

<u>CAA Proposed Changes</u>

The paragraph should be rewritten as:

"At the end of February, four months after the SQ006 accident, the CAA asked the MOTC to approve the ASDE procurement process in the first part of that year and the request was approved six months later. It is not known what factors affected the timing but in light of the high cost and limited effectiveness of the ASDE in adverse weather, the time to conduct the appropriate assessment and weigh the project against other safety priorities appears reasonable."

✈ Section 2.5.2.1 NOTAMS and INTAMS

Ref: Paragraph 2, which ends with "works in progress on Runway 05R."

<u>CAA Issues and Discussion</u>

The discussion is mostly speculative and provides an unfounded basis for the crew not taking in the kind of information they receive and must understand before every flight involving adverse weather.

<u>CAA Proposed Changes</u>

The paragraph should be edited and reconstructed to read: The flight crew was provided with information contained in the various flight documents prepared by the EVA dispatchers. Further, the flight crew stated after the accident that they were fully aware that sections of Runway 05R were only available for taxi and there were construction works in progress on Runway 05R.

✈ Section 2.5.4.1 Taxiing

Ref: Paragraph 2, which ends with "will be discussed in Section 2.5.7.1 of the report."

<u>CAA Issues and Discussion</u>

The comments about the distraction of the crew are without specific support. Since they were operating within the range of expected performance and there were three crewmembers to do the work designed for two, specific reasons would be required to justify any finding of distraction or mental overload.

CAA Proposed Changes

From the beginning of the third sentence the paragraph should read:

"The flight crew was operating toward the busy end of the range of normally expected activity. However, there were three crewmembers to handle the work expected of two. The flight crew indicated that they did not monitor the final phase of the taxi (the turn from Taxiway NP onto Runway 05R via N1) in accordance with the airport chart and the associated aircraft-heading indications. Further, the crew did not check the taxiway and runway signage and markings to verify their position when the aircraft turned from Taxiway NP onto Runway 05R via Taxiway N1. Nor did they react to the green centerline lights, the absence of bright TDZ lights and the PAPI, the narrow maneuvering surface, the PVD anomaly or the primary flight display indications. The pilot's field of view during the critical turn from NP onto Runway 05R will be discussed in Section 2.5.7.1 if this report.

✈ Section 2.5.4.2 Flight Crew Awareness

Ref: Paragraph 4, which ends with "the final phase of the taxi".

CAA Issues and Discussion

It seems that the presumption is that because the crew did not get onto the assigned runway, they must have been distracted. While the winds were near the crosswind limit and worse weather was expected in the coming hours, there was nothing that should have distracted the crew. The normal oral briefing on what to do in the event of a take-off emergency (e.g. engine failure) was omitted which suggests less than full attention to takeoff procedures. The "Before Take-off" procedures are required on every flight and are part of normal routine, thus, they cannot be considered distracting in themselves. Also, there is no evaluation of the reliability of the flightcrews' after accident recollections.

CAA Proposed Changes

It is suggested that the last sentence of Section 2.5.4.2 be deleted.

✈ Section 2.5.4.3 Intra-flight Deck/Cockpit Verbal Coordination

Ref: Paragraph 2, which ends with "was not used effectively."

CAA Issues and Discussion

This section implies that the flightcrew complied with the FAA Advisory Circular that states, in part, "before entering a runway for takeoff, the flight crew should verbally coordinate to ensure correct identification of the runway." Although the ASC report states that "They had verbally coordinated to ensure that they all knew that Runway 05L was the takeoff runway..," this is NOT the same thing as "verbally coordinating to ensure correct runway identification before turning onto it."

CAA Proposed Changes

The paragraph should be revised to read as follows:

"Although the crew had verbally coordinated to ensure they all knew that Runway 05L was the takeoff runway, and they had received ATC clearance to use it, the crew did not confirm that they were actually on 05L. Further, as the CM-1 taxied into position for takeoff, the crew accepted that they were on Runway 05L without verifying their position using the aircraft instrument indications, taxiway/runway signage, the runway environment or the anomalous PVD indication."

✈ Section 2.5.4.5 SIA Low Visibility Taxi Training

Ref: Paragraph 1, which ends with "did not receive low visibility taxi training."

CAA Issues and Discussion

Additional information could be added to the paragraph to enhance the discussion.

CAA Proposed Changes

CM-1 stated that he did not receive low visibility taxi training. However, he was qualified for CAT III operations, which infers operating at visibilities considerably below those at CKS on the night of the accident.

✈ Section 2.5.5 Before Take-Off Check

Ref: Paragraph 2, which ends "practice for low visibility conditions."

CAA Issues and Discussion

There is no mention of other common practices that are usually included under the heading of good airmanship. In limited visibility conditions pilots routinely count the runway edge lights, which are a nominal 200 (60 meters) feet apart to cross check the RVR reading. In addition it is common to ask to have the runway lights turned up to strength 5 in adverse weather. Such a request would have quickly shown the crew that there were no edge lights on, or in the unlikely event that they were on they would not be the ones that increased in strength.

CAA Proposed Changes

It is suggested that the following text be added to the end of the paragraph:

"The crew did not employ the 'rule-of-thumb' check to verify the RVR by counting the visible (60 meter spaced) edge lights and they did not ask for brighter lighting for the reduced visibility takeoff."

✈ Section 2.5.6.1 Primary Flight Displays

Ref: Paragraph 3, which ends "these indications before take-off."

CAA Issues and Discussion

Pilots routinely use the ILS localizer and other information on the PFD before takeoff to verify the runway, and to set up the return to the departure airport in the event of a takeoff emergency.

CAA Proposed Changes

It is suggested that the last paragraph be revised as follows:

"Pilots routinely use the ILS localizer indicator and the runway symbol on the PFD as a runway alignment reference for landing. However, there were no SIA procedural requirements for the flight crew to utilize the localizer alignment to validate assigned runway alignment before takeoff."

✈ Section 2.5.6.3.3 Operational Use of PVD

Ref: Bullet point list

CAA Issues and Discussion

Bullet 2 – "the aircraft is not within the valid localizer region." For clarity additional information should be added to expand on "valid localizer region.

CAA Proposed Changes

Add the following text after the "region" (i.e. not on the assigned runway); or…

✈ Section 2.5.7.1 Markings and Signage [2 issues]

Issue 1:
Ref: Opening paragraph, which begins "During the airport site survey…"

CAA Issues and Discussion

An introductory sentence, before the present beginning, that cites the information reported by the pilots would enhance this section.

CAA Proposed changes

It is suggested the following text be added as the 1st paragraph:

"During interviews with the pilots of SQ006 after the accident, they stated they did not recall seeing any markings and signage except the piano keys when the aircraft was turning from Taxiway NP onto Runway 05R."

Then delete the last sentence in the paragraph which begins, "However, during interviews, the pilots…"

Issue 2:
Ref. Figure 2.5-1

CAA Issues and Discussion

A note indicating that the diagram is based on the pilot not moving his head would be informative. (Unless the related section is revised)

CAA Proposed Changes

Add: The diagram is based on the pilot looking forward and not moving his head. (Unless the related section is revised)

✈ Section 2.5.7.2.1 Taxiway Centerline Lights

Ref: Paragraph 2, which ends with "was achieved prior to take-off."

CAA Issues and Discussion

In light of the limited reliability of post accident memory, the representations of the flight crew should be qualified. Also, the conjecture about the crew's attention resources should be eliminated.

CAA Proposed Changes

It is suggested the text of paragraph 2 be modified as follows for accuracy:

"The crew indicated that the attention focus of CM-2 and CM-3 was "inside" the cockpit for the checklist and crosswind component calculation during the turn onto the runway. In addition, CM-1 indicated that he was concentrating on maintaining minimum taxi speed and following the green lights onto the runway. The aircraft is designed for operations in all conditions within its flight envelope with two pilots. The operational envelope includes the handling of emergencies, such as the failure of two engines on the same side of the aircraft in the most critical stages of flight. The preparation for takeoff at night in adverse weather could be considered a high workload situation but it is not extreme. Further, the flightcrew of SQ006 was in a favorable situation because there were three pilots to conduct the work typically expected of two. Additionally, the flight crew did not seek or make use of all the pertinent information available nor did they prioritize the information to ensure they were on the assigned runway."

✈ Section 2.5.7.2.2 Spacing of the Taxiway Centerline Lights [2 issues]

Issue 1:
Ref: Paragraph 1, which ends with "believing it to be Runway 05L."

CAA Issues and Discussion

The assertion in the first sentence is too strong to be supported by the facts. Taxiway centerline lights are not used for lining up on the runway, but in fact are only guidance to the runway. Thus, the assertion that the spacing of the taxiway light influenced the crew to "believe they were lining up on the correct runway" cannot be supported.

Further, the report includes the statement that the "Safety Council has concluded that during the turn from Taxiway NP onto Runway 05R, the green taxiway centerline lights leading into Runway 05R attracted CM-1's attention." This statement and others leading up to it imply that the green lights were responsible for, or controlled, the CM-1's attention allocation processes. In the human factors literature, this reflects a stimulus-driven or bottom-up process. However, given that the PIC of the Asia-Pacific 747-400 was able to follow the green taxi lights from NP to 05L, suggests the green lights leading to 05R were driven, at least in part, by more top-down or mental processes rather than driven solely by environmental factors such as the saliency of the lights.

CAA Proposed Changes

It is suggested that the beginning text of the 1st paragraph be revised as follows for clarity and accuracy:

"The spacing difference between the taxiway centerline lights on Taxiway N1 that let to Runway 05L and those that turned right on to Runway 05R might appear ambiguous and may have been a factor that influenced the flightcrew to believe that they were taxiing into position on the "correct" runway."

Issue 2:

CAA issues and Discussion

Revise the ASC conclusion.

CAA Proposed Changes

The conclusion statement should be rephrased to state:

"The Safety Council has concluded that the captain's expectation that he was approaching the departure runway coupled with the saliency of the lights leading onto runway 05R resulted in the captain allocating most of his attention to these centerline lights. He missed the centerline lights that led to Runway 05L…"

✈ Section 2.5.7.2.3 Color of the Centerline Lights [2 issues]

Issue 1:
Ref: Last Paragraph, which ends with "centerline lights were green."

CAA Issues and Discussion

The last paragraph in this section states, "the flight crew were probably fully occupied by the high workload induced by concern about the degrading weather…" The term "high workload" is used throughout the report to imply that this flight crew experienced an exorbitant workload that was above that experienced by any other flight crew that departed CKS around the time of the accident. However, there are no facts offered to support this claim. Furthermore, one must question whether three pilots operating under conditions for which they have been trained to typically operate with only two pilots, were really experiencing the effects from a high workload. In any case, the term is certainly not used appropriately here. "Workload," in the human factors literature, is not induced by "concern." The term preoccupation might be a better term.

In addition, a review of the CVR transcript revealed that the flightcrew had approximately 56 seconds between the times the “Before Take-off” checklist was completed and the takeoff commenced. Additionally, of those 56 seconds, the last 30 seconds was with the aircraft holding in the takeoff position on runway 05R.

Furthermore, the CVR transcript indicates that the majority of the discussion occurring among the flight crew during this period was regarding the anomalous PVD indication.

CAA Proposed Changes

It is suggested that the last paragraph be revised for clarity and accuracy to the following:

“When the aircraft taxied into takeoff position and held on runway 05R for approximately 33 seconds, the focus of the flightcrew’s attention was apparently the PVD and the reason it had not un-shuttered. During that period there were no further discussions about the degraded visibility, fluctuating weather conditions, approaching typhoon or crosswind limitations. Consequently, despite the fact that they had a brief period of time, prior to commencing the takeoff, to look out the windscreen at the runway environment, the reason for the flight crew’s incorrect perception that the centerline lights were white rather than green, and the significance of this fact, could not be determined.”

✈ Section 2.5.7.4 Runway Difference Issues [2 issues]

Issue 1:
Ref: First Paragraph, second bullet

CAA Issues and Discussion

The second bullet, there is no mention of the PAPI on Runway 05L.

CAA Proposed Changes

Following TDZ, add: and a four-light PAPI to the left of the runway.

Issue 2:
Ref: Last paragraph of the section, which ends “runway configuration information.”

CAA Issues and Discussion

Based on previous discussions about the flight crew’s actions during the final moments of taxiing to the runway and the misuse of the term “high workload,” the last sentence is speculative and should be deleted.

CAA Proposed Changes

Delete the final sentence of the paragraph, which deals with experience and workload.

✈ **Section 2.5.7.5 Runway 05L Guard Lights**

Ref. Second Paragraph, which ends "location of Runway 05L."

CAA Issues and Discussion

The second part of the concluding sentence is speculative and cannot be supported by the facts.

CAA Proposed Changes

It is suggested that the last sentence be revised to end after the words "holding position." The remainder of the sentence should be deleted.

It is suggested that a new paragraph 3 be inserted as follows: The lack of stop bar or guard light is unrelated to flight crew's judgment in this event, because if flight crew should have expected the existence of stop bar or guard light before Runway 05L, they would not have taken off on Runway 05R in the absence of them. On the other hand, the AIP already indicated the lack of stop bar and guard light and flight crew should not have expected to rely on them to identify the correct runway.

✈ **Section 2.5.7.6.1 Runway 05R Edge Lights**

Ref: 1st sentence, which ends "time of the accident."

CAA Issues and Discussion

Additional text should be inserted after the first sentence to bring the paragraph fully in line with the factual information in the report. Also amend the final sentence.

CAA Proposed Changes

Insert the following text after the words, "…time of the accident:"

"Based on the facts, the Safety Council believes that there is a high probability that the edge lights were out during the SQ006 takeoff."

Amend the last sentence to read:

"Regardless of the status of the Runway 05R edge lights, the crew took off from Runway 05R."

✈ Section 2.5.7.6.1.1 If Runway 05R Edge Lights Were Off

Ref: End of section, which reads "on the incorrect runway."

CAA Issues and Discussion

The report includes the statement, “They saw what they expected to see – a normal picture of a runway.” However, all three pilots were aware that they would be taking off on a CAT II runway and they discussed the use of the runway as a landing alternate in case they had to divert the flight, because it was a CAT II runway. The report now also states that all three pilots were qualified for CAT III operations. Therefore, given the pilots’ training and experience, and the recency in which they discussed the runway information, the flight crew should have expected to see a “normal picture” of a CAT II runway (typically illuminated with touchdown zone lights). During the interview process, however, they were never asked about what a normal CAT II runway should look like. Therefore, it is unknown what their actual knowledge was at the time of the accident. Nonetheless, the fact that they interpreted 05R as the CAT II Runway 05L, suggests that their expectation of what a CAT II runway should look like was inaccurate.

CAA Proposed Changes

It is suggested that the concluding paragraph be revised to include the following text beginning with the second sentence:

“Based on the fact that the pilots’ were CAT III qualified and experienced, in addition to the recency in which they discussed the runway information, they should have expected to see a “normal picture” of a CAT II runway. During the interview process, however, they were never asked about their perception of what a normal CAT II runway should look like. Therefore, it is unknown what their actual knowledge was at the time of the accident. Nonetheless, the fact they interpreted 05R as the CAT II Runway 05L, suggest that they had an inadequate mental model of what a normal CAT II runway should look like.”

✈ Section 2.5.7.6.1.2 If Runway 05R Edge Lights Were On [2 issues]

Issue 1:
Ref: End of section which reads “and carried out the take-off.”

CAA Issues and Discussion

The first paragraph in this section refers to statements made during the interview of the freighter captain.

CAA Proposed Changes

In light of the concerns previously expressed about the dubious nature of this testimony, the discussion of this captain’s statements should be deleted.

Issue 2:

CAA Issues and Discussion

The third paragraph in this section states, “Under high workload of taking off in severe weather conditions…” Again, the term “high workload” appears throughout this document without any consistent meaning. In this context, it appears that workload is not being used to refer to task characteristics at all, but to the internal emotional state of the pilots’, such as stress or anxiety. The liberal use of this term makes it a “catch-all,” and often negates the true meaning in favor of a meaningless explanation of pilot performance.

CAA Proposed Changes

The use of the term “workload” in general, and “heavy workload” in particular, should be clearly defined and its use carefully re-examined throughout the entire report. If the term workload is being used in this section of the report to refer to an internal emotional state of the crew, then the sentence should be restated to read “Under the stress and anxiety of taking off in severe weather conditions…”

✈ Section 2.5.7.7 Expectation of Runway Picture [2 issues]

Issue 1:
Ref: End of section, which reads “from seeing those lights”

CAA Issues and Discussion

The first paragraph ends with the statement “Furthermore, CM-1 stated that the timing of the take-off clearance gave him an impression that CKS Tower could see him.” This is contrary to the fact that he told the CM-2 at 23:14:58, “tell them [the controller] we are ready.” Based on this request, the controller would issue the clearance based on the pilot’s verbal statement not visual identification of the aircraft.

CAA Proposed Changes

It is suggested that the following statement be included at the end of the 1st paragraph:

“However, neither CM-2 nor CM-3 was under the impression that CKS Tower could see them. Therefore, although the perceived timing of the takeoff clearance received from ATC (CM-1 had instructed CM-2 to tell the controller that they were, “…ready”) may have confused the CM-1, it did not have an impact on the situation awareness of CM-2 and CM-3.”

Issue 2:

CAA Issues and Discussion

The 2nd paragraph indicates that when the flightcrew was asked about their mental picture of what a normal CAT II runway should be, they responded that a closed runway should be black and the runway should not be illuminated. In addition, the crew commented that there should be obstruction lights and barricades for the work-in-progress area, and lighted no-entry signs at the beginning of the runway." These are not entirely correct statements. According to the flight crew interviews, only CM-2 and CM-3 were asked this question but not CM-1. Furthermore, CM-2 and CM-3 did not give entirely the same answers. For example, CM-2 did not mention barricades or illuminated no-entry lights. Therefore, implying that the flight crew all shared this same impression or mental model of a closed runway is incorrect and unfounded. Also, it was noted earlier that none of the flight crew was asked what a CAT II runway should look like. Therefore, it is unknown what their actual "expectation of the runway picture" was at the time of the accident.

CAA Proposed Changes

It is suggested that this paragraph be revised and the following text inserted as follows after the words, "were still available for taxi.":

"When queried about their mental picture of a closed Runway 05R, CM-2 and CM-3 stated that a closed runway should not be illuminated and should have warning lights. In addition, CM-3 commented that there should be barricades for the work-in-progress area and lighted no-entry signs. This question was not asked of the CM-1, and it could not be determined whether he too had the same impression of a closed runway. Regardless, all three flight crew members were aware of the NOTAM indicating that Runway 05R was available for taxi operations only on the night of the occurrence."

✈ Section 2.5.7.7.1 Confirmation Bias [2 issues]

Issue 1:
Ref: As noted.

CAA Issues and Discussion

The first paragraph in this section ends with the statement that, "Essentially, the crew may only seek information that confirms their present interpretation of the runway." Consequently, this is the reason why formal procedures and checklist are used in complex systems such as aviation. They are utilized to overcome nuances and idiosyncrasies of human behavior. The FAA stated in its Advisory Circular (AC) that "before entering a runway for takeoff, the flight crew should verbally coordinate to ensure correct identification of the runway." This was intended as tool to provide a safety barrier against confirmation biases, hasty decisions, and loss of situational awareness. However, as noted in section 2.5.4.4, SIA did not have such procedures in place.

CAA Proposed Changes

It is suggested that the following text be added to the end of the first paragraph:

"Procedures and checklist are often used in complex systems such as aviation to overcome these nuances and idiosyncrasies of human behavior. Consequently, the FAA stated in its Advisory Circular (AC) that "before entering a runway for takeoff, the flight crew should verbally coordinate to ensure correct identification of the runway" in order to provide a safety barrier against confirmation biases, hasty decisions, and loss of SA. However, as noted in section 2.5.4.4, SIA did not have such procedures in place."

Issue 2:

CAA Issues and Discussion

The second paragraph in this section includes a statement that "The crew also believed the timing of the Air Traffic Control clearances for taxiing into position and hold and takeoff seemed to confirm that they were in the correct location for takeoff." This statement is inaccurate. Only CM-1 made this statement. CM-2 understood the timing of this statement, because he is the one who asked for the clearance. CM-3 stated in his interviews that he was not under the impression that ATC tower could see them.

CAA Proposed Changes

The statements should be modified to read "CM-1 stated that the timing of the Air Traffic Control clearances for taxiing into position and hold and takeoff seemed to confirm that the aircraft was in the correct location for takeoff." However, CM-2 likely understood the timing of the ATC clearances, because he was the one who made the requests. CM-3 also stated in his interviews that he was not under the impression that ATC tower could see them."

✈ Section 2.5.7.8 Summary [2 issues]

Issue 1:
Ref: Final sentence of first paragraph.

CAA Issues and Discussion

The last part of the final sentence is too conjectural to be considered analysis. Recast the sentence to remove the conjecture.

CAA Proposed Changes

The final sentence should read:

"If runway guard lights or stop bars or densely spaced centerline lighting along Taxiway N1 had been provided, they would have increased the conspicuity of the Runway 05L holding position and would have increased the probability that the crew would have been alerted to the location of Runway 05L."

Issue 2:
Ref: Last paragraph of the section.

CAA Issues and Discussion

The paragraph could be restructured to increase accuracy and eliminate conjecture.

CAA Proposed Changes

Beginning with the third sentence:

"The crew was experienced in night operations and was familiar with runway and taxiway lighting. They were aware that taxiway centerline lighting is green and runway lights are white or near white. There was nothing in the workload that should have impeded the crew's processing of runway configuration information. When CM-1 elected to takeoff, he could see an adequate distance down the runway, and none of the visual cues prompted him to realize his error. Finally, the contrary cockpit instrument indications (PFD &PVD) were not resolved by the crew.

Additionally, the CM-1 stated that the timing of the Air Traffic Control clearance for taxiing into position and holding and takeoff seemed to confirm that they were in the assigned position for takeoff. However, this perception should be balanced against the known difficulties in recounting events accurately following an accident."

✈ Section 2.5.8 Additional Human Factors issues – An Elaboration of Factors Influencing the Flight Crew during Taxi from NP to Runway 05R

CAA Issues and Discussion

This section appears to include more exploration and conjecture than it does the analysis of facts that are known to have played a role in this accident. Furthermore, the series of sections from 2.5.8.2 through 2.5.8.5 are almost entirely speculation.

COMMENT ONLY, FOR CONSIDERATION BY THE AUTHORS

✈ Section 2.5.8.1 Time Pressure to Take-Off Before Typhoon Was Closing

Ref: Second to last sentence.

CAA Issues and Discussion

Accuracy could be increased and conjecture could be removed from the last part of the paragraph.

CAA Proposed Changes

The second to last sentence should read:

"It could not be determined whether the crew's concerns about the approaching typhoon enticed them to hasten their departure to the point where they did not make appropriate checks to identify and confirm that they were on the assigned runway."

The last sentence should be deleted.

✈ Section 2.5.8.2 Attention Allocation, Workload, and Situation Awareness [2 issues]

Issue 1:
Ref: General to section.

CAA Issues and Discussion

In this section, the report states that "Under high workloads,…individuals may load shed to the point that important information is not given priority or not fully examined. Furthermore, scanning of information may be scattered and poorly organized." While this statement may be true, the report should also point out to the reader that this is why the aviation industry requires more than one pilot to fly the airplane, so that the pilots can share the workload and monitor each other's actions and maneuvers. Given that there were three crew members on this particular flight rather than the normal two, should have helped reduce the workload in the cockpit on the night of the accident.

CAA Proposed Changes

Since the report attempts to educate the reader on situation awareness and workload, it should also educate the reader on what the industry has done to place barriers in place to prevent the occurrence of such performance decrements. The report should include the following text to provide clarity and enhance the discussion:

"The aviation industry is aware of the possible problems that can arise from high workload in the cockpit. This is the reason why more than one pilot is often required to fly an airplane, so that the pilots can share the workload and monitor each other's actions and maneuvers. Given that SQ006 had three flight crew members in the cockpit, rather than the required two, should have helped reduce the workload in the cockpit on the night of the accident."

Issue 2:

<u>CAA Issues and Discussion</u>

This section also contains the statement "Interview and CVR data showed that the pilots experienced high workload induced by taxiing in the severe weather conditions, cockpit tasking and planning." Again, the term "high workload" is used to imply that this flight crew experienced an exorbitant amount of workload that was above the workload experienced by any other flight crew that departed CKS around the time of the accident. However, there are no facts offered to support this assertion. Furthermore, the CVR data does not "show" that pilots experienced high workload. Rather, it reveals that pilots were having difficulty managing the workload that they were experiencing. Given SQ006 was operating with three flight crew members, rather than the required two flight crew members, severely undermines the validity of this analysis.

<u>CAA Proposed Changes</u>

It is suggested that the discussion be modified to read:

"Interview and CVR data indicated that the pilots had difficulty managing the workload induced by taxiing in the severe weather conditions, cockpit tasking and planning."

Additionally, we also recommend that the term "workload" be clearly defined and its use carefully re-examined throughout the entire report.

Following the third sentence, insert:

"The PVD is a simplified form of head-up display and is designed to be captured by peripheral vision while the pilot's attention is on the runway ahead of the aircraft. CM-2 did not notice any runway marking or runway signs. However, he recalled seeing lights leading onto the runway and CM-1 following the lights onto the runway. CM-2 stated that he saw bright lights in the middle of the runway."

✈ Section 2.5.8.3 Pattern Matching

Ref: General to section

CAA Issues and Discussion

The report states that "the flight crew believed that Runway 05R was Runway 05L because their mental pictures lead them to believe that Runway 05R was a normal runway at night." However, as stated previously, given the pilots' CAT III training and experience, and the recency in which they discussed the runway information, the flight crew should have expected to see a "normal picture" of a CAT II runway. However, they were never asked about what such a normal CAT II runway should look like during the interview process. Therefore, it is unknown what their actual knowledge was at the time of the accident. Nonetheless, the fact they interpreted 05R as the CAT II Runway 05L, suggest that their mental picture of a normal CAT II runway was inaccurate.

The last sentence in this section also states, that "…it is normally not necessary to devote a large component of the residual attention resources to the matching process to see if the runway is in fact the correct runway for takeoff." However, the report fails to add that in keeping with the best practices in the industry, it is customary for flight crews to verify that they are on the correct runway prior to takeoff in order to avoid any problems that might arise from the pattern matching process.

CAA Proposed Changes

This whole section is entirely speculative and conjectural and should be deleted from the report. If the ASC believes that it should remain, a sentence at the end of the section should be added that reads:

"However, in keeping with the best practices in the industry, it is customary for flight crews to verify that they are on the correct runway prior to takeoff in order to avoid any problems that might arise from the pattern matching process."

✈ Section 2.5.8.4 Taxiway Lighting Issues

Ref: Paragraph 4 which ends with "from NP onto Runway 05R."

CAA Issues and Discussion

This section of the report states that "…it is possible that CM-1 inadvertently reverted to the most dominant previously formed mental model under high workload to follow the green taxiway centerline lights, which generally takes him to where he is supposed to go, and he reverted to this habit while turning from NP onto Runway 05R." Again, this statement is highly speculative and there are an unlimited number of "possible" human factors issues that could be discussed. Furthermore, there is no evidence that what is describe here is CM-1's "most dominant previously formed mental model." As indicated in footnote 58, the majority (56%) of the airports that CM-1 operated into during the two months prior to the accident were NOT equipped with "follow the green systems."

CAA Proposed Changes

This section should be deleted from the report. However, if the ASC believes it should remain, the following text should be added:

"Although the Safety Council considered possible pattern matching issues, there was no way of knowing what the most dominant previously formed mental model would have been for the flight crew and therefore, no conclusions could be made."

Such a statement is already included in section 2.5.8.5 on airport layout.

✈ Section 2.5.9 Water-affected Runway Issues

Ref: Paragraph 4, which ends with "all runways are the same"

CAA Issues and Discussion

SIA could have given its pilots a practical means of using the rainfall rate to assess whether a runway is contaminated. By the practices adopted by some other carriers, the runway would have been determined contaminated.

CAA Proposed Changes

Add at the end of the paragraph the following text:

"While SIA had established a conservative measure for determining when a runway was contaminated, they did not convey a practical means to their pilots to make the determination, which largely defeated the effect of the company standard."

✈ Section 2.5.9.1 SIA Crosswind Limitation and Runway Condition Determination Procedure

Ref: General to the section.

CAA Issues and Discussion

Based on the wind information presented in Table 1.7-1, the wind condition recorded by the AWA at 23:14, 23:15, 23:16 and 23:17 were, 018 degrees at 56 knots, 029 degrees at 59 knots, 013 degrees at 59 knots and 360 at 41 knots. The crosswind magnitude (also cited in Table 1.7-1) as calculated by the ASC for the same time period were from the left side of runway at 29 knots, 20 knots, 34 knots and 31 knots respectively.

The flightcrew received several wind updates from the controller prior to commencing the takeoff. The controller issued SQ006 a takeoff clearance at 23:15:22, and reported the wind to be 020 degrees at 28 knots, gusting to 50 knots. There was no discussion among the crewmembers regarding the crosswind limitations based on the latest wind conditions. Further, the CM-1 did not commence the takeoff until 23:16:44, or 1 minute and 22 seconds after the last wind report.

Based on the wind conditions reported by the controller at 23:15:22, the recorded AWA wind condition at 2316 (013 degrees at 59 knots) and the crosswind magnitude of 34 knots calculated by the ASC, it is highly probable that the flightcrew departed in conditions that exceeded the SIA crosswind limitation of 30 knots. Additionally, the wind conditions may have also precluded the flightcrew from using CKS Airport as their "alternate" because the conditions would have exceeded the landing limitations.

CAA Proposed Changes

Based on the factual information presented, it is suggested that the crosswind values be re-validated and that the wind direction and magnitudes, as recorded from both the AWA and the provided to crew by the controller at 23:15:22 be used to determine if the flightcrew attempted to operate in wind conditions that exceeded the limitation imposed by the aircraft manufacture and SIA.

If the crosswind limitation was exceeded, then the report should be modified with a brief analysis of the information and an appropriate 'Finding' included.

✈ Section 2.5.10 Crew Coordination

Ref: One paragraph section.

CAA Issues and Discussion

The paragraph can be made more accurate and comprehensive.

CAA Proposed Changes

The flight crew's dismissal of the PVD in concert with not referring to the Primary Flight Display eliminated two of the last lines of defense to ensure during the final stage before takeoff that the aircraft was in position on the assigned runway. The CVR transcript indicated that CM-2 questioned the lack of a PVD indication while the aircraft was turning onto Runway 05R. CM-1 and CM-3 then engaged in the following discussion regarding the PVD: CM-1 stated: "Yeah, we gotta line up first," followed by CM-3 stating, "We need 45 degrees." The CM-1 continued, "Not on yet PVD, never mind, we can see the runway, not so bad."

After SQ006 lined up on the runway, the 3 pilots did not resolve why the PVD did not unshutter. CM-2 did not continue to resolve the unshuttered PVD indication nor did CM-1 and CM-3 attempt to support or resolve this issue. This indicated the flight crew did not apply basic CRM principles in resolving a critical operational problem. In addition, they did not employ 'rule of thumb' cross checks on visibility by counting edge lights or asking for strength five lighting. The opportunity was lost to discover that the aircraft was not on the appropriate runway and was not within the usable signal of the preset ILS.

✈ Section 2.6.1 SIA Crewmember's Emergency Evacuation Operations and Training

Ref: Paragraph 2, which ends "declare emergency evacuation."

CAA Issues and Discussion

A little more credit could be given to the crew for initiative during the evacuation.

CAA Proposed Changes

Add to the end of the paragraph, the following text:

"Some did use what was immediately available such as flashlight beams to direct survivors to exits and they made some use of deflated slides as a form of exit ladder."

✈ Section 2.6.4.3 Work Designation and Human Resources in Rescue Operations of Fire Fighters

Ref: General to section.

CAA Issues and Discussion

The CKS firefighting capability should be seen in light of the total resources available. The surrounding communities provide significant supplementary vehicles and personnel, which is not the case at numerous other airports**.**

CAA Proposed Changes

Add the following text to the second to the last paragraph:

"Several communities around the CKS airport provide supplementary firefighting equipment and personnel as required. These readily available resources should be factored in when assessing the operational firefighting capability of the airport. The on airport fire fighter numbers may be low, but the airport appears to be well covered when nearby available resources are added."

✈ Section 2.7.2 Airport Incident Reporting and Tracking

Ref: Last paragraph of the section.

CAA Issues and Discussion

There is a very important point to be made here that is different from the ASC recommendation.

CAA Proposed Changes

It is well known in countries that have fairly long experience with independent accident investigation bodies that flight and ground crews together with ATC personnel are much more likely to report on incidents if the report can be made to someone other than the regulator and preferably to the independent accident/incident investigation authority. The fear of prosecution associated with reporting incidents to the regulator leads to significant underreporting. The ASC will seek authority to develop an incident reporting system.

Part 4

Representations on Section 3, Conclusions

Section 3 Conclusions

Ref: Second paragraph, which ends “leading to the accident.”

CAA Issues and Discussion

There is a logic problem with the highlighted title, 3.1 Findings Related to Probable Causes. When a group of things happened or almost certainly happened the word ‘probable’ is not necessary or even desirable. Those elements that are shown to have operated are beyond the concept of being probable. The term ‘probable’ could be applied to those that almost certainly operated. However, the definition of the term, as developed by the ASC and shown in Para 2 of the ‘Conclusions’ section includes both certain and highly probable events, and it would be much preferable to drop the word ‘probable’ and make the title “Cause Related Findings”.

CAA Proposed Changes

Make the heading: Cause Related Findings in both section 3 and section 3.1

✈ Section 3.1 Finding Related To Probable Causes

Finding 1

CAA Issues and Discussion

The information presented in Finding No. 1 is confusing because it states the wind condition at the time of the accident was from 020 degrees with a magnitude of 36 knots, gusting to 56 knots, and the values are not attributed to a specific location on the airport. However, Table 1.7-1 indicates the wind condition at 2317 for “runway 05” was “ 360 degrees at 41 knots with a crosswind magnitude of 31 knots. The Table does not state whether these values are for runway 05L or 05R. Further, the Table does not represent the wind gusts that also occurred during that period and that would have had to be factored into the flight crew’s determination of headwind and crosswind limitations for the “wet” runway.

The variance in these values is significant because the reduced steady-state wind conditions are “more acceptable” and well within the SIA operating limits. However, as the CM-3 has stated in his interview, he was concerned the wind conditions were at values that were close to the SIA maximum limit when they began their takeoff.

Additionally, refer to CAA discussion addressing Section 2.5.9.1, SIA Crosswind Limitation and Runway Condition Determination Procedure for additional information about the wind values.

CAA Proposed Changes

The CAA proposes that the factual text in Section 1.7 be accurately reflected in Finding No. 1. Additionally, expand as necessary to discuss whether the flightcrew attempted to depart in crosswind conditions that exceeded both the manufacturer and SIA limitations.

✈ Section 3.1 Finding 4

CAA Issues and Discussion

Finding No. 4 is correct, but contains a very long sentence that could be re-written for clarity.

CAA Proposed Changes

It is suggested that following revision be made:

The flight crew had CKS Airport charts available and the CM-2 and CM-3 initially monitored the progress of the flight immediately after departing the parking bay. However, as the flight approached Taxiway N1 from NP, both crewmembers diverted their attention to other tasks and CM-1 made a continuous turn from N1 on Runway 05R. The flight crew did not verify their taxi route in accordance with the airport chart, which would have shown the need to make a 90 degree turn from Taxiway NP and then taxi straight ahead for a distance of 210 meters on Taxiway N1, rather than to make a continuous 180 degree turn onto Runway 05R. Further, none of the flight crewmembers confirmed orally whether the runway they entered was Runway 05L. (1.18.1.1; 2.5.2.2; 2.5.4.3).

✈ Section 3.1 Finding 5

CAA Issues and Discussion

The report states that "The flight crew did not build a mental picture of the taxi route to Runway 05L that included the need for the aircraft to pass Runway 05R before taxiing onto Runway 05L." However, this statement should be made in behavioral terms that allow interventions to be developed.

CAA Proposed Changes

The finding should be restated as "The flight crew did not review the taxi route in a manner that was sufficient to ensure that they all understood that the route to Runway 05L, including the need for the aircraft to pass Runway 05R, before taxiing onto Runway 05L."

✈ Section 3.1 Finding 6

CAA Issues and Discussion

The report states, that "…runway conditions subtly influenced the flight crew's decision making and ability to maintain situation awareness." The use of such human factors terms as "situation awareness" should be avoided in finding statements, since most readers will not be familiar with the true meaning of the term.

CAA Proposed Changes

The statement should be reworded to read: "The moderate pressure to depart before the inbound typhoon closed in around CKS Airport, and the fairly high workload of taking-off in low visibility and slippery runway conditions, subtly degraded the flight crew's decision-making and their ability to monitor and maintain awareness of their location along the taxi route."

Section 3.1 Finding 7 [2 issues]

Issue 1:
Ref: List of bullets.

CAA Issues and Discussion

The seventh bullet is qualified by the words "if the runway edge lights were on." This is unnecessary, as the aircraft landing lights would have illuminated the surface well enough to make the width difference apparent. The eighth bullet should be introduced by the word "Significant." The introductory word following the ninth bullet should be corrected from "Parallel" to 'Para.' Wording associated with the tenth bullet should be supplemented to show what the PFD did show.

CAA Proposed Changes

End the wording following the seventh bullet at the coma between the words "05R" and "if". Start the wording after the eighth bullet with the word 'Significant." For the ninth bullet the introductory word should be "Para". Add to the end of the wording associated with the tenth bullet "which showed the aircraft to the right of the assigned runway."

Issue 2:

Ref: Final two sentences of the finding.

CAA Issues and Discussion

The last two sentences state, "The flight crew did not comprehend the available information. They lost situation awareness and commenced takeoff from the wrong runway." Again, the use of the term "situation awareness" is not informative in this context.

CAA Proposed Changes

The statement should read "The flight crew did not comprehend the available information and were therefore unaware that they were actually on Runway 05R. Since they did not utilize the many visual cues available to verify which runway they were actually on, they commenced takeoff from the wrong runway."

✈ **Section 3.2 Findings 1 & 2 [2 issues]**

Issue 1:

CAA Issues and Discussion

Finding 1 should be moved to "Other Finding." According to CAA guidelines for the control of air traffic, the primary purpose of the air traffic control system is to prevent a collision between aircraft operating in the system. On the evening of the accident, the only aircraft operating at CKS Airport was SQ006, and the flight crew taxi normally within ground controller's responsible area. Therefore, in the professional judgment of the air traffic controller, there was no possibility of a collision between SQ006 and any other aircraft operation. Additionally, this finding has no direct relation to the accident or cause of the accident. Furthermore, Finding 1 is considered an element that has the potential to enhance aviation safety rather than considered a safety deficiency or an unsafe condition or act. The weather related findings lead off the findings in 3.1, so for consistency, finding 2 could be moved to 6.

CAA Proposed Changes

Move finding 1 to "Other Finding" & finding 2 to have it become finding 6.

Issue 2:

CAA Issues and Discussion

As discussed in the Factual and Analysis, the ATP-88 requires the controller to issue progressive taxi instructions if requested by the pilot. Further, the ATP-88 makes it optional for the controller to issue progressive taxi instruction if a request is not received from a pilot. Therefore Finding No.1 should reflect this information.

CAA Proposed Changes

It is suggested that Finding No. 1 be revised as follows:

The local controller provided the flightcrew of SQ006 with a precise taxi routing and was not required to provided progressive taxi instructions unless requested by the pilot. Although, the ATP-88 permitted the controller to exercise judgment in providing progressive taxi instructions if he did not receive a request from the flightcrew, the controller did not use the required low visibility taxi phraseology to inform the flightcrew to slow down during taxi.

✈ Section 3.2 Finding 4 (original number)

CAA Issues and Discussion

The finding should be amended to increase its accuracy and to note that other carriers have effective procedures. NOTE: This finding may need to modified if it is determined that the CM-1 attempted the takeoff in crosswind conditions that exceed the manufacture and SIA limitations.

CAA Proposed Changes

Revise the finding to read:

"The SIA crosswind limitation for a "wet" runway was 30 knots and for a "contaminated" runway was 15 knots. CM-1 assessed that the runway condition was "wet" and determined that the crosswind was within company limitations. The lack of equipment and procedures for quantitatively determining a "wet" versus "contaminated" runway creates ambiguity for flight crews when evaluating takeoff crosswind limitations. (1.18.4; 2.5.9) By the practices adopted by some other carriers, the runway would have been assessed as contaminated."

✈ Section 3.2 Finding 5 (original number)

CAA Issue and Discussion

Finding No. 5 may need to be revised based on the discussion in Section 1.17.3.2**.**

CAA Proposed Changes

The CAA proposes that Finding No. 4 be revised to reflect any changes to the discussion found in 1.17.3.2.

✈ Section 3.2 Finding 8 (original number)

CAA Issue and Discussion

Finding No. 8 states "It is possible that CM-1 inadvertently reverted to the most dominant mental model…"

CAA Proposed Changes

As stated previously in the Analysis, this conclusion is entirely speculative and not supported, and therefore should be deleted from the findings.

✈ Section 3.2 Finding 9 (original number)

CAA Issues and Discussion

For accuracy add a reference to the PFD.

CAA Proposed Changes

Reword finding to read: "SIA did not have a procedure for the pilots to use the PVD or the PFD…"

✈ Section 3.2 Finding 11 (original number)

CAA Issues and Discussion

For accuracy add a reference to the PFD.

CAA Proposed Changes

Reword finding to read: "SIA procedures and training documentation did not ensure that the approved B747-400 AFM supplement regarding use of the PVD and the PFD . . ."

✈ Section 3.2 Finding 13 (original number) [2 issues]

Issue 1:
Ref: Accuracy wording in finding.

CAA Issues and Discussion

Reword the finding to increase its accuracy.

CAA Proposed Changes

Reword finding to read: "The deficiencies in SIA training and procedures for low visibility taxi operations did not ensure that . . ."

Issue 2:
Ref: Possible revision consequent on review of factual records in Taiwan.

CAA Issues and Discussion

Finding No. 13 may need to be revised based on the discussion in Section 1.17.3.2.

CAA Proposed Changes

The CAA proposes that Finding No. 13 be revised to reflect any changes to the discussion found in 1.17.3.2.

✈ **Section 3.2 Finding 14 (original number)**

CAA Issues and Discussion

There is a logic problem in that the second sentence does not necessarily follow from the first.

CAA Proposed Changes

If the 'Therefore' is replaced by an 'and' it will be OK**.**

✈ **Section 3.2 Finding 16 (original number)**

CAA Issues and Discussion

Several adjustments are required to increase the accuracy of the finding.

CAA Proposed Changes

Revise the first sentence " there were a number of items …" change to "there were several items …".

Revise the second sentence of the introductory paragraph to read: A standardized environment could have contributed to the situation awareness of the SQ006 flight crew while taxiing to Runway 05L for takeoff.

The second paragraph is too speculative for a finding and should be deleted.

The following changes are proposed for the list of bullets:

The first bullet item should be revised to read: The green centerline lights leading from Taxiway NP onto Runway 05R were more visible than the Taxiway N1 centerline lights leading toward Runway 05L because they were more densely spaced. In order to meet the most recent (1999) ICAO recommendation, there should have been 16 centerline lights spaced 7.5m apart along the straight segment of Taxiway N1 where the curved Taxiway centerline markings from Taxiway NP meet Taxiway N1 up to the Runway 05L holding position. (1.10.3.2.4; 2.3.1.2.2)

The second bullet item should be revised to read: Taxiway N1 centerline marking of CKS Airport met the latest version of ICAO and FAA specifications. (1.10.3.1.3; 2.3.1.1)

The fourth bullet item should be moved to "Other Finding." The lack of stop bar or guard light is unrelated to flight crew's judgment in this event, because if flight crew should have expected the existence of stop bar or guard light before Runway 05L, they would not have taken off on Runway 05R in the absence of them. On the other hand, the AIP already indicated the lack of stop bar and guard light and flight crew should not have expected to rely on them to identify the correct runway.

The seventh bullet item should be revised to read: Although the flight crew was aware that Runway 05R was closed, there were no runway-closed markings in the area where SQ006 entered Runway 05R, nor would it have been practical to have put them there. (1.10.4.2)

The ninth bullet item should be revised to read: In accordance with CKS ATC procedures, simultaneous use of the Runway 05R edge lights and the taxiway centerline lights were not permitted, and the ATC Ground controller and the tower controller coordinate and manually select the appropriate lights for the specific operation being conducted on the runway. However, there was no interlocking system installed at CKS Airport to preclude the possibility of simultaneous operation of the runway lighting and the taxiway centerline lighting. (1.10.5.1.1; 2.3.1.2.1)

The tenth bullet item should be revised to read: The serviceability monitoring mechanism of the CKS airfield lighting system was accomplished both electronically and manually. However, there was a lack of a continuous monitoring feature of individual lights, or percentage of unserviceable lamps, for any circuit for CKS Airport lighting. (1.10.5.1.2)

The eleventh bullet item should be revised to read: ASDE is designed to enhance airport ground operations in low visibility. There is no requirement for installation of Airport Surface Detection Equipment (ASDE) at CKS Airport. The Safety Council was not able to determine whether ASDE would have provided information to the ATC controllers about SQ006 taxiing onto the incorrect runway because of the attenuation of the signal from heavy precipitation that diminishes the effectiveness of the radar presentation. (1.18.2.4; 2.4.2)

Section 3.2 Finding 18 (original number)

CAA Issues and Discussion

The finding would benefit from rewording to align it better with the facts and analysis.

CAA Proposed Changes

There was a lack of a specified safety regulation monitoring organization and mechanism within CAA that resulted in the absence of a mechanism to highlight conditions at CKS Airport for taxiways and runways lighting markings, and signage that did not meet internationally accepted safety standards and recommended practices. (1.17.9; 2.3.6)

✈ Section 3.2 Finding 23

CAA Issues and Discussion

The finding would benefit from minor rewording to increase its accuracy.

CAA Proposed Changes

The main deck mid cabin from row 31 to 48 was not survivable during this accident due to fuel tank fire and explosion. Sixty-four out of 76 passengers died in this area. All passengers in tail section survived where there was much less fire damage. (1.2)

✈ Section 3.2 Finding 25

CAA Issues and Discussion

Minor word change is justified to recognize the efforts of the cabin crew in difficult circumstances.

CAA Proposed Changes

The crewmembers did some improvising to assist with the emergency evacuation when the Public Announcement (PA) system was found inoperative. (1.15.1.2; 2.6.1)

✈ Section 3.2 Finding 31

CAA Issues and Discussion

1. The CKS Airport have had an Emergency Medical Treatment Procedures with CAA medical center in charge of all the emergency medical services since its opening to service in 1979.
2. After the withdrawal of CAA medical center from the airport in 1995, various supporting contracts with Chan Gan Memorial Hospital in Lin Kou , Branch of Ming Shen Hospital in Da Yuan and some other major hospitals in the neighborhood were signed for emergency operations and also with the Ming Shen Hospital setting up airport medical clinic to pick up the services left over.
3. With all the related medical treatment commissioned to the contracted airport clinic and also being accepted as one of the local emergency medical network, the said plan and procedures developed at this airport was not only well extended, but also marked in a form of appendix in our emergency plan.
4. In hope of mobilizing all the available sources effectively for the potential heavy casualties, Min Shen Hospital established its own Emergency Medical Treatment Measures for major massive casualties.
5. According to our Airport Civil Aircraft Accident Handling Procedures and Regulations, once the medical team of the airport clinic gets informed on the accident at the airport, it should act and report immediately to the accident site, setting up interim triage in the neighborhood and beginning operations as required in the plan. As said in the contract it should also coordinate and help those from the local hospitals and medical network to carry out the earliest medical treatment and rescue.

6. As specified in our Medical Treatment Procedures, the command job resides first with the airport clinic doctor, then it will be passed over to the arriving doctor from the Da Yuan Branch, then in sequence to the Chan Gan , and finally falls with the Chief of the County Health Bureau or his agent.

CAA Proposed Changes

In light of these observations, it is proposed that the findings be deleted.

✈ Section 3.2 Finding 32

CAA Issues and Discussion

1. In response to adverse weather conditions, we have formulated our own specific plan against the most threatening typhoon namely the CKS Airport Typhoon Precaution and Handling Measures, which expresses well all the duty and equipment assigned for the individual team of the interim taskforce.

2. When the moment comes, all the members of the taskforce will be called upon to stand by as required to meet the potential situations and thus help lower the risk to the minimum effectively.

CAA Proposed Changes

In light of these observations, it is proposed that the findings be deleted.

✈ Section 3.2 Finding 33

CAA Issues and Discussion

1. We have collected in hand the medical rescue capacity in the neighboring Taoyuan area and affixed it in no.4 to our civil aircraft accident handling procedures as an important reference material.

2. The policy taken in the early stage was to move the injured to the hospitals for better care, then the commander center of the local medical network will take over to monitor all the injured get best treated according to the status of each patient and the facilities and specialty provided of various hospitals.

CAA Proposed Changes

In light of these observations, we propose deleting the item.

✈ Section 3.2 Finding 36

CAA Issues and Discussion

The finding should be reviewed in the light of supplementary firefighting resources in the area.

CAA Proposed Changes

The fire-fighting department was understaffed in handling a major accident (1.14.1.2;1.15.3.2; 2.6.4.3). While technically correct, this should be reviewed in light of the large amount of close-by support, which is not available at many other airports.

✈ Section 3.3 Other Findings Finding 12

CAA Issues and Discussion

There is a minor departure from the ICAO standard in expressing injuries to persons.

CAA Proposed Changes

Combine the totals for minor and none.

✈ Section 3.3 Finding 18

CAA Issues and Discussion

1. Under the effect of severe weather, the medical rescue couldn't be conducted as usual in accordance with CKS Airport (not CAA regulations) procedures. In the early stages after the accident, some of the injured were given first aid while on the way to the hospitals, for those seriously injured we provided EMT members as escorts. As for those slightly injured, we sent our transport to carry them to hospitals for further care.

2. Later on we set up the interim medical center at A9 the flight operation office. All the doctors and nurses from both the contracted hospitals and local medical network checked in one after another and came into service immediately.

CAA Proposed Changes

CAA proposes that the ASC revise the Finding to reflect CKS Airport procedures and delete "CAA Regulations". Furthermore the Finding should be amended in light of the additional information.

✈ Section 3.3 General

CAA Issues and Discussion

The Findings in the three different sections are very complete and provide a significant amount of detail regarding the accident. There are several areas where findings could be combined without disrupting the meaning or intent, yet would serve to reduce the overall length of the findings section. An example of this would be to combine both the flight and cabin crew statement regarding the fact that they were both qualified in accordance with SIA standards, etc.

CAA Proposed Changes

It is suggested that the findings be reviewed to determine those findings that could be combined to reduce the overall number of findings without losing the intent of the ASC's assertions.

Part 5

Representations on Section 4, Safety Recommendations

✈ Section 4 To CAA Recommendation 2

CAA Issues and Discussion

Suggest the ASC qualify the priority in the light of other priorities

CAA Proposed Changes

Amend the finding as follows: Place appropriate priority on budgetary processes and expedite, if justified, the procurement and installation of ASDE at airports with high traffic volume.

✈ Section 4.1 To CAA Recommendation 7

CAA Issues and Discussion

Aviation safety would be better served by broadening the recommendation.

CAA Proposed Changes

Delete the words ". . . for enhancing air traffic controller's abilities . . . "

✈ Section 4.1 To CAA Recommendation 11

CAA Issues and Discussion

The responsibility for post accident/incident testing is currently the responsibility of the "Prosecutor" and the ASC, in accordance with the regulator Articles. Unless a change is made to the regulation, the CAA has no authority to require these tests.

CAA Proposed Changes

Delete the Recommendation

✈ Section 4.1 To ICAO Recommendation 1

CAA Issues and Discussion

The recommendation would benefit from further definition.

CAA Proposed Changes

Add to the end of the recommendation the words: "and significant periods of adverse weather."

✈ Section 4.2 Safety Actions Taken ROC (CAA)

CAA Issues and Discussion

Please add to safety action taken under item 4.

CAA Proposed Changes

As of June 2001, the fire staff will conduct, during their respective shifts, three different missions: fire fighting, rescue and medical services respectively.

The Airport Emergency Medical Treatment Procedures are being redrafted with the recently contracted Lee Shin Hospital who will take over the remaining duties. These procedures are anticipated to be implemented by April 30, 2002.

Redefining the Emergency Radio Communication Channels as follows: CH1 for on-site command, CH2 for medical rescue Services, CH3 for executive and logistical support, CH5 for emergency rescue operations, and CH6 for firefighting. This will take effect in April 2002**.**

✈ Section 4.2 3. CKS Airport Facility Improvement

CAA Issues and Discussion

The following information updates the information in the ASC draft report

CAA Proposed Changes

The information is current as of March 2002 and the text, as written, could be inserted**:**

Bullet 1 - Painting:	-North Section construction was completed on November 27, 2001. -Taxiway centerline marking was completed January 31, 2002, in accordance with the ICAO Standards.
Bullet 2 Airport Lighting:	-Taxiway centerline lighting installation from N1 was completed January31, 2002. -Renew sign boards for runway 05/23 were completed January 31, 2002; and the sign boards for 06/24 were completed March 1, 2002. -Installation of Runway Guard Lights for runway 05/23 was completed January 31, 2002.

-Installation of yellow-green taxiway centerline lights in Runway 05/23 was completed on January 31, 2002.

Bullet 3 Airport Pavement: -Taxiway S1-S2 indicating boards base adjustment was completed July 31, 2001.

-Appropriate sections of Runway 06/24 and related taxiway resurfacing was completed July 31, 2001.

-Appropriate sections of Runway 05/23 and related taxiway resurfacing was completed January 31, 2002.

{NEW} – completed repainting and repositioning of "hold" lines on N1 through N11 taxiways with pattern "A" on January 31, 2002.

✈ Section 4.2 5. Improvement to Air Traffic Control System

CAA Issues and Discussion

The CAA established new "Low Visibility procedures, AIP A002C003/02, effective February 1, 2002, for operations at the Taipei/CKS international Airport.

CAA Proposed Changes

Add new bullet: The CAA established new "Low Visibility procedures, AIP A002C003/02, effective February 1, 2002, for operations at the Taipei/CKS international Airport.

✈ Section 4.2 Safety Action Taken - New Item 6

CAA Issues and Discussion

Add actions taken subsequent to the previous draft.

CAA Proposed Changes

Improvements to CKS Emergency Communications
To respond to the potential emergency situations, CKS Airport has redefined the use for radio communication channels as thus:

- CH1 for on-site command operations (459.2MHZ).
- CH3 for executive and logistical supports. (467.15MHZ)
- CH6 for fire fighting and rescue operations. (462.75MHZ).

SQ006 FACTUAL DATA COLLECTION REPORT

Distribution：

State of Registry and the Operator: Singapore

State of Manufacture: USA

ICAO

00 – OCCURRENCE IDENTIFICATION

FILING INFORMATION

State Reporting 0001 •	Code	TAIWAN, CHINA REPUBLIC OF Plain text
State File number 0002		

WHERE

State/Area of occurrence 0004 •	Code	TAIWAN, CHINA, REPUBLIC OF Plain text
Location N( ) Near 0005		CHIANG KAI-SHEK AIRPORT Local spelling using Roman letters

WHEN

Date of occurrence 0008	00 10 31 Year Month Day
Local time of occurrence 0009(24h clock)	23 17 Hour Min

AIRCRAFT

Manufacturer 0010 •	Code	BOEING Plain text
Model 0011 •	Code	747-412 Plain text
Registration 0012		9V-SPK Include hyphens as appropriate
State of registry 0013 •	Code	SINGAPORE Plain text
Operator’ s name 0014 40 ( ) 40 ( ) 40 ( )	Code	SINGAPORE AIRLINES Name

01 – HISTORY OF FLIGHT

AIRLINE OPERATION（AIR TRANSPORT OPERATIONS）

Type of Operation
0101 1 ( ) Passenger 2 ( ) Cargo 3 (X) Passenger/Cargo 4 ( ) Ferry/Positioning 5 ( ) Training/Check 6 ( ) Other Z ( ) Unknown
0102 S (X) Scheduled N ( ) Non-scheduled Z ( ) Unknown
0103 D ( ) Domestic I (X) International Z ( ) Unknown

GENERAL AVIATION

Type of Operation
0104 Instructional 10 ( ) Dual 11 ( ) Solo 12 ( ) Check 1Y ( ) Other 1Z ( ) Unknown Non-commercial 20 ( ) Pleasure 21 ( ) Business 22 ( ) Government/State 23 ( ) Aerial work 24 ( ) Off-shore operation 2Y ( ) Other 2Z ( ) Unknown Commercial 30 ( ) Aerial application 31 ( ) Fire control 32 ( ) Aerial observation 33 ( ) Aerial advertising 34 ( ) Construction/Sling load 3Y ( ) Other 3Z ( ) Unknown Miscellaneous 40 ( ) Test/Experimental 41 ( ) Illegal(smuggling/ 42 ( ) ferry 43 ( ) Search & rescue 44 ( ) Airshow/Race 45 ( ) Demonstration 4Y ( ) Other 4Z ( ) Unknown
Type of Operator 0205 1 ( ) Flying club/School 2 (X) Corporate/Executive 3 ( ) Gov.Agency 4 ( ) Private owner 5 ( ) Sales/Rental/Service Y ( ) Other Z ( ) Unknown

ITINERARY

Last departure point 0106	TAIPIE, TAIWAN Local spelling using Roman letters Or S ( ) if same as 0005
Planned destination 0107	LOS ANGELES, USA Local spelling using Roman letters Or S ( ) if same as 0005
Duration of flight(time airborne) 0108•	12 Hour 15 Min or Y ( ) if accident occurred on ground

07 – METEOROLOGICAL INFORMATION

General weather in the area of occurrence
0705 1 ( ) Visual meteorological conditions 2 (X) Instrument meteorological conditions Z ( ) Unknown
Light conditions 0706 1 ( ) Dawn 2 ( ) Daylight 3 ( ) Dusk/Twilight 4 ( ) Night – moonlight 5 (X) Night – dark Z ( ) Unknown

SEQUENCE OF EVENTS

EVENTS		PHASES	
1. 03Y	COLLISION WITH CONSTRUCTION EQUIPMENT	1. 031	TAKE-OFF RUN
2.		2.	
3.		3.	
4.		4.	
5.		5.	

On October 31, 2000, approximately 2317 Taiwan time (1517 UTC), a Singapore Airlines Flight SQ006, with Singapore registration 9V-SPK, Boeing 747-400 airplane entered the incorrect runway at Chiang- Kai-Shek(CKS) Airport, Taiwan. Heavy rain and strong wind from typhoon "Xiang Sane" prevailed at the time of the accident. The airplane was destroyed by its collision with the runway construction equipment and by post impact fire. There were a total of 179 people on board with 159 passengers, 3 flight crewmembers and 17 cabin attendants. A total of 83 people died (including 4 cabin crews), and 44 people injured.

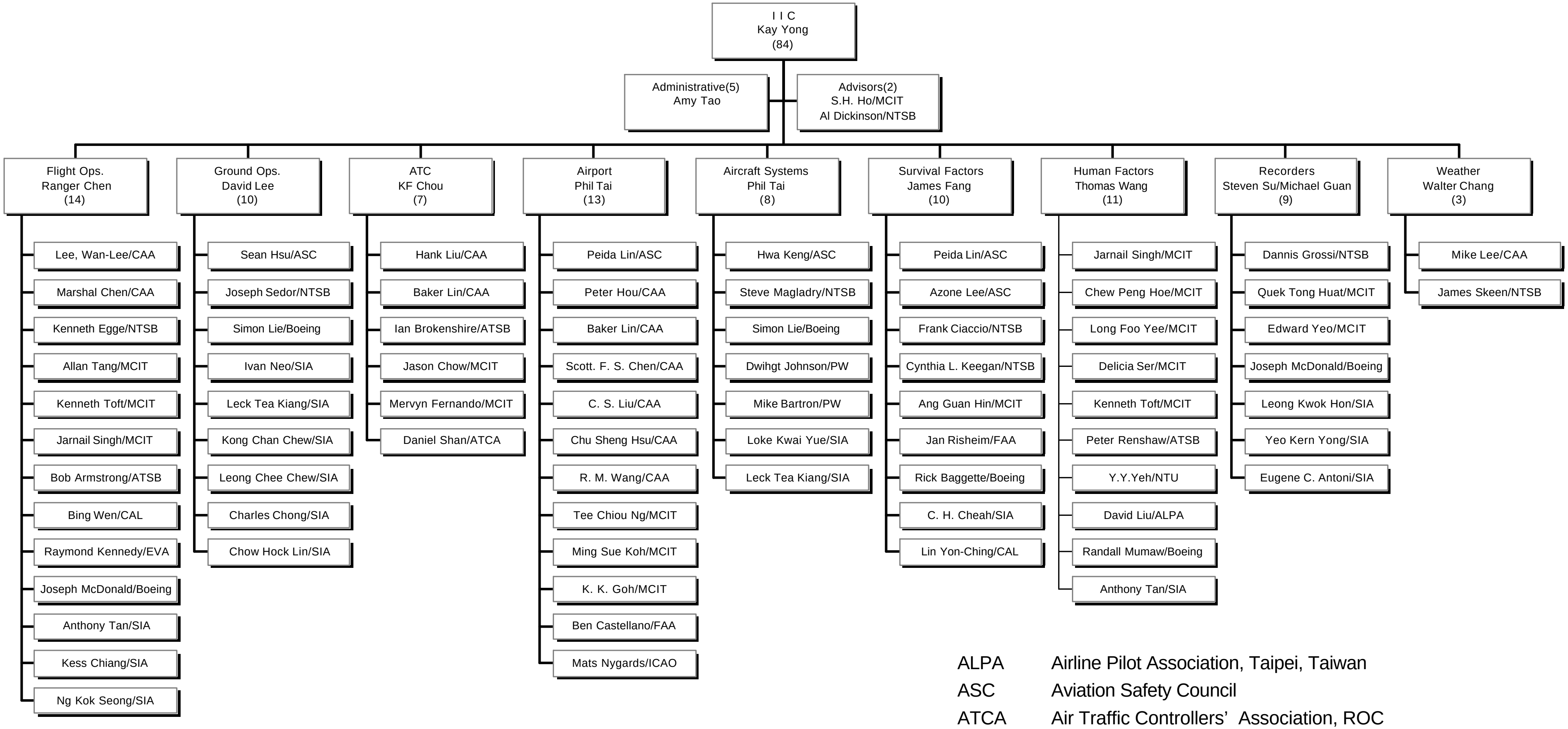
According to ICAO Annex 13 and Taiwan Civil Aviation Law Article 84, Aviation Safety Council, an independent government organization of Taiwan responsible for civil aviation accidents and serious incidents investigation, has immediately formed a team to conduct the investigation of this accident. NTSB of USA, the state of manufacture and MCIT of Singapore, the state of registry and the operator joined the investigation team as the Accredited Representatives. The investigation effort was commenced immediately after the accident. Based on the nature of this accident, the investigation team is organized into nine groups: Flight Operations, Recorders, ATC, Weather, Ground Operations, Systems, Survival Factors, Aerodrome, and Human Factors (the Aerodrome and Human Factors groups were added on at a later stage). Organization of the investigation team is shown in Attachment 0-1.

After nearly four months of investigation including on-scene investigation and data collection, the investigation team presents the factual data collected relevant to this accident. It should be noted that this report contains only factual information. The analysis portion of the investigation process will commence immediately after the release of this report. It is expected that the draft report will be furnished to the Accredited Representatives for comments in September 2001 and the final report will be published towards the end of the year. Should it be any new factual data surface during the time of the analysis, ASC shall notify the Accredited Representatives immediately and the factual report will be modified accordingly.

This report is organized by the reports from each individual group. Individual group report contains the name of the group members and their background, histories of activities, factual description of the group, and data list. The factual description in each group report will follow the format of Chapter 1 of ICAO Annex 13. It should be noted that since each group conducted its own data collection, similar information may appear in the report of several groups. Text of the report will be published on ASC web site:

http://www.asc.gov.tw

Atachment 0-1 Organization chart of SQ006 accident investigation team



Overall Logistics:K.F.Chou / Victor Liang

ALPA	Airline Pilot Association, Taipei, Taiwan
ASC	Aviation Safety Council
ATCA	Air Traffic Controllers' Association, ROC
ATSB	Australian Transportation Safety Board
BCAG	Boeing Commercial Airplane Group
CAA	Civil Aeronautics" Administration
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
MCIT	Ministry of Communications & Information Technology
NTSB	National Transportation Safety Board
NTU	National Taiwan University
SIA	Singapore Airlines

Aviation Safety Council
Taipei, Taiwan

SQ006 Accident Investigation Factual Data Collection Group Report

Flight Operations Group

February 20, 2001

ASC-FRP-01-01-001

I. Team Organization

Chairman:
Captain Ranger Hsueh-Jen Chen Aviation Safety Council, R.O.C.
Members:
1. Captain Lee Wan-Lee Civil Aeronautics Administration, R.O.C.
2. Captain Marshal Yan-Chan Chen Civil Aeronautics Administration, R.O.C.
3. Kenneth L. Egge National Transportation Safety Board, U.S.A.
4. Bob Armstrong Australian Transport Safety Bureau
5. Allan Tang CAAS, MCIT, Singapore
6. Captain Kenneth Edward Toft CAAS, MCIT, Singapore
7. Dr. Jarnail Singh CAAS, MCIT, Singapore
8. Captain Bing Wen China Airlines, R.O.C.
9. Captain Raymond C. Kennedy EVA Airways Corporation, R.O.C.
10. Captain Joseph M. MacDonald Boeing Commercial Airplane Group
11. Captain Anthony C. K. Tan SIA, Singapore
12. Captain Ng Kok Seong SIA, Singapore
13. Kess Chiang Hui Sien SIA, Singapore

(i) R.O.C. – Republic of China
(ii) U.S.A. – United States of America
(iii) MCIT – Ministry of Communications and Information Technology
(iv) CAAS – Civil Aviation Authority of Singapore
(v) SIA – Singapore Airlines

II. History of Activities

Date	Activities
Nov 03, 2000	1. Study SQ-006's Flight Data Recorder / Cockpit Voice Recorder (FDR / CVR). 2. The first interview of the three pilots and flight dispatcher. 3. Second interview of the three pilots.
Nov 04, 2000	1. Captain (CM –1), First Officer (CM-2) and Relief Pilot (CM-3) personnel information collected. 2. Completed the interview report of CM-1.
Nov 06, 2000	1. Completed the interview reports of CM-2, CM-3 and flight dispatcher. 2. Reenactment of the taxi route taken by SQ-006 using B747-400 Freighter airplane.
Nov 07, 2000	1. Completed the second interview reports of the 3 pilots. 2. Completed report of the taxi route reenactment.
Nov 08, 2000	1. Interviewed CI-004 First Officer. Completed the interview report of CI-004 First Officer.
Nov 09, 2000	1. Interviewed CI-004 Captain. 2. Completed the interview report of CI-004 Captain. 3. Interviewed CI-065 Captain by telephone.
Nov 12, 2000	Completed a Preliminary Group Report.
Nov 27, 2000	1. Interviewed Captain. (Flew with CM-2) 2. Interviewed Captain. (Flight Operations Deputy Head, CAAS) 3. Interviewed First Officer. (Flew with CM-1)
Nov 28, 2000	1. Interviewed Captain. (Performed CM-2's line check) 2. Interviewed Captain. (Performed CM-1's base check) 3. Interviewed Captain. (Performed CM-1's line check)
Nov 29, 2000	1. Interviewed Captain. (Performed CM-3's base check) 2. Interviewed Captain. (Flew with CM-3) 3. Interviewed Captain. (Performed CM-3's line check)
Nov 30, 2000	1. Interviewed CI-065 First Officer by telephone. 2. Completed the reports of the 10 interviews done from Nov 27 to 30, 2000.
Dec 01, 2000 to	Reviewed documents pertaining to the management of SIA's Flight Operations Division. 1. Reviewed Civil Aviation Authority of Singapore approval

Dec 15, 2000	documents for SIA's operations. 2. Reviewed Civil Aviation Authority, R.O.C., approval letter for SIA CAT-II operations at CKS Airport. 3. Reviewed SIA's Flight Operations Manual and/or Policy Manual pertaining to low visibility procedures and policies. 4. Reviewed SIA's Internal Notice to Airmen (INTAM) and Bulletins to determine the company procedures for updating crews as well as record keeping of flight operations documents. 5. Reviewed Training Manual to ascertain the low visibility and Para-Visual Display (PVD) procedures for crew. 6. Reviewed Training Records of the three pilots. 7. Reviewed the company's Crew Resource Management (CRM) training program. [known as Aircrew Resource Management (ARM) in SIA] 8. Reviewed Crew Competency Records for the three pilots especially pertaining to area and route, airports flown to, takeoffs and landings. 9. Reviewed airplane records such as Certificate of Airworthiness, Radio License and CAT-III currency. 10. Reviewed the three pilots' flight schedules to ensure compliance with Flight Time Limitations prior to the SQ-006 flight on Oct.31, 2000. 11. Reviewed Simulator approval ratings. 12. Interviewed the CAAS Flight Operations Inspector. 13. Interviewed 8 pilots who had flown with CM-1, CM-2 and CM-3 recently. 14. Checked if the three pilots had been paired before on previous flights. 15. Interviewed Check Airmen (known as Authorized Flight Examiners in Singapore) and Instructor Pilots. 16. Verified the periodicity of Base Checks, Instrument rating and Line/Route checks for pilots. 17. Verified the number of times each crewmember has operated into Taipei and if possible ascertain which runway the crew may have used on these occasions. 18. Reviewed contents of airplane library documents. 19. Verified Weight and Balance and Fuel sheet for the SQ-006

	flight on Oct. 31, 2000.
Feb 01, 2001 to Feb 06, 2001	Technical review meeting at ASC in Taipei.

III. <u>Factual Description</u>

1. FACTUAL INFORMATION

1.1 History of Flight

On October 31, 2000, at 1517 Universal Coordinated Time (UTC) (2317 Taipei local time), Singapore Airlines Flight SQ-006, a Boeing-747-400 airplane, bearing registration no. 9V-SPK, crashed on a partial closed runway during takeoff. Heavy rain and strong winds from typhoon "Sangsane" prevailed at the time of the accident. SQ-006 was on a scheduled passenger flight from Chiang-Kai-Shek（CKS）International Airport , Tao-Yuan, Taiwan, Republic of China to Los Angeles International Airport, Los Angeles, California, U.S.A. The flight departed with 3 pilots, 17 flight attendants, and 159 passengers aboard.

The airplane was destroyed by its collision with construction equipment, runway construction pits on Runway 05R and by post impact fire. The tail section of the fuselage, the engines and landing gear separated from the rest of the airplane. The forward and mid sections of the fuselage and the wings were totally destroyed by the fire. The tail section was slightly damaged by fire.

On August 31, 2000, Civil Aeronautics Administration (CAA), R.O.C., issued a Notice to Airmen (NOTAM) number A0606, indicating that a portion of the Runway 05R between Taxiway N4 and N5 was closed due to work in progress from September 13, 2000, to November 22, 2000.

The pilots commenced duty on October 30, 2000, in Singapore, for the scheduled Singapore→Taipei→Los Angeles→Taipei→Singapore trip sequence. They completed the Singapore→Taipei sector on October 30, and arrived at the hotel in Taipei city around midnight local time and stayed at the hotel until departure for the airport on the evening of October 31, 2000.

At 1235 UTC, the 3 pilots departed the hotel to CKS Airport and reported for duty at 1355 UTC. The flight SQ-006 had 3 pilots on board: one Captain (Crew Member-1, CM-1) and one First Officer (CM-2) with another First Officer as Relief Pilot (CM-3). SQ-006 was parked at Bay B5 where the airplane was prepared for departure. CM-1 was the pilot flying and conducted taxi and takeoff.

At 1507 UTC, after pushback from Bay B5, SQ-006 commenced taxiing via Taxiway SS, turned north and entered Taxiway WEST CROSS, and then turned left to Taxiway NP proceeding in a southwest direction.

At 1515:22 UTC, just before reaching the end of Taxiway NP, SQ-006 received takeoff clearance for Runway 05L. The pilots acknowledged the takeoff clearance for Runway 05L. The airplane made a right turn from Taxiway NP into Taxiway N1 and continued the right turn onto Runway 05R.

At 1516:36 UTC, after a 6-second hold, SQ-006 commenced takeoff roll from Runway 05R. Approximately 41 seconds later, it collided with the concrete jersey barriers, 2 excavators, 2 steamrollers, a bulldozer, an air compressor cart, and a pile of metal reinforcement bars on Runway 05R, between Taxiways N4 and N5.

At 1517:36 UTC, CKS Airport Control Tower signaled the emergency bell to the fire station after seeing explosions. Fire was seen along the takeoff path of the airplane. There were 123,800 kilograms of Jet A1 Aviation fuel on board the airplane. The fire fighters initiated the emergency response and informed Tao-Yuan County's Fire Fighting Action Center and Emergency Medical Service Center. The first fire fighting truck began discharging its chemical extinguishing agent at the accident site within approximately 3 minutes after the alarm. The fire was very intense at the forward and mid sections of the wreckage. The tail section fire was less intense and was brought under control by the fire fighters. Heavy rain, low visibility and strong winds prevailed at the time of the accident. The fire fighting group used a total of 2,300 gallons of chemical and 40,000 gallons of water during the fire fighting process.

A temporary command center was established at the accident site in a large passenger transportation vehicle. The security system established by the Airport Police Service Center consisted of a combination of airport police, local county police and military police. Nine fire trucks and 4 ambulance vehicles from CKS airport, and another 34 fire trucks and 54 ambulance vehicles from the local area were used.

All injured passengers and crewmembers were gathered at A9 terminal and sent to the local hospitals. Passengers that sustained burn injuries were sent to fire and burn intensive care center of the local hospital.

Seventy-nine passengers and 4 flight attendants were fatally injured. Thirty-five passengers and 4 flight attendants sustained serious injuries in this accident.

1.1.1 Sequence of Events During Taxiing and Takeoff

1457:16 UTC	SQ-006 copied Air Traffic Control (ATC) clearance.
1459:06 UTC	Tower approved SQ-006's request to use Runway 05L for departure, start and pushback clearance was issued.
1500:53 UTC	CVR began recording at this time. The engine start sequence was 1, 2, 3, and 4.
1501:25 UTC	The Automatic Terminal Information Service (ATIS) broadcast: "Taipei International Airport: Information Tango, one four five four Zulu. Runway zero five Left is in use, Runway zero six for departure only. Expect ILS Runway zero five Left, category-two approach, wind zero two zero at three six, gust five two, visibility five hundred meters, Runway zero five Left RVR four hundred fifty meters, Runway zero six, five hundred meters with heavy rain, cloud broken two hundred feet, overcast five hundred feet, temperature two one, dew point two zero, QNH one-zero-zero-one

	hectopascal, departure frequency one-two-five point one, caution windshear on Runway zero-five Left final. Due to radio interference, Tower frequency changed to one-two-nine point three. Caution Taxiway November Sierra has been re-marked, aircraft using November Sierra advise taxi slowly with caution. Taxiway November Papa behind Alpha one and Alpha three closed, Runway zero-five Right between November four and November five closed, due to work in progress, Taxiway November four and November five still available. Inform Taipei Approach or Tower initial contact you have Tango".
1504:35 UTC	CM-1 asked for the removal of the ground equipment, this was followed by response from Maintenance.
1505:22 UTC	The Crew commenced “after start checklist”.
1505:57 UTC	With the completion of pushback, taxi clearance was requested by SQ-006 and Ground Control provided the following: "Singapore Six taxi to Runway Zero Six via Taxiway…, correction Runway Zero Five Left via Taxiway Sierra Sierra, WEST CROSS and November Papa".
1506:08 UTC to 1506:29 UTC	CM-2 read back the taxi instructions to Control Tower with the assistance of CM-1. Taxi instructions discussed by Crew.
1507:10 UTC	CM-1 commenced taxi.
1507:21 UTC to 1507:53 UTC	CM-1, CM-2 and CM-3 discussed the weather details and return Alternate Airports.
1508:04 UTC	The flight controls check was commenced and carried out by CM-1 and CM-2.
1508:56 UTC to 1509:58 UTC	The before takeoff check was initiated and completed to the line by CM-1 and CM-2, and they set V_1-142, V_R-156, V_2-169.

1510:14 UTC to 1512:01 UTC	The 3 pilots commented on the weather.
1512:02 UTC	The ATIS Broadcast: "Taipei Chiang Kai Shek International Airport Information UNIFORM one five zero zero zulu runway zero six for departure only runway zero five left for category two approach and departure wind zero two zero at three six gust five six visibility six hundred meters runway zero five RVR four hundred fifty meters downward runway zero six RVR five hundred fifty meters downward with heavy rain cloud broken two hundred feet overcast five hundred feet temperature two one dew point two zero QNH one zero zero one hectopascal."
1512:25 UTC	The airplane turned left into Taxiway November Papa.
1513:28 UTC	CM-2 contacted Control Tower on frequency 129.3 MHz and was told to hold short of Runway 05L.
1513:38 UTC	Tower advised: "Surface wind zero two zero at two four, gust four three, say intention".
1514:41 UTC to 1514:53 UTC	CM-1 and CM-2 discussed the turn into Taxiway N1, which is the second right turn at the end of Taxiway November Papa.
1515:02 UTC	SQ-006 called: "Singapore six ready".
1515:04 UTC	Tower cleared SQ-006 to taxi into position and hold on Runway 05L: "Singapore Six roger, Runway Zero Five Left, taxi into position and hold".
1515:22 UTC	Tower reported: "Singapore Six, Runway Zero Five Left, wind zero two zero at two eight, gust to five zero, cleared for takeoff". The position of the Airplane at this time was on Taxiway NP between N1 and N2.
1515:48 UTC	Before takeoff checks below the line was completed by CM-1 and CM-2.

1515:50 UTC	Approaching Runway 05 Right, CM-2 commented: "OK, green lights are here".
1515:52 UTC	CM-1 said: "It's going to be very slippery. I am going to slow down a bit, slow turn here".
1516:07 UTC	CM-2 said: "And the PVD hasn't lined up ah".
1516:10 UTC	CM-1 said: "Yeah we gotta line up first".
1516:12 UTC	CM-3 said: "We need 45 degrees".
1516:23 UTC	CM-1 said: "Not on yet er PVD huh never mind we can see the runway, not so bad. OK, I am going to put it to high first. OK, ready eh, so zero one zero is from the left lah OK".
1516:36 UTC	Takeoff roll was commenced.
1516:55 UTC	CM-2 called: "Eighty knots".
1517:13 UTC	CM-2 called: "VEE one".
1517:16 UTC	CM-1 said: "- - - - something there".
1517:16 UTC	The FDR recorded the highest airspeed of 158 knots and Ground Speed 130.8 knots at the end of the data recording.
1517:17 UTC	Sound of first impact was recorded, followed by sounds of a series of impacts.
1517:22 UTC	The CVR recording ended.

1.1.2 Highlights from Flight Crew Interviews（Appendix 1-1）

1.1.2.1 CM-1 and CM-2 arrived at CKS Airport late in the evening of October 30, 2000 on SQ-006 from Singapore. CM-3 was a passenger on the same flight.

1.1.2.2 All 3 pilots were picked up from the hotel at about 1235 UTC, and reported for duty at CKS Airport, about 1355 UTC.

1.1.2.3 Upon request, the Crew of SQ-006 was assigned departure Runway 05L.

1.1.2.4 CM-1 selected this runway on the basis of the extra operational length available and the lower minimum visibility published for takeoff from this runway. Takeoff speeds had been set as follows: V_1 –142, V_R –156 and V_2 –169 KIAS. The Crew reported that they reduced the V_1 by 10 knots because the runway was wet.

1.1.2.5 CM-1 reported that he had operated into CKS Airport on more than 10 occasions using various runways, and had done about 10 night takeoffs from CKS Airport. He confirmed that he had previously operated into CKS Airport in rain and conditions of poor visibility.

1.1.2.6 CM-1 determined that the visibility, wind strength and crosswind component were within Company limits. CM-3 determined that the crosswind component was 28.5 knots. The maximum was 30 knots. The visibility was better than the minimum required for takeoff. CM-3 monitored the crosswind component from ATIS information as well as wind and weather information that the Control Tower provided to other flights.

1.1.2.7 CM-1 stated that he was aware of the NOTAM, which applied to works in progress on the northern apron and on Runway 05R. CM-1 stated that pre-briefed their taxi route to departure runway 05L via Taxiway SS, EAST CROSS, backtracking down Runway 05R, vacating via Taxiway N7, thence onto NP and N1.

1.1.2.8 CM-1 knew about the NOTAM relating to the closure of Runway 05R during his self-brief in Singapore. He said that he also noted the closure during his self-brief during the pre-brief for SQ-006 departure out of CKS Airport on October 31, 2000.

1.1.2.9 Both the official NOTAM and the Scandinavian Air System NOTAM were provided to the Flight Crew. The NOTAM made a reference to Aeronautical Information Publication (AIP) Supplement A007C015/00 dated October 3, 2000 for details. The Crew of SQ-006 could not recall the details of the supplementary SIA INTAM relating to runway lighting on Runway 05R, which was provided to them by the Flight Dispatcher as part of the pre-flight briefing package at CKS Airport.

1.1.2.10 CM-1 stated that the taxi clearance issued by Air Traffic Control (ATC) was different from the route that he had anticipated and briefed earlier. The final ATC taxi clearance was via Taxiway SS, WEST CROSS, NP for Runway 05L. CM-1 said he re-briefed the other pilots accordingly.

1.1.2.11 All 3 Pilots remarked about the power failures that occurred in the CKS Airport Main Terminal Building during their pre-flight preparations.

1.1.2.12 CM-1 stated that he had initially intended to let CM-2 operate the Taipei→Los Angeles sector, but CM-1 decided to carry out the takeoff from CKS Airport because of the typhoon. CM-1 performed pilot flying duties.

1.1.2.13 CM-1 stated that he taxied the airplane following the green centerline taxiway lighting via Taxiway SS, WEST CROSS, NP, and N1 onto Runway 05R.

1.1.2.14 All 3 Pilots stated that they thought that they were on Runway 05L.

1.1.2.15 CM-2 stated that as they were turning onto the runway, the Para-Visual Display (PVD) was not working. CM-3 stated that the airplane was not within 45 degrees of the runway heading as the reason for the PVD not activating. CM-1 said that he could see the runway.

1.1.2.16 CM-1 and CM-2 stated that the view of the runway ahead of them was normal. CM-3 stated that he was comfortable with the runway picture. CM-2 could not remember seeing any lights on the sides, but he stated that the runway picture looked correct. CM-1 did not recall seeing any other lights on the left side of the airplane.

1.1.2.17 CM-1 and CM-3 stated that they did not see any markings or obstruction lights that would indicate that the runway was closed. All airplane lights were switched on prior to commencing the takeoff roll.

1.1.2.18 CM-1 and CM-2 indicated that the airplane had already accelerated past V_1, when they saw objects on the runway. CM-1 said that he applied the elevator in an attempt to lift the airplane off the ground to avoid the object. All 3 pilots stated that they heard a thump/bang and the nose of the airplane slammed down on the runway and came to a stop.

1.1.2.19 CM-1 said that he made an evacuation announcement. All 3 pilots stated that the cockpit lost all electrical power when the airplane came to a stop. They stated that the cabin Passenger Address system (PA) and Very High Frequency (VHF) radio did not work. CM-1 ordered the evacuation of the cockpit. All 3 pilots stated that they evacuated the airplane via the upper left door.

1.1.3 Highlights from Flight Dispatch Interviews（Appendix 1-1）

1.1.3.1 SIA contracted with EVA Airways to provide flight dispatchers at CKS Airport. These dispatchers handle all computer flight plans and dispatch documentation for flights departing out of CKS Airport. The SQ-006 pilots were provided with a standard pre-flight briefing package. This contained weather information, NOTAM (from CKS Flight Information Service), the company INTAM and Scandinavian Airways Systems NOTAM.

1.1.3.2 EVA Airways Flight Dispatchers retrieve computer flight plans and INTAM from SIA. The EVA Airways licensed Flight Dispatchers check the documents to ensure compliance with SIA company policy before sending a dispatch release to its Operations Officer at CKS airport who then delivers the pre-flight briefing documentation to the flight crew.

1.1.3.3 On October 31, 2000, the SQ-006 pilots received this documentation at about 1353 UTC at the aerobridge leading to Bay B5.

1.1.3.4 The EVA Airways Operations Officer stated that he highlighted (using a highlighter pen) certain information on the paperwork for SQ-006 on October 31, 2000.

[Note: Paragraphs 1.2 to 1.15 are covered in other Group Reports.**]**

1.16 Tests and Research

1.16.1 Taxi Trail Simulation（Appendix 1-2）

1.16.1.1 On Nov 6, 2000 a reenactment of the taxi route as taken by SQ-006 on Oct 31, 2000 was carried out using a Boeing 747-400 Freighter airplane at CKS Airport in visibility more than 10 kilometers and with slight rain. The aim of the reenactment was to familiarize accident investigators with aspects of the taxi route as well as the Runway 05L and 05R markings, signs and lighting. The weather and visibility conditions were much better on the night of the reenactment as compared to the night of the accident. A video and sound recording was made from the cockpit during the reenactment. （Attachment #1）

1.16.1.2 Observation according to the flight deck occupants during the taxi trail simulation:

1.16.1.2.1 The following markings and signs were observed in the vicinity of the approach end of Runway 05R:

(a) A black/red sign marked “N1/5R-23L” on the southwest side of N1.
(b) A white marking on the Runway 05R indicating “05” and “R”.
(c) A red “CAT 2” sign on N1 between 05R and 05L.
(d) A red/black sign marked “5L-23R/N1” on the northeast side of N1.

1.16.1.2.2 Additional Observations:

(a) The Instrument Landing System (ILS) localizer needle on both Primary Flight Displays (PFD) indicated full left deflection.

(b) The glide slope indicator showed one dot high on the left PFD and one dot low on the right PFD.

(c) The Navigation Display (ND) at the 10 NM range showed a small map error.

(d) There was no change (no map shift) on the Flight Management Computer (FMC) latitude & longitude when Takeoff/Go-Around (TOGA) button was activated.

(e) Runway lights on Runway 05L were difficult to see at ATC intensity level steps 1 & 2. (Runway 05L runway edge lights, touchdown zone lights and centerline lights has five intensity level steps.).

(f) There was no indication that the runway was closed nor was it possible to see any obstructions or obstacle lightings on the runway.

(g) After the airplane was lined up, the runway markings “05” and “R” were no longer visible from the flight deck.

1.17 Organizational and Management

1.17.1 Organization and Management of Civil Aviation Authority of Singapore

1.17.1.1 Organization

1.17.1.1.1 CAAS is a statutory board under the Ministry of Communications & Information Technology (MCIT) of Singapore. CAAS is the body responsible for the safety regulation of civil aviation in Singapore, and also the safety regulation of Singapore aircraft outside Singapore.

1.17.1.1.2 CAAS's aviation safety regulatory role and responsibilities cover the following:

(a) Regulating the operations and airworthiness of Singapore registered airplanes.
(b) Regulating the aerospace industry in Singapore.
(c) Licensing of flight personnel and maintenance engineers.
(d) Advising the Government on civil aviation matters.

1.17.1.2 Regulating the operations and airworthiness of Singapore-registered aircraft

1.17.1.2.1 Air Operator Certificate

CAAS issues an Air Operator Certificate (AOC) to Singapore operators for an aircraft to be operated for the purpose of public transport in Singapore. CAAS has established AOC requirements which are in accordance with ICAO Annex 6 – Operation of Aircraft and are published in the Air Operator Certificate Requirements (AOCR).

1.17.1.2.2 Operations Supervision

1.17.1.2.2.1 All aspects of airplane operation, including the management structure, adequacy of ground and flight crew and arrangements for their training, premises, equipment and airplane are assessed in relation to the scale, scope and circumstances of the operations. The operator is required to comply with, among other requirements, the ICAO Annex 6.

1.17.1.2.2.2 CAAS has a regular plan for inspection visits of each operating base (airplane ramp inspections and hangar maintenance inspections) and the operator's line stations. These checks are conducted to assess the suitability of an operator's organization, base facilities, overall standard of operation and level of compliance with regulatory and operations manual requirements.

1.17.1.2.2.3 Flight inspections are also carried out. The purpose of these checks is to assess the adequacy of the procedures and facilities provided by the operator to enable the crew to perform their duties both in the air and on the ground; to examine the standard of flight deck management and operations by the crew; and to assess the level of compliance with regulatory and operations manual requirements. The conduct of tests by CAAS authorized examiners and of crew training are also observed by CAAS.

1.17.1.3 Engineering and Maintenance Support

1.17.1.3.1 CAAS also assesses the operator's arrangements for engineering and maintenance support for the number, type and complexity of the airplane and the area and type of operations before issue or re-issue of the Air Operator Certificate.

1.17.1.3.2 CAAS performs regular safety oversight of the operator and his maintenance organization to check that they discharge their responsibilities to ensure that the airplane is airworthy for flight and that the airplane operated by the operator on such flights are operated safely in accordance with ICAO and Singapore airworthiness requirements. Regular inspection visits and audits are conducted on the operator, maintenance organization and line stations.

1.17.2 SIA Organization

1.17.2.1 The SIA Flight Operations Division (Appendix 1-3) is headed by a Senior Vice President who is responsible for the Division and also its organization, and development. The Division consists of 4 departments:-

(a) Line Operations,
(b) Training,

(c) Safety, Security and Environment, and,
(d) Flight Control Center.

1.17.2.2 The Line Operations Department is responsible for all Technical and Line matters related to operation of the four fleets in SIA and to ensure compliance with Singapore and international regulations.

1.17.2.3 The Training Department is responsible for all the flight and ground school training of technical crew, including recurrent training, base checks and line checks. The Training Department also oversees the safety equipment and procedures training for both flight and cabin crew.

1.17.2.4 The Safety, Security and Environment Department is responsible for:

(a) The reporting and investigation of all mandatory reportable occurrences,
(b) Training of flight and ground crew on security matters,
(c) Review and update of flight security,
(d) Cabin safety,
(e) Handling of Dangerous Goods procedures,
(f) Administration of a Flight Data Analysis Program.
(g) Security of all company property.

1.17.2.5 The primary function of the Flight Control Center Department is to ensure that Singapore Airlines' services operate with the least possible disruption or delay and that where services are disrupted or delayed, these services are rescheduled with the least possible inconvenience to passengers and at a minimal cost level consistent with safety, efficiency and service.

1.17.3 SIA Management

1.17.3.1 SIA Line Operations

1.17.3.1.1 The line operations management oversees the day-to-day operation of all fleets in SIA. This includes conduct and discipline of line crew, assignment of crew on all fleets, validity and currency of manuals and formulation of policies on operational matters.

1.17.3.1.2 The line management also ensures that crew comply with the procedures in the Flight Administration Manual and Operations Manual.

1.17.3.1.3 Singapore Airlines uses the Operations Manual as provided by the airplane manufacturers. SIA Line Management develops only the Operational and Fuel Policy chapters. The Normal Procedures and Checklist are customized for SIA. The SIA generated chapters and pages are submitted to CAAS for approval before promulgation.

1.17.3.1.4 The line management personnel also monitor and ensure the compliance of Air Operators Certificate Requirement (AOCR) by:

(a) Checking the Crew Operating Pattern (COP) for compliance with the approved flight time limitation scheme e.g. maximum permitted duty and minimum rest periods.
(b) Using computerized check-in system (Flight Reporting and Messaging System [FRAMS]) for flight crew to ensure validity of flight crew licenses, Base Checks, Line Checks and Safety Equipment and Procedures Training Competency Certificate and recency experience requirements before operating any flight.
(c) Reviewing of returned flight records documentation to ensure compliance.
(d) Conducting of all proficiency tests required by the AOCR (Base Checks, Instrument Rating Checks, Line Checks, CAT III/Low Visibility validation etc.) on each crew to ensure their competency.

Note: Aircrew Resource Management (ARM) – SIA's version of CRM for pilots is the responsibility of the Divisional Vice President (Projects).

1.17.3.2 SIA Training Department

1.17.3.2.1 The training department oversees training matters relating to flight crew, and, safety training for both flight and cabin crew. The department provides the following training:

(a) Aircraft Type Training
(b) Reactivation Training
(c) Recurrent Training

(d) Recency Training
(e) Reinforcement Training

1.17.3.2.2 In addition, the training department also provides joint safety and emergency procedures training and CRM training for cabin crew.

1.17.3.2.3 The training department also carries out command training for first officers selected for promotion to commanders and transitional training from piston engine airplane to jet engine airplane for pilots who have graduated from ab-initio training with the minimum 200 flying hours experience.

1.17.3.2.4 Selected training department personnel are also delegated by CAAS to carry out Authorized Flight Examiner responsibilities (Check Airmen) and to conduct ground school examinations on behalf of CAAS.

1.17.3.2.5 Six monthly Base Checks/Instrument Rating Test:
The Training Department conducts the Base Checks twice a year and the annual Instrument Rating Tests for all pilots in accordance with CAAS requirement.

1.17.3.2.6 Airplane Type Rating Training (Conversion Training):
The normal airplane type training comprises of the following:

(a) Two to 3 weeks of Computer Based Training on airplane systems, airplane performance and safety and emergency procedures.
(b) Ten to 15 simulator sessions covering Normal and Non-Normal procedures, including windshear, CFIT, FANS, CAT 3, TCAS, Unusual Attitude Recovery and Takeoff Safety Training.
(c) Airplane Base Training which includes engine-out approach, go-around and landing.
(d) At the end of the Ground/Simulator training phase, candidates will be required to pass the Airplane Rating Flight Test, Instrument Rating and an initial line check before commencing route training for 4 to 5 weeks.
(e) At the end of route training, candidates will be required to pass a final line check prior to being cleared for line duties.

1.17.3.2.7 Reactivation Training: This training is conducted for pilots who are returning to an airplane type they had flown previously or for familiarising newly employed crew to SIA operational procedures and policy. The course comprises an abbreviated version of the Airplane Type Rating Training. (Conversion Training).

1.17.3.2.8 Recurrent Training: The department also provides a recurrent training program for all pilots twice a year. The program consists of 6 lessons which include Line Oriented Flying Training (LOFT) scenarios to refresh pilots on significant supplementary Normal and Non-Normal procedures not covered during the airplane rating tests. The emphasis in the LOFT focuses on flight deck management, situational awareness, leadership and resource management.

1.17.3.2.9 Recency Training: Recency Training is provided to pilots who have not operated an airplane for more than 28 days. The Recency training can be carried out in an airplane or in an approved simulator.

1.17.3.2.10 Reinforcement Training: The training department provides training for pilots who failed their proficiency tests and those who need extra training to address weaknesses.

1.17.3.2.11 Low Visibility Training: Low Visibility Training is given to pilots to qualify for CAT-III and Para Visual Display operations. It covers topics like ILS Critical Areas, lighting systems, runway and taxiway markings and the equipment required. The pilots are also required to view a video-tape on low visibility operations followed by training in an approved Level 2 simulator.

1.17.3.3 SIA Safety, Security and Environment Department

1.17.3.3.1 The Safety, Security & Environment Department is responsible for coordinating matters relating to flight, ground, industrial and fire safety; ground and flight security, and the environment.

1.17.3.3.2 The department manages a system for the reporting and investigation of all reportable airplane incidents and publishes a two-monthly summary of airplane incidents (for review and action) and an in-house safety magazine, the Flight Safety Review. This system is augmented by the administration of a Flight Data Analysis Program and the maintenance of replay facilities for all QARs (Quick Access Recorders), FDRs and CVRs installed on SIA's airplane by the department. All ground incidents/accidents are investigated, and recommendations are made to prevent a recurrence.

1.17.3.3.3 In addition, it also produces and amends the Safety Equipment and Procedures Manual for cockpit and cabin crew. It also updates procedures for cabin safety and for the carriage of Dangerous Goods.

1.17.3.3.4 The department develops and promulgates security standards and provides specialist expertise and professional advice to Line Management on aspects of the security functions, e.g. intelligence, protection of company property and investigation. The department also provides training on security procedures to crew members, Station and Front-line Staff.

1.17.3.4 SIA Flight Control Center Department

1.17.3.4.1 Flight Control Center is responsible for the following decisions:-

(a) Cancellation of flights.

(b) Rescheduling flights due to weather, airport limitations, civil disturbances, crew duty time or sector limitations.

(c) Over-flights due to weather, airport limitations, crew duty time or sector limitations.

(d) Other issues related to delay, aircraft diversions, re-routing, rescheduling and recalling of flights, re-allocation of aircraft, recalling flights and/or repositioning of crews.

1.17.3.4.2 The function of the Flight Control Center Department is to ensure that a high level of discipline and operational efficiency are maintained especially when flights are disrupted, such services are re-scheduled with the least possible delay. This is achieved by carrying out regular evaluation of route and operational information, such as the serviceability of navigation aids, curtailment of airport facilities, refueling facilities and situations, meteorological warnings, crew duty and flight time limitations and other matters of immediate operational significance.

1.17.3.4.3 The department provide flight planning and associated dispatch services for flights operating out of Singapore, and for flights at line stations and planning flight re-routings as a result of tropical depressions, volcanic eruptions and airspace closures. This includes ensuring crew duty time and changes to crew operating patterns (as a result of flight delays or schedule disruptions) do not infringe any statutory requirement.

1.17.3.4.4 The department also ensures that manuals, documents and charts carried on board each airplane are kept up-to-date.

1.18 Additional Information

1.18.1 Witness Interviews

1.18.1.1 On the night of the accident, China Airlines Flight CI-004 was taxiing via Taxiway NP for takeoff on Runway 05L. The Pilot-In-Command (PIC) reported that wind conditions were gusty and it was raining heavily. The PIC stated that the performance calculations for takeoff had been based on a contaminated runway. The PIC stated that the visibility was not too bad and he did not think it was as bad as the RVR (Runway Visual Range) reported on the ATIS. He recalled that from Gate A7 he could see all the way to the end of Taxiway NP. The PIC reported that when his airplane was in the vicinity of Gate A7 he saw an airplane's landing lights on Runway 05R, followed almost immediately by an explosion. When he first saw the airplane he thought that it was about halfway between the runway threshold for 05R & Gate A6 and mentioned it to his crew. He did not recall seeing any lights on Runway 05R or 05L. The Taxiway NP taxi lights were switched on. The PIC also said that one has to have local knowledge and an alert mind otherwise one could mistakenly line up on Runway 05R.
（Appendix 1-4）

1.18.1.2 China Airlines Flight CI-065 had departed 16 minutes before the accident. The PIC recalled that he pushed back from either gate A5 or A7 and that he had been issued a taxi clearance along taxiway NP to Runway 05L. The PIC reported that he had made his takeoff calculations on the basis of ½ inch standing water on the runway. It was raining heavily at the time of his departure. The ATC Controller had appeared to lose visual contact with his airplane as they taxied along Taxiway NP in the vicinity of the Taxiway WEST CROSS. The PIC recalled that the airport was below landing minima. He did not require high intensity runway lighting for his departure and he confirmed that Runway 05L had the standard CAT-II runway lighting illuminated at the time his airplane departed. He held on the Runway threshold for 4 to 5 minutes before the crosswind component dropped sufficiently for the flight to proceed with the takeoff. The PIC could not recall if the runway lights were on or off for Runway 05R. （Appendix 1-5）

1.18.2 Interviews with Pilots who had flown with or checked the SQ-006 Pilots

1.18.2.1 Interviews were conducted with SIA pilots who had flown with or checked the SQ-006 pilots. Their views were consistent for each of the pilots and are summarized below:

(a) CM-1—A disciplined and skillful pilot who is thorough with his work. He is one of the better pilots in SIA. He is also a friendly and approachable person on and off duty.

(b) CM-2—An above average and disciplined pilot. He is also mature and would not hesitate to speak out on safety issues on a flight.

(c) CM-3—A mature and disciplined pilot with good flying skills. He is also forthright and respectful. He has the potential of becoming a commander in due course.

1.18.3 The Para-Visual Display (PVD) System

(Refer to Appendix 1-6)

IV. Attachments

1-1 **Taxi Trail Simulation**

V. Appendices

1-1	Interviews with the Accident Flight Crew and Dispatcher
1-2	Taxi Trail Simulation
1-3	Flight Operations Division Organizational Structure of Singapore Airlines
1-4	Interviews with CI-004 Captain
1-5	Interviews with CI-065 Captain
1-6	Para-Visual Display (PVD) System
1-7	Interviews with CI-004 First Officer
1-8	Interviews with CI-065 First Officer

Note： Appendices 1-7 and 1-8 are currently not cited in the report.
These may be used as future references for the investigation.

Aviation Safety Council
Taipei, Taiwan

SQ006 Accident Investigation

Factual Data Collection

Group Report

Ground Operation Group

February 21, 2001

ASC-FRP-01-01-002

I. Team Organization

Chairman:
DAVID LEE Aircraft Accident Investigator, ASC
Members:
1. SEAN HSU Air Safety Engineer, ASC
2. JOSEPH M. SEDOR Aerospace Engineer, NTSB
3. SIMON LIE Air Safety Investigator, BCAG
4. IVAN NEO SEOK-KOK Senior Manager Quality, SIAEC
5. LECK TEA KIANG Base Maintenance Supt, SIAEC
6. CHARLES CHONG Manager Quality, SIAEC
7. CHOW HOCK LIN Quality Superintendent, SIAEC
8. LEONG CHEE CHEW Asst Manager Quality, SIA
9. KONG CHAN CHEW Technical Manager, SIA

ASC – Aviation Safety Council, Taiwan, R.O.C.

NTSB – National Transport Safety Board, United States of America

BCAG – Boeing Commercial Airplanes Group, United States of America

SIA – Singapore Airlines, Singapore

SIAEC – SIA Engineering Company, Singapore

II. History of Activities

Date	Activities
10/31/00~ 11/01/00	Notification 1. 2317 hours local time - Accident occurred 2. 2340 hours - Notified by duty officer 3. 0020 hours - Arrived at accident site
11/01/00~ 11/08/00	Site survey 1. Aerial photography 2. Wreckage identification 3. Wreckage distribution area mapping 4. Tire track mapping 5. Deflation of stored energy devices on the site. 6. Structure failure analysis
11/09/00~ 11/12/00	Wreckage removal 1. Wings and tail section of wreckage were cut to smaller pieces to facilitate transportation. 2. Engines, landing gears, door slides and tagged parts are kept in six 20-foot locked containers. 3. All other parts were kept in an open and secured area.
2/02/01	Technical review meeting 1. ASC investigators and MCIT representatives reviewed and fine tuned the factual report. 2. Group members attending the meeting agreed with the contents of the report by signature.

III. Factual Description

1.3 Damage to aircraft

The aircraft was completely destroyed by impact force and post-crash fire.

1.4 Other damage

The construction crew had left 6 units of ground equipment (ref. Table 1.4-1) on site of runway 5R, namely 2 excavators (Fig. 1.4-1,2), 2 vibrating rollers (Fig. 1.4-3,4,5), 1 small bulldozer (Fig. 1.4-6) and 1 air compressor. All 6 equipment suffered serious impact damage. With the exception of one excavator and the bulldozer, the rest of the equipment had been scattered from their original positions in the various pits.

Table （1.4-1）Ground equipment on site of runway 5R

Name	Unit	Qty	Length(M)	Width (M)	Height (M)
Excavator KOMATSU PC200-6	EA	1	4.15	2.65	2.75
Excavator KOMATSU PC200-5	EA	1	4.15	2.65	2.75
Bulldozer KOMATSU D21-A6	EA	1	3.35	2.3	1.5
Vibrating Roller SAKAI SW25	EA	1	3	1.23	1.65
Vibrating Roller KOMATSU JV100WA-1	EA	1	5.05	2.55	2.65
Air Compressor	EA	1	3	1.45	1.5

Fig. 1.4-1 Excavator（in No.5 pit）

Fig. 1.4-2 Excavator（in No.11 pit）

Fig. 1.4-3　Vibrating Roller（in pit No.11）

Fig. 1.4-4　Vibrating Roller

Fig. 1.4-5　Vibrating Roller

Fig. 1.4-6　Bulldozer (in pit No.11)

1.6 Aircraft Information

1	Aircraft Registration Mark	Singapore-registered 9V-SPK
2	Type of Aircraft	Boeing 747-412B
3	Manufacturer	Boeing Commercial Airplane Group
4	Manufacturer' s Serial Number	28023
5	Delivery Date	21 January 1997
6	Operator	Singapore Airlines Limited Airline House, 25 Airline Road, Singapore 819829
7	Owner	Singapore Airlines Limited Airline House, 25 Airline Road, Singapore 819829
8	Certificate of Registration Number	S151
9	Certificate of Airworthiness Number Validity Period	AWC431 21 January 2000 ~20 January 2001
10	Total Flight Hours	18459 hours (as at 29 Oct 2000)
11	Total Cycles	2274 cycles (as at 29 Oct 2000)
12	Last Maintenance Check	A Check
13	Last Maintenance Check Date	16 Sep 2000 @ 17838 flight hours / 2187 cycles
14	Hours / Cycles Elapsed Since Last Maintenance Check	621 flight hours / 87 cycles (as at 29 Oct 2000)

1.6.1 Weight and Balance

Weight and Balance calculations for SQ006 were performed by the China Airlines load agent at Taipei. ASC investigators reviewed load sheet for the accident flight and found that the aircraft Weight and Balance were within operational limits.

Dry Operating Weight:	187,334 kg
Payload:	31,327 kg
Zero Fuel Weight Actual:	218,661 kg
Max. Zero Fuel Weight Limit:	244,939 kg
Fuel on Board:	124,800 kg
Ramp Weight:	343,461 kg
Take Off Weight Actual:	342,461 kg
Max. Take Off Weight Limit:	396,200 kg
Estimated Weight at the time of Accident:	342,461 kg
Estimated Fuel at the time of Accident:	123,800 kg
MACTOW:	16.4 % MAC
Fore and Aft CG Limits:	8.5 ~ 33.0 % MAC

1.6.2 Maintenance Records

Aviation Safety Council investigators reviewed the Flight technical log book records covering a 3-month period from August 1, 2000 to October 31, 2000 （Appendices 5-8 and 5-9）. Review of the maintenance log books revealed no deferred or open items for the flight. The review also showed no evidence indicating that the aircraft was un-airworthy.

1.12 Wreckage and Impact Information

Ground survey of the wreckage field, including aircraft wreckage and ground marks were conducted from N1 through N8, and documented the marks made by the landing gear tires on the runway from the beginning of taxiway N1 through runway 5R threshold to the initial impact point.

The group contracted with a local survey company (Hunter Survey Company) to survey all runway marks, construction wreckage, and airplane wreckage using a differential GPS. Each point designated by the group to be surveyed was numbered and a short description assigned for future reference. A wreckage distribution chart was produced from the data collected from this survey （Appendix 1.12-1, Wreckage Distribution Chart）.

The survey group was divided into two teams, each comprising a minimum of three people from MCIT advisors[1], two ASC members and the survey service support personnel – each covering one half of the runway breadth. The surveyed area along runway 5R extended from the threshold to the point where the forward fuselage came to rest and also beyond the edge of the paved area, stretching as far as any significantly sized debris resided (5 ft × 3 ft and larger).

A total of 396 pieces of wreckage was identified and logged with details of part numbers (where required or available), latitudinal and longitudinal co-ordinates. They were also individually photographed with designated identification markings (Appendix 1.12-2, Wreckage Identification List).

Except for parts that had been destroyed or consumed by fire, all major parts had been accounted for and identified.

1.12.1 Runway 5R

Runway 5R is a concrete non-grooved runway that had been undergoing repairs prior to the accident. The runway consists of individually poured concrete sections approximately 20 feet wide by 23 feet in length. Several of the concrete sections had been removed from the runway between N4 and N5 by the construction crew prior to the accident. The removed concrete sections formed 11 different pits that existed at the time of the accident. The group numbered each pit sequentially along the path of the airplane (Fig. 1.12.1-1).

Concrete jersey barriers had been set up around the construction site on

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[1] MCIT(Ministry of Communications and Information Technology) advisers are from SIA and SIAEC.

runway 5R to close that section of the runway. Each jersey barrier is 32" high by 49" long. Dimension of the barrier is shown in Fig.1.12.1-2. There was a red light on the top of each jersey barrier around the perimeter of the construction area. One of these lights was found on the ground and was still operational when ASC investigators reached the site.

Fig.1.12.1-1 Removed Concrete Sections formed 11 different pits.

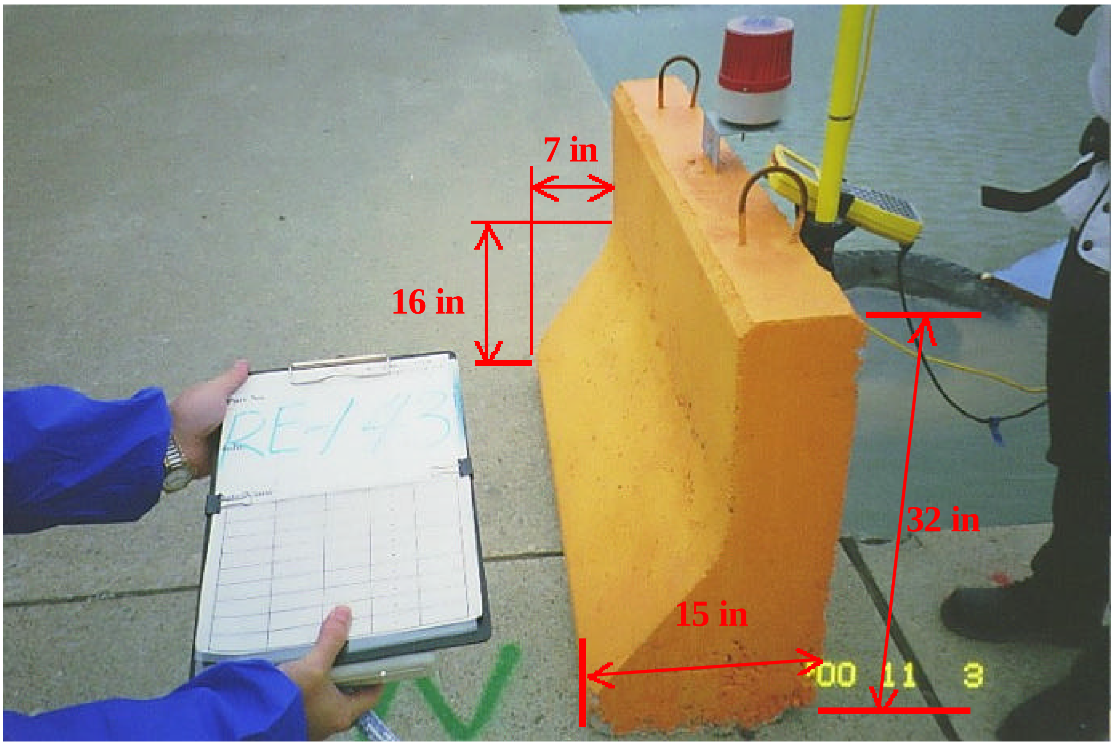

Fig.1.12.1-2 Dimension of jersey barrier

1.12.2 Wreckage Distribution and Impact Information

The aircraft wreckage was distributed along runway 5R (Fig. 1.12.2-1), beginning at initial impact point (Fig. 1.12.2-2) approximately 4,080 feet from the runway threshold. The airplane broke into two main sections at about fuselage Body Station 1560 and came to rest approximately 6,840 feet from the runway threshold. The left and right wings remained attached to the forward fuselage section, which came to rest on a heading of approximately 085°. The tail section (aft of Body Station 1560) was found upright on a heading of approximately 40°. It was reported that this section had been moved by the rescue personnel and high winds, and that the original orientation was on a heading of approximately 130° resting on its left side (Fig. 1.12.2-3,4,5). The rest of the major components were scattered along runway 5R (Fig. 1.12.2-1).

Fig.1.12.2-1 Wreckage and Airport Related Location

Fig. 1.12.2-2 Initial Impact Point (Shown circled)

Fig1.12.2-3 Wreckage Distribution from Beginning

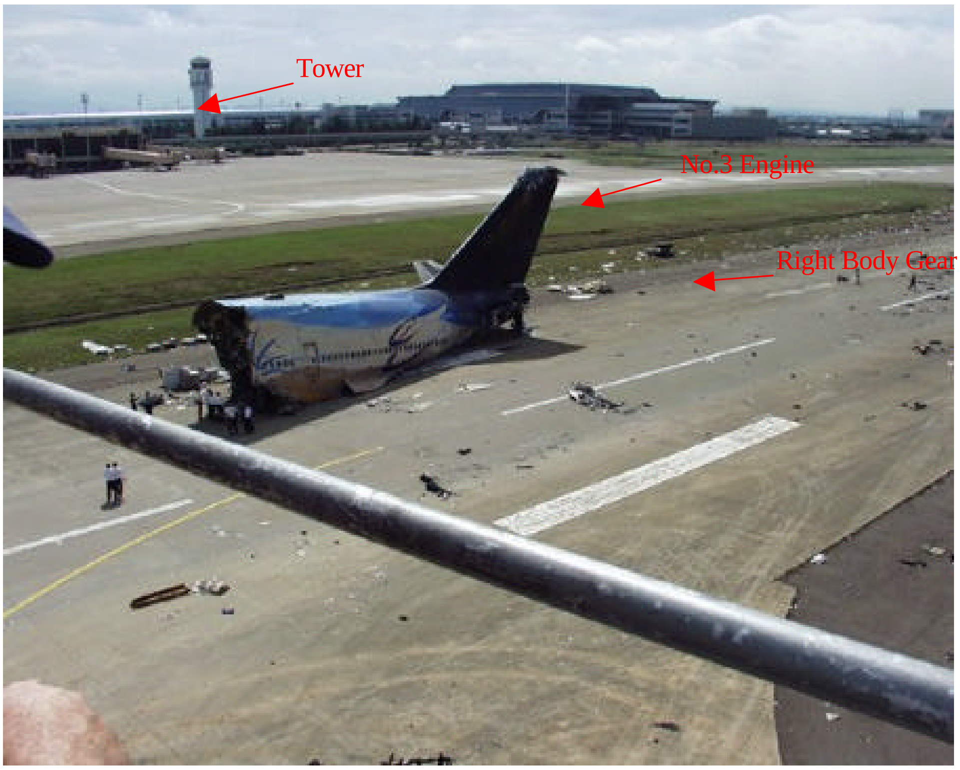

Fig. 1.12.2-4 Wreckage Distribution towards the End

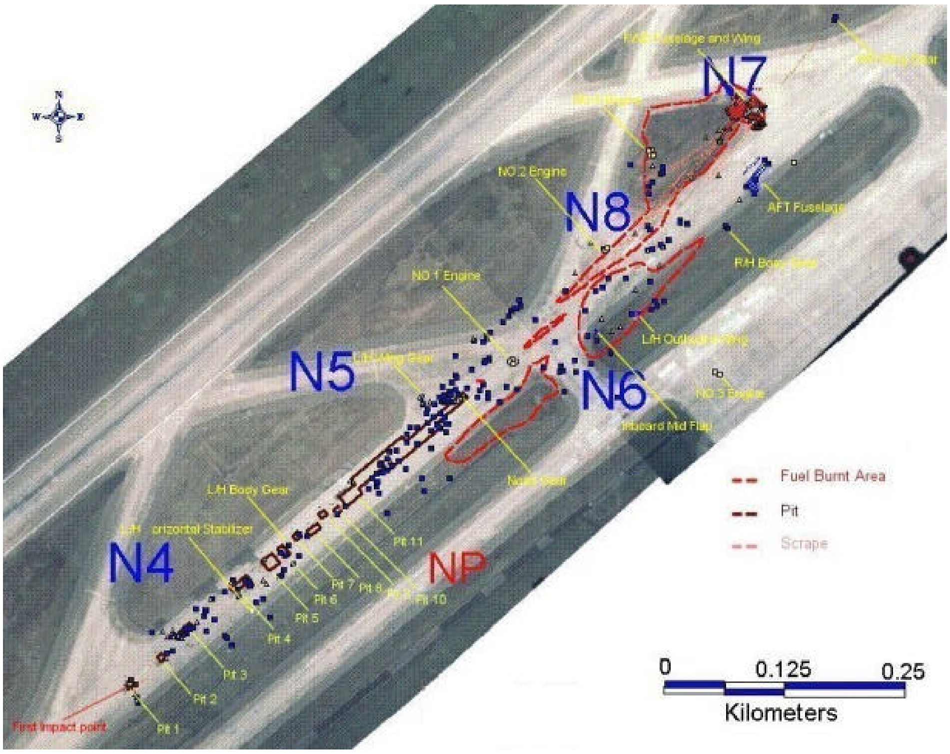

Fig. 1.12.2-5 Major Components Distribution and Construction Pits, Post-fire Zone Related Location

Table（1.12.2-1） Major Components Distribution Location

A/C Components	Lat.	Lon.	Alt.
LW gear	25-04'53.44537"N	121-13'47.19523"E	42.352
LB gear	25-04'48.30244"N	121-13'42.03626"E	42.096
RB gear	25-04'59.50242"N	121-13'58.30453"E	41.167
RW gear	25-05'06.50239"N	121-14'02.23095"E	39.958
NO.1 engine	25-04'54.83561"N	121-13'50.60190"E	42.596
NO.2 engine	25-04'58.66950"N	121-13'53.82520"E	41.805
NO.3 engine	25-04'54.59410"N	121-13'57.99425"E	42.567
NO.4 engine	25-05'01.83064"N	121-13'55.47426"E	39.662
Left outboard wing	25-04'56.64086"N	121-13'55.29190"E	40.848
Inboard mid flap	25-04'55.91551"N	121-13'53.64071"E	41.685
Left horizontal stabilizer outboard end	25-04'46.61528"N	121-13'41.14042"E	42.477

1.12.3 Wreckage Examination

1.12.3.1 Front portion

1 The portion comprising remains of Sections 41[2] and 42, and part of Section 44 and the wings came to rest on the left side of runway 5R (Fig. 1.12.3.1-1).

2 Extensive fire damage to these sections was observed.

3 The RH side of the fuselage from the forward pressure bulkhead up to the RH wing root area, the main equipment center and forward cargo compartment had been completely damaged by fire.

4 The LH side of the fuselage above the main deck floor structure from Body Station 130[3] to approximately Body Station 1284 remained intact but in a badly burnt state.

5 Approximately 30% of the main deck floor structure from Body Station 320 to 1000 was visible but in a badly burnt and distorted condition.

6 The right hand wing was extensively damaged by fire. Some portions of the front and rear spars and the winglet were still visible. (Fig. 1.12.3.1-2)

7 The profile of the LH wing was still visible with most of the fire damage occurring on the outer portion. The outboard portion of the LH wing outboard of Wing Station 1360[4] had broken off. (Fig. 1.12.3.1-3)

1.12.3.2 Aft Portion

1. The aft portion comprising part of the Sections 46 and 48 of the aircraft came to rest on the right side of the centerline of runway 5R. (Fig.

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[2] A certain section of the fuselage, ref. Appendix 1.12.3, Fuselage Station & Section Diagram
[3] Distance measured in inches along aircraft longitudinal centreline, ref. Appendix 1.12.3, Fuselage Section & Station Diagram
[4] Distance measured in inches along wing front spar, ref. Appendix 1.12.4, Wing Station Diagram

1.12.3.2-1,2)

2. The fuselage broke off forward of the #4 door, with a fracture running from approximately Body Station 1560 on the left side diagonally aft across the fuselage.
3. The left side of the belly skin including supporting frames and stringers had separated and the right hand belly skin was crushed, from door 4 all the way to door 5. There were severe skin abrasions and skin loss at the belly areas from Body Station 2410 to 2742. The left side of the fuselage had a large area of abrasion marks around the passenger window area and above.
4. Fire damage was visible at the Section 48 area and the empennage.
5. The RH horizontal stabilizer was still intact but was damaged by fire. The portion of the LH horizontal stabilizer outboard of approximately Stabilizer Station 270[5] had broken off. (Fig. 1.12.3.2-3,4)
6. The vertical stabilizer was blackened by fire but was still attached the fuselage. The upper portion had broken off.
7. There were no longitudinal scrape marks on the lower skin on Body Section 48.

1.12.3.3 Major components

Major components scattered along the crash path on runway 5R were found in a heavily damaged shape condition caused by impact force and post-crash fire.

1. No. 1 Engine (Fig. 1.12.3.3-1).

[5] Distance measured in inches along horizontal stabilizer front spar, ref. Appendix 1.12.5, Horizontal Stabilizer Station Diagram

2. No. 2 Engine (Fig. 1.12.3.3-2,3).
3. No. 3 Engine (Fig. 1.12.3.3-4,5)
4. No. 4 Engine (Fig. 1.12.3.3-6).
5. Nose Gear (Fig. 1.12.3.3-7,8).
6. Right Body Gear (Fig. 1.12.3.3-9).
7. Right Wing Gear (Fig. 1.12.3.3-10).
8. Left Body Gear (Fig. 1.12.3.3-11).
9. Left Wing Gear (Fig. 1.12.3.3-12).

Fig. 1.12.3.1-1 Front Portion of Aircraft

Fig. 1.12.3.1-2 Right Wing

Fig. 1.12.3.1-3 Left Wing

Fig. 1.12.3.2-1 Aft Portion of Aircraft

Fig. 1.12.3.2-2 Aft Portion of Aircraft (front view)

Fig. 1.12.3.2-3 RH Horizontal Stabilizer

Fig. 1.12.3.2-4 LH Horizontal Stabilizer

Fig. 1.12.3.3-1 No. 1 Engine

Fig. 1.12.3.3-2 No. 2 Engine

Fig. 1.12.3.3-3   No. 2 Engine

Fig. 1.12.3.3-4   No.3 Engine

Fig. 1.12.3.3-5　　　No.3 Engine

Fig. 1.12.3.3-6　No. 4 Engine

Fig. 1.12.3.3-7　　　Nose Gear (in pit No. 11)

Fig. 1.12.3.3-8　　　Nose Gear (Shown circled)

Fig. 1.12.3.3-9　　Right Body Gear

Fig. 1.12.3.3-10　　Right Wing Gear

Fig. 1.12.3.3-11 Left Body Gear

Fig. 1.12.3.3-12 Left Wing Gear

1.12.4 Runway Edge Light Wire Strands

2 wire strands were retrieved from the right hand side and left-hand side of the runway edge lights at locations identified by the grids RE239 (Fig. 1.12.4-1) and RE 240 (Fig. 1.12.4-2) respectively. The runway edge light at grid RE240 was located in the path of the aircraft wreckage.

Fig. 1.12.4-1 RE239 Runway Edge Light

Fig. 1.12.4-2 RE240 Runway Edge Light

1.12.5 Tire Tracks

The group documented the marks made by the nose landing gear (NLG) and the main landing gear (MLG) tires on the runway from the beginning of taxi way N1 through runway 5R threshold to the initial impact point 4,080 feet from the runway threshold (Fig. 1.12.5-1). The tire marks were cleaner than the surrounding areas and no rubber deposits were found.

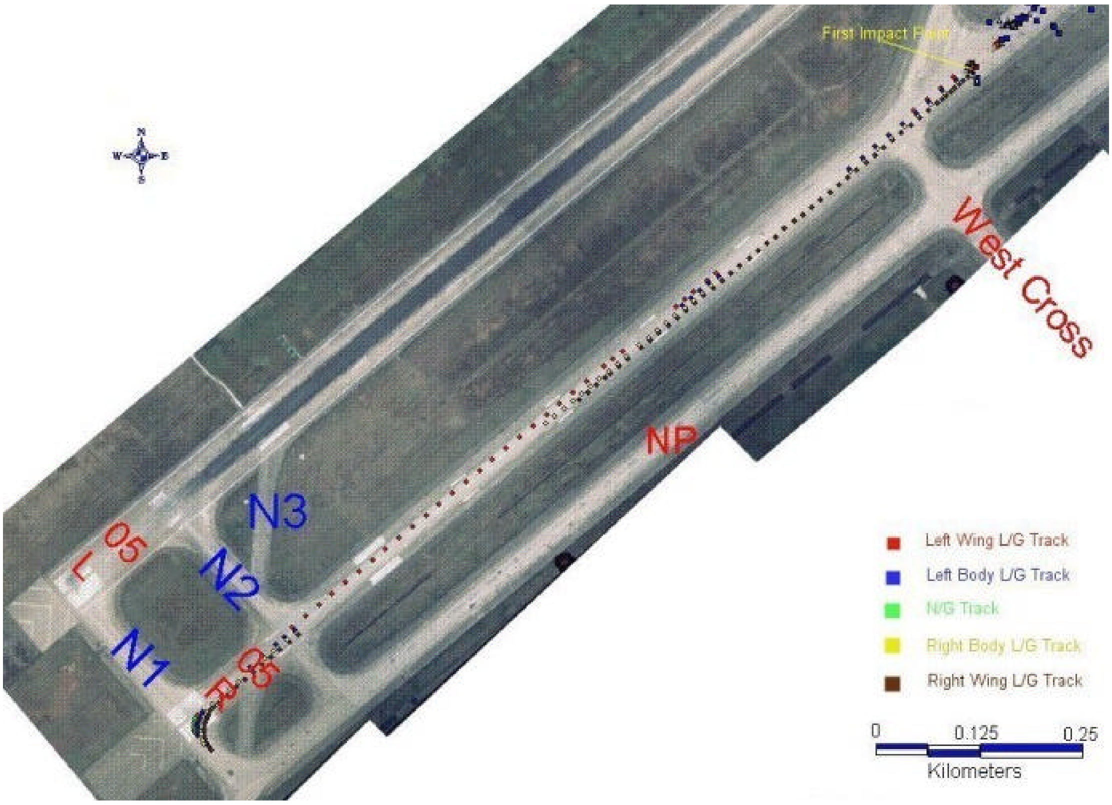

Fig. 1.12.5-1 Mapping of Tire Tracks

IV. Appendices

1.12-1	Wreckage Distribution Chart
1.12-2	Wreckage Identification List
1.12-3	Fuselage Section & Station Diagram
1.12-4	Wing Station Diagram
1.12-5	Horizontal Stabilizer Station Diagram

Aviation Safety Council

Taipei, Taiwan

SQ006 Accident Investigation

Factual Data Collection

Group Report

Air Traffic Control Group

February 21, 2001

ASC-FRP-01-01-003

I. Team Organization

Chairman: K.F. Chou
Members:
1. Hank Liu Chief, Air Traffic Control Branch, ATSD, CAA
2. Baker Lin Chief, Air Traffic Services Management Office, ANWS, CAA
3. Daniel Shan Board Director, Air Traffic Controllers' Association
4. Ian Brokenshire Transport Safety Investigator, ATSB
5. Chow Chee Khiang Jason ATC Watch Manager, CAAS, MCIT
6. Mervyn Fernando Senior ATC Manager, CAAS, MCIT
7. Soon Boon Hai Chief Air Traffic Control Officer, CAAS, MCIT

II. History of Activities

Date	Event
Nov 1	1. Obtained Statements made by the Duty Controllers at CKS Tower
Nov 2	1. ATC / Weather / Airport Group Formed 2. Inspection of crash site and adjacent paved areas by day
Nov 3	1. Inspection of crash site and adjacent paved areas by day 2. Noted data obtained from the Digital Flight Data Recorder 3. Review of Cockpit Voice Recorder data
Nov 4	1. Examined the lighting control panel in the CKS Tower and clarified operating procedures 2. Inspection of crash site and adjacent paved areas by day 3. Inspection of crash site and adjacent paved areas by night 4. Interviewed local controller 5. Interviewed ground controller
Nov 5	1.Examined the taxiway lighting control panel in the CKS Tower and clarified operating procedures
Nov 6	1. Examined the lighting control panel in the CKS Tower and clarified operating procedures 2. Reviewed the Terminal Approach Radar tape recording
Nov 7	1. Interviewed Civil Aeronautics Administration officials 2. Interviewed Senior Flight Operations Officer 3. Viewed recordings of airport security cameras
Nov 8	1. Interviewed CKS Airport Management officials 2. Viewed recordings of airport security cameras
Nov 9	1. Transcribed ATC voice recordings on frequencies 121.7, 121.8 and 129.3 (from 2250LT/1450UTC on Oct.31, 2000 to 0030LT

	on Nov.1,2000 (1630 UTC on Oct.31, 2000) 2. Viewed recordings of airport security cameras
Nov 10	1. Examined the lighting control panel in the CKS Tower and clarified operating procedures 2. Interviewed local controller 3. Transcribed ATC voice recordings on frequencies 121.7, 121.8 and 129.3 (from 2250LT/1450 UTC on Oct.31, 2000 to 0030LT/1630UTC on Nov.1, 2000 on Oct.31, 2000) 4. Viewed recordings of airport security cameras
Nov 11	1. Transcribed ATC voice recordings on frequencies 121.7, 121.8 and 129.3 (from 2250LT/1450UTC on Oct.31, 2000 to 0030 LT on Nov.1, 2000(1630UTC on Oct.31, 2000) 2. Transcribed voice recordings of Channel 1 (communications between CKS Tower and ground vehicle at the scene of the crash) 3. Viewed recordings of airport security cameras
Nov 12	1. Transcribed ATC voice recordings on frequencies 121.7, 121.8 and 129.3 from 2250LT/1450UTC on Oct.31, 2000 to 0030 LT on Nov.1, 2000(1630UTC on 31 Oct 2000) 2. Transcribed voice recordings of Channel 1 (communications between CKS Tower and ground vehicle at the scene of the crash)
Nov 13	1. Transcribed ATC voice recordings on frequencies 121.7, 121.8 and 129.3 (from 2250LT (1450UTC) on 31 Oct 2000 to 0030 LT on 1 Nov 2000(1630UTC on 31 Oct 2000)) 2. Transcribed voice recordings of Channel 1 (communications between CKS Tower and ground vehicle at the scene of the crash)
Nov 14	1. Transcribed voice recordings of Channel 1 (communications between CKS Tower and ground vehicle at the scene of the crash)

Nov 15	1. Transcribed voice recordings of Channel 1 (communications between CKS Tower and ground vehicle at the scene of the crash)
Nov 16	1. Transcribed voice recordings of Channel 1 (communications between CKS Tower and ground vehicle at the scene of the crash)
Nov 17	1. Transcribed voice recordings of Channel 1 (communications between CKS Tower and ground vehicle at the scene of the crash)
Nov 18	1. Transcribed voice recordings of Channel 1 (communications between CKS Tower and ground vehicle at the scene of the crash)
Nov 25	1. Authentication of ATC transcripts
Nov 29	1. Interviewed Ground Controller & Flight Data Controllers
Nov 30	1.Interviewed Clearance Delivery controller
Dec 1 ~ Feb 3	1.Preparation of ATC Group Report Draft
Feb 20 ~ Feb 21	1.ATC Group Draft Report Review Meeting

III. <u>Factual Description</u>

(1.1 ~ 1.7 deliberately left blank)

1.8 Aids to Navigation

There were no reported difficulties with navigational aids at CKS International Airport.

1.9 Communications

There were no communications problems between SQ006 and CKS Airport Control Tower.

(1.10 ~ 1.17 deliberately left blank)

1.18 Additional Information

1.18.1 ATC Operations

1.18.1.1 ATC Staffing (see Appendix 3 -01)

At the time of accident, the CKS International Airport Control Tower was staffed with four controllers: one local controller, one ground controller, one clearance delivery controller and one flight data controller.

There is no cab coordinator working in night shift however, the supervisor at approach control should take charge when traffic situation requires.

1.18.1.2 ATC Workload

During the course of the event, Local Controller communicated with the accident aircraft, which was the only traffic under his jurisdiction and the Ground Controller communicated with two aircraft starting engines. The Local Controller pressed the crash alarm in response to the accident as he observed the event. The remaining controllers were working at Clearance Delivery and Flight Data positions.

1.18.1.3 ATC Procedures (see Appendix 3-02)

The Standard Operating Procedure for Ground Control and Clearance Delivery Positions of CKS Control Tower requires the ground controller to inform the aircraft in maneuvering area when visibility drops to below 2000 meters:

The relevant phraseology is as follows: （Ref:Para.3.5.6, SOP, CKS Approach and Tower）

"PART OF AIRPORT IS INVISIBLE FROM TOWER,
TAXI SLOW DOWN WITH CAUTION."

There are procedures in ATP-88（see Attachment 3-2A）for controller to issue progressive taxi / ground movement instructions when:

1. Pilot/operator requests.
2. The controller deems it necessary due to traffic or field conditions ,e.g., construction or closed taxiways.
3. As necessary during reduced visibility, especially when the taxi route is not visible from the tower.

The progressive taxi instruction was not issued for SQ006.

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1.18.1.4 Runway lighting controls

(see details in Airport Group Report)

1.18.1.5 Airport Surface Detection Equipment (ASDE) (see Appendix 3-03)

The airport is not equipped with an ASDE though the control tower has been requesting for the installation of such radar system since 1994.

CAA has the budget to purchase two ASDEs in 2001. The date to commission the ASDEs has been scheduled in December 2004.

The following are the summary of CAA ASDE procurement process：

Date	Summary	Attachment
Jul.19,' 94	ANWS declined the request to install ASDE at CKS due to the limited use of ASDE in foggy season (only a few hours in a year)	1
Aug.17,' 94	Withdraw the budget of ASDE at Kaohsiung	2
Aug.30,' 94	CAA instructed ANWS to research the installation of ASDE at CKS	3
Sept.8,' 94	ANWS suggested CAA to suspend the ASDE installation due to fewer requirements in foggy season and budgetary considerations.	4
Apr.18,' 96	ANWS requested ASDE installation to upgrade the ATS services.	5
May 24,' 96	CAA meeting concluded to schedule a survey of ASDE siting.	6
Jul.3,' 96	CAA meeting after survey concluded: ✧ Site of ASDE proposed at ramp close to jet way. ✧ To plan for a new tower with ASDE installation.	7
Jul.18,' 96	ANWS agreed the conclusion.	8
Jan.7,' 98	CAA meeting concluded: ✧ To plan the installation of ASDE. ✧ ANWS to collect ASDE related information and to observe ASDE operation in adjacent countries ✧ A proposal of ASDE installation is submitted to CAA no later than May 1998 and to be included in budget of year 2000.	9
May 12,' 98	ANWS submitted 10 preferable sites for ASR and ASDE.	10
Jun.8,' 98	CAA meeting discussing 2nd ASR, ASDE installation and Doppler radar phase-in projects.	11
Sept.28,' 98	CAA suspended ASDE site proposal to accommodate CKS future expansion and a discussion be scheduled later date.	12
Jan.6,' 99	CAA approved ANWS' s request of ASDE sites and installation plan.	13
Jan.14,' 00	CAA delayed the ASDE procurement for a year due to other prioritized projects.	14
May 5,' 00	ANWS requested budget of ASDE in 2001,CAA	15

	replied: ✧ to collect more information re:ASDE ✧ to consider whether to install one set ASDE first. ✧ Other feasible alternatives.	
Jul.1,' 00	CAA instructed ANWS to carry out the ASDE procurement project in stages starting from 2002.	16
Nov.28,' 00	CAA requested approval from MOTC to escalate the ASDE procurement project one year earlier (2001).	17

1.18.1.6 Safety management (Incident reporting and tracking)

Incident reports are actioned by pilots, ATC and airport management. Serious incidents are also reported to Aviation Safety Council.

1.18.1.7 ATC Interviews

The air traffic control positions and legend used in the roster in CKS Airport Tower at the time of SQ006' s accident are as follows: (see Attachment 3-01 & 3-05)

i) Local Control（LC）
ii) Ground Control（GC）
iii) Flight Data（FD）
iv) Clearance Delivery（CD）

The duty air traffic controllers were:

i)Controller A
ii)Controller B
iii)Controller C
iV)Controller D

The ATC Group interviewed Controller A and B on November 4, 2000, Controller A on November 10, 2000, Controller B&C on November 29, 2000 and Controller D on November 30, 2000 . Controller A and B were interviewed together on November 4, 2000. The Chief of Air Traffic Services Management Office and the Tower Chief were present during all interviews.

1.18.1.7.1 Summary of Interviews with Controller A (see Appendix 3-05 & 3-06)

According to Controller A , weather conditions were poor when he took over the Local Control Position. SQ006 was taxiing out for departure and there were two other aircraft (CX2043 and CI004) pushing back from the parking bays at the time.

SQ006 contacted Taipei Tower on frequency 129.3 MHz at about the time it turned from taxiway WC onto NP. Controller A could only see the aircraft' s lights which gradually disappeared as the aircraft taxied towards N1.

As there was no other aircraft on approach or taxiing, Controller A cleared SQ006 for take-off from runway 05L when the crew reported ready. The crew read back runway 05L correctly. Controller A said that he could not see SQ006 line up for take-off when it began its take-off roll due to the low visibility. His first eye contact of the aircraft after he issued the take-off clearance was when he saw sparks, followed by an explosion. Controller A said that he pressed the crash alarm and that Controller C transmitted initial instructions to the rescue fire fighting crew on a hand-held radio (Channel 1). He also said that Controller B notified the approach radar controller of the accident.

Controller A said that the intensity of the Runway 05L runway lights and the red and yellow zone taxiway lights had been selected in accordance with a matrix (lighting intensity setting table) displayed near the lighting console. （re: ATP-88, Para. 3-4-10,TAB. 3-4-4.）

The ATC Group interviewed Controller A a second time on November 10, 2000 (see Attachment 3-06). During the second interview, Controller A explained that the airport lights are inspected by the maintenance unit daily. He said that this is done one zone of the airport at a time. The lights of each zone are switched on/off according to the maintenance unit' s request.

1.18.1.7.2 Summary of Interviews with Controller B (see Appendix 3-05 & 3-07)

Controller B was interviewed by the ATC Group on November 4 and 29, 2000. He had proceeded on his planned vacation leave after the Group' s first interview with him on November 4.

When Controller B took over the Ground Control Position at 2300 LT, only SQ006, CX2043 and CAL004 were on frequency 121.7 MHz. He said that he cleared SQ006 for taxi to runway 05L via taxiways SS, West Cross, NP and N1

As Ground Controller, he was responsible for activating the appropriate taxiway lights. He had activated the taxiway lights for the White, Yellow and Red zones. He added that the Local Controller was responsible for the runway lights. As a general rule, these are switched on when landing aircraft are about 15 nautical miles from touch down. For continuous landings, the approach and runway lights would be left on and there would not be frequent switching on and off of the lights. The SOP for lights did not require the approach lights to be switched on for departures.

1.18.1.7.3 Summary of Interview with Controller C (see Appendix 3-08)

Controller C recalled that she had been in the Ground Control Position prior to taking over the Flight Data position. While at Ground Control Position, she handled flight SQ006. She had initially informed SQ006 to expect runway 06 but subsequently approved SQ006's request for departure on runway 05L. No reason was given by the pilot for the request.

After the accident occurred, Controller C instructed Ground Controller to inform Taipei Approach that SQ006 had crashed and that runway 05L was closed. She then took over from the Local Controller, who asked to be relieved.

Controller C said that she did not, during her stint, turn on any of the lights as it was not her duty. It was the duty of the Ground Controller to switch on the taxi lights and the duty of the Local Controller to switch on lights associated with the runway.

Controller C said that she did not switch any of the runway / taxiway lights on or off after she took over the Local Control Position subsequent to the accident. Regarding the request by the "Yellow Vehicle" driver for the lights to be switched on, she said she knew that the Ground Controller at the time had responded to the request, but she did not know which lights he selected.

Regarding the maintenance of airport lights, Controller C explained that there was no pattern to the requests by maintenance to switch on any particular set of lights for checking. The requests were, to her knowledge, quite random, and Tower staff would turn on and off the lights as requested. On the night of the occurrence she had not done any light switching for maintenance purposes.

1.18.1.7.4 Summary of Interview with Controller D (see Appendix 3-09)

According to the rotation of staff, Controller D was on his rest break at the time of the accident. He was also monitoring the Clearance Delivery frequency. [Although Taipei AIP states that Clearance Delivery position is suspended after 2200LT hrs daily, the radio frequency for Clearance Delivery was still monitored.]

Controller D said that just as he completed making the ATIS broadcast, he heard a loud explosion and saw a fire on one of the runways. He immediately alerted the fire service through the radio.

He did not notice which taxiway lights had been selected because he was kept busy answering the various telephone calls that followed the accident. Controller D said he did not know if runway 05R edge lights had been selected prior to the accident.

Controller D explained that according to the SOP in CKS Tower, the taxiway and runway lights should be switched off if there was no traffic. When asked whether the approach lights for runway 05L were on at the time of the accident, he said that according to their SOP the approach lights for runway 05L should have been switched off as there was no arrival traffic.

1.18.1.7.5 Summary of Interview with Senior Flight Operations Officer （SFOO） - Driver of the Yellow Vehicle (see Appendix 3-10)

The SFOO from Flight Operations Section was on Apron B at the time of the accident. He said that he rushed to the accident scene via the shortest route he could find. He thought that he routed via taxiway N7 for the runway.

The SFOO said that some time after the accident occurred, he asked the Control Tower to switch on all the runway lights of runway 05 (he did not specify 05L or 05R). When the lights came on, he realized that he was on the grass patch beside taxiway N6.

1.18.1.7.6 Summary of Interview with Civil Aeronautics Administration Officials

(see details in Airport Group Report)

1.18.1.7.7Summary of Interview with Airport Management Division of CAA

(see details in Airport Group Report)

1.18.1.8 ATC Communication Tape Recording Transcripts

The radio frequencies used by Taipei Tower are:

129.3 MHz	Local Control Position（LC）
121.7 MHz	Ground Control Position (GC)
121.8 MHz	Clearance Delivery Position（CD）

1.18.1.8.1 Local Control Position- 129.3 MHz (see Appendix 3-11)

The flights in contact with Local Controller prior to the accident were BR858 CI065 and SQ006. BR858 was a B747-400 aircraft from Hong Kong to Taipei. The flight had initiated a “missed approach” at 2252 LT (1452 UTC). It made several subsequent calls to Local Control for updates on the weather conditions. Following the SQ006 accident, BR858 was informed that runway 05L was closed and asked if it needed “to be diverted”. The transcript does not capture the pilot’s reply.

CI065 was a departing B747-400 aircraft bound for Bangkok, Thailand. It took off from runway 05L at 2302 LT (1502 UTC). While taxiing out for departure, CI065 reported that the intensity of the runway lights was “OK”. CI065 held on the runway until informed that the surface wind was gusting from 26 kts to 45 kts with a crosswind component of 12 kts from “the left”.

SQ006 contacted Local Control at 2313 LT (1513 UTC) and was cleared to “hold short runway 05L”. Surface wind information (020 deg 24 kts gusting to 43 kts) was passed to SQ006 while the aircraft was taxiing. SQ006 was cleared for take-off from runway 05L at 2315 LT (1515 UTC). Surface wind information in the take-off clearance was 020 deg 28 kts gusting to 50 kts.

1.18.1.8.2 Ground Control Position - 121.7 MHz (see Appendix 3-12)

The flights in contact with Ground Control prior to the accident were CI 065, CX2043, CI004 and SQ006.

CI065 was cleared for taxi to runway 05L via NP with instruction to hold short of runway 05R. The flight was informed of BR858 holding for weather improvement. CI065 requested to be allowed to contact Local Control as soon as possible in order to get the latest wind information.

CX2043 was a Hong Kong bound departure. It reported that cargo loading could not continue owing to wind conditions. Later when the flight reported ready, CX2043 was initially informed that Hong Kong could not accept the flight. ATC did not elaborate. However, the flight was later cleared to start and pushback for runway 06. Following the accident, CX2043 was instructed to tow into bay B7.

CI004 was a B747-400 aircraft bound for San Francisco. The aircraft was parked in Bay A5. After receiving its ATC clearance, the aircraft was cleared to pushback for runway 05L. Following the accident, CI004 reported fire on an "aircraft landed on runway 05R" and requested permission to enter parking bay A8. Ground Control approved the request.

SQ006 requested permission to taxi for departure at 2305 LT (1505 UTC) and was cleared to runway 05L via taxiway SS, west cross and NP. The read-back by SQ006 was consistent with the clearance issued by Ground Control. SQ006 was instructed to contact Local Control at 2313 LT (1513 UTC).

1.18.1.8.3 Clearance Delivery Position - 121.8 MHz (see Appendix 3 -13)

SQ006 first contacted Clearance Delivery at 2253 LT (1453 UTC). The aircraft was parked at bay B5. Communication between Clearance Delivery and SQ006 was for ATC clearance to Los Angeles. The flight was asked to contact Ground Control at 2257 LT (1457UTC).

1.18.1.8.4 Transcript of Channel 1 Communications - 459.2 MHz (see Appendix 3 -14)

Channel 1 transcript captured communications with several parties including Yellow Vehicle 101 which was driven by Senior Flight Operations Officer. According to the transcript, Yellow Vehicle 101 requested for runway 05 lighting to be switched on. This request was made at 2357 LT (1557 UTC). Following this request, the driver of Yellow Vehicle 101 reported that he thought he was at taxiway N6.

1.18.1.8.5 Transcript of Intercom at Taipei Tower (see Appendix 3 -15)

In the transcript, a lady's voice is captured stating that an aircraft "during take-off at runway 05L, currently located at N7 is now on fire. We wanted to notify the fire service but could not reach them. Please notify them immediately". The transcript does not indicate whom the lady was talking to.

1.18.1.9 Security Video Cameras (see Appendix 3 -16)

Videotapes recorded between October 31and November 1,2000 from a total of 14 cameras at CKS Airport were reviewed. In addition, recordings made on November 4 and 6, 2000 during known activation of the runway lights were also viewed.

Cameras 22, 23, 64, 66, 77, 78 and 79 were directed at the burning wreckage of SQ006 after the accident occurred. A row of lights was observed at 2359 LT (1559 UTC) on camera 64. On camera 66, a row of blue lights was observed at 2343 LT (1543 UTC). The runway lighting status after the accident could not be determined.

Camera 77 captured what appeared to be aircraft lights in the distance. The definition of the lights improved as the aircraft approached to abeam the camera. A flash was seen and almost at the same time a white shape observed followed by an explosion just out of camera view.

On Camera 92, which was located on the domestic terminal near the taxiway N1, aircraft lights could be seen at the time SQ006 was expected to take-off. Green and blue lights could be seen at 2356 LT (1556 UTC).

Runway lights for 05L and 05R could not be distinguished on the recordings made on November 4 and 6, 2000.

1.18.1.10 NOTAMs & AIP Supplement

1.18.1.10.1 NOTAMs (see Appendix 3- 17)

On August 31,2000, Taipei published NOTAM A0606 (replacing NOTAM A0604) stating that a portion of runway 05R/23L between taxiway N4 and N5 would be closed with effect from 0900 LT (0100 UTC) on September 9,2000 until 0900 LT (0100 UTC) on November 22,2000. It added that taxiway N4 and N5 would remain available.

On November 1,2000, NOTAMs A0758 and A0759 were published on the closure of runway 05L/23R and taxiway NP and NS "due to FOD".

On December 22,2000, Taipei issued a NOTAM A0907 (replacing A0860). It stated that with immediate effect, runway 05R/23L was to be used as a taxiway. Take-off or landings were prohibited.

1.18.1.10.2 AIP Supplement (see Appendix 3 -18)

AIP Supplement A007 C015/00 dated October 3, 2000 informed that runway 05R/23L would be re-designated taxiway NC with effect from 0100 LT on November 2,2000 (1700 UTC November 1,2000). The runway centerline lights (green) and the edge lights (white) would remain on taxiway NC until further notice. Runway markings would be changed.

On October 23,2000, the Air Traffic Services Division of CAA Taipei published a NOTAM informing that the re-designation of runway 05R/23L to taxiway NC would be postponed until further notice.

1.18.1.11 Lighting SOP - ATP 88 (see Appendix 3 -19)

Taipei Airport lighting SOP (ATP 88) provides information on when airport lights should be switched on.

Intensity settings guidance for approach and runway lights is included in the lighting SOP. The usual maximum intensity the controller could select for approach lights is level 3 and level 4 for the edge, centerline and touch down zone lights. Greater intensity (up to level 5) may be selected on request.

1.18.1.12 CKS Approach / Tower Operations Manual (see Appendix 3-02)

The CKS Approach/ Tower Operations Manual gives detail guidance on energy conservation without jeopardizing flight safety. It is stated that the airport lights should be switched off when not in use.

1.18.1.13 Runway Visual Range (see Appendix 3-20)

The Runway Visual Range (RVR) print-out on October 31, 2000 indicates that runway 05L lights were switched on at 2313LT (1513 UTC) and switched off at 2324 LT (1524 UTC). The lights had been set at level 3 out of 5 levels.

1.18.1.14 Incidents at CKS Airport

The ATC/Weather Group was able to obtain six reports of incidents that had occurred in CKS Airport since March 1998. These are:

✧ March 27, 1998
A Cathay Pacific B747 aircraft (CX006) was cleared for take-off on runway 05L while another aircraft was taxiing on the runway. CX006 held on the runway until the other aircraft was clear.

✧ July 6, 1998
A Cathay Pacific aircraft (CX420) entered a closed taxiway. Pilot' s view of the incident was that it was a misunderstanding arising from usage of language. He also observed that although the taxiway had been NOTAMed as closed, there had been no obstruction lighting to mark the limit of the work area.

✧ March 24, 1999
A Cathay Pacific aircraft (CX421) was directed by ATC into a closed taxiway (no additional details available).

✧ March 5, 2000
A China Airlines B747-400 (CI065) aircraft took off on runway 05L while another aircraft, a B747-100 (UP7846) was turning into the runway.

- ✧ March 23, 2000

  A CM922 flight (B737) was cleared for take-off on runway 05L while another aircraft, a MD11 (BR671) was still on the runway. CM922' s take off clearance was cancelled when BR671 alerted the tower that it was still on the runway.

- ✧ October 22, 2000

  A Singapore Airline flight SQ7693 initiated a go-around at decision height (DH) on runway 05L as the crew could not make visual contact with the runway. During the go-around, the Captain of the flight noted that the runway and approach lights had not been switched on. The controller later apologized for forgetting to switch the lights on.

IV. Appendices

3-01	Chiang Kai-Shek Approach / Tower Duty Roster of October, 2000.
3-02	Standard Operating Procedures – Chiang Kai-Shek Approach / Tower
3-2A	ATP-88 Para.3.7.2
3-03	CAA' s Procurement of Airport Surface Detection Equipment
3-04	AIP-ENR 1.14-1 Air Traffic Incident Reporting
3-05	Record of interview with Duty Tower Controllers (local and ground)
3-06	Record of second interview with local controller on Nov 10, 2000
3-07	Record of second interview with ground controller on Nov 29, 2000
3-08	Record of interview with flight data controller on Nov 29, 2000
3-09	Record of interview with clearance delivery controller on Nov 30, 2000
3-10	Record of interview with Senior Flight Safety Operations Officer on Nov 7, 2000
3-11	Transcript of VHF129.3 MHz recording
3-12	Transcript of VHF121.7 MHz recording
3-13	Transcript of VHF121.8 MHz recording
3-14	Transcript of UHF459.2MHz (Channel 1) recording
3-15	Transcript of conversation between Approach Control and Control Tower
3-16	Report of Airport Security Tape Review
3-17	NOTAMs
3-18	AIP Supplement A003, A004
3-19	Air Traffic Control Procedures – Airport Lighting
3-20	Runway Visual Range & Runway Lights Intensity
3-21	Chart on CKS Airport Security Camera Locations
3-22	Chiang Kai-Shek Approach / Tower Facility Logs
3-23	Chiang Kai-Shek Airport Office Organization Chart
3-24	Facility Fault records in October 2000, CKS Tower
3-25	Flight progress strips for SQ 006
3-26	Flow Chart of Chiang Kai-Shek Airport Runway Maintenance Project
3-27	ICAO Annex 14, Relevant Chapters
3-28	Lighting Fault records, CKS Tower
3-29	Lighting Operations Procedures of Chiang Kai-Shek Approach / Tower
3-30	Manual on Runway Edge and Taxiway Centerline lights for Runway 05R/23L
3-31	Navaids Fault records in October 2000, CKS Tower
3-32	Physical Certificate for Local and Ground Controllers, CKS Tower
3-33	Rating Certificate for Local and Ground Controllers, CKS Tower

3-34	Report of observations on Airport Lighting Panel
3-35	Runway 05R Maintenance work Schedule & Related Schedules
3-36	Runway incursions at CKS Tower in March 2000
3-37	Statements by Duty Controllers of Chiang Kai-Shek Tower controllers
3-38	Statements by Watch Supervisor of Chiang Kai-Shek Approach / Tower
3-39	Chiang Kai Shek Runway 05L/23R Localizer critical and sensitive areas
3-40	Meeting Minutes regarding conversion of Runway 05R to taxiway NC.
3-41	Proposal/Approval correspondence re: conversion of Runway 05R to Taxiway NC
3-42	Statement from CAA regarding CAA policy/criteria for Runway operation
3-43	Ground reports regarding confusion of Runway 05R and 05L
3-44	Reopening of Runway 05L after SQ006 Occurrence

＊Appendix 21 through 44 were not directly referenced in this factual description however, there are relevant data that may be referenced in future application.

Aviation Safety Council
Taipei, Taiwan

SQ006 Accident Investigation

Factual Data Collection

Group Report

Airport Group

February 21, 2001

ASC-FRP-01-01-004

I. Team Organization

Chairman:
Phil Tai Aviation Safety Investigation, **ASC**
Members:
1. Peida Lin Aeronautical Engineer, **ASC**
2. Peter Hou Deputy Managing Dir, CKS, **CAA**
3. Baker K.H. Lin Chief, ATS, **CAA**
4. Scott. F.S. Chen Chief, Engineering, ANWS, **CAA**
5. C.S. Liu Dir. Flt Ops CKS, **CAA**
6. Chu Sheng Hsu Chief, Main/Engineering. CKS, **CAA**
7. R. M. Wang Chief, Civil Engineering, **CAA**
8. Tee Chiou Ng Assistant Dir. (Ops), **CAAS/MCIT**
9. Ming Sue Koh Exec. Engineer. (Airport Planning), **CAAS/MCIT**
10. K. K. Goh Captain, B744 (SIA), **SIA/MCIT**
11. Ben Castellano Adviser, Airport Safety Manager, **FAA**
12. Mats Nygards Consultant, **ICAO**

II. History of Activities

Date	Activities
(Phase 1) 15 Nov 2000	The first site survey of CKS Airport was conducted. Data collection of CKS airfield specifications was carried out. The areas visited include airside facilities on Runway 05L/23R, Runway 05R/23L, the CKS Control Tower and the Airfield Lighting Substation / Maintenance Workshop.
16 Nov 2000	1. Convened the first Airport Group meeting with representatives from CAA/ROC, CKS Airport and MCIT to set the agenda and work plan. 2. Issues on organization of the CAA/ROC and obstruction control procedures were discussed with associated documents provided by the CAA.
17 – 18 Nov 2000	1. Data collected from CKS Airport was recorded in a Field Report. These findings were checked against SARPs stipulated in ICAO Annex 14 and documented. 2. Discussed issues on obstruction marking for airside works. 3. Prepared a list of detailed questions relevant to airport facilities, maintenance activities and work procedures for clarifications by CAA/ROC and CKS Airport. 4. A second site visit to CKS Airport was arranged on 18 Nov. 2000 to obtain supplementary information. Checks were conducted on the visual aids on Runway 05R/23L and the line of sight between the Control Tower and the thresholds of Runways 05L and 05R. During the visit to Tower, Mr. Frank Lin, Chief of CKS Tower, provided clarifications on the operations of the airfield lighting control panel and RVR system. An interview with Mr. Liu Chuang-shen, Chief of Flight Operations, was conducted at the Flight Operations section office.
19 – 23	Prepared the draft Data Collection Report.

Nov 2000	
4-5 December	Wire test carried out by ARL/CSIST at Taichung.
(Phase 2) 7 December 2000	The Airport Group reconvened with the participation of Mats Nygards from ICAO and Ben Castellano from FAA. These advisors would check the data collected on CKS Airport against ICAO international standards and recommended practices and FAA standards.
8 December 2000	The Airport Group conducted another site visit to CKS Airport to verify the data collected in Phase 1. A briefing by Mr. Wang Ying-chuan, Chief of Airfield Lighting Maintenance was conducted. The positions of the two Runway 05R/23L edge lights RE239 and RE240 were checked and confirmed during the site survey. ASC also made arrangements for some of the taxiway light fitting positions installed near the thresholds of Runway 05L and 05R to be plotted using GPS coordinates. A visit to the CKS Tower was made.
11-15 December	1. A night visit to CKS Airport was conducted on 12 December 2000 (Tuesday). CKS Airport staff made arrangements for the Group to be driven in a vehicle following the taxi route taken by SQ006 from the apron to the take-off runway on the night of the crash. 2. The Airport Group compiled the data collected, together with relevant ICAO SARPs and FAA standards, in an updated Data Collection Report.
18 Dec. 2000	Peida made a complete briefing to Mr. Peter Hou, Deputy Managing Director of CKS airport, covering contents of observations and findings related to CKS airport during both phases of group effort.
22 Dec 2000	Wire Test by ATSB
26 Dec. 2000	Received wire examination report from ATSB.
11 January 2001	Received ARL/CSIST wire test report (English version).

15 January 2001	Reviewed a Videotape produced and provided by an on scene passenger of CI-004 during the time of the accident. Tape provider interview was conducted.
16 January 2001	Received reply from TSB, Canada after they have review both reports from ARL/CSIST and ATSB.
16 January 2001	Meeting with CAA for feedback on the draft group report
2 February 2001	Group Meeting with MCIT group members.
5 February 2001	Group Meeting with CKS/CAA group members.

III. Factual Description

1.10 Airport Information

1.10.1 General

The largest aircraft operating at CKS Airport i.e. the Boeing 747 series (64.44 m wingspan and 11 m outer main gear wheel span), exceeds 1,800m. In accordance with ICAO specification in Annex 14, Vol. I Table 1-1, the aerodrome reference code of CKS Airport is 4E.

The Aerodrome Reference Point (ARP) is Lat 25º04’48.6’’N, Long 121º13’56.0’’E (threshold runway 05L 063 bearing 1,800 m). CKS Airport Aerodrome is 16.7 nautical miles west of Taipei city.

The layout of CKS Airport is shown in the following Figure 10-1.

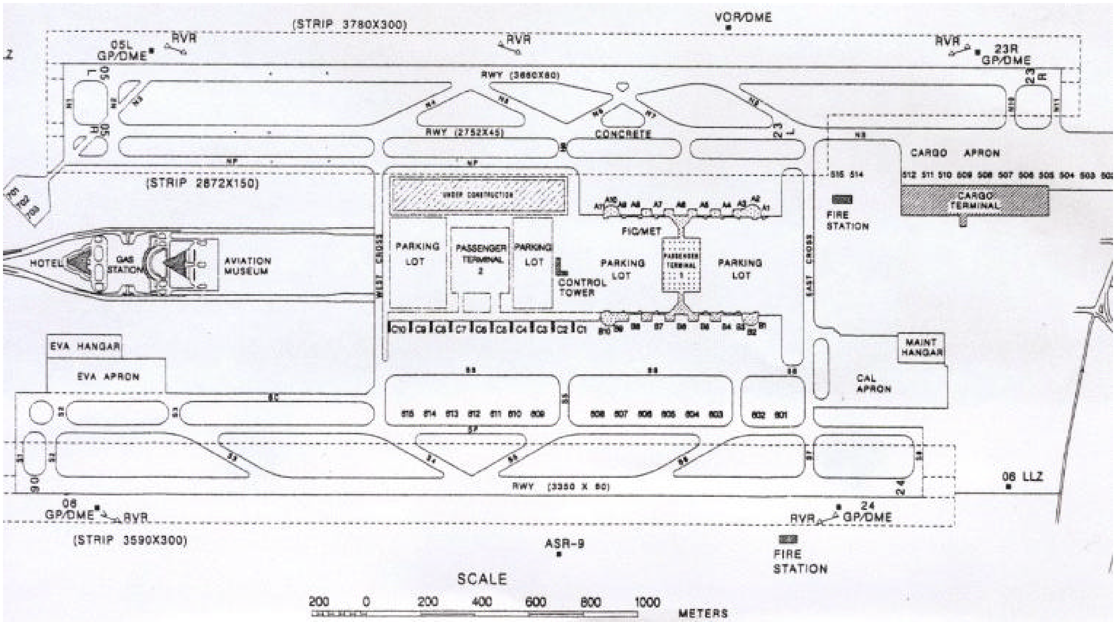


Figure 10-1 Layout of Chang Kai-Shek (CKS) Airport

1.10.2 Runway Physical Characteristics

CKS Airport has three parallel runways, viz. 05L/23R, 05R/23L and 06/24. Runway 05L/23R is for Category II ILS. Runway 06/24 is for Category I ILS. Runway 05R/23L is a non-instrument. It can be used at pilot’s request for take-off only, provided the cloud ceiling is at least 200 feet and visibility is at least 1,600m. Simultaneous use of Runway 05R/23L and Taxiway NP will not be approved if the crosswind component is more than 22 knots (dry runway) or 17 knots (wet runway). Based on the AIP, Aircraft can take off from Runway 05L/23R above RVR of 200m.

The physical characteristics of Runways 05L/23R and 05R/23L, as published in the Taiwan Aeronautical Information Publication (AIP), are summarized in the following table10-1:

Table 10-1 Physical characteristic of runway 05L/23R and 05R/23L

Designations Rwy	Dimensions	Strength (PCN) and surface of Rwy and Swy	Swy dimensions (m)	Cwy dimensions (m)	Strip dimensions (m)
05L	3,660 X 60	AUW 100t/2, 170t/4, 266t/5, 378t/8 PCN 60 RBXU, All cement concrete	60 X 60	300 X 300	3,780 X 300
23R	3,660 X 60	AUW 100t/2, 170t/4, 266t/5, 378t/8 PCN 60 RBXU, All cement concrete	60 X 60	300 X 300	3,780 X 300
05R	2,752 X 45	AUW 100t/2, 170t/4, 266t/5, 378t/8 PCN 60 RBXU, All cement concrete	Nil	300 X 180	2,872 X 150
23L	2,752 X 45	AUW 100t/2, 170t/4, 266t/5, 378t/8 PCN 60 RBXU, All cement concrete	120 X 45	300 X 180	2,872 X 150

Runway shoulders are provided on Runway 05L/23R and 05R/23L. The widths are 8 m and 11m respectively.

Requirements for Runway End Safety Area are stipulated in ICAO Annex 14, Vol. I paragraph 3.4 and FAA Advisory Circular No. 150/5300-13, Table 3-3. This is similarly reflected in the CAA ROC design document for Aerodromes. However, this is not established in the AIP as a facility for Runways 05L/23R at CKS Airport, although the land appears available to accommodate this requirement between the runway end and the existing Localizer installation.

Runway 05R/23L is separated from Runway 05L/23R by 214 m.

The marking, lighting and signage layout of threshold area at Runway 05R and Runway 05L including Taxiways N1 and NP, are shown in Figure 10-20.

1.10.3 Taxiway Physical Characteristics

This report focuses on the taxiways in the northern part of CKS Airport. The taxiways are: NP, NS, N1, N2, N3, N4, N5, N6, N7, N8, N9, N10, N11, West Cross and East Cross.

The width of taxiway NP is 30 m with 11m for each shoulder. Other taxiways (e.g. N1, N2…and rapid exit taxiways N4, N5, N7, N8..) are designed with 35m width and 11m shoulders. The angle between the high-speed exit taxiways and Runway 05L/23R is 150 degrees.

NP is the taxiway parallel to Runways 05R/23L (non-instrument runway) and 05L/23R (instrument runway). The separation distance between the center line of Taxiway NP and Runway 05R/23L is 110 m, while that with Runway 05L/23R is 324 m.

1.10.4 Location of Runway-Holding Positions

Refer to 1.18.1.1 for related information

CKS Airport has two runway-holding positions for runway 05L end of the runways, one each at N1 and N2; both are 120m away from 05L runway centerline. Another runway-holding position is marked on Taxiway NP, which is 76m toward N1 taxiway centerline. The locations of the runway-holding positions are shown in the Figure 10-2:

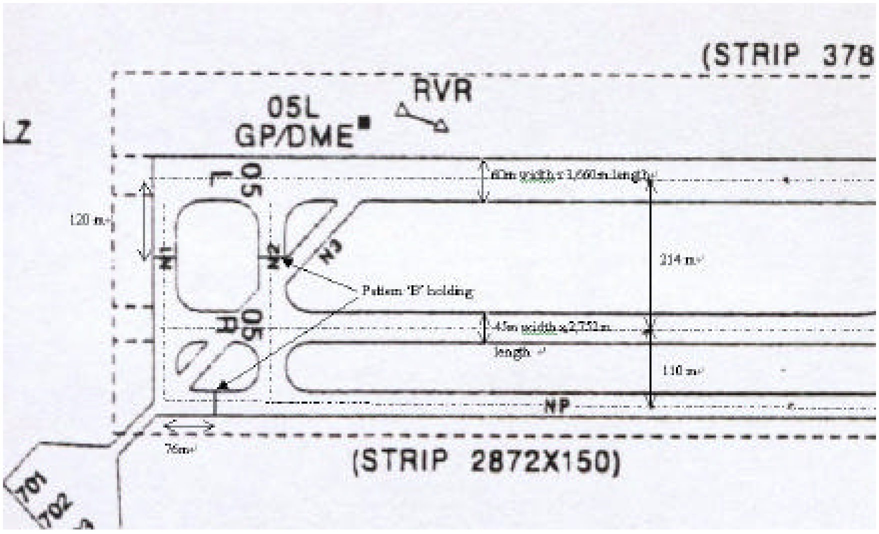


Figure 10-2 Separation distances between runway/taxiway and runway-holding positions

1.10.5 Runway Holding Position Marking

Refer to 1.18.1.2 for related information

Runway holding position markings pattern 'B' are provided at the various holding positions identified in Section 1.10.4. (See Figure 10-3 and 10-4)

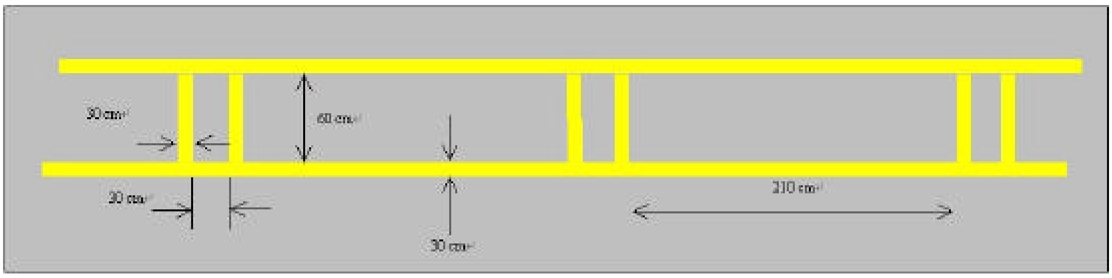


Figure 10-3 Dimensions of runway holding position marking at CKS Airport

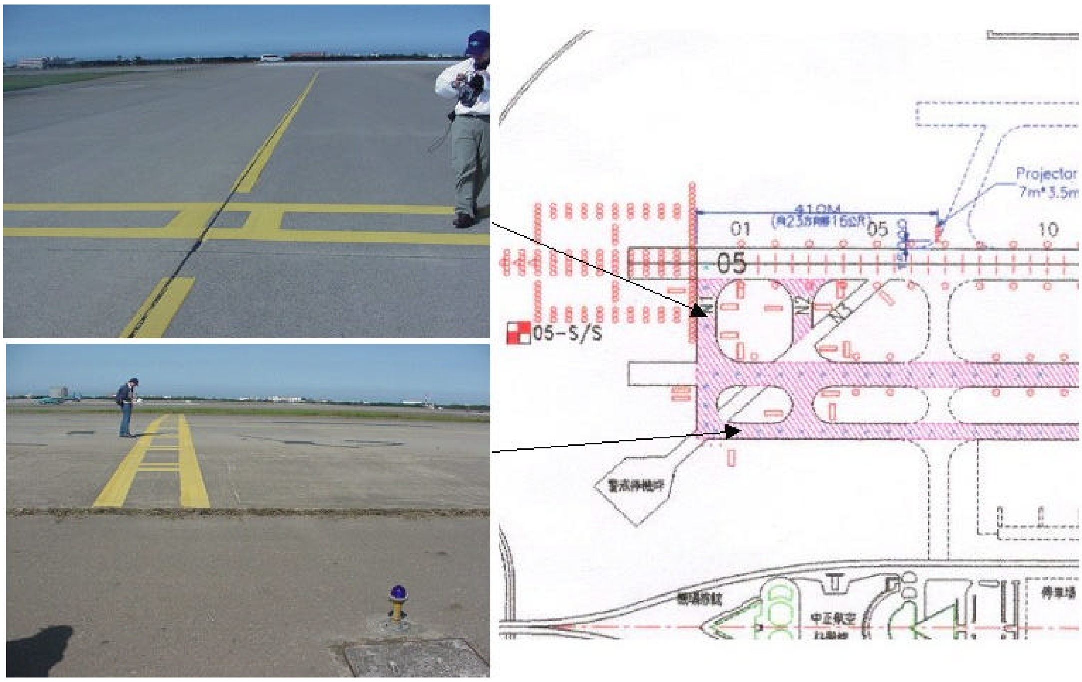


Figure 10-4 Runway holding position markings provided at N1 and NP taxiways

1.10.6 Intermediate Holding Position Marking

Refer to 1.18.1.3 for related information

Intermediate holding position markings are not provided at taxiway intersections at CKS Airport.

1.10.7 Threshold Marking

Refer to 1.18.1.4 for related information

Threshold markings are provided for each of the Runways 05L, 05R, 23L and 23R. The photographs and sketches in Figure 10-5 and 10-6 show these markings on the runway and their measured dimensions. Runway 05R/23L threshold marking is same as the 05L/23R threshold marking.

Figure 10-5 Runway 05R, 05L Threshold Markings

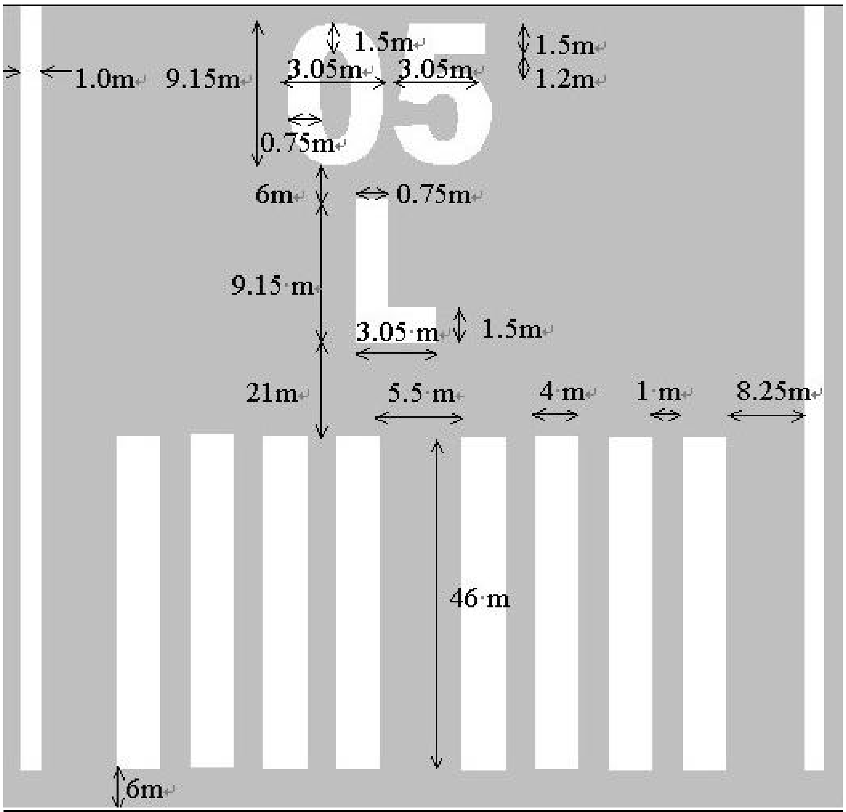


Figure 10-6 Dimensions of Threshold and Runway Designation Markings at Runway 05L(Not to scale)

1.10.8 Taxiway Center Line Marking

Refer to 1.18.1.5 for related information

Generally, yellow taxiway centerline markings of 20cm width are provided at CKS Airport. However, a segment of the straight portion of the taxiway center line marking on Taxiway N1 providing guidance in the direction of the entry point to Runway 05L was missing. This missing segment of the taxiway center line marking was located between the end of the curved portion providing lead-in guidance from Taxiway NP to Taxiway N1 and the end of the curved portion of the taxiway center line marking providing lead-in guidance from Runway 05R/23L to the northern part of Taxiway N1. Reference is made to Figure10-7 and10-8 and the figure shown in Figure 10-20.

Figure10-7 Taxiway center line marking leading into Runway 05L

Figure 10-8 Taxiway centerline markings at the vicinity of Runway 05L and 05R threshold areas

1.10.9 Runway Lighting

The runway lighting system are shown in Table10-2

Table10-2 General list of Runway 05L and 05R lighting system

Facility	Runway lighting circuits in use
Runway 05L/23R	Approach lights(white, CATII with red side row barrettes) Runway centerline lights(white/red) Runway edge lights (white/yellow) and end lights(red) Touchdown zone lights(white) Threshold lights(green) PAPI(white/red) Taxiway edge lights (blue) at runway/taxiway intersections
Runway 05R/23L	Runway edge lights (white/yellow) and end lights(red) Taxiway centerline lights(green) Taxiway edge lights (blue) at runway/taxiway intersections

1.10.9.1 Runway edge lights

Refer to 1.18.1.6 for related information

Bi-directional high intensity runway edge lights are provided for both Runway 05L/23R and Runway 05R/23L at CKS Airport. These are spaced at between 55-60m apart. These lights are both of identical make and model (Crouse Hinds L-862 elevated and L-852 inset, FAA specification) for either runway. The lamps used on the elevated runway edge light fittings are found to be 6.6A/T4Q/CL/2PPF and Philips 6372/200W/6.6A/8L. It is observed that several of the inset bi-directional runway edge lights for each runway are either missing (e.g. along Runway 05R/23L across N2 taxiway), or incorrectly installed in that the orientation of the light windows are aligned away from the direction of the runway (i.e. pointing in directions other than along the runway length). The Figure 10-9 and 10-10 show the runway edge light installations at Runway 05L/23R and 05R/23L.

Figure 10-9 Runway 05L/23R and Runway 05R/23L (bottom right) edge lights

Figure 10-10 Incorrectly oriented inset runway edge lights (L-852) for Runway 05L/23R (left) and 05R/23L (right)

1.10.9.2 Runway End lights

Refer to 1.18.1.7 for related information

Runway end lights are provided for Runway 05L/23R and 05R/23L at CKS Airport. There are 8 runway end lights at each location. These are linked to the runway edge light circuits and therefore share the same activation button from the Control Tower. The runway end lights are located symmetrically about the runway centerline as shown Figure 10-11.

Top:
Runway edge lights at the 05L end of Runway 05L/23R
Left:
Rear view of elevated Runway 05R/23L end light fitting

Figure 10-11 05L and 05R runway end light

1.10.9.3 Runway Center Line Lights

Refer to 1.18.1.8 for related information

High intensity runway centerline lights (L-850A 200W) are provided for Runway 05L/23R but not for Runway 05R/23L. These lights are fixed lights showing variable white from the threshold to the point 900m from the runway end; alternate red and variable white from 900m to 300m from the runway end; and red from 300m to the runway end. They are spaced at 15m apart, and offset by 60cm from the runway centerline.(see Figure 10-12)

Figure 10-12　05Runway Center Line Light
(Left: Red runway centerline lights near the runway end at 05L
Right: White runway center line lights at the commencement of Runway 05L)

1.10.10 Stop bar Lights

Refer to 1.18.1.9 for related information

Stop bars are not provided at CKS Airport (see Figure 10-13).

Figure 10-13 Entry taxiways into Runway 05L/23R
at N1 (top left and bottom right) shown without stop bar light protection

1.10.11 Runway Guard lights

Refer to 1.18.1.10 for related information

Runway guard lights are not provided at CKS Airport.(see Figure 10-14)

Figure 10-14 View of entrance into Runway 05R/23L from taxiway N1 (picture taken during site survey)

1.10.12 Taxiway Center Line Lights

Refer to 1.18.1.11 for related information

Taxiway centerline lights (L-852, FAA specification) are provided on all taxiways at the north part of the airport. The southern part of the airport is not equipped with taxiway centerline lights. At exit and entry taxiways, these centerline lights also extend into the runway up to the runway centerline area. Taxiway centerline lights are also provided along the centerline of Runway 05R/23L (No runway center line lights are installed). These lights are found to be installed at varies distances from the taxiway centerline, e.g. 0.6m, 1.2m and 1.6m. On straight sections of taxiways, the centerline lights are found to be spaced 30m apart, while taxiway centerline lights on curved segments are at 7.5m spacing. On the curved taxiway sections, the taxiway centerline light fixtures are identical to those used along straight sections. All taxiway centerline lights are bi-directional and emit green light. There are no alternate green/yellow taxiway centerline lights on exit taxiways to demarcate the limits of the ILS sensitive area. The lamps used for taxiway centerline lighting are rated at 65W. (see Figure 10-15)

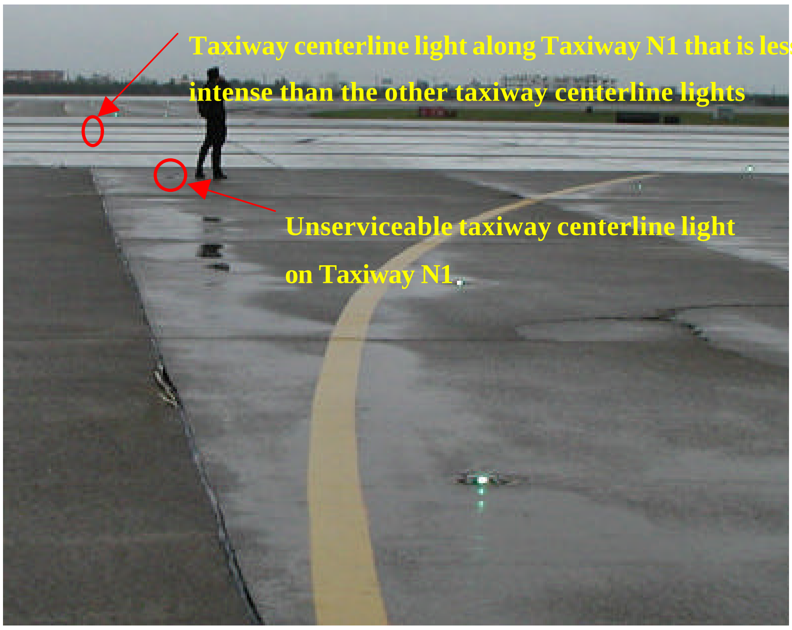


Figure 10-15 Configuration of taxiway center line lights
Installed around Taxiway N1 (picture taken during site survey)

For an aircraft taxiing along Taxiway NP, the spacing of the green taxiway center line lights on the striaght portion of txiway NP is 30m As it turns right into Taxiway N1, the spacing of taxiway center line lights along the curved section is 7.5m up to the point of tangency with the Taxiway N1 center line. For aircraft taxiing onward:

(a) into Runway 05R, the spacing of taxiway center line lights along the curved section from this point is again, 7.5m up to the point of tangency with the Runway 05R center line. Beyond that, the spacing of green taxiway center line lights are 30m along the Runway 05R/23L.

(b) towards Runway 05L, there are 4 taxiway center line lights are provided along the straight segment of Taxiway N1 up to the Runway 05L holding position. These taxiway center line lights are located at a distance of 30m, 55m and 116m respectively from the point of tangency (where the curved taxiway center line marking from Taxiway NP meets Taxiway N1).

During site survey(on Nov 4, 2000), it was noted that the first taxiway center line light after the point of tangency was unserviceable while the second light was less intense than the other lights. (See Figure 10-13)

Taxiway center line light fittings installed along curved segments are identical with those provided for the straight segments (see Figure 10-16).

Taxiway center line lights along the curved segment are required to have a toe-in angle of 15.75 degrees.

Figure10-16 Taxiway centerline light installed a curved taxiway section with straight bi-directional light windows (picture taken during site survey)

1.10.13 Airfield Lighting Control and Monitor

1.10.13.1 Circuit Interlocking

Refer to 1.18.1.12 for related information

Runway 05R-23L was primarily used as a standard taxi-route and as such provided with green taxiway centerline lights. Other than having green taxiway centerline lights, Runway 05R is also provided with high-intensity runway edge lighting, runway threshold/end lights. No interlocking capability exists to preclude the possibility of simultaneous operation of the runway lighting and the taxiway centerline lighting.

As can be seen from Figure 10-17 of the runway and taxiway lighting control panel located in the Control Tower, individual pushbuttons are provided to switch on/off different airfield lighting circuits. These pushbuttons are hardwired directly to relevant Constant Current Regulators located directly below the Control Tower, thus turning on/off the lights for the respective circuits. No form of electromechanical interlock or computerized control was implemented to prevent the simultaneous operation of both runway and taxiway lighting on Runway 05R/23L. A turning knob is provided for each of these circuits to enable the selection of different intensity levels for the airfield lights.

The ATC controller will turn on the taxiway lights when runway 05R/23L is used for taxi only. If the pilot request to use runway 05R/23L for takeoff and the weather and operation conditions permit, the ATC controller will turn on the runway 05R/23L edge lights.

For operations as a runway, the runway 05R edge lights must be on and the 05R taxiway centerline lights must be off. In addition, night time operations would require taxiway NP centerline lights to be on as well.

Based on the lighting control system diagram given in figure 10-19, the centerline lights on taxiway NP and centerline lights on runway 05R are controlled by the same switch for each of the three different zones. Therefore, it does not seem possible to establish a single lighting configuration that would allow for night operation of runway 05R. That is, it is not possible to select the taxiway NP centerline lights on while selecting the runway centerline lights off simultaneously.

The ATC procedures provided in Mandarin state that taxiway NP and runway 05R may not be used concurrently, however, they do not appear to provide a specific procedure to turn select the taxiway lighting off once the airplane is positioned on runway 05R.

Figures 10-18 and 10-19 provide explanation on typical airfield lighting circuit switching function on one typical section of the control panel.

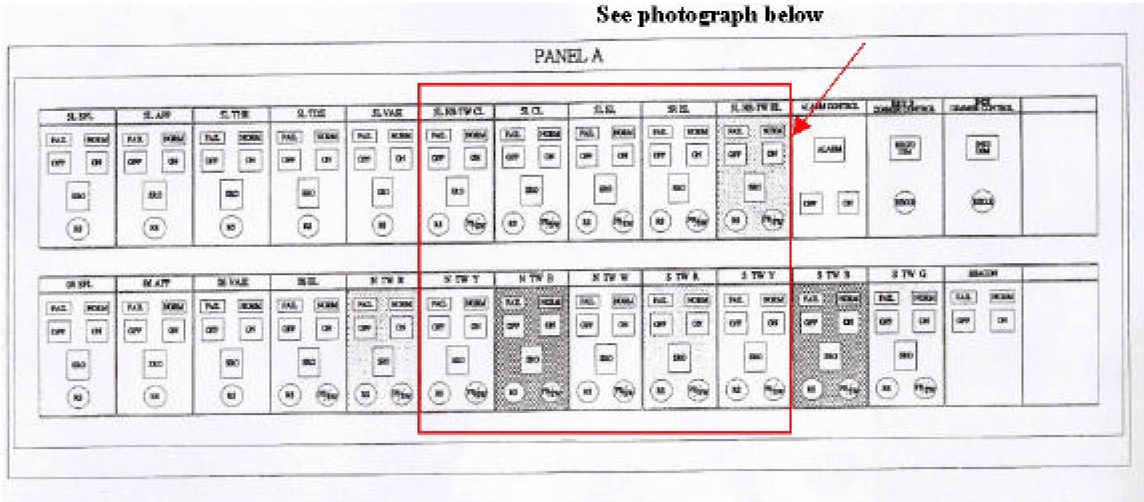


Figure 10-17 Drawing showing the layout of the airfield lighting Control panel located in the Control Tower

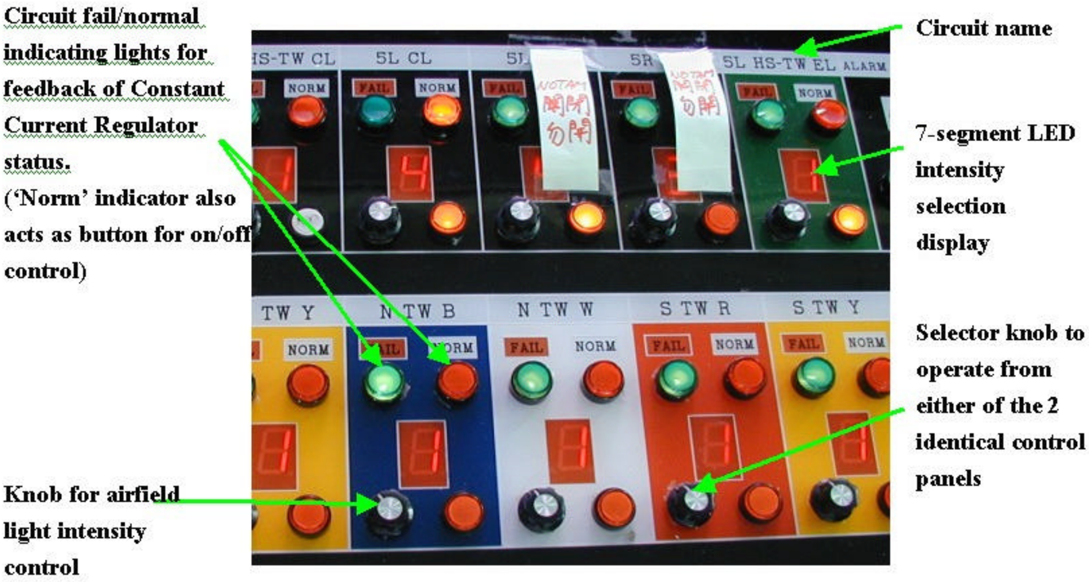


Figure 10-18 Section of airfield lighting control panel
(picture taken during site survey)
(One of 2 identical panels located in CKS Airport Control Tower)

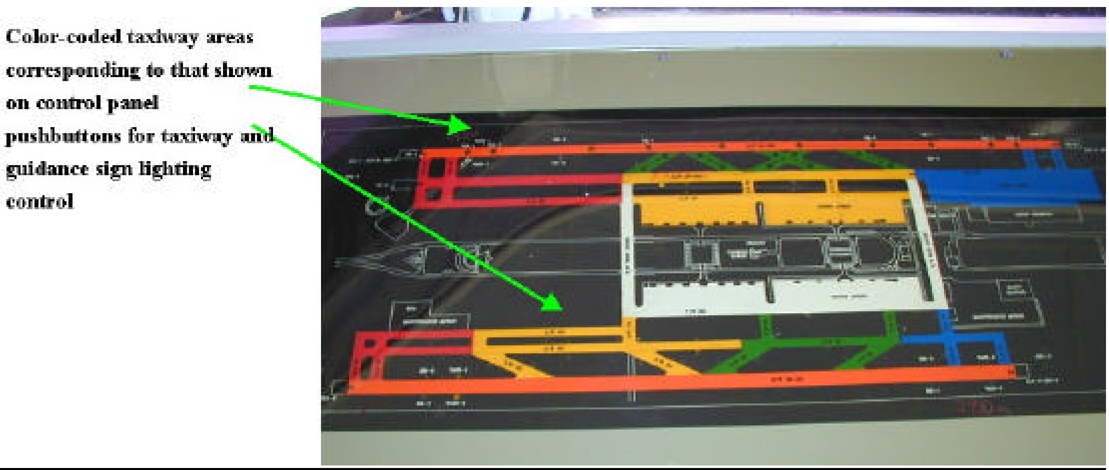


Figure 10-19 One of two airfield lighting mimic panel
located at CKS Airport Control Tower
(picture taken during site survey)

1.10.13.2 Circuit Monitoring

Refer to 1.18.1.13 for related information

The monitoring of airfield lighting system serviceability is implemented through hardwiring relay contacts from Constant Current Regulator to indicate the status for the related circuits. This provides feedback on the status of entire circuits. There is no monitoring of individual lights, or percentage of unserviceable lamps for any circuit. A simple hardwired electromechanical relay control and monitoring system is used at CKS Airport. As illustrated in previous section, the normal or failure status for each lighting circuit is presented through 2 corresponding indicator lamps on the control panel in the Control Tower. Feedback on intensity selection is displayed via a 7-segment LED module for each circuit.

There is also no system of data logging to register on hard or soft media the actual status of the airfield lighting circuit and the selected circuits in use at any time. The only form of logging indicating actual status of any airfield lights was found on a computer record of the Runway 05L/23R RVR system. The runway edge lights of Runway 05L/23R was recorded by the RVR System to provide an input parameter for calculation of RVR values presented to the Control Tower. The record showed that the Runway 05L/23R edge lights were selected at intensity level 3 during the time of the SQ006 occurrence. There was no record of the on/off status of any other airfield lights, including those on Runway 05R/23L.

1.10.14 Mandatory Instruction Signs

Refer to 1.18.1.14 for related information

Mandatory instruction signs (L-858, FAA specification) are provided at CKS Airport. The location and inscription of these signs around Taxiway N1 are shown as Figure 10-20.

Mandatory signs, installed at entries to runways, are of white inscription on red background. These signs are of the internally illuminated type, and are around 1.1m heights. The nearest edge of these sign is around 20m from the nearest taxiway edge.

The mandatory instruction sign installed on the left side of Taxiway N1 at approximately 54m before the center line of Runway 05R threshold shows the runway designation "5R-23L" (see Figure 10-21).

The mandatory instruction sign installed on the left side of Taxiway N1 at approximately 75m before the center line of Runway 05L shows "CAT 2" (see Figure10-22). The mandatory instruction sign installed on the right side of taxiway N1 at the same distance before the center line of Runway 05L threshold shows "5L-23R|N1" (see Figure 10-23). The inscriptions on this combined runway designation (white lettering on red background) and taxiway location (yellow lettering on black background) sign has a white rectangle encircling the runway designation sign and a yellow rectangle encircling the taxiway location sign. The above 2 signs are located after the holding position for Runway 05L and not collocated with runway holding position marking.

For an aircraft entering Runway 05R from the southern side of Taxiway N1, the runway designation sign showing "N1|5R-23L" is located at 54m before the runway centerline and is not collocated with the runway holding position along Taxiway NP. For an aircraft entering Runway 05R from the northern side of Taxiway N1 (i.e. exiting from Runway 05L), the runway designation sign showing “N1|5R-23L” is located at 75m before the runway centerline and is not collated with the runway holding position.

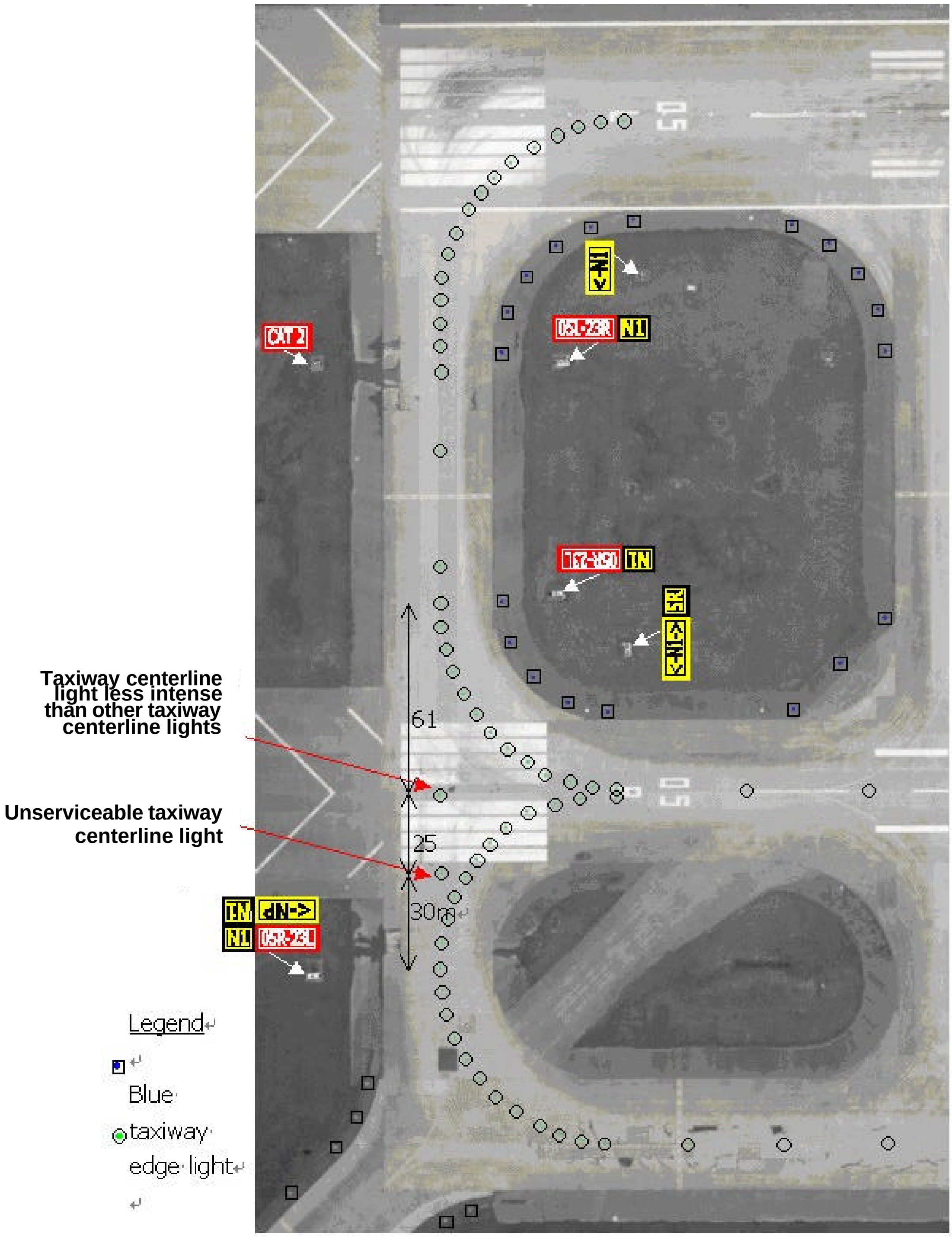


Figure 10-20 Aerial picture showing runway and taxiway markings, lights and signs at the threshold areas of Runway 05R and Runway 05L (picture taken during site survey)

Figure 10-21 Closed-up view of mandatory runway designation sign removed from Taxiway N1 before Runway 05R/23L

Figure 10-22 Mandatory CAT II sign found only at the left side of N1 taxiway leading to Runway 05L/23R

Figure 10-23 Mandatory runway designation sign found only at the right side of Taxiway N1 leading to Runway 05L/23R

1.10.15 Visual Aids for Denoting Restricted Use Areas

1.10.15.1 Background

Since 13 September 2000, Runway 05R-23L has been closed for take-off due to on-going construction works in the middle portion of the runway between Taxiways N4 and N5; however, the remainder of Runway 05R-23L and Taxiways N4 and N5 remained available for taxiing operations (NOTAM A0606).

CAA ROC initiates projects to improve airfield facilities. This could arise from requests from internal departments or through consultation with users / airport operators. For example, the need for two additional Rapid Exit Taxiways at Runway 05L/23R was suggested by the CKS Control Tower (under ANWS) based on their operational requirements.

CKS Airport Management (Ground Operations Department) chairs a bimonthly meeting involving the Airport Operators Committee (airlines representatives), concessionaires, and government agencies such as Customs etc. CKS Flight Operations section and Maintenance & Engineering section are represented at the meeting too. Other CAA departments / sections such as ANWS, CAA headquarters and CKS cargo section may attend the meeting from time to time, whenever necessary. The meeting discusses issues on airport operations and facilitation matters. During this meeting, airport operators / users may give suggestions on improvements to the airport / airfield.

Improvement works in the airfield are budgeted by CKS Airport or the Aerodrome Engineering Division, depending on the cost. Once approved, the project is contracted to private contractors but supervised by the Maintenance & Engineering section Safety regulations are given to the contractor.(Refer to Appendix 4-1)

Airport users are notified of airfield works that affect operations through the issuance of NOTAM. NOTAM is issued by the Flight Information Center of the airport, which is under the ANWS. Request for issuance of NOTAM is coordinated between the Maintenance & Engineering section, Flight Operations section and the Control Tower. Operational requirements are taken into account prior to determining closure periods for different phases of the project.

1.10.15.2 Pavement Improvement on Runway 05R/23L

Refer to 1.18.1.15 for related information

1.10.15.2.1 Scope of Works

The need to repair the pavement of Runway 05R/23L arose from inspection reports by the Aerodrome Engineering Division in early-2000. (Refer to Appendix 4- 2) It was reported that the pavement at Runway 05R/23L and part of apron taxiways (NP and NS) have reached their designed lifespan and showed signs of "bleeding" (i.e., seepage of water through cracks in the pavement, resulting in surfacing of subsoil through these cracks). Frequent repairs of the cracked and chipped surfaces were required. It was thus decided to carry out a major repair of the pavements on Runway 05R/23L, Taxiways NP and NS.

The portion of Runway 05R/23L between Taxiways N4 and N5 was closed from 13 September 2000 to 22 November 2000 for repair of the pavement. This work was duly notified through the issuance of a NOTAM.0606. This information was also made available on the ATIS.

At the time of the SQ006 occurrence on 31 October 2000, the equipment left on Runway 05R/23L is shown Figure 10-24.

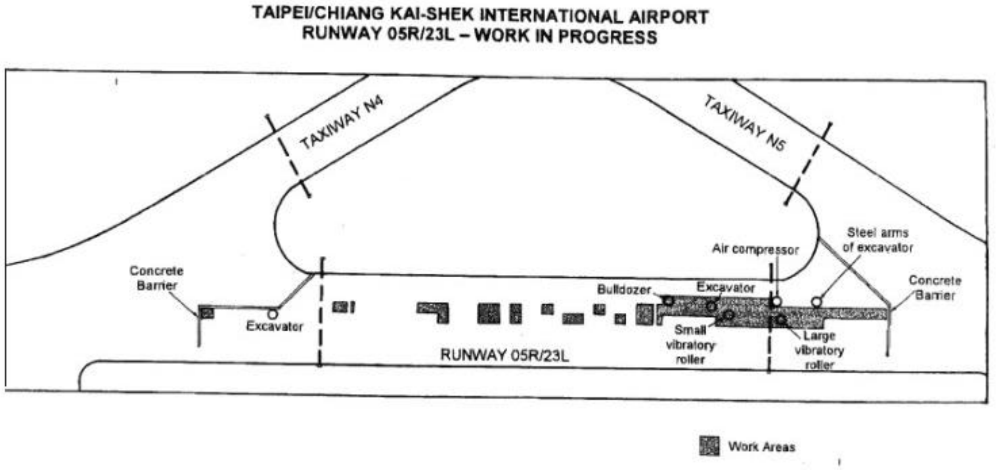


Figure 10-24 Layout of works in progress and construction equipment On Runway 05R/23L between Taxiways N4 and N5

1.10.15.2.2 Obstacle Height Control for Machinery Working on Runway 05R/23L

The construction site on Runway 05R/23L is located about 200 m from the centerline of Runway 05L/23R. Based on the 1:7 slope of the Runway 05L/23R transitional surface, the height limit at the edge of the runway is about 5.92m (see Figure 10-25).

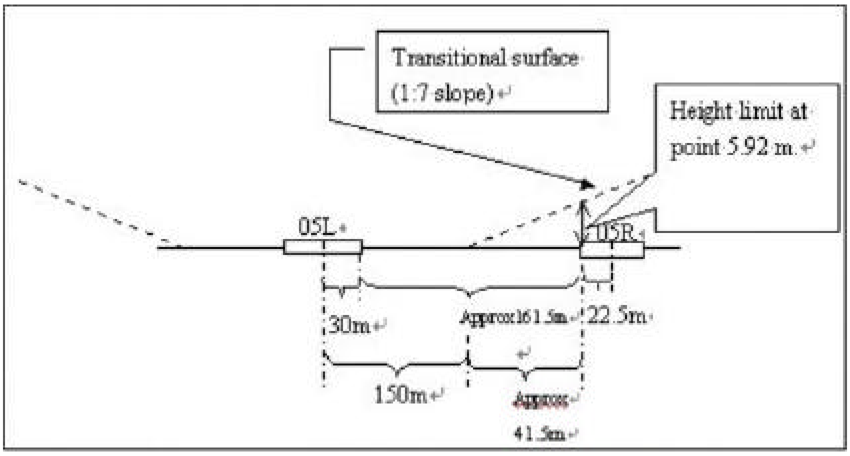


Figure 10-25 Cross Sectional View of the Runways and 05L Transitional Surfaces

The construction equipment (2 excavators, 1 bulldozer, 2 vibratory rollers) parked on the middle of Runway 05R/23L on 31 October 2000 range from 1.5m to a maximum of 2.75 m height and do not exceed this height limit. As such, they do not constitute obstacles to Runway 05L/23R transitional surface, as specified in Annex 14, Volume I, Chapter 4.

1.10.16 Closed Runways or Taxiways, or parts thereof

Refer to 1.18.1.16 for related information

No closed markings were provided close to the construction area along Runway 05R-23L.

1.10.17 Unserviceable Areas

Refer to 1.18.1.17 for related information

The closed portion of the runway is provided with barriers consisting of Jersey blocks made of solid concrete. (see Figure 10-26,10-27) The dimensions of these concrete blocks are 0.8m high, 1m long and 0.15m to 0.45 m wide. The blocks are marked with yellow, orange or a mix of yellow and black stripes. In addition, battery-powered, flashing red unserviceable lights spaced at a distance of 2 to 5m are provided on top of the blocks for nighttime use.

Figure 10-26 Closed work area along Runway 05R/23L and closed taxiway work area viewed from Runway 05L/23R

Figure 10-27 Jersey blocks of different colors used on the airfield at CKS Airport

1.10.18 Surface Movement Guidance and Control System (SMGCS)

Refer to 1.18.1.18 for related information

An SMGCS provides guidance to, and control or regulation of, an aircraft from the landing runway to the parking position on the apron and back again to the take-off runway, as well as other movement on the aerodrome surface. It comprises an appropriate combination of visual aids, non-visual aids, procedures, control, regulation, management and information facilities.

The visual aids components of CKS Airport's SMGCS (i.e., markings, lighting and signs) have been described in previous sections of this report. There is no detailed Airport SMGCS plan for low visibility operations provided at CKS Airport.

Guidance on the use of visual aids in a SMGCS is contained in Appendix 4-43.

1.10.19 Maintenance of Visual Aids

Refer to 1.18.1.19 for related information

1.10.19.1 Airfield Lighting

Airfield lighting system is maintained by Air Navigation and Weather Services (ANWS). ANWS has a maintenance unit stationed at the Control Tower of CKS Airport. The unit comprises ten staff – six supervisors and four artisans. They are scheduled on two three-man shifts round the clock. (Refer to Appendix 4-3)

ANWS maintenance staffs inspect the airfield lights twice a day, once in the morning (0900 – 1100 hours) and once in the afternoon (1300 – 1500 hours). They need to coordinate with the Control Tower for an available time slot to enter the airfield. Faults are recorded in the morning and rectified in the afternoon on the same day. No night maintenance is conducted on the runways and taxiways. In addition to the daily checks, ANWS has weekly and monthly checks for different airfield lights that require attention to greater detail. (Refer to Appendix 4- 3)

1.10.19.2 Airfield Signs

Like airfield lighting, technical specifications of airfield signs are provided by the Air Navigation Facilities Division of CAA ROC. ANWS installs the airfield signs according to these specifications. According to CAA ROC, ICAO standard and recommended practices are adopted.

ANWS also maintains the airfield signs of CKS Airport. Inspection of airfield signs takes place concurrently with inspection of the airfield lights daily. Blown fluorescent tubes are replaced on the same day. In addition to the daily checks and maintenance, there are weekly and monthly preventive maintenance scheduled which could involve dismantling of signs for off-site repairs. (Refer to Appendix 4-3)

1.10.19.3 Airfield Markings

The CKS Maintenance & Engineering section is responsible for maintaining airfield markings. Repainting of runway markings coincide with removal of rubber deposits on the runways. Repainting of airfield markings in other areas is carried out once every two to three years. (Refer to Appendix 4- 3)

1.10.20 Black Outline Markings

Refer to 1.18.1.20 for related information

Only apron centerline markings are outlined in black for added conspicuity. Taxiway centerline markings and holding position markings are not outlined at CKS airport.

1.16 Tests and Research

Two wire strands were picked up from 05R, one from right hand side of the center line (placard as RE239) and the other (RE240) from left hand side, both were verified as runway edge lights during site survey using GPS to check their localities.

At location RE240, the runway edge light fitting was fractured approximately 1.5 to 2 inches above ground level. The fracture was circumferential at a constant height. The base of the fitting remained bolted in place, but the upper portion was not located. No fragments of metal or glass were found in the immediate area. Two wires were observed protruding approximately 2-6 inches from the remaining portion of the light base. Globules were visible on some of the wire strand ends. The wires were lying parallel to the ground and oriented generally along the direction of the runway (away from the runway 05R threshold). When the wires were lifted, the plug was found still connected to the mating receptacle under the ground. The connector was disconnected and tagged for identification purposes.

A multimeter was used to test continuity between the conductors (sockets) in the mating receptacle in the ground and the light fitting. The meter read "open circuit" between each of the mating receptacle sockets and the runway edge light fitting. No attempt was made to read continuity between the two sockets themselves.

Both wires had been sent to Aviation Research Labs (ARL) of Chung Shan Institute of Science and Technology (CSIST) of Taiwan and Australian Transport Safety Bureau (ATSB) for examination. Both reports indicate that some RE240 wire ends have the phenomenon of electric arcing. Examination reports are shown in Appendix 4-4 and 4-5 respectively.

The reports of the tests carried out by CSIST and ATSB were emailed to the Canadian Transportation Safety Board for assessment. The assessment result is shown as Appendix 4-44.

1.17 Organizational and Management Information

1.17.1 Organization Chart of Civil Aeronautics Administration (CAA) of the Republic of China

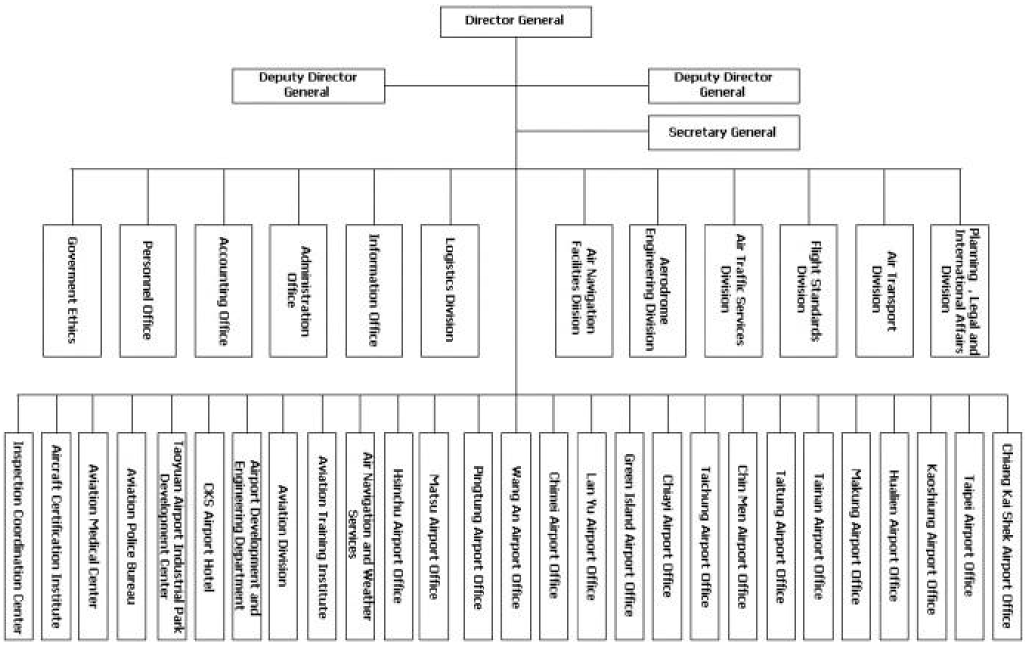


Figure 17-1 CAA Organizational Chart

As shown on the above organization chart, the CAA ROC is headed by the Director-General who is assisted by two Deputy Directors-General.

The general roles and responsibilities of the CAA divisions involved in stipulating design standards, overseeing airport works and providing air traffic services are described below. Detailed maintenance / operating procedures are described later in this report.

1.17.2 Aerodrome Engineering Division

The Aerodrome Engineering Division is responsible for stipulating technical standards for the design of airfield facilities such as taxiways and runways. This includes specifications on the marking of taxiways and runways. CAA ROC generally uses ICAO standards and recommended practices, although it adopts the U.S. Federal Aviation Administration (FAA) specifications in some areas.

The Aerodrome Engineering Division has previously compiled a manual on airport design standards in 1987. Prior to the SQ006, the Division had already commenced reviewing the aerodrome design specifications and standards to reflect with the ROC standard; however the new manual has not yet completed at the time of this occurrence.

CAA headquarter undertakes civil engineering works that cost between NT$50 million to NT$1 billion. (Refer to Appendix 4-45) The Aerodrome Engineering Division may use external organizations as consultants to design their airfield facilities, such as runways, taxiways and passenger terminal buildings. (For example, Aerodrome Engineering Division engages a company called AirPlan Consultancy to design the airport master plan.)

1.17.3 Air Navigation and Weather Services

The Air Navigation and Weather Services (ANWS) is responsible for providing flight information, air traffic control (ATC), aeronautical telecommunication, and aeronautical meteorological services. Management of the control tower, Flight Information Center (i.e., aeronautical information service) and meteorological service in CKS Airport and other airports is by the ANWS.

The ANWS is responsible for the runway and taxiway lighting system as well as airfield signs. It has a maintenance unit in CKS airport, which is based at the ground floor of the CKS control tower. This maintenance unit is responsible for checking and replacing the runway / taxiway lights and signage. It also maintains the lighting control system and Constant Current Regulator (CCR) power supply system.

1.17.4 CKS Airport Management

CKS Airport Management is responsible for the day-to-day running of the airport facilities. Two key departments involved in airside operations and maintenance are the Flight Operations section and the Maintenance & Engineering section.

The Flight Operations section is responsible for ensuring smooth operations and enforcing safety on the ground. Its role includes licensing of drivers, airfield inspections, checking for obstacles, foreign objects and animal hazards, etc. The section has duty officers on shift to conduct these duties round the clock. Three airfield inspections are scheduled each day. Any requests for airfield pavement repair works are channeled to the Maintenance & Engineering section for follow up.

The Maintenance & Engineering section is responsible for maintaining the airfield pavements, including the runway / taxiway repair works, painting of obscured markings in the airfield. From the inspection reports made by the inspection team from the Flight Operations section, the Maintenance & Engineering section prioritizes the urgency of the works, and then the contractor will do the repair / repainting works. The Maintenance & Engineering section undertakes civil works less than NT$50 million. The Maintenance & Engineering Section follows the CAA design criteria stipulated by the Aerodrome Engineering Division. However, it does not report to the Aerodrome Engineering Division. The Maintenance & Engineering section is responsible for supervision of worksite to ensure that its contractors comply with safety regulations (including marking and lighting of obstacles). The Maintenance & Engineering section has a team of staff to conduct pavement inspections. It is currently looking into safer alternatives to the Jersey blocks that can be frangible and are lighter, and yet can withstand the strong winds / typhoons experienced at CKS Airport.

CKS Airport Management is required to submit reports on surface damage to the Aerodrome Engineering Division. The Aerodrome Engineering Division monitors the progress of the repair works, and conducts checks on airports every 4 to 6 months.

1.17.5 Conversion of Runway 05R/23L to Taxiway NC

CAA ROC is aware that use of Runway 05R will affect safety as well as the operations of the cargo apron. According to them, coordination is complicated; ATC has to ensure no aircraft is pushing back at the cargo apron before it can allow any aircraft to take off at Runway 05R. As such, Runway 05R/23L is rarely used in recent times. According to the AIP, Runway 05R/23L can only be used for take-off under VFR conditions (visibility > 1,600m). The last time Runway 05R/23L was used at least before 3 months ago under VFR conditions.

Furthermore, the presence of Runway 05R/23L imposes an obstacle limitation surface on the Air Cargo Complex, which limits the future redevelopment of the Air Cargo Complex. The height of structures under the future Phase 1 and Phase 2 of the Air Cargo Complex (to be built at the present cargo parking bays) will be limited to about 16.42 m only. This will not be sufficient to cater for future capacity demand. It is understood that CAA ROC had engaged a company, AirPlan Consultancy, in 1995 to amend its master plan, including the planning of future runways and taxiways. AirPlan Consultancy had since 22 November 1999 been looking into converting Runway 05R/23L to a taxiway, which will alleviate the height limit of the Cargo Complex.

The decision to decommission Runway 05R/23L and to convert it to a taxiway was made by CAA ROC in 17 February 2000. This proposal was submitted to the Ministry of Transportation and Communications, and approval was obtained to proceed with the necessary works on 11 April 2000. Between April 2000 and October 2000, there were several planning meetings between the various Divisions of CAA ROC. It was decided to officially convert Runway 05R/23L to a taxiway on 1 November 2000. Necessary follow up works include removal of Runway 05R/23L markings and painting of taxiway markings (to be undertaken by the CKS Airport Maintenance & Engineering section) as well as changing of signs / lights (to be undertaken by ANWS). An AIP Supplement (A007C015/00) was issued on 3 October 2000 to inform of the change with effect from 1 November 2000. However, conversion of Runway 05R/23L to Taxiway NC was subsequently postponed as the necessary painting works and procurement of signs was not complete. The AIP Supplement was cancelled by a NOTAM dated 23 October 2000. After the conversion works, the closed Runway 05R/23L was re-opened as Taxiway NC on 1 February 2001.

1.18 Additional Information

1.18.1 Standards and Recommend Practices

1.18.1.1 Runway-Holding Positions Location

(Refer to 1.10.4 for the provision at CKS airport)

According to ICAO Annex 14, Vol. I paragraph 3.11.6 / Table 3-2, the minimum distance from the runway center line to a runway-holding position for a non-instrument / take-off runway is 75 m, while that to a precision approach runway is 90m, or whatever would be required to protect the critical/sensitive areas of ILS/MLS.

FAA Advisory Circular 150/5340-1H, Standards for Airport Markings, Table 4 calls for distance from the runway centerline of a precision approach runway to a runway/taxiway holding position line to be 85m. For a visual or non-precision runway, the distance is 75 m. For ILS critical areas, the FAA Airways Facilities Office will designate this area. Normally it will follow closely the ICAO standard of 90 m. Where the distance between the taxiway/runway holding position and the holding position for an ILS critical area is 15 m or less, one holding position may be established, provided it will not affect capacity. In this case, the runway holding position is moved back to the ILS holding position and only the runway holding position markings are installed.

1.18.1.2 Runway Holding Position Marking

(Refer to 1.10.5 for the provision at CKS airport)

ICAO Annex 14, Vol. I Paragraph 5.2.9.2-

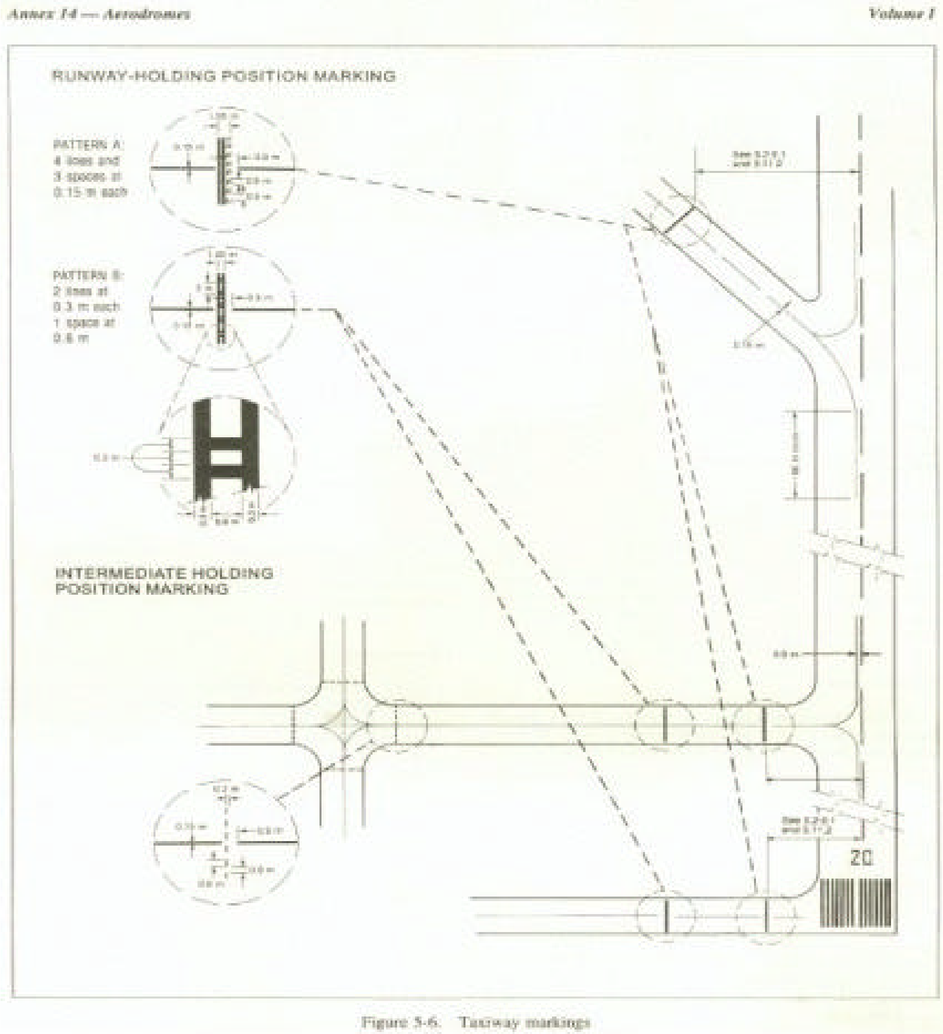
At an intersection of a taxiway and a non-instrument, non –precision or take-off runway, the runway holding position marking shall be as shown in Figure 5-6, pattern A.

ICAO Annex 14, Vol. I Paragraph 5.2.9.3-

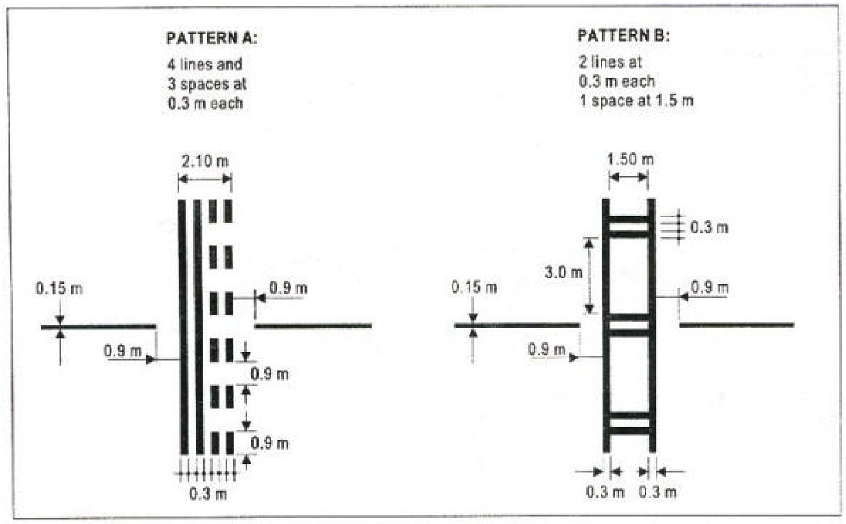
Where a single runway-holding position is provided at an intersection of a taxiway and a precision approach category I, II, III runway, the runway-holding position marking shall be as shown in figure 5-6, pattern A. Where two or three runway-holding position are provided at such an intersection, the runway-holding position are provided at such an intersection, the runway holding position marking closer to the runway shall be shown in figure 5-6, pattern A and the markings farther from the runway shall be as shown in figure 5-6, pattern B.

ICAO Annex 14, Vol. I Paragraph 5.2.9.5-

Recommendation - Where increased conspicuity of the runway holding position is required, the runway holding position marking should be as shown in Figure 5-7, pattern A or pattern B, as appropriate.



Extract from Figure 5-6 of ICAO Annex 14, Vol. I



Extract from Figure 5-7 from ICAO Annex 14, Vol. I

Runway holding position markings, as described in FAA Advisory Circular 150/5340-1H, Standards for Airport Markings consist of a set of 4 yellow lines (2 solid and 2 dashed) and 3 spaces each 15cm in width. The width of the lines may be doubled to 30cm. The use of this wider marking is strongly encouraged at locations where pilots have difficulty discerning the location of the holding position. As of 1 Dec 2000, this doubling of line width has become a FAA standard.

Holding position markings for ILS critical areas (similar to ICAO pattern ‘B’ markings shown above) identify the location on a taxiway or holding bay where an aircraft is to stop when it does not have clearance to enter ILS critical areas. The critical area is the area needed to protect the navigational aid signal. Where the distance between the runway holding position and the holding position for an ILS critical area is 15m or less, one holding position may be established. In this case, the runway holding position is moved back to the ILS holding position and only the runway holding position markings are installed.

All runway holding position markings must be outlined in black on concrete and light-colored pavement.

1.18.1.3 Intermediate Holding Position Marking

Refer to 1.10.6 for the provision at CKS airport)

ICAO Annex 14 Vol. I Paragraph 3.11.4

FAA Advisory Circular 150/5340-1H

ICAO Annex 14, Vol. I Paragraph 5.2.10.1-

Recommendation - An intermediate holding position marking should be displayed along an intermediate holding position.

According to FAA Advisory Circular 150/5340-1H, intermediate holding position markings should be used at airports with an operating airport Control Tower where there is an operational need to hold traffic at a taxiway/taxiway intersection or holding bay to define the edge of the taxiway object-free area to assure adequate clearance from taxiing aircraft.

1.18.1.4 Runway Threshold Marking

(Refer to 1.10.7 for the provision at CKS airport)

ICAO Annex 14, Vol. I Paragraph 5.2.4.5 –

A runway threshold marking shall consist of a pattern of longitudinal stripes of uniform dimensions disposed symmetrically about the centerline of a runway as shown in Figure 5-2(A) and (B) for a runway width of 45m. The number of stripes shall be in accordance with the runway width as follows:

Runway width	Number of stripes
18m	4
23m	6
30m	8
45m	12
60m	16

Except that on non-precision approach and non-instrument runways 45m or greater in width, they may be as shown in Figure 5-2(C).

ICAO Annex 14, Vol. I Paragraph 5.2.4.6 –

The stripes shall extend laterally to within 3m of the edge of a runway or to a distance of 27m on either side of a runway centerline, whichever results in the smaller lateral distance. Where a runway designation marking is placed within a threshold marking there shall be a minimum of three stripes on each side of the centerline of the runway. Where a runway designation marking is placed above a threshold marking, the stripes shall be continued across the runway. The stripes shall be at least 30m long and approximately 1.80m wide with spacing of approximately 1.80m between them except that, where the stripes are continued across a runway, a double spacing shall be used to subparagraphs the two stripes nearest the center line of the runway, and in the case where the designation marking is included within the threshold marking this spacing shall be 22.5m.

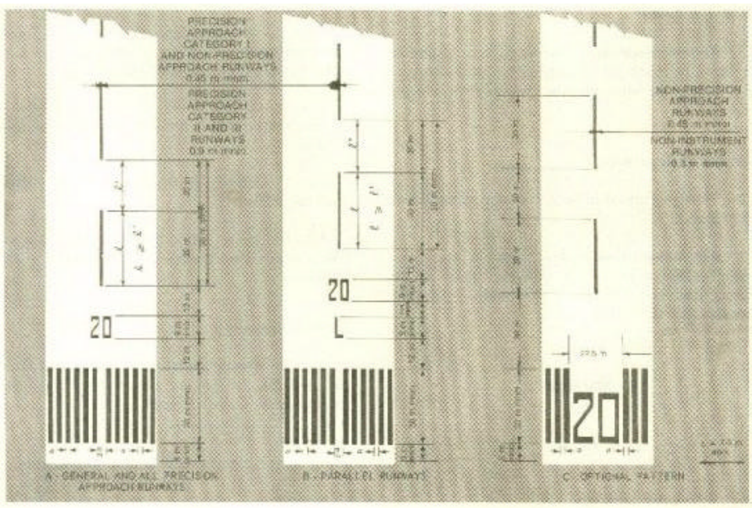


Figure 5-2. Runway designation, centre line and threshold markings

Extract from Figure 5-2 of Annex 14, Vol. I

FAA Advisory Circular 150/5340-1H, Standards for Airport Markings, requires one of 2 configurations for threshold markings. Configuration B is in accord with ICAO standards and all airports will convert to this configuration no later than January 1, 2008. Runway threshold marking for Configuration A consists of eight longitudinal stripes of uniform dimensions spaced symmetrically about the runway centerline. The stripes are 45m long and 3.6m wide and spaced 1m apart, except for the center space, which is 4.8 m. For runways greater than 45m in width, the width of the markings and spaces between the markings may be increased proportionally or additional stripes may be added to both sides.

1.18.1.5 Taxiway Center Line Marking

(Refer to 1.10.8 for the provision at CKS airport)

ICAO Annex 14, Vol. I Paragraph 5.2.8.1

Taxiway centerline marking shall be provided on a paved taxiway, de/anti-icing facility and apron where the code number is 3 or 4 in such an away as to provide continuous guidance between the runway center line and aircraft stand.

ICAO Annex 14, Vol. I Paragraph 5.2.8.5

Recommendation--At an intersection of a taxiway with a runway where the taxiway serves as an exit from the runway, the taxiway centerline marking should be curved into the runway centerline marking as shown in Figures 5-6 and 5-21. The taxiway centerline marking should be extended parallel to the runway centerline marking for a distance of at least 60 m beyond the point of tangency where the code number is 3 or 4, and for a distance of at least 30 m where the code number is 1 or 2.

ICAO Annex 14, Vol. I Paragraph 5.2.1.3

At an intersection of a runway and taxiway, the markings of the runway shall be displayed and the taxiway marking shall be interrupted, except runway side stripe markings may be interrupted.

FAA Advisory Circular 150/5340-1H, Standards for Airport Markings, requires that at taxiway intersections with runway ends, the taxiway centerline is terminated at the runway edge except that the taxiway centerline continues across the runway when it is a crossing route as designated by the local Air Traffic Facility. For taxiways crossing a runway, either straight across or offset and normally used as a taxi route, the taxiway centerline marking may continue across the runway but is normally interrupted for any runway markings. For low visibility operations, when the runway visual range is below 360 m, taxiway centerline markings continue across all runway markings with the exception of the runway designation marking.

1.18.1.6 Runway edge lights

(Refer to 1.10.9.1 for the provision at CKS airport)

ICAO Annex 14,Vol.I Paragraph 5.3.9

5.3.9.1 Runway edge lights shall be provided for a runway intended for use at night or for a precision approach runway intended for use by day or night.

5.3.9.3 Runway edge lights shall be placed along the full length of the runway and shall be in two parallel rows equidistant from the centerline.

5.3.9.7 Runway edge lights shall be fixed lights showing variable white, except that:

c) in the case of a displaced threshold, the lights between the beginning of the runway and the displaced threshold shall show red in the approach direction; and

d) a section of the lights 600 m or one-third of the runway length, whichever is the less, at the remote end of the runway from the end at which the take-off run is started, may show yellow.

FAA Advisory Circular 150/5340-24

3. RUNWAY EDGE LIGHT CONFIGURATIONS.

A runway edge lighting system is a configuration of lights which define the lateral and longitudinal limits of the usable landing area. Two straight lines of lights which are parallel to and equidistant from the runway centerline define the lateral limits. The longitudinal limits of the usable landing area are defined at each end of the area by straight lines of lights called threshold/runway end lights which are installed perpendicular to the lines of runway edge lights. Figure 1 depicts typical configurations.

a. Color of Lights. The runway edge lights emit white (clear) light except that yellow light is substituted for white light on the last 2,000 feet (610 m) of an instrument runway, or one-half the runway length, whichever is less, for indicating the caution zone. The yellow lights are intended for rollout information after landing and are installed on the runway end opposite the landing threshold. They are installed on both ends of a runway only when there is an instrument approach to both ends. The lights in the caution zone emit yellow light in the direction facing the instrument approach threshold and white light in the opposite direction. The threshold lights emit green light toward the approach area while the runway end lights emit red light toward the runway. These lights are usually combined into one fixture and special lens or filters are used to give the desired light coverage.

b. Location and Spacing. The runway edge lights are located on a line not more than 10 feet (3 m) from the edge of the full strength pavement which is designated for runway use. For runways used by jet aircraft, it is usually advisable to install the lights at the maximum distance to avoid possible damage by jet blasts. For smaller air ports a distance of approximately 2 feet (0.6 m) is recommended. The longitudinal spacing of the lights should not exceed 200 feet (61 m) and be located such that a line between light units on opposite sides of the runway is perpendicular to the runway centerline. The lights should be spaced as uniformly as possible with the threshold/runway end lights used as the starting reference points. Where a runway is intersected by other runways or taxiways, a semiflush light, type L-850C as described in AC 150/5345-46, should be installed to maintain the uniform spacing for HIRL's. For MIRL's and LIRL's a single elevated edge light should be installed on the runway side opposite the intersection to avoid gaps in excess of 400 feet (122 m) where the matching of lights on opposite sides of the runway cannot be maintained as illustrated in figure 1.

1.18.1.7 Runway end lights

(Refer to 1.10.9.2 for the provision at CKS airport)

ICAO Annex 14, Vol. I Paragraph 5.3.11.3

Recommendation – Runway end lighting should consist of at least 6 lights. The lights should be either:

(a) equally spaced between the rows of runway edge lights; or

(b) symmetrically disposed about the runway center line in two groups, with the lights uniformly spaced in each group, and with a gap between the groups of not more than half the distance between the rows of runway edge lights.

FAA Advisory Circular 150/5340-24

For instrument runways each group of lights contains not less than 4 lights; for other runways, not less than 3 lights.

1.18.1.8 Runway Center Line Lights

(Refer to 1.10.9.3 for the provision at CKS airport)

ICAO Annex 14,Vol.I Paragraph 5.3.12

5.3.12.1 Runway centerline light shall be provided on a precision approach runway category II or III.

5.3.12.7 Runway center line lights shall be fixed lights showing variable white from the threshold to the point 900m from the runway end; alternate red and variable white from 900m to 300m from the runway end; and red from 300m to the runway end, except that for runway less than 1800 m in length, the alternate red and variable white lights shall extend from the mid-point of the runway usable for landing to 300m from the runway end.

FAA Advisory Circular 150/5340-4C

a. Runway Centerline Lighting.

(1) Location. The lights are located along the runway centerline at 50-foot (15 m) intervals as shown in Figure 1. The line of lights is offset a maximum of 2 feet (0.6 m) to either the right or left side of the runway marking and should be to the opposite side of the centerline marking from the major taxiway turnoffs.

(2) Color Coding. The last 3,000-foot (900 m) portion of the lighting system is color coded to warn pilots of the impending runway end. Alternate red and white lights are installed as seen from 3,000 feet (900 m) to 1,000 feet (300 m) from the runway end, and red lights are installed in the last 1,000-foot (300 m) portion.

(3) Displaced Threshold. On runways having centerline lights, the centerline lights are extended into the displaced threshold area. If the displaced area is not used for takeoffs, or if the displaced area is used for takeoffs but is less than 700 feet (110 m) in length, the centerline lights are blanked out in the landing direction. For displaced threshold areas over 700 feet (110 m) in length and used for takeoffs, the centerline lights in the displaced area are circuited separately from the centerline lights in the nondisplaced runway area to permit turning "off" the centerline lights in the displaced area during landing operations. If the displaced threshold area also contains a medium intensity approach light system, the control of the approach lights and displaced threshold area centerline lights are interlocked to insure that when the approach lights are "on" the displaced area centerline lights are "off" and vice versa. If the displaced threshold area contains a high intensity approach lighting system, separate circuiting of the centerline lights in the displaced area is not required since the high intensity approach lights will "wash out" the centerline lights.

1.18.1.9 Stop bar Lights

(Refer to 1.10.10 for the provision at CKS airport)

ICAO Annex 14, Vol. I

Paragraph 5.3.17.1

Stop bar shall be provided at every runway-holding position serving a runway when it is intended that the runway will be used in runway visual range conditions less than a value of 350m, except where:

a) appropriate aids and procedures are available to assist in preventing inadvertent incursions of aircraft and vehicles onto the runway; or
b) operational procedures exist to limit, in runway visual range conditions less than a value of 550m, the number of:
    1) aircraft on the maneuvering area to one at a time; and
    2) vehicles on the maneuvering area to the essential minimum.

Paragraph 5.3.17.2

Recommendation – *A stop bar should be provided at every runway-holding position serving a runway when it is intended that the runway will be used in runway visual range conditions of values between 350m and 550m, except where:*

a) appropriate aids and procedures are available to assist in preventing the inadvertent incursions of aircraft and vehicles onto the runway; or

b) operational procedures exist to limit, in runway visual range conditions less than a value of 550m, the number of:

1) aircraft on the maneuvering area to one at a time; and

2) vehicles on the maneuvering area to the minimum.

Paragraph 5.3.17.3

The provisions of 5.3.17.2 shall apply as a Standard as of 1 January 2001.

Paragraph 5.3.17.4

Recommendation - *A stop bar should be provided at an intermediate holding position when it is desired to supplement markings with lights and to provide traffic control by visual means.*

FAA Advisory Circular

FAA Advisory Circular 150/5340-28, Low Visibility Taxiway Lighting Systems, contains the FAA standards for Stop bars. Stop bars are required for operations below 183m RVR at illuminated taxiways that provide access to the active runway.

1.18.1.10 Runway Guard Lights

(Refer to 1.10.11 for the provision at CKS airport)

ICAO Annex 14, Vol. I Paragraph 5.3.20.1

Runway guard lights, Configuration A, shall be provided at each taxiway/runway intersection associated with a runway intended for use in:

a) runway visual range conditions less than a value of 550m where a Stop

bar is not installed:

b) runway visual range conditions of values between 550m and 1200m

where the traffic density is heavy.

FAA Advisory Circular FAA standards for runway guard lights (RGL) can be found in Advisory Circular 150/5340-28, Low Visibility Taxiway Lighting Systems. RGLs provide a distinctive warning to anyone approaching the runway holding position that they are about to enter an active runway. Elevated and in-pavement runway guard lights serve the same purpose and are generally not both installed at the same runway holding position.

FAA Advisory Circular 120-57A Paragraph 8b (1)(a) requires runway guard lights to be provided when operating below a RVR of 365m.

1.18.1.11 Taxiway Center Line Lights

(Refer to 1.10.12 for the provision at CKS airport)

ICAO Annex 14, Vol. I

Paragraph 5.3.15.1

Taxiway center line lights shall be provided on an exit taxiway, taxiway, de/anti-icing facility and apron intended for use in runway visual range conditions less than a value of 350 m in such a manner as to provide continuous guidance between the runway center line and aircraft stands, except that these lights need not be provided where the traffic density is light and taxiway edge lights and center line marking provide adequate guidance.

Paragraph 5.3.15.2

Recommendation —*Taxiway center line lights should be provided on a taxiway intended for use at night in runway visual range conditions of 350 m or greater, and particularly on complex taxiway intersections and exit taxiways, except that these lights need not be provided where the traffic density is light and taxiway edge lights and center line marking provide adequate guidance.*

Paragraph 5.3.15.4

Taxiway center line lights shall be provided on a runway forming part of a standard taxi-route and intended for taxiing in runway visual range conditions less than a value of 350 m, except that these lights need not be provided where the traffic density is light and taxiway edge lights and center line marking provide adequate guidance.

Note. —See 8.2.3 for provisions concerning the interlocking of runway and taxiway lighting systems.

Paragraph 8.2.3

Where a runway forming part of a standard taxi-route is provided with runway lighting and taxiway lighting, the lighting systems shall be interlocked to preclude the possibility of simultaneous operation of both forms of lighting.

Paragraph 5.3.15.6

Taxiway center line lights on a taxiway other than an exit taxiway and on a runway forming part of a standard taxi-route shall be fixed lights showing green with beam dimensions such that the light is visible only from aero planes on or in the vicinity of the taxiway.

Paragraph 5.3.15.7

Taxiway centerline lights on an exit taxiway shall be fixed lights. Alternate taxiway center line lights shall show green and yellow from their beginning near the runway center line to the perimeter of the ILS/MLS critical/sensitive area or the lower edge of the inner transitional surface, whichever is farthest from the runway; and thereafter all lights shall show green (Figure 5-20). The light nearest to the perimeter shall always show yellow. Where aircraft may follow the same centerline in both directions, all the centerline lights shall show green to aircraft approaching the runway.

Paragraph 5.3.15.8

Taxiway centerline lights shall be in accordance with the specifications of:

a) Appendix 2, Figure 2-12, 2-13, or 2-14 for taxiways intended for use in runway visual range conditions of less than a value of 350 m; and

b) Appendix 2, Figure 2-15 or 2-16 for other taxiways.

Taxiway centerline lights on rapid exit taxiways

Paragraph 5.3.15.10

Recommendation —*Taxiway centerline lights should normally be located on the taxiway centerline marking, except that they may be offset by not more than 30cm where it is not practicable to locate them on the marking.*

Taxiway centerline lights on rapid exit taxiways

Paragraph 5.3.15.11

Recommendation — *Taxiway center line lights on a straight section of a taxiway should be spaced at longitudinal intervals of not more than 30m, except that:*

a) larger intervals not exceeding 60m may be used where, because of the prevailing meteorological conditions, adequate guidance is provided by such spacing;

b) intervals less than 30m should be provided on short straight sections; and

c) on a taxiway intended for use in RVR conditions of less than a value of 350m, the longitudinal spacing should not exceed 15m.

Paragraph 5.3.15.12

Recommendation — *Taxiway center line lights on a taxiway curve should continue from the straight portion of the taxiway at a constant distance from the outside edge of the taxiway curve. The lights should be spaced at intervals such that a clear indication of the curve is provided.*

Paragraph 5.3.15.13

Recommendation —*On a taxiway intended for use in RVR conditions of less than a value of 350m, the lights on a curve should not exceed a spacing of 15m and on a curve of less than 400m radius the lights should be spaced at intervals of not greater than 7.5m. This spacing should extend for 60m before and after the curve.*

Note 1. —Spacing on curves that have been found suitable for a taxiway intended for use in RVR conditions of 350m or greater are:

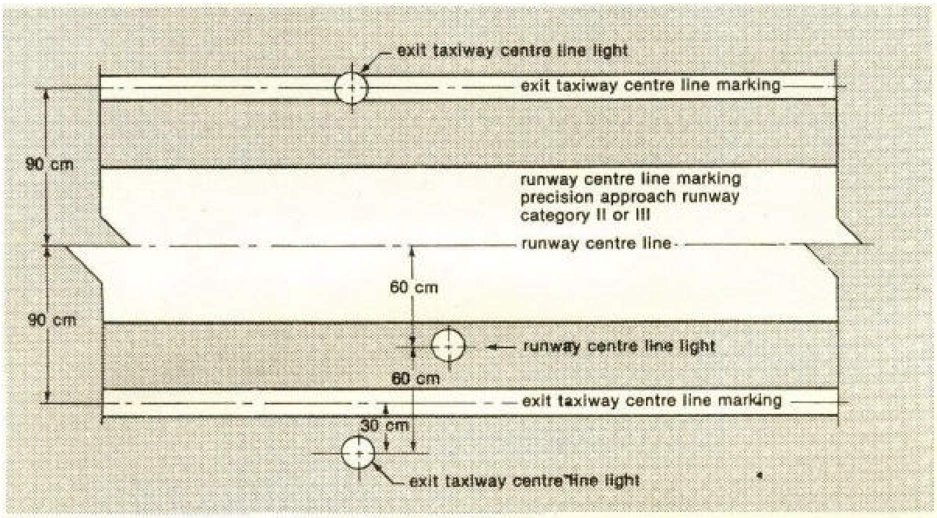
Curve radius *Light spacing*

up to 400m	*7.5m*
401m to 899m	*15m*
900m or greater	*30m*

Taxiway centerline lights on rapid exit taxiways

Paragraph 5.3.15.14

Recommendation —*Taxiway centerline lights on a rapid exit taxiway should commence at a point at least 60m before the beginning of the taxiway centerline curve and continue beyond the end of the curve to a point on the centerline of the taxiway where an aero plane can be expected to reach normal taxiing speed. The lights on that portion parallel to the runway center line should always be at least 60cm from any row of runway center line lights, as shown in Figure 5-21.*



Tolerances for offset runway centre line lights and taxiway centre line lights to maintain 60 cm separation.

Extract from Figure 5-21 of ICAO Annex 14, Vol. I

Paragraph 5.3.15.15

Recommendation —*The lights should be spaced at longitudinal intervals of not more than 15m, except that, where runway center line lights are not provided, a greater interval not exceeding 30m may be used.*

Taxiway centerline lights on other exit taxiways

Paragraph 5.3.15.16

Recommendation — *Taxiway centerline lights on exit taxiways other than rapid exit taxiways should commence at the point where the taxiway centerline marking begins to curve from the runway centerline, and follow the* *curved taxiway centerline marking at least to the point where the marking leaves the runway. The first light should be at least 60cm from any row of runway centerline lights, as shown in Figure 5-21.*

Paragraph 5.3.15.17

Recommendation —*The lights should be spaced at longitudinal intervals of not more than 7.5 m.*

Taxiway centerline lights on runways

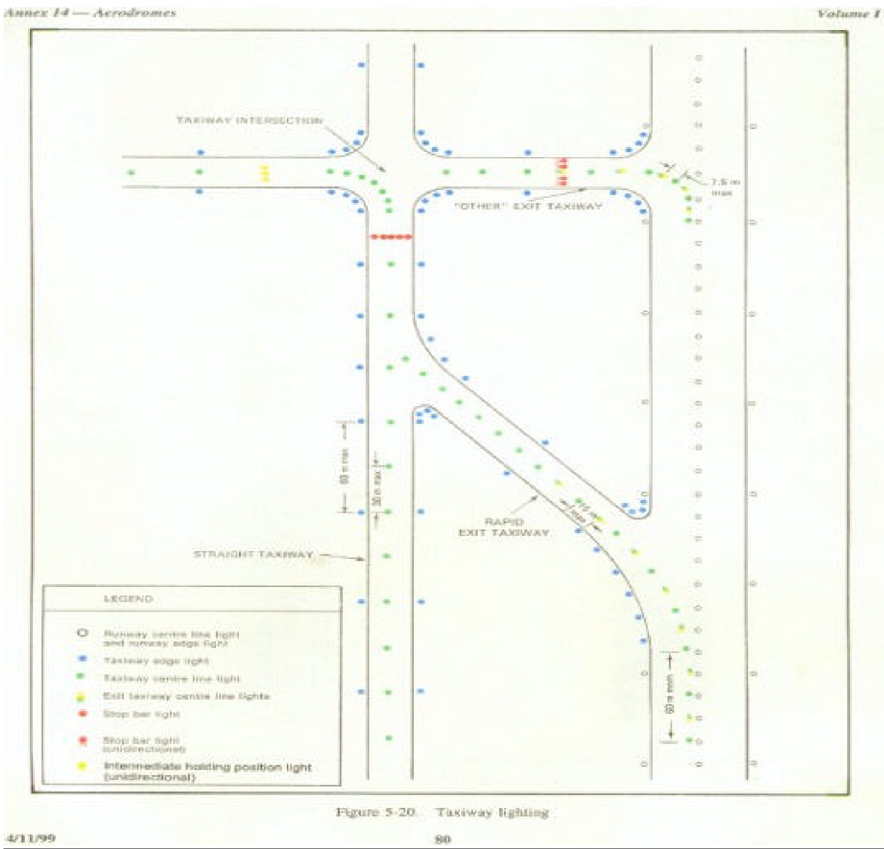
Paragraph 5.3.15.18

Recommendation —*Taxiway centerline lights on a runway forming part of a standard taxi-route and intended for taxiing in runway visual range conditions less than a value of 350m should be spaced at longitudinal intervals not exceeding 15m.*

ICAO Annex 14, Vol. I Appendix 2

Notes for Figure 2-14 and 2-16:

Lights on curves to be toed-in 15.75 degrees with respect to the tangent of the curve.



<u>Extract from Figure 5-20 of ICAO Annex 14, Vol. I</u>

Paragraph 9.4.20

A light shall be deemed to be unserviceable when the main beam average intensity is less than 50 per cent of the value specified in the appropriate figure in Appendix 2. For light units where the designed main beam average intensity is above the value shown in Appendix 2, the 50 percent value shall be related to that design value.

FAA Advisory Circulars

The FAA standards for taxiway centerline lights can be found in Advisory Circular 150/5340-28, Low Visibility Taxiway Lighting Systems. It is recommended that centerline lights continue across a runway for operations below 365m RVR where the taxiway is an often-used route.

When taxiway centerline lights go across a runway, the lights are color-coded green/yellow starting from the center of the runway (Advisory Circular 150/5340-28, paragraph 3b). Spacing on straight section of taxiway where operations are 365m RVR or greater is 30m between lights. When operations occur below 365m RVR, spacing on straight segments is 15m. FAA standards call for lateral spacing of 0.6m from taxiway centerline. Taxiway center line lights which are visible to aircraft exiting the runway ("lead off" lights) are color-coded to warn pilots and vehicle drivers that they are within the runway safety area or ILS critical area, whichever is more restrictive. Alternate green and yellow lights are installed (beginning with green) from the runway center line to one center line light position beyond the runway holding position or ILS critical area holding position, whichever is more critical.

<u>Excerpt from FAA Advisory Circular 150/5340-28</u>

Table 1. Longitudinal Dimensions

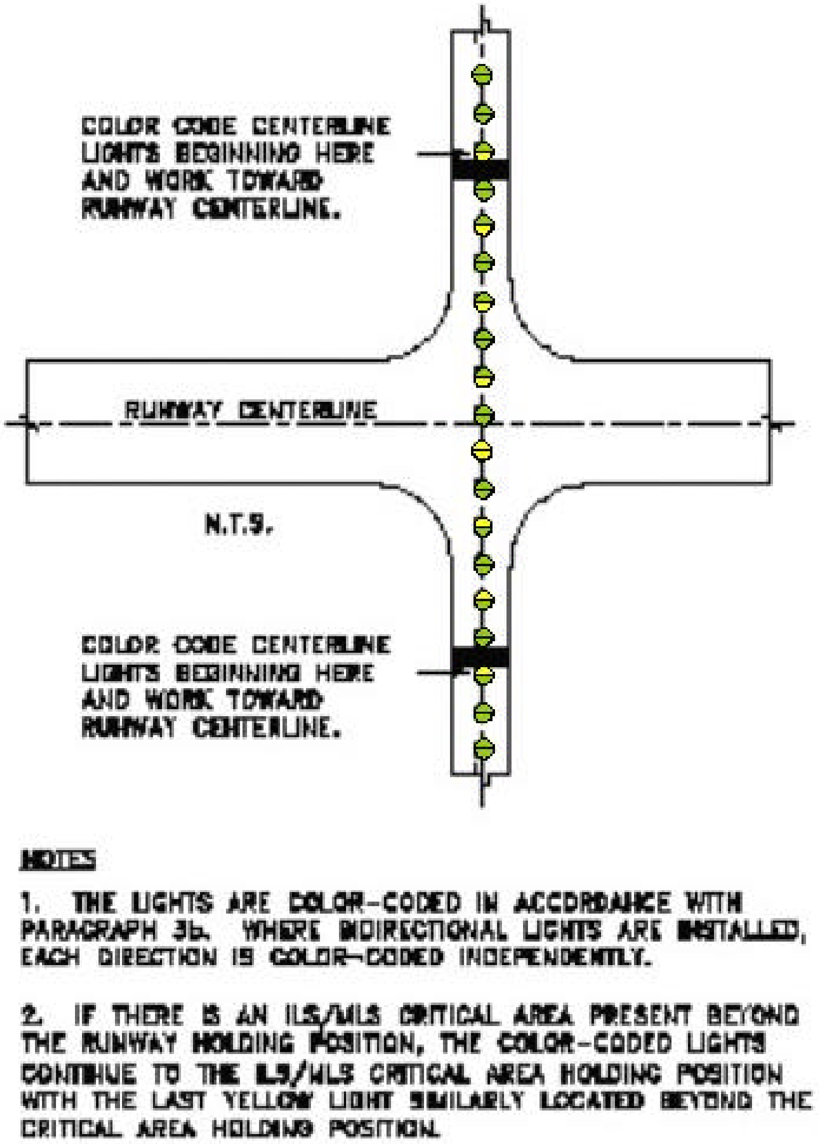
Maximum Longitudinal Spacing Allowed For Taxiway Center Line Lights

	1,200 Feet (365 m) RVR and above	Below 1,200 Feet (365 m) RVR
Radius of Curved Center lines 75ft (23m) to 399ft (121m)	25ft (7.5m)	12.5ft (4m)
400ft (122m) to 1199 ft (364m)	50ft (15m)	25ft (7.5m)
1200ft (365m)	100ft (30m)	50ft (15m)
Acute-Angled Exits (See AC	50ft (15m)	50ft (15m)

150/5300-13)		
Straight Segments	*100ft (30m)	*50ft (15m)

*Short straight taxiway segments may require shorter spacing in accordance with Paragraph 3h (a minimum 4 taxiway center line lights are required).

FAA Advisory Circular 150/5340-28f Paragraph 3f Taxiways Crossing a Runway. At airports where operations below 600 ft (183 m) RVR are conducted, taxiway centerline lights should continue across a runway if they are installed on a designated low visibility taxi route. It is recommended that centerline lights continue across a runway for operations below 1,200 ft (365 m) RVR where the taxiway is an often-used route or there is a jog (i.e. kink) in the taxiway at the intersection with the runway. Otherwise, taxiway centerline lights should not extend into the confines of the runway.



(B) TAXIWAY CROSSING A RUNWAY

1.18.1.12 Circuit Interlocking

(Refer to 1.10.13.1 for the provision at CKS airport)

ICAO Annex 14, Vol. I, Paragraph 8.2.3

Where a runway forming part of a standard taxi-route is provided with runway lighting and taxiway lighting, the lighting systems shall be interlocked to preclude the possibility of simultaneous operation of both forms of lighting.

FAA AC150/5340-24 is being revised to include such a standard.

1.18.1.13 Circuit Monitoring

(Refer to 1.10.13.2 for the provision at CKS airport)

ICAO Annex 14, Vol. I

Paragraph 8.3.3

Recommendation — *For a runway meant for use in runway visual range conditions less than a value of 550 m, the lighting systems detailed in Table 8-1 should be monitored so as to provide an immediate indication when the serviceability level of any element falls below the minimum serviceability level specified in 9.4.26 to 9.4.30, as appropriate. This information should be immediately relayed to the maintenance crew.*

Paragraph 8.3.4

Recommendation — *For a runway meant for use in runway visual range conditions less than a value of 550 m, the lighting systems detailed in Table 8-1 should be monitored automatically to provide an immediate indication when the serviceability level of any element falls below the minimum level specified by the appropriate authority below which operations should not continue. This information should be automatically relayed to the air traffic services unit and displayed in a prominent position.*

FAA Advisory Circular 150/5340-26

Maintenance of Airport Visual Aid Facilities, provides recommended guidelines for maintenance of airport visual aid facilities.

1.18.1.14 Mandatory Instruction Signs

(Refer to1.10.14 for the provision at CKS airport)

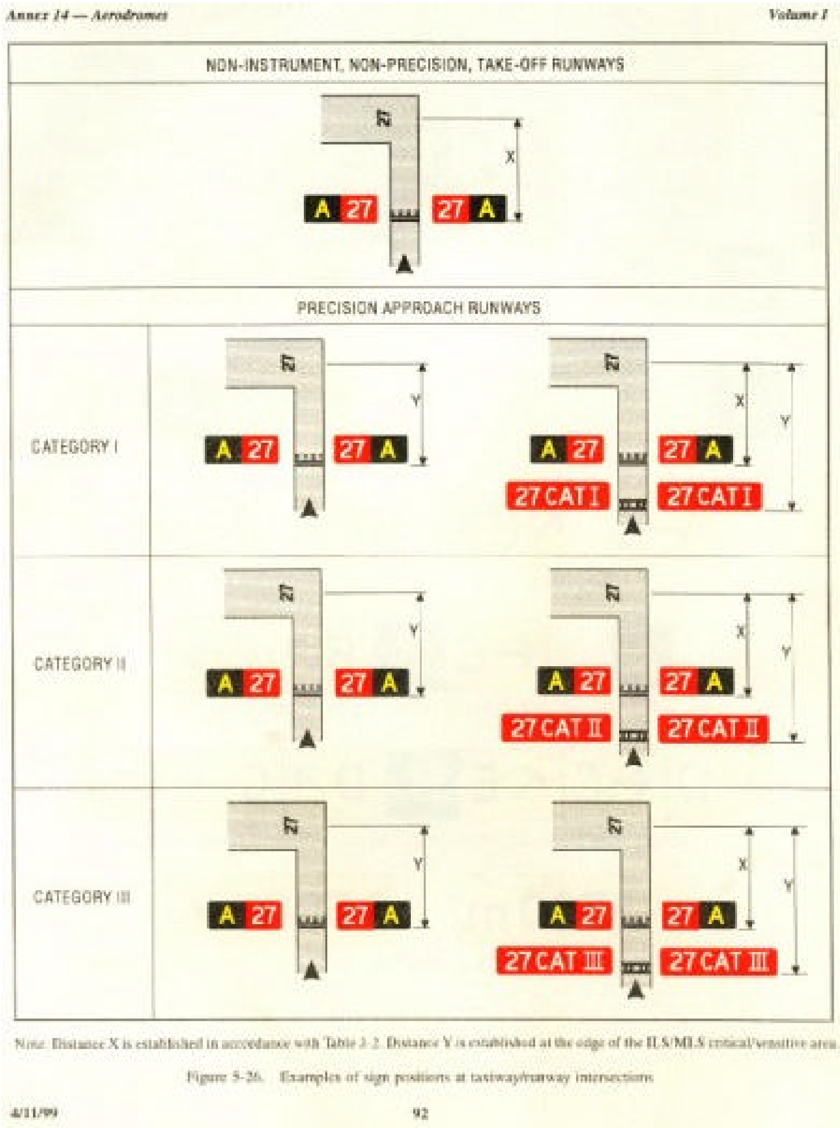
ICAO Annex 14, Vol. I

Paragraph 5.4.1.6

The inscriptions on a sign shall be in accordance with the provisions of Appendix

Paragraph 5.4.2

See Figure below for example of locating signs at taxiway/runway intersections.



Extract from Figure 5-26 of ICAO Annex 14, Vol. I

Paragraph 5.4.2.8

A runway designation sign at a taxiway/runway intersection or a runway/runway intersection shall be located on each side of the runway-holding position marking facing the direction of approach to the runway.

ICAO Annex 14, Vol. I Paragraph 5.4.2.9

A category I, II, III holding position sign shall be located on each side of the runway-holding position marking facing the direction of the approach to the critical area.

ICAO Annex 14, Vol. I Paragraph 5.4.2.12

Existing installations need not meet the requirement of 5.4.2.8, 5.4.2.10, and 5.4.2.11 to provide a sign on each side of the taxiway until 1 January 2001.

ICAO Annex 14, Vol. I Paragraph 5.4.2.14
The inscription on a runway designation sign shall consist of the runway designations of the intersecting runway properly oriented with respect to the viewing position of the sign, except that a runway designation sign installed in the vicinity of a runway extremity may show the runway designation of the concerned runway extremity only.

ICAO Annex 14, Vol. I Paragraph 5.4.2.15
The inscription on a category I, II and III or joint II/III holding position sign shall consist of the runway designator followed by CAT I, CAT II, CAT III or CAT II/III, as appropriate.

FAA Advisory Circular
FAA Advisory Circular 150/5340-18C, Standards for Airport Sign Systems, contains the standards for the type of signs, the size of the signs and the location of the signs. The airfield signs may be one of three sizes, with the largest being approximately 1m high.

The size 3 signs are set back from the taxiway or runway edge 10.5 – 18m. Unless the taxiway or runway is wider than 45m, a single mandatory hold sign (white numbers on a red background) is installed on the left side of the taxiway or runway intersection. When the taxiway or runway is wider than 45m, then a mandatory sign shall be placed on both sides of the taxiway or runway. These mandatory hold signs are collocated with holding position lines and may be a maximum of ±3m in front of or after the holding position marking.

Mandatory ILS signs are to be used only where necessary to hold aircraft or vehicles outside the instrument landing system critical area and would be collocated with the ILS holding position marking. Where the distance the runway hold line and the hold line for an ILS critical area is 15m or less, a mandatory runway hold sign may be installed, provided it will not affect capacity, by moving the runway hold line and its corresponding mandatory hold sign back to the ILS hold line position. FAA standards do not allow ILS signs on one side of a taxiway and a mandatory hold sign with runway designations on the other side of the taxiway.

FAA AC150/5340-18C – FAA standards call for signs to be oriented so that the face is perpendicular to the centerline of the taxiway or runway. For special situations where visibility would be improved, single sided signs may be canted.

1.18.1.15 Pavement Improvement on Runway 05R/23L

(Refer to 1.10.15.2 for the provision at CKS airport)

ICAO Airport Services Manual, Part 8 – Airport operational services

ICAO Airport Services Manual, Part 6 – Control of obstacles

FAA Advisory Circular 150/5370-2C – Operational Safety On Airports During Construction

1.18.1.16 Closed Runways or Taxiways, or parts thereof

(Refer to 1.10.16 for the provision at CKS airport)

ICAO Annex 14, Vol. I

Paragraph 7.1.1

A closed marking shall be displayed on a runway or taxiway, or portion thereof, which is permanently closed to the use of all aircraft.

Paragraph 7.1.2

Recommendation —*A closed marking should be displayed on a temporarily closed runway or taxiway or portion thereof, except that such marking may be omitted when the closing is of short duration and adequate warning by air traffic services is provided.*

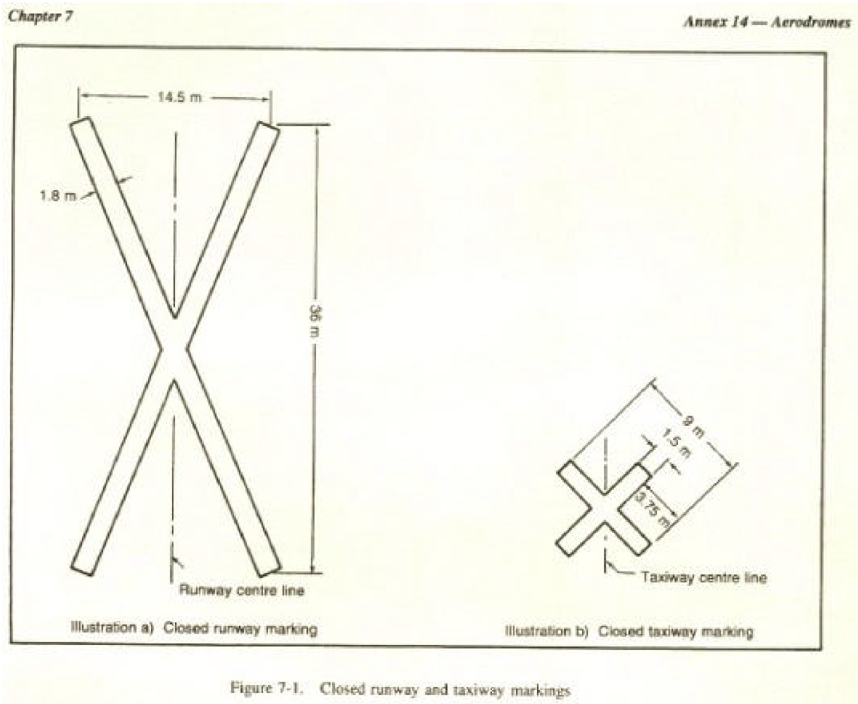
Paragraph 7.1.3

On a runway a closed marking shall be placed at each end of the runway, or portion thereof, declared closed, and additional markings shall be so placed that the maximum interval between markings does not exceed 300 m. On a taxiway a closed marking shall be placed at least at each end of the taxiway or portion thereof closed.

Paragraph 7.1.4

The closed marking shall be of the form and proportions as detailed in Figure 7-1, Illustration a), when displayed on a runway, and shall be of the form and proportions as detailed in Figure 7-1, Illustration b), when displayed on a taxiway. The marking shall be white when displayed on a runway and shall be yellow when displayed on a taxiway.

Note —When an area is temporarily closed, frangible barriers or markings utilizing materials other than paint or other suitable means may be used to identify the closed area.



Extract from ICAO Annex 14, Vol. I Figure 7-1

Paragraph 7.1.5

When a runway or taxiway or portion thereof is permanently closed, all normal runway and taxiway markings shall be obliterated.

Paragraph 7.1.6

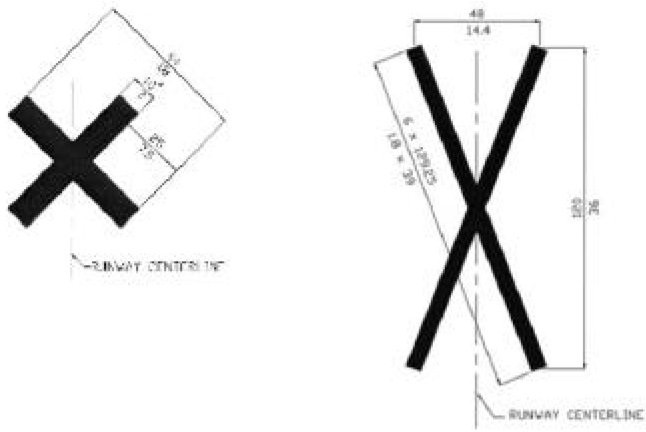
Lighting on a closed runway or taxiway or portion thereof shall not be operated, except as required for maintenance purposes.

Paragraph 7.1.7

In addition to closed markings, when the runway or taxiway or portion thereof closed is intercepted by a usable runway or taxiway, which is used at night, unserviceability lights shall be placed across the entrance to the closed area at intervals not exceeding 3 m (see 7.4.4).

FAA Advisory Circular 150/5340-1H – STANDARDS FOR AIRPORT MARKING

Paragraph 40. MARKING AND LIGHTING OF PERMANENTLY CLOSED RUNWAYS AND TAXIWAYS. For runways and taxiways that have been permanently closed, the lighting circuits are disconnected. The runway threshold, runway designation and touchdown zone markings are obliterated and solid, not striated, yellow crosses are placed at each end and at 300m intervals. If the closed runway intersects an open runway, crosses should be placed on the closed runway on both sides of the open runway. For taxiways, a yellow cross is placed on the closed taxiway at each entrance. The crosses shown in Figures 20a and 20c are normally used, but the crosses shown in Figures 20b and 20d are more readily seen from aircraft on final approach and may be used. (See following figures)

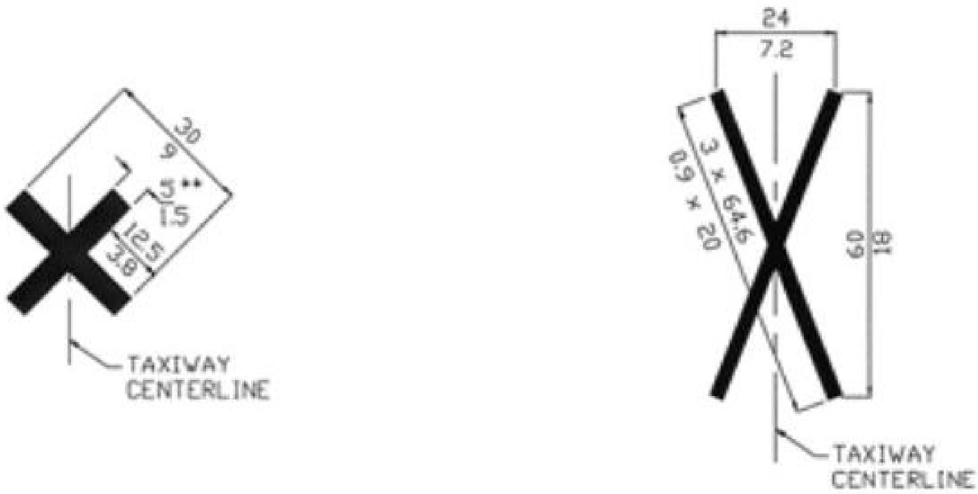


(A) CLOSED RUNWAY (B) ALTERNATE CLOSED RUNWAY

DIMENSIONS ARE EXPRESSED THUS: FEET/METERS e.g., 10/3.

FOR TEMPORARY X's THIS DIMENSION MAY BE CHANGED TO 8 FEET

NOTE: X'S ARE ALWAYS YELLOW



(C) CLOSED TAXIWAY (D) ALTERNATE CLOSED TAXIWAY

Extract from Figure 20 of FAA Advisory Circular 150/5340-1H

TEMPORARILY CLOSED RUNWAYS AND TAXIWAYS.

When it is necessary to provide a visual indication that a runway is temporarily closed, crosses are placed only at each end of the runway on top of the runway designation markings or just off the runway end when required by construction activity. The crosses are yellow in color and conform to the dimensions specified in the advisory circular. Since the crosses are temporary, they are usually made of some easily removable material, such as plywood or fabric rather than painted on the pavement surface. Any materials used for temporary crosses should provide a solid appearance. Since these crosses will usually be placed over white runway markings, their visibility can be enhanced by a 15 cm black border.

A raised-lighted cross may be placed on each runway end in lieu of the markings described to indicate the runway is closed. Normally the raised-lighted cross would be located on the runway; however, it may be located in the safety area on the extended runway centerline.

Temporarily closed taxiways are usually treated as hazardous areas. However, as an alternative, a yellow cross that conforms to the dimensions in figure 20 may be installed at each entrance to the taxiway.

If the runway or taxiway will be closed during nighttime, the runway lights will normally be disconnected so that they cannot be illuminated unless such illumination is needed to perform maintenance operations on or adjacent to the runway.

1.18.1.17 Unserviceable Areas

(Refer to 1.10.17 for the provision at CKS airport)

ICAO Annex 14, Vol. I

Note to 7.1.4. —When an area is temporarily closed, frangible barriers or markings utilizing materials other than paint or other suitable means may be used to identify the closed area.

Paragraph 7.4.1

Unserviceability markers shall be displayed wherever any portion of a taxiway, apron or holding bay is unfit for the movement of aircraft but it is still possible for aircraft to bypass the area safely. On a movement area used at night, unserviceability lights shall be used.

Note —Unserviceability markers and lights are used for such purposes as warning pilots of a hole in a taxiway or apron pavement or outlining a portion of pavement, such as on an apron that is under repair. They are not suitable for use when a portion of a runway becomes unserviceable, or on a taxiway when a major portion of the width becomes unserviceable. In such instances, the runway or taxiway is normally closed.

Paragraph 7.4.2

Unserviceability markers and lights shall be placed at intervals sufficiently close so as to delineate the unserviceable area.

Note — Guidance on the location of unserviceability lights is given in Attachment A, Section 13.

Paragraph 7.4.3
Unserviceability markers shall consist of conspicuous upstanding devices such as flags, cones or marker boards.

Paragraph 7.4.4
An unserviceability light shall consist of a red fixed light. The light shall have intensity sufficient to ensure conspicuity considering the intensity of the adjacent lights and the general level of illumination against which it would normally be viewed. In no case shall the intensity be less than 10 cd of red light.

FAA AC 150/5370-2C – OPERATIONAL SAFETY ON AIRPORTS DURING CONSTRUCTION.
Temporarily closed taxiways are usually treated as hazardous areas. However, as an alternative, a yellow cross that conforms to the dimensions in figure 20 may be installed at each entrance to the taxiway.

Hazardous areas, in which no part of an aircraft may enter, are indicated by use of barricades with alternate orange and white markings. The barricades are supplemented with orange flags at least 20 by 20 inches (50 by 50 cm) square and made and installed so that they are always in the extended position and properly oriented. For nighttime use, the barricades are supplemented with flashing yellow lights. The intensity of the lights and spacing for barricades, flags, and lights must be such to delineate adequately the hazardous area.

1.18.1.18 Surface Movement Guidance and Control System (SMGCS)

(Refer to 1.10.18 for the provision at CKS airport)

ICAO Annex 14, Vol. I

Paragraph 8.9.1
A surface movement guidance and control system shall be provided at an aerodrome.

Note —Guidance on surface movement guidance and control systems is contained in the Manual of Surface Movement Guidance and Control Systems (SMGCS).

Paragraph 8.9.2

Recommendation —*The design of a surface movement guidance and control system should take into account:*

a) the density of air traffic;
b) the visibility conditions under which operations are intended;
c) the need for pilot orientation;
d) the complexity of the aerodrome layout; and
e) movements of vehicles.

Paragraph 8.9.3

Recommendation — *The visual aid components of a surface movement guidance and control system, i.e. markings, lights and signs should be designed to conform with the relevant specifications in 5.2, 5.3 and 5.4, respectively.*

Paragraph 8.9.4

Recommendation — *A surface movement guidance and control system should be designed to assist in the prevention of inadvertent incursions of aircraft and vehicles onto an active runway.*

FAA Advisory Circular 120-57A

A SMGCS plan should be developed for an airport where scheduled air carriers are authorized to conduct operations when the visibility is less than 1 200 feet (350 m) visual range. Each plan should describe the low visibility operation and taxi route along with the appropriate equipment and facilities on the airport or planned for the airport. It should also identify the responsibilities of those involved, such as Air Traffic Control, the airport operator, aircraft rescue and fire fighting units. Runway guard lights should be installed at all taxiways that provide access to an active runway, regardless of whether they are part of the low visibility taxi route. Because of the complexity of visual aids and facilities associated with the surface movement and guidance control system operations, the SMGCS plan becomes extremely important as it will dictate what type of equipment will be installed, how it will be operated and who will operate it.

1.18.1.19 Maintenance of Visual Aids

(Refer to 1.10.19 for the provision at CKS airport)

ICAO Annex 14, Vol. I

Paragraphs 9.4.20 and 9.4.32

ICAO Airport Services Manual, Part 9 – Airport Maintenance Practices

Various FAA advisory circulars contain maintenance standards and practices:

1. Advisory Circular 150/5340-21Airport Miscellaneous Lighting Visual Aids describes standards for the system design, installation, inspection, testing, and maintenance of airport miscellaneous visual aids; i.e., airport beacons, beacon towers, wind cones, wind tees, and obstruction lights.
2. Advisory Circular 150/5340-24, Runway and Taxiway Edge Lighting System describe standards for the design, installation, and maintenance of runway and taxiway edge lighting.
3. Advisory Circular 150/5340-26, Maintenance of Airport Visual Aid Facilities, provides recommended guidelines for maintenance of airport visual aid facilities. ”

1.18.1.20 Black Outline Markings

(Refer to 1.10.20 for the provision at CKS airport)

ICAO Annex 14, Vol. I Paragraph 5.2.1.4.

Note 1 - It has been found that on runway surfaces of light color, the conspicuity of white markings can be improved by outlining them in black.

ICAO Annex 14, Vol. I Paragraph 5.2.1.5.

Recommendation – At aerodromes where operations take place at night, pavement markings should be made with reflective materials designed to enhance the visibility of the markings.

The standards found in FAA Advisory Circular 150/5340-1H, Standards for Airport Markings require glass beads in all runway and taxiway holding position markings, runway threshold markings, runway threshold bars, runway aiming point markings, runway touchdown zone markings, runway centerline markings, taxiway centerline markings, geographical position markings, surface painted signs, and non-movement area boundary markings. Glass beads are recommended for the runway side stripes, taxiway edge markings, displaced threshold markings, and demarcation bars.

The contrast of markings on light colored pavements can be increased by outlining them with a black border at least 15cm in width. This is a particularly effective means of highlighting holding positions markings and taxiway centerlines. All runway holding position markings on light-colored pavements are to be outlined with a black border. This procedure is required on concrete pavement surfaces and light-colored asphalt surfaces.

1.18.2 Videotapes Regarding Crash Scene (Appendix 4-42)

1.18.2.1 Videotape Provided by Passenger

Provider is a passenger sat in the upper deck row 12 of CI-004 flight (a China Airlines' Boeing 747-400) during the time of the occurrence. CI-004 airplane was pushed back from Gate A5 and taxiing along NP toward N1 during the crash. The videotape showed the crashed aircraft was burning on the runway. Passengers were escaping from the broken tail section. The taxiing aircraft then turned into and parked at gate A8. Duration of the recording is approximately one minute.

1.18.2.2 Videotapes Provided by CKS Airport Office

Terminal video camera number 66 was located at the building of gate A6 facing apron and NP taxiway. The time shown on the frame of the SQ aircraft explosion and fuming was at 23:16:35 in the screen while CI004 aircraft appeared in the screen with same background was at 23:18:03. Elapsed time was 1' 28".

Terminal videotape taken from camera number 77 located at the roof of the building between gate A6 and A5 showed the Runway 05R edge light being turned on and off during a test conducted on November 08, 2000.

Camera number 78 located at gate A7 and A8 shot same scene with same background alternately with camera number 77.

IV. Appendices

4-1	Safety Regulations for the Contractors of CKS airport.
4-2	Letter for Repairing NS Taxiway Surface
4-3	Questionnaire & CAA's Answer Letter of clarification and feedback of airport group raised queries from CAA and CKS
4-4	Materials Test Report on Runway Light Pigtail (ARL/CSIST)
4-5	Analysis of Runway Lighting Secondary Cable Assemblies (ATSB)
4-6	NOTAM A0605, NOTAM A0606 AIP SUP A003, AIP SUP A004
Following Documents may be needed for later references in analysis.	
4-7	ICAO Annex 14 version 1971,version 1999
4-8	AC 150/5370-2C Operational safety on airport
4-9	AC NO 150/5340-1D Standards for marking serviceable runways and taxiways as well as deceptive, closed and hazardous area on airports
4-10	AC 150/5340-1H-Standards for airport markings
4-11	AC 70/7460-1J-obstmction marking and lighting
4-12	Subpart C-Obstruction Standards
4-13	05R/23L Runway（N4-N5 Taxiway Repairing Diagram）
4-14	Flight Safety Standards and Aerodrome Surrounding Construction Restrictions
4-15	Aerodrome Civil Engineering Design Standard and Spec.
4-16	Technical Spec for Airport Engineering Vol.1, 1990/6
4-17	Technical Spec for Airport Vol.2, 1990/6
4-18	RCTP 2.20 TPE/CKS Flight Rules
4-19	2000/2/17 Minutes of Meeting (1) on CKS 05R/23L Conversion
4-20	Minutes of Meeting (2) on CKS 05R/23L Conversion
4-21	Letter of Agreement for CKS 05R/23L Conversion
4-22	Follow Up Measures Meeting for CKS 05R/23L Conversion (2000/05/08)
4-23	Follow Up Measures Meeting for CKS 05R/23L Conversion

	(2000/09/25)
4-24	Letter to Convert 05R to NC (2000/10/20)
4-25	Letter to CAA Procurement Authorization
4-26	Denominating Meeting for Perpendicular Taxiway
4-27	Daily Record for CKS Runway/Taxiway/Apron and surrounding security inspections
4-28	Letter of Improving Runway/Taxiway/Apron and terminal building facilities
4-29	Letter of Flight Safety Inspections
4-30	Letter of Recheck on Flight Safety Inspections
4-31	Airfield lighting system technical specifications
4-32	CKS Airfield Lighting Layout Drawing
4-33	CKS Airport Construction Details.
4-34	List of Fu Rong Contractor' s Equipment on05R
4-35	AWO System EXCO/VIS/RVR Conversion Chart
4-36	Layout of Airfield signs at CKS airport
4-37	Airfield Lighting Control Circuit Drawing
4-38	Airfield Lighting Control Panel for Control Tower
4-39	CKS FOS & ANWS MOU
4-40	Interview Record with CAA Officials on Nov.7, 2000
4-41	Interview Record with CKS Airport Officials on Nov.8, 2000
4-42	Videotape provided by CI004 passenger and CKS airport authority.
4-43	Surface Movement Guidance and Control System
4-44	Coordination with Mr Jim Foot of TSB regarding wire test
4-45	Interview summaries with CAA Officials and Airport Office

Aviation Safety Council
Taipei, Taiwan

SQ006 Accident Investigation

Factual Data Collection

Group Report

Aircraft Systems Group

February 21, 2001

ASC-FRP-01-01-005

I. Team Organization

Chairman:
Phil Tai Group Chairman, ASC
Members:
1. Keng Hwa Aeronautical Engineer, ASC
2. Steven Magladry Aerospace Engineer, Aircraft Systems, NTSB
3. Loke Kwai Yue Vice President, Line Maintenance (OPS), SIA,MCIT
4. Leck Tea Kiang Base Maintenance Superintendent, SIA,MCIT
5. Mike Bartron Flight Safety Officer, Commercial Engines, P&W
6. Dwight Johnson Customer Service Representative, P&W
7. Simon Lie Air Safety Investigator, BCAG

II. History of Activities

Date	Activities
11/03/00	1. Identified major system components 2. Assisted Ground Ops Group in mapping and identification of debris.
11/04/00	Continued with identified major system components including PVDS, the Para Visual Display System
11/05/00	Break
11/06/00	1. Reviewed 30 days of Tech Log prior to date of accident 2. FDR data analysis
11/07/00	1. Discovered last piece of left wing trailing edge flaps track drive unit with jackscrew at pit #1. 2. Issue raised by Survival Factors Group regarding PEEPLS (Passenger Emergency Escape Path Light System)
11/08/00	PEEPLS battery test.
11/09/00	PEEPLS function check.

III. Factual Description

Detailed description of the damages are shown in Appendices 5-1 to 5-6.

1.3 Damage to aircraft

1.3.1 General

Aft fuselage was intact in general. Mid and forward portion of the fuselage, except the radome, were seriously damaged by fire. Cockpit instruments and panels were consumed by fire; the control quadrant with all four thrust levers was recovered. All landing gears and tires were identified.

The left wing, right wing, and forward fuselage were found intact but heavily damaged by fire. The left wing outboard section, right wing, and forward fuselage section were almost totally consumed by the fire while the left wing inboard section suffered less fire damage. Molten aluminum present in the forward fuselage showed vertical drip patterns. Airframe skin and structure components were scattered along the runway over the crash site.

1.3.2 Fuselage and Systems

All system components from the nose of the airplane to the wheel well were consumed by fire, except those components that separated prior to the airplane coming to rest. Surviving components included avionics equipment and wire bundles from the main equipment center(MEC) as well as pressurization and air conditioning components from the pack bay areas. Those components that departed and were found closer to the threshold .

The MEC compartment had separated from the airframe and several control boxes were found in a small area near N5/N6 taxiway, including the quick access recorder.

1.3.3 Power plant

The No. 2 engine was extensively damaged by impact force and the post crash fire. None of the four engines exhibited any indication of an uncontained disk / blade separation, or of fire prior to impact.

?? **Engine Number 1, Serial Number 727545**

The fan inlet, fan cowling, and lower half of both thrust reversers were missing from the engine. The fan inlet and spinner, along with thrust reverser and cowling debris, were found approximately 100 yards behind the engine core along the takeoff path. The fan case was fractured circumferentially and split open between 5:00 and 2:00 o'clock position. Two steel reinforcing bars, from the runway construction area, were driven axially through the fan case flanges at the 5:00 and 6:00 positions. Four fan blades were missing from the fan hub, and three blades were fractured roughly mid-span. The remaining fan blades displayed severe leading edge impact damage and were bent slightly opposite the direction of rotation. The fan case rubstrip material was severely gouged and missing around the entire circumference of the fan case. The low-pressure compressor (LPC) was crushed axially rearward by the fan hub, thereby exposing the stages of LPC blades and vanes. The LPC did not exhibit any signs of pre-impact distress.

The engine gearbox was fractured open along the bottom surface. The low-pressure turbine (LPT) case cooling tubes were crushed against the LPT case. Otherwise, the engine core remained intact.

The pylon structure remained attached to the engine; however, the pylon structure separated vertically just aft of the rear engine mount.

The turbine exhaust case (TEC) was crushed radially inward between 10:00 and 2:00 o'clock positions. Steel reinforcing bar, from the runway construction area, was found lodged in the lower portion of the core cowl doors. The exhaust nozzle was missing. The exhaust plug displayed impact damage at the aft tip in an upward direction.

?? **Engine Number 2, Serial Number 727632**

The entire engine nacelle, fan module, LPC module, and turbine exhaust case (TEC) were missing from the engine core. The fan case and TEC were found roughly 150 yards behind the engine core along the takeoff path.

The fan hub and LPC drum rotor were located 150 yards further down the takeoff path. The inlet cone remained attached to the fan hub and exhibited puncture damage. The fan blades that remained in the fan hub, as well as the blades that remained in the LPC drum rotor, were all severely bent opposite the direction of rotation. The coupling for the fan hub to low-rotor (N1) shaft was captured inside the LPC drum rotor, along with an 8" section of N1 shaft still attached to the coupling. The shaft fracture surface on the section captured within the LPC drum rotor displayed rotational and bending distress, consistent with the damage on the intermediate case. The No. 1 bearing remained attached to the fan hub; while the No. 1 bearing rear support fractured at the forward mounting flange. Fragments of the No. 1 bearing rear support were found resting in the LPC drum rotor.

The forward engine mount remained attached to the intermediate case.

The engine pylon was severed just aft of the forward engine mount location. The intermediate case struts were all fractured from the intermediate case. The No. 1.5 bearing support was fractured and deformed radially outward from 12:00 to 6:00 o'clock position. The low-rotor (N1) shaft was fractured in plane with the towershaft drive gear and exhibited a bending in a direction consistent with the No. 1.5 bearing support. The 4th stage stators were crushed or missing between the 12:30 and 6:00 o'clock positions. The angle gearbox remained attached to the intermediate case.

The main gearbox, oil tank, and externals remained attached to the engine core. Soot from an external fire was found across the majority of the engine core.

The low-pressure turbine (LPT) blades from stages 4, 5, and 6 were fractured just above the platform. The outer air seals and LPT case showed signs of blade fracture during rotation, consistent with fan and LPC damage. The No. 4 bearing surface on the N1 shaft did not show signs of distress.

?? **Engine Number 3, Serial Number 727705**

Portions of the fan inlet, between 3 inches and 24 inches long axially, remained attached to the fan case, primarily between 10:00 and 4:00. The fragments that remained attached were bent inward toward the engine core. The inlet cone was crushed axially rearward, not showing a singular impact point, but rather a broad crushing rearward. The fan case cowling was missing from the engine.

The thrust reversers, core cowling, exhaust nozzle and tailcone, and the entire engine pylon remained attached to the engine. The inboard side of the thrust reverser exhibited scrape marks from 6:00 to 10:00 o'clock position, with significant scraping damage around the 7:30 position.

The rear drag link remained attached to the engine pylon, with the rear clevis exhibiting a bending in the direction away from the aircraft centerline.

The rear stages of the low-pressure turbine did not exhibit any signs of blade and vane failure. The exhaust nozzle and tailcone were undeformed.

?? **Engine Number 4, Serial Number 727634**

The fan inlet remained attached to the engine, with only three impact marks on the inlet leading edge. The fan blades were found straight and with minor leading edge marks and tip curling. The fan rub strip showed heavy rubbing around the 6:00 position. The fan cowling and thrust reverser cowling displayed several fractures and broad impact marks, many with dirt and grass lodged in the fractures. The lower surfaces of the thrust reversers displayed ground scrapes. The lower rear surface of the core cowl also exhibited ground scrape marks and was crushed radially inward.

The same radially inward crushing was found on the top of the turbine exhaust case. The rear engine mount remaining attached to the engine and engine pylon. The 6th stage low-pressure turbine blades were fractured above the platform.

The exhaust nozzle and tailcone were missing from the engine, and found roughly 20 yards from the engine.

The engine pylon and rear drag link remained attached to the engine. The drag link displayed ground scraping on the 6:00 position, along nearly the entire length of the link.

1.3.4 Flight Controls

1.3.4.1 Left Wing

The left wing had substantial fire damage to the outboard section and lesser fire damage to the inboard section. The flap surfaces and flap tracks departed the wing and were found as noted in the wreckage distribution chart. The inboard aileron surface and actuator departed the wing and were not recovered. The spoiler surfaces were consumed by the fire. All spoiler PCU's except #2 were identified and were either still attached or in the vicinity of the normally installed position. The outboard 25 feet of the wing separated from the remainder of the wing and was found as indicated in the wreckage distribution chart. The outboard aileron surface and actuator separated from the wing. The surface was found as indicated in the wreckage distribution chart, but the actuator was not recovered. The outboard aileron lockout mechanism was found lodged in the side of the section 48 as indicated by the wreckage distribution chart. The lockout actuator separated from the mechanism and was found further up the runway (closer to the threshold) as indicated in the wreckage distribution chart.

1.3.4.2 Right Wing

The right wing had substantial fire damage, and all control surfaces were consumed by fire. The two inboard flap tracks and two outboard flap tracks and jackscrews were still in the correct location relative to the wing. The inboard aileron PCU was found still attached to the wing structure. The #7 spoiler PCU was found in the area of the as installed location. The #8 - #12 spoiler PCU's, and outboard aileron PCU were attached to the rear spar in the normal locations. The outboard aileron lockout mechanism was consumed by fire.

1.3.4.3 Horizontal Stabilizer

The horizontal stabilizer trim actuator mechanism and jackscrew showed no visual signs of damage. The right horizontal stabilizer showed only minor fire damage. Approximately 15 feet of the outboard portion of the left horizontal stabilizer separated and was located as shown in the wreckage distribution chart.

1.3.4.4 Elevator

The elevator feel actuators and quadrant were not visibly damaged. The right elevator received only minor fire damage and the actuators and linkages not examined. The left inboard elevator PCU was found attached to the rear spar of the horizontal stabilizer, in that portion still attached to the stabilizer box in the section 48. The outboard elevator PCU was attached to the rear spar of the horizontal stabilizer in that portion which separated and was located as indicated above.

1.3.4.5 Vertical Stabilizer and Rudder

The vertical stabilizer and rudder received only minor fire damage. The rudder actuation components were not examined.

1.3.5 PVD Computer

The para visual display computer was found damaged with some electronic parts separated.

1.6 Aircraft Information

1.6.1 Airworthiness and Maintenance

1.6.1.1 Airworthiness

The Maintenance Logs were showed in Appendices 5-8 and 5-9.

1.6.1.2 Aircraft Maintenance

No related defects were found in the 30 days of Tech Log Entries (Appendix 5-9).

1.6.2 Basic Information

1.6.2.1 Power Plant

Position	1	2	3	4
Serial number:	727545	727632	727505	727634
Total time (hours)	21,392	18,503	24,903	18,503
Total cycles	2,799	2,280	3,374	2,280
Time since overhaul(hours)	665	*	659	*
Cycles since overhaul	93	*	91	*
Time since installed (hours)	665	18,503	659	18,503
Cycles since installed	93	2,280	91	2,280
Date of installation	15 Sep. '00	4 Dec. '96	16 Sep '00	4 Dec. '96
* Engines on-wing since aircraft delivery				

1.16 Tests and Research

The function of the Passenger Emergency Evacuation Path Lighting System (PEEPLS) has been tested using a new battery provided by the operator. Test result showed 4 battery packs removed from the aft fuselage were fully discharged. Test report is shown as Appendix 5-10.

1.18 Additional Information

1.18.1 Para Visual Display System

The PVD system provides pilots with visual indication of airplane deviation from the runway centerline during poor visibility conditions when the aircraft is in a take off configuration. The PVD will unshutter (become visible) when selected on and all of the following conditions are met: the airplane is within the valid localizer region, the airplane heading is within 45 degrees of runway heading, and the radio altitude is less than 5 feet. The valid localizer region is that area within 2 degree of the localizer beam centerline. Once the PVD becomes active, the valid localizer increases to that area within 3.2

degree of the localizer centerline.

The PVD computer processes guidance commands from the Flight Control Computers(FCC), which provide a data bus to the PVD computer: PVD enable, PVD guidance command, PVD sensor fail, in the air and ground test inhibit signals are contained on the data bus. The PVD enable signal ensures the airplane is in a valid localizer region. For detailed description of PVD, see Appendix 5-11.

IV. Appendices

5-1	Field Notes, SGMR-1 (Keng)
5-2	Field Notes, SGMR-2 (Steve)
5-3	Field Notes, SGMR-3 (Mike)
5-4	Field Notes, SGMR-4 (Loke)
5-5	Reference-efile(Simon)
5-6	Reference-1(Simon)
5-7	Reference-2(Wen Cheng Bin)
5-8	9V-SPK 30 day' s Tech Log
5-9	30 day' s Tech Log Entry
5-10	PEEPLS Wiring Diagram and TEST Report
5-11	Para Visual Display System

Aviation Safety Council

Taipei, Taiwan

SQ006 Accident Investigation Factual Data Collection Group Report

Survival Factors Group

February 22, 2001

ASC-FRP-01-01-006

I. Team Organization

Chairman:
James Fang Aviation Safety Investigator, ASC
Members:
1. Pei-Da Lin Engineer, ASC
2. Lin Yon-ching Instructor Chief ,Emergency Training, China Airlines
3. Azone Lee Assistant Engineer, ASC
4. C. H. Cheah Senior Manager Safety Training, Singapore Airlines
5. Ang Guan Hin Commander,(Changi)Airport Emergency Service Division, CAAS
6. Cynthia L. Keegan Survival Factors Engineer, NTSB
7. Frank Ciaccio, M.P.A. Manager, Forensic Science, NTSB
8. Jan L. Risheim Aerospace Engineer, FAA
9. Rick Baggette Lead Engineer, Boeing Commercial Airplane Group

II. History of Activities

Date	Activities
11/01/00	1. Reached the accident site for general view 2. Set up temporary command post at Tower area 3. Taking pictures 4. Communication with Operations of Airport 5. Reception and General Briefing of accident procedures in Taiwan to Accredited Representatives of Singapore 6. Prepared to interview pax and cabin crew 7. Took CVR and DFDR under the permission of District Attorney. 8. Set up telephone and fax system for CP with the help of CKS Airport Weather Station
11/02/00	1. Made general briefing of factual information to Dr.Yong after his disembarkation from CI-007. 2. Looking for a better command post at terminal 2 with Dr.Yong. Dr.Yong decided to choose room 2009. 3. Reviewed the accident tape, which was made by a passenger in Central Control Room. 4. Took pictures and made site survey. 5. Arranging PWA, Boeing and Singapore representatives to join each of the investigation group. 6. Dr.Yong and all representatives have the first official meeting including AR of NTSB and MCIT of Singapore at 10 PM at CP 2009.
11/03/00	1. Receiving documentation from SIA 2. Obtaining information from Manager Tsai of SIA 3. Interviewing the fire fighter chief 4. Interviewing injured passengers and cabin crew 5. Rear cabin damage inspection 6. Emergency exit slides inspection
11/04/00	1. Continued interviewing injured passengers and cabin crew

	2. After section structure integrity inspection 3. Emergency equipment inspection 4. Passenger and crew injury table making 5. Over head bin structure inspection 6. Removing tie rods and batteries of emergency lights
11/05/00	Free
11/06/00	1. Started writing Survival Factors Report 2. Started compiling a passenger questionnaire 3. Visited the morgue and found out that all bodies had been released to the families and no death causes were determined for fatalities 4. Interviewed more passengers and cabin crew
11/07/00	1. Working on factual report of S.F. 2. 1L, 2L slides inspection as they were not fully inflated 3. Removed 4 overhead bin tie rods for further metallurgical examination 4. Removed floor lighting batteries for inspection 5. Asked system group to help to check batteries condition 6. Completed pax questionnaire 7. Interviewed passenger who was from seat number 64H
11/08/00	1. Interviewed a CKS airport senior flight operation officer who was one of those to reach the accident site first. 2. Factual report writing 3. Injured passenger and crew chart compiling 4. Requesting ATC group to get the tower transcript after the accident
11/09/00	1. One more passenger interviewed 2. Requesting passenger address for sending the questionnaire 3. Slide condition further inspection by contacting BFGoodrich 4. A new battery was used to power up the door side emergency light. Found lights could be illuminated.

11/10/00	1. Compiling S.F. preliminary report 2. Prepare to request for the report of cause of death from Ministry of Justice 3. Compiling interview report
11/13/00	1. Connecting with BFGoodrich representative in Singapore and requesting BFG to send specialist to inspect the slides 2. Interviewing data compiling 3. Passing NTSB accident report number AAR-84/10, a KAL -084 ,DC-10 runway incursion and collision with PA-31-350 4. SF report compiling –Appendix and photos
11/27/00~ 11/28/00	Trip to SIA for cabin safety information
12/01/00~ 12/30/00	Factual report compiling
01/03/01~ 01/20/01	Factual report review
01/15/01	Slides 1L,2L and 4R were shipped to BFGoodrich, Phoenix
02/02/01	Pilot Interview
02/05/01~ 02/06/01	Final review of factual report of survival factors
02/15	Slides 1L,2L,4R examination in Phoenix
02/19	Fire Engine Running Test from Southern Station to far end of Runway 05L
02/20-21	Factual report verification

III. Factual Description

1.2 Injuries to persons

1.2.1 Injury Table:

Table 1.2-1 Injury table

Injuries	Flight Crew	Flight Attendants	Passengers	Other	Total
Fatal	0	4	79	0	83
Serious	0	4	35	0	39
Minor	1	9	22	0	32
None	2	0	23	0	25
Total	3	17	159	0	179

Note 1: 49 CFR 830.2 defines “Fatal Injury” as: any injury which results in death within 30 days of the accident” and “Serious Injury” as: “an injury which (1) Requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) Results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorages, nerve, muscle, or tendon damage; (4) involves many internal organ; or (5) involves second or third degree burns, or any burn effecting more than 5 percent of the body surface.”

1.2.2 Distribution of Injuries

The Boeing 747-400 was configured with 12 first class seats, 28 business class seats, and 316 economy class seats on the main deck and 30 business class seats on the airplane’s upper deck. There were 2 pilots seats and 2 observer seats in cockpit; sixteen cabin crew seats positioned in forward, mid and aft section of the main deck cabin and 3 seats situated in the upper deck.

The following diagram (Figure 1.2-1) shows the passenger seat positions and the severity of injuries that they sustained. The information on the passenger seat position is from the airline-seating plan and from interviews with passengers.

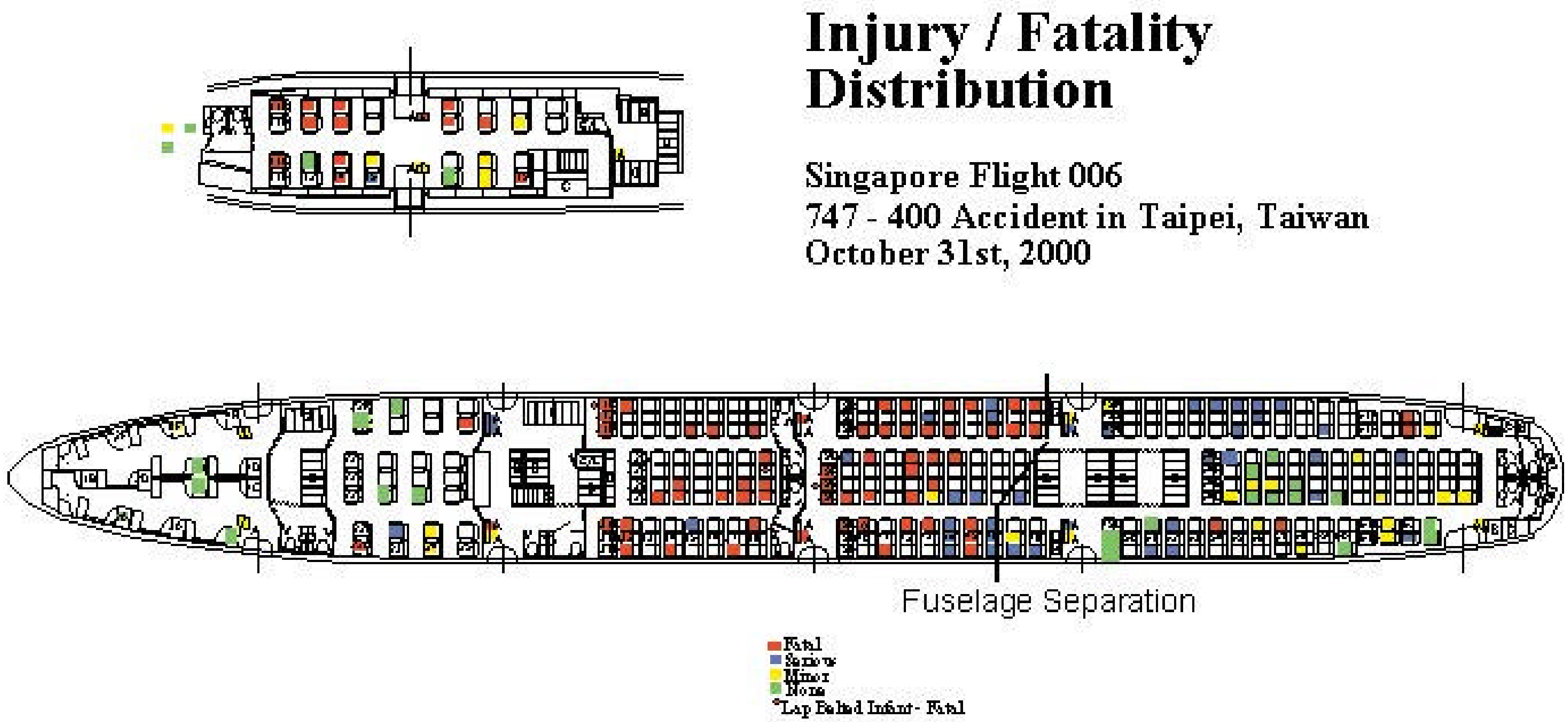


Figure 1.2-1 Injury/Fatal Distribution

1.3 Damage to Aircraft

The airplane broke into two main sections at about fuselage station 1560 and came to rest approximately 6,840 feet beyond the runway 05R threshold. The left and right wing remained attached to the forward fuselage section, which came to rest on a heading of about 085 degrees. It was reported from the fire fighters that the aft section was originally oriented on a heading of approximately 150 degrees resting on its left side. The final position of the aft section was found in the upright position and on a heading of 050 degrees.

The passenger seats that remained in the cabin of the tail section consisted of rows numbering from 49 to 64. The fuselage and the windowpanes along the left side of the fuselage were scraped and crazed.

The forward cabin and upper deck including the cockpit, first class, and business class were consumed by fire through to row 48 in economy class. The exterior left side of the fuselage from the upper deck door to the 3L door was not [1]consumed by fire.

1.3.1 Cockpit Damage

The cockpit was consumed by fire.

1.3.2 Cabin Damage

The forward cabin from business class on the upper deck, and first class at the nose of the airplane all the way through the cabin to row 48 was consumed by fire. The aft cabin which contained the seats and cabin furnishings from rows 49 through 64 separated from the airplane.

The airplane was equipped with 9 galleys. The forward galleys (G1, G2, G3, G3A, and G4) were consumed by fire. Galleys G5 and G6 had separated from the cabin floor and were found near the aft fuselage wreckage. The G7 and G8 galleys remained in the aft fuselage and were found leaning toward the left side of the cabin.

Examination of the emergency lights and floor proximity emergency lighting system positioned between doors 4 and 5 (figure 1.3-1,1.3-2) area revealed that each of the battery packs showed that they were completely discharged. See 1.16.2 for the emergency exit lights examination.

Figure 1.3-1 Illuminated Floor Proximity Lights during Testing

Figure 1.3-2 Illuminated Door 5 Left Emergency Light during testing

(The over door fairing panel was removed to access the emergency light battery check)

1.3.2.1 Cabin Crew Seats

The airplane was configured with 19 cabin crew seats. The seats are described as below table 1.3-1.

Table 1.3-1 Cabin crew seats condition

Crew Seat Position	Condition of Cabin Crew Seats
Upper Deck Left	Consumed by fire
Upper Deck Right	Consumed by fire
Upper Deck Galley	Consumed by fire
Door 1L	Consumed by fire
Door 1R	Consumed by fire
Door 2L Outboard	Consumed by fire
Door 2L Inboard	Consumed by fire
Door 2R Inboard	Consumed by fire
Door 2R Outboard	Consumed by fire
Door 3L Outboard	Consumed by fire
Door 3L Inboard	Consumed by fire
Door 3R Inboard	Consumed by fire
Door 3R Outboard	Consumed by fire
Door 4L Inboard and Outboard	Forward inboard footing separated, significant structural damage surrounding the seat, inboard side of the seat frame separated from the seat back, seat pan is down and covered with debris. No fire or smoke damage.
Door 4R Inboard and Outboard 	Smoke and burn damage , handset interphone disconnected ,Seal broken on flashlight
Door 5L 	Not damaged
Door 5R	Not damaged

1.3.2.2 Doors and Evacuation Slide/Rafts

The Door and Slide status are listed in the following table1.3-2:

Table 1.3-2 Doors and slides conditions

Doors	Status	Open By	Slide Condition
Upper Deck Left	Open	Unknown	Deployed and burnt
Upper Deck Right	Open	Unknown	Not found
Door 1 Left	Open	1L F/A	Not fully deployed
Door 1 Right	Closed		Minor burn damage
Door 2 Left	Open	2R(outboard) F/A	Not Fully Deployed
Door 2 Right	Destroyed by Fire		Not found
3L	Partially Open	Unknown	Moderate burn damage
3R	U Destroyed by Fire		Not found
4L	Closed		In Package
4R	Open	Unknown	Auto Deployed in the Cabin
5L	Closed		In Package
5R	Closed		Auto Deployed in the Cabin

Door 1L

Door 1L was found intact and in the "opened" position, its Mode selection lever: Found in the "Automatic" (i.e. Armed) position, Handle position: 11:00 relative to the door interior. The Power assist status: Power assist bottle was found burned – not able to determine status after accident

Slide Condition: The following information was obtained from this slide:

Door 1L Slide-BF Goodrich control drawing no. 7A1467-21 Rev M

S/N GH1651, date mfg. 1/96

Overhaul manual 25-66-19 Rev 6 or later

TSO 69B

The slide was found partially deployed outside the airplane. The fuse pins remained connected near the base of the girt skirts preventing the slide from fully deploying. The following fuse pin numbers were found connected:

?? 70 - connected

?? 480 - connected

?? 375 – connected

- ?? Burn damage was found at the door end of the slide
- ?? Found 1 inflator unit w/ the baffles sealed closed

Surrounding Structure: No significant damage noted to the door frame structure

Door 1R

Door 1R was found located in a pile east of door 1L. The post crash fire damaged the mechanism, however inspection of the Mode Selection lever mechanism revealed it to be in the " Manual" (i.e. Unarmed) position. Its handle was destroyed.

Power Assist status: Power assist bottle was found burned – not able to determine status after accident

Slide Condition: Un-deployed slide pack was found adjacent to the door frame structure. The slide pack appeared to have sustained minor burn damage

Surrounding Structure: None Found

Door 2L

Door 2L was found intact and in the " opened" position, its Mode selection lever: Found in the " Automatic" (i.e. Armed) position, its Handle was in the 9:00 o' clock position relative to the door interior. The Power assist status: Power assist bottle was found burned – not able to determine status after accident

Slide Condition: The following information was obtained from this slide:

Door 2L - BF Goodrich control drawing no. 7A1479-13 Rev 13
S/N G691, date mfg. 7/93
Refurbished per B.F.G. overhaul manual 25-66-18 Rev 6 or later Revision
TSO 69A

The slide was found partially deployed outside the airplane. The fuse pins remained connected near the base of the girt skirts preventing the slide from fully deploying.

- ?? 410 - connected
- ?? 70 - disconnected
- ?? 310 –main (larger) – connected 2 smaller – disconnected
- ?? Significant burn damage was found to the slide

?? The slide was burned away from the girt bar

?? Found 1 inflator with the baffle seal broken

Surrounding Structure: No significant damage noted to the door frame structure

Door 2R and Door 3R

Door 2R and Door 3R were found located in a pile east of the main wreckage of Zones B&C. The doors were badly damaged (burned), only a small portion of the door mechanism remained. It was not possible to identify which mechanism belonged to Door 2R or Door 3R.

Mode Selection lever: Not enough of the mechanism left to determine mode selector status, Handle Position: Not enough of the mechanism left to determine handle position, Power Assist status: Not enough of the door left to determine power assist status.

Slide Condition: Not Located

Surrounding Structure: None Found

Door 3L

Door 3L was found intact and in the "partially opened" position. Its Mode selection lever: Found in the "Automatic" (i.e. Armed) position. Handle position: 9:00 relative to the door interior. Power assist was destroyed by fire.

Slide Condition:

The slide was found on the ground below Door 3L.The slide did not appear to have inflate. Slide sustained moderate burn damage

Surrounding Structure: Door deformation noted in the girt bar area

Left Upper Deck Door

The L UD door was found intact and in the "opened" position. The bottom of the door structure was in contact with the ground. The door structure was supporting the remainder of the U/D frames

Its mode selection lever was found in the "Automatic" (i.e. Armed) position. Its handle was in the ' Up" position (90 degree relative to the door.) The power assist bottle was found burned – not able to determine status after accident.

Slide Condition:

The slide was found deployed but deflated outside of the airplane. Significant burn damage was found to the slide – only top 7 feet of the 46.5 foot

slide remain. Girt bar found attached to the sill
Surrounding Structure: Interior of the door shows no signs of exposure to fire

Right Upper Deck Door

The R UD door was found west of the main wreckage.
Mode selection lever: Not found
Handle position: Handle in the down (closed) position (10 degree relative to the door)
Power assist status: Not found
Surrounding Structure:

The door structure suffered significant burn damage. The area below the opening handle was missing. Burn damage to the exterior of the door was more significant than to the interior. Broomstrawing of hinge area indicates impact while hot

Slide condition was not found

Door 4R

Door 4R was not opened by cabin crew but found intact and in the "opened" position by the rescue people, its mode selection lever: Found in the "Automatic" (i.e. Armed) position, its handle was found in the 1:00 o'clock position relative to the door interior. Power assist status: Power assist bottle was found discharged

Slide Condition:

The slide was found deployed (deflated) inside the airplane – extended laterally to Door 4L. The cabin crew of 4R Inboard revealed that this slide inflated in cabin automatically. One inflator found with a scarf ingested into the unit (ser # 4079). One Inflator found with significant burn damage to the slide material adjacent to the inflator (Ser# 4089). Both Inflators P/N - 5A2870-1 Rev F.Slide pack board and door bustle found inside the cabin forward of the door. Inflator cable had NO "bullet"

Door 4L

Door 4L was found intact and in a "cocked open" position. According to interview data of the cabin crew the door handle was not touched during evacuation. Its mode selection lever: Found in the "Automatic" (i.e. Armed) position, It' s handle was found in the 11:00 o' clock position relative to the door interior. Power assist status: Power assist bottle was found discharged.

Slide Condition:

The slide was found intact, not inflated and charged

Surrounding Structure:

Door frame/surround structure fractured on the forward side. Door frame separated from lining.

Door 5R

Cabin crew did not open door 5R that was found intact and in the "opened" position. This door was opened by the CVR/FDR retrieving people. Its mode selection lever found in the "Automatic" (i.e. Armed) position, its handle was found in the 12:00 o' clock position relative to the door interior, its Power assist status: Power assist bottle was found discharged.

Slide Condition:

Door 5R Slide–Slide/Raft Assembly Model 747

B.F. Goodrich drawing No. 7A1469-14 Rev 11

S/N G518

Date if Mfg 9/92

Overhaul Manual 25-66-20

Revision 4 or later

The slide was found deployed (deflated) on the tarmac near door 5R. Found slide w/ girt bar end attachment bracket engaged on the aft side.Forward girt attachment bracket found wrapped in the slide.Slide Pack board was found on the door. Door bustle found on the door with the aft upper attachment engaged..Inflator cable had "bullet" .

Surrounding Structure:

No damage noted

Door 5L

Door 5L was found intact and in the "closed" position, its mode selection lever: Found in the "Automatic" (i.e. Armed) position, its handle was found in the 2:00 o' clock position relative to the door interior, its power assist status: Power assist bottle was found charged

Slide Condition:

The slide was found intact, not inflated and charged

Surrounding Structure:

?? Upper door lining separated at all 3 upper bracket

?? Center tie rod clevis found fractured

The door 1 left, door 2 left and door 4 right slides recovered from the accident airplane were sent to the manufacturer, BF Goodrich for testing. The Survival Factors Group reconvened in Phoenix, Arizona, on February 15, 2001, at BF Goodrich Aerospace to examine the slide/rafts. See 1.16.3 for the test result.

1.3.2.3 Aft Fuselage Overhead Bins Damage

The center overhead bins separated from the upper fuselage frames at the tie rod ends (Figure 1.3-3) in the aft cabin between seats 54 D, F, G & H, and 60 D, F, G & H. Four of the fractured tie rods and one intact tie rod were removed for further metallurgical inspection and testing. The tie rods were removed from left to right and from the rear of the airplane to the front of the aft end of the cabin and were identified with masking tape as follows:

Tie rods - A, B, and C (from left to right)

Assembly: 1-6 (aft to forward)

Removed Tie Rods: 2A, 2B, 2C (intact), 3C, 5A, and 6B

The details of tie rod condition see the Table 1.3-3

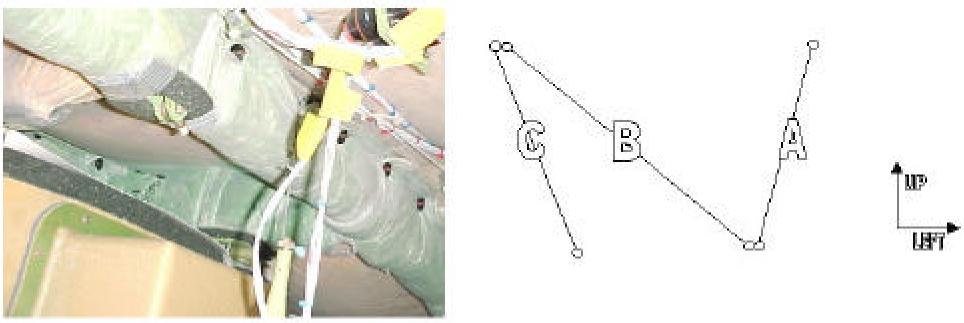


Figure 1.3-3 Tie rod photo

Table 1.3-3 Tie Rod Condition

Assy #	A Upper	A Lower	B Upper	B Lower	C Upper	C Lower
1	Fractured	Attached	Fractured	Attached	Attached	Fractured
2	Attached	Fractured	Attached	Fractured	Attached	Attached
3	Fractured	Attached	Attached	Attached	Fractured	Attached
4	Attached	Fractured	Attached	Fractured	Fractured	Attached
5	Fractured	Fractured	Fractured	Fractured	Fractured	Attached
6	Attached	Fractured	Fractured	Attached	Fractured	Attached

Frames at the following stations ruptured at stringer 1R near the B-Upper, C-Upper Tie rod connections: Station 1900,1960,1980,2000,2020,2040,2060 and 2080.

The fractured tie rods were inspected by the material lab of Chung Shan Institute of Science and Technology. Initial report stated that the main cause of fracture is overstress. (See Appendix 6-1)

1.5 Personal Information

There were 3 pilots and 17 cabin crewmembers onboard SQ006

1.5.1 Cockpit Crew Interview

The Captain and the two First Officers were interviewed in survival factor aspects. See Appendix 6-2 for the interview notes.

1.5.2 Cabin Crew Interview

The 13 surviving cabin crewmembers were interviewed. See Appendix 6-3 for the interview notes.

1.5.2.1 Summary of Cabin Crew Interview Notes

Takeoff

There was nothing unusual about the take off, except for the rain and wind. There were 9 and 19 passengers seated at the main deck ands upper deck business class section respectively. Though the visibility was poor, the crew seated at door 5 left seat could see the runway edge light.

Impact

Cabin crew heard loud " bangs" and explosions on impact. Fire could be seen outside the aircraft. Fire appeared at door 2 left and 2 right areas and fire, smoke and fumes entered the aft fuselage cabin section before the aircraft came to a stop. Fire was seen coming to the forward section from the mid-section.

Door Operation

The 1 left and 2 left main deck doors were open by the cabin crew seated at the respective positions. One of the two surviving cabin crew seated at the upper deck cabin, reported that the left upper deck door was opened by the cockpit crew and saw the other cabin crew who was seated at the right upper deck door seat attempting to open the right upper deck door but it did not open.

The 1 right and 2 right main deck doors were not opened because of the fire outside the door. The main deck doors 4 left and 5 left could not be opened as the left side of aft fuselage section was resting on the ground. Door 4 right was reported to have opened on impact without any operator action. Operation of door 5 right could not be attempted because the right side of the aft fuselage section was overhead and not reachable

Slide Operation

The door 1 left and 2 left slides did not inflate fully before it deflated. The cabin crew seated at the left upper deck door crew seat reported that the left upper deck slide did not inflate.

The slides at door 4 right inflated inside the cabin without any operator action. The inflated slide trapped the cabin crew seated at that position and separated the crew from the passengers seated opposite her. The slide at door 5 right inflated inside the cabin without any operator action. The inflated slide pinned the crew seated at that position and obstructed the escape path and vision of the crew.

Exits Used

The exits used for evacuation were the left upper deck door, the 1 left and 2 left main deck doors and the severed end of the aft fuselage section.

Evacuation

The 2 cabin crew seated at doors 1 left and 1 right evacuated with about 5 to 9 passengers through door 1 left. One cabin crew seated at door 2 left, the 2 seated at door 2 right and the 1 seated at the upper deck galley seat evacuated through door 2 left with about 3 to 4 passengers. All the 6 cabin crew seated at doors 4 left and right and 5 left and right evacuated through the severed end of the aft fuselage section with about 30 passengers. The cabin crew fatality seated at door 2 left was momentarily seen at the upper deck. The first office (right hand seat) after evacuating through the upper deck left door signaled to those at the upper deck to follow him.

Emergency Lighting

The emergency lights and floor track path lights did not illuminate, except for the emergency exit light at door 4 left.

Seat Belts and Shoulder Harness

Cabin crew did not encounter any difficulties removing their seat belt and shoulder harness.

Evacuation Commands

The cabin crew did not hear any evacuation commands from the pilots. Passengers in the forward, mid and the aft cabin sections were given evacuation instructions.

Evacuation Conditions

The upper deck and forward cabin sections were filled with dense smoke and fumes and it was dark and difficult to see. The visibility within the forward cabin was about arms length and only silhouettes can be seen. Fire spread to the forward cabin during evacuation. The fire inside and outside the wreckage, poor visibility within the cabin because of smoke, the presence of fumes in the cabin and the heat from the fire hampered the evacuation process. The lack of useable exits, and the obstructions in and the orientation of the aft fuselage section also added to the difficulties

Aft Overhead Storage Compartment

The aft fuselage cabin section ceiling and center overhead storage compartments collapsed during the impact. The forward overhead storage bins collapsed.

Post Evacuation

After evacuating, cabin crew did not see any rescue personnel or noticed any fire fighting activities. The pilots assisted passengers at the crash site.

Some cabin crew had to guide and help their passengers to cross a drain and to get to the terminal building. Some of them were pickup by a bus approximately halfway between the drain and the terminal building.

There were a lot of comments by cabin crewmembers that there were barely any first aid facilities and medical assistance provided to them including the injured at the terminal building. Most of the assistance they received were from their fellow crewmembers and passengers. When help arrived at the terminal building, there was poor co-ordination and identification of those who needed urgent medical attention.

1.5.3 Cabin Crew Training Record

The cabin crewmembers onboard SQ-006, received their initial and recurrent training at Singapore Airlines on the following date as listed in table1.5-1.

Table1.5-1 Cabin crew training record list

Crew Seat Position	Initial Training Date	Recurrent Training Date	C-I-C(Crew-In-Charge) Recurrent Training Date
Upper Deck Left	29 Oct 97	10 Oct 00	Not Applicable
Upper Deck Right	30 Jun 78	19 Sept 00	28 Apr 00
Upper Deck Galley	11 Nov 97	10 Oct 00	Not Applicable
Door 1L	25 Sept 90	30 Mar 00	Not Applicable
Door 1R	3 May 89	23 Aug 00	Not Applicable
Door 2L, Inboard	3 Aug 73	25 Nov 99	23 May 00
Door 2L, Outboard	21 Oct 98	11 Oct 00	Not Applicable
Door 2R, Inboard	23 Dec 87	13 Sept 00	Not Applicable
Door 2R, Outboard	7 Nov 79	20 Jul 00	13 Jan 00
Door 3L, Inboard	Not occupied	Not Applicable	Not Applicable
Door 3L, Outboard	13 Jul 92	31 Aug 00	Not Applicable
Door 3R, Inboard	Not occupied	Not Applicable	Not Applicable
Door 3R, Outboard	30 Apr 96	27 Apr 00	Not Applicable
Door 4L, Inboard	16 Oct 95	22 Aug 00	Not Applicable
Door 4L, Outboard	11 May 92	6 Apr 00	Not Applicable
Door 4R, Inboard	10 Aug 00	Not due	Not Applicable
Door 4R, Outboard	13 Jan 95	23 Dec 99	Not Applicable
Door 5L	24 Feb 00	Not due	Not Applicable
Door 5R	23Feb 00	Not due	Not Applicable

1.13 Medical and Pathological Information

The injured passengers were transported to the following hospitals: Chung-Li Ten-Chen Hospital, Tai-Yuan Ming-Sheng Hospital, Taipei Veteran Memorial Hospital, McKay Memorial Hospital, Lin-Kou Chang-Geng Hospital, Chung-Li Li-Shin Hospital, Taoyuan Min-Sheng Hospital, Tao-Yuan Hsin-Yang-Min Hospital. The pilots were sent to National Taiwan University Hospital.

The Department of Forensic Pathology Institute of Forensic Medicine, Ministry of Justice conducted some autopsy. The reports have not been submitted to ASC.

1.14 Fire

The forward and mid section of the B747-400 burst into flames immediately after the impact. There was a total of 123,000 kilograms of aviation jet fuel carried in the aircraft fuel tanks from load sheet. According to the CKS Fire Chief, the fire kept burning at the forward and mid section of the wreckage and consumed most of them. The fire was under control after 10 to 15 minutes, but flashback and re-ignition occurred and was fully extinguished after 40 minutes. There was only minor exterior fire damage to the aft section of the severed rear section.

As the fire fighters rushed to the site, they found the fuselage had broken into two parts. They found the engines had separated and debris were scattered on runway 05R. The airplane nose section, mid-section and wings were all on fire. The fire was intense because of the gusty wind conditions. .

Fire fighter chief ordered the fire fighters to position at up wind side and discharge the extinguishing chemical at the burning forward and mid-section of the aircraft. The fire fighters also sprayed chemical extinguishing agent into the cabin. Three passengers at the door 1 left area were rescued by fire fighters. The fire fighters saw two pilots waving their arms and shouting to the fire fighters. The fire fighters also rescued several burnt passengers who jumped out of cabin at the right hand side of the aircraft.

Fire fighters encountered intense fire around the nose and mid-section of fuselage. The fire at the tail section was less intense and was brought under control quickly. .

After other fire engines from Taipei County, Taipei city and Shin-Chu county arrived, fire fighting was concentrating on the forward and mid section fuselage. By midnight most of the fire was extinguished except for the bottom of the wreckage. Water was used to cool the wreckage .

CKS airport fire fighting group (Figure 1.14-1) had used 40,000 gallons of water and 2,300 gallons of chemical in this action.

Figure 1.14-1 Fire Fighting Condition

1.14.1 Crash/Fire/Rescue (CFR) Response

Paragraph 1.14.1 is based on interview with the CFR of CKS Airport and Channel 1 Radio Communication Transcript. See appendix 6-4 for the interview notes.

1.14.1.1 Activation phase

On 31 Oct 2000, the CKS South Fire Station audio crash alarm sounded followed by a RT transmission from ATC at 15:17:36 hours according to the translation of the Channel 1 Radio Communication Transcript. A telephone call from ATC was also made to CFR subsequently. The location of the crash site was given by ATC as on the runway in use, instead of a grid map position.

1.14.1.2 Response phase

The initial responding fire-fighting vehicles by South Fire Station were 2 RIVs, 4 foam tenders, 1 nursing truck, 4 ambulances and 2 lighting units.

The driver of the first arriving vehicle, Fire Tender No. 3 was alerted by the sound of explosion and responded immediately in the general direction of Runway 05/23 by the appearance of fire prior to the alarm from the standby room. He encountered low visibility strong winds and heavy rain while responding to the crash site due to the typhoon conditions and monsoon flow. The fire vehicles responding from the South Fire Station were required to cut across an active runway (RW 06/24) and a taxiway before entering the north runway. They were guided along by the green centerline taxi lights along East Cross and the visual sighting of the fire at the crash site. According to Channel 1 Radio Communication Transcript, there was a transmission "Shoot chemical first. Shoot chemical first" at 15:20:45. The accident occurred at 15:17:17. There is no record on the arrival time of the second and subsequent fire tenders. The first responding vehicle, Fire Tender No. 3 did not communicate with ATC for clearance to cross the active runway while en-route to the crash site.

. The South Fire Station is operated at all times. Due to the closure of the North Fire Station, two tire tenders are stationed at the Domestic Terminal daily from 0100 hours to 1400 hours. The crash occurred 15:17:17.

The external supporting vehicles from other agencies started congregation at 15:40 from the North Gate, some requesting for directions to the crash site.

1.14.1.3 Fire-fighting and rescue operations

Upon arrival, all the fire tenders were positioned on the upwind side, surrounding the forward fuselage, in an arc formation from the North East to the Southeast. However, CFO was unable to recall the actual position of the individual fire tenders. On 21 February 2001, CFO provided ASC with a chart indicating the positions of the fire tenders at the crash site.

Accordingly to the driver of the first fire tender (Fire Tender No. 3), on arrival he immediately took up position on the upwind side of the crash site, between the nose and the left wing. He quickly carried out fire fighting intervention with the discharge of aqueous film fighting foam (AFFF) which was activated by a master switch from the driver cabin console panel.

Fire fighting efforts were concentrated initially on the critical area at the left fuselage and left wing root area. The fire subsequently spread to the rest of the aircraft. According to fire chief report, the fire was brought under control within 10 to 15 minutes. However, flash back and re-ignition occurred and the fire was extinguished approximately 40 minutes after the crash.

The fire at the APU area on the aft fuselage/tail section was extinguished within 40 to 60 seconds by Fire Tender No. 6. Entry was made into the tail section after the fire had been extinguished, however, CFR reported that they did not find any passengers or crewmembers inside the tail section. (It was reported by the pilots that a female passenger was carried out of the tail section by rescuers).

The initial fire fighting capabilities of CKS CFR deployed at the crash site were:

2 RIVs of 6000 litres,

4 foam tenders of 12,000 litres each,

1 foam tender of 14,000 litres,

for a total of 74,000 litres.

The extinguishing agents used were:

Water - 160,000 litres

AFFF- 7,000 litres

Fluoroprotein- 2,300 litres

Another 34 fire trucks, 54 ambulances and 7 lighting units from local fire stations, hospitals, police and military were arrived subsequently to support the fire fighting and rescue operations. A total of 4336 personnel were involved in the entire fire/rescue operations. The fire fighting and rescue people interview and communication reports see Appendix 6-4.

Table 1.14-1Emergency vehicle and manpower used in this occurrence

Organization	**Fire Engine**	**Ambulance**	**Spot light Vehicle**	**Logistics Vehicle**	**Number of people**
CKS Airport	9	4(One large Vehicle)	3	15	100(64 in Fire Fighting)
Tao-Yuan County	32	8			351
Taipei City		7	3		24
Taipei County		16	2		40
Shin-Chu County			1		2
Taoyuan Hygienic				2	3
Tao-Yuan County Hospitals		17			34
Tao-Yuan Police station				65	260
Armed Forces Hospital		4			12
Taoyuan airforce Base	1	2		20	350
CPC Taoyuan Petroleum	1				3
Air Police station			1		253
Security Police Group #1					330
Communication Police				1	9
Taoyuan Military Police					120
Military Group#249				30	720
Taoyuan				7	20

Airport Service Co.					
Eva Ground Service					156
Eva airlines					37
Eva Group Aviation Tech					20
China Airlines					40
Coast Guard					30
CAA,CKS Station					20
Dentist ASSO.					21
Medical Doctor Asso.					21
Tzeu-Gi Charity					170
Fa-Gu-San Foundation					20
Lin-Geo-San Foundation					200
Yuan Kwang Buda College					300
International Buda Asso.					500
Da-Yuan Catholic					15
China Christian Rescue Asso.					150
Yan-Ming Sea Transportation				5(40 feet refrigerator)	
Total	43 Vehicles	58 Vehicles	10 Vehicles	145 Vehicles	4336 people

Immediate rescue efforts were conducted by the firefighters upon arrival on site. Two passengers on the ground by the side of the aircraft and a passenger still strapped to his seat by the doorsill were rescued by the fire crew during the initial phase of rescue operations. All these three passengers had sustained severe burn injuries and were sent to the hospital by the CFR ambulances. No breathing apparatus was used during the rescue attempt (it was explained by CFO that the breathing apparatus were not used because the rescuers were in the upwind position).

Accordingly to the Chief of Flight Operations Section, he picked up 7 to 8 passengers with minor or no injuries and suffering from shock and sent them to the CCS.

None of the CFR personnel were injured during the entire rescue efforts.

Replenishment of the fire tenders with water was from the hydrant near to the north fire station as well as from the south fire station.

No complimentary extinguishing agents, i.e. dry chemical powder, BCF or CO2 were used in the entire operation.

1.14.1.4 Casualty Clearance Station

No triage and mobile casualty clearance areas were set up at the crash site due to the typhoon conditions. The Chief of Flight Operations Section who was the on-scene commander instead established Flight Operation Information Services, which was below A9 boarding gate as the Casualty Clearance Station (CCS). There was no medical facility initially at the temporary designated CCS. Two of the staff from Flight Operations Section with first aid skills were tasked to take charge of the CCS and also to inform all agencies of the establishment of A9 as the CCS. The command of the CCS was subsequently handed over to the Medical Coordinator from the Bureau of Hygienic and Health, Touyan County.

The first 10 survivors were sent directly to the local hospital by the 4 CFR ambulances because of the typhoon conditions. CFR was unable to recall the time when the first casualty was picked up or when the first ambulance departed with the casualties. The subsequent casualties were sent to the temporarily designated CCS, below A9 boarding gate.

After the CFR ambulances were dispatched to the local hospitals, there was no medical aid at the crash site until the arrival of the first local hospital ambulances at about 15:40 hours. Some of the local hospital ambulances were dispatched to CCS.

Survivors from the crash site were transported to CCS by ground service vehicles, airport authority vans and ambulances. Some passengers walked to the CCS drawn by the flashing beacon lights of the emergency vehicles that had responded there.

1.14.1.5 On Scene Command & Control

A bus was set up at 50 meters east of the tail section as a mobile command post about one hour after the crash and was manned by flight operations of the airport authority. No common radio frequency was used. The rescue agencies were operating on their individual organization's radio frequencies to communicate with their own units at the site.

The security of the crash site was handled initially by the airport police, who were subsequently assisted by the local military police.

1.14.2 Exercises of airport emergency response

According to the airport emergency response planing, the aircraft crash exercises of CKS airport were conducted twice annually, of which one is on a large scale involving all external agencies. The last large-scale exercise was conducted on 5 July 2000.

The Breathing Apparatus(BA) and hot fire training for CFR personnel are conducted once every three months. The hot fire training is conducted at their hot fire training area while BA training is accomplished without any simulated conditions.

1.15 Survival Aspects

1.15.1 Evacuation

According to cabin crewmember, flight crewmember and passenger statements, the passengers and crewmembers evacuated the airplane through the left upper deck door, the 1 left and 2 left main deck doors and the severed end of the aft fuselage section around row 49.

The cabin crewmembers did not receive the evacuation command from the cockpit. Attempts by the commander of the aircraft to order the evacuation over the PA were unsuccessful because there was no electrical power on the aircraft.

1.15.2 Environmental Conditions

The evacuation was conducted in darkness and typhoon conditions. The weather at the time of the accident was reported by ATC as heavy rain with wind of 020 degrees at 36 knots, with gusts up to 56 knots.

1.15.3 Evacuation Conditions

Interview statements from the survivors indicates that there was fire, smoke and fumes in the cabin before the aircraft came to a stop. Crewmembers reported that, the fire inside and outside the wreckage, poor visibility within the cabin because of smoke, the presence of fumes in the cabin and the heat from the fire made evacuation very difficult. The lack of useable exits and the orientation of the tail section also added to the difficulties. Despite the difficulties they were able to evacuate the passengers.

1.15.4 Exit Door Operation

Interviews with both the flight and cabin crewmembers found that both the left and right upper deck doors and the 1 left and 2 left doors were opened by cabin crew. The cabin crew did not attempt to open doors 1 R and 2 R because of fire at the vicinity of the doors. Doors 4 L and 5 L could not be opened because it was lying against the ground. Door 4 R was reported to have opened on impact without any operator action. Operation of door 5 right could not be attempted because the right side of the aft fuselage section was overhead and the door was not reachable. The door 3L was found partially opened. The operation of door 3 R cannot be established because the cabin crew assigned to this door was amongst the fatalities

1.15.5 Slide Operation

Both the flight and cabin crewmembers indicated that the slides of the left upper deck door and doors 1 L and 2 L used for evacuation were automatically inflated, but subsequently deflated because of fire damage.

The door 1 left and 2 left slides did not inflate fully before it deflated.

The slides at doors 4 R and 5 R inflated inside the cabin without any operator action. The slides at doors 1 L, 2 L and the 4 R were examined by BF Goodrich for physical examination and lab type test.

1.15.6 Slide Operating Limits

At the accident site, the wind was reported up to 56 knots. Slides are tested for use in up to a 25 knots wind in the most critical wind direction in accordance with FAA requirement. See Appendix 6-5.

1.15.7 Post Evacuation

Based on cabin crew and passengers reports, after evacuating from the aft fuselage section, they did not see any rescue personnel or noticed any fire fighting activities taking place. Cabin crew had to guide and help their passengers to cross a drain and to get to the terminal building. Some of them were pick-up by a bus approximately halfway between the drain and the terminal building. A review of the videotape (see appendix 6 -8) taken during the time of the accident by a passenger onboard China Airline CI 004 departing for San Francisco showed that some passengers walked all the way to the terminal building. There were a lot of comments by crewmembers and passengers that there were barely any assistance provided to them including the injured at the terminal building. Most of the assistance they received was from their fellow crewmembers and passengers. When help arrived, there was poor co-ordination and identification of those who needed urgent medical attention.

1.15.8 Passenger Information

There were 153 adults, 3 children and 3 infants onboard SQ006. Nineteen adult passengers from the flight were interviewed. See Appendix 6-7 for the passengers' interview notes. Additionally, a set of questionnaires was developed and sent to all the surviving passengers. A sample of the passenger questionnaire is included in Appendix 6-8 of this report.

1.16 Tests and research

1.16.1 The post emergency response time tests

From South Station to Crash Site

A test was conducted on 12 December 2000 at 1355 hours to determine the response time for the CKS Airport ARFF to respond to a crash alert. It was conducted at a close to optimum conditions, i.e. good visibility, no rain but damp surface. Prior clearance was obtained from ATC to conduct the test, as the CKS airport runways were active. The route taken for the test was across runway 06/24, along East Cross to its intersection of RW 05R/23L, along RW 05R/23L to the intersection of N7 and RW 05R/23L (crash site).

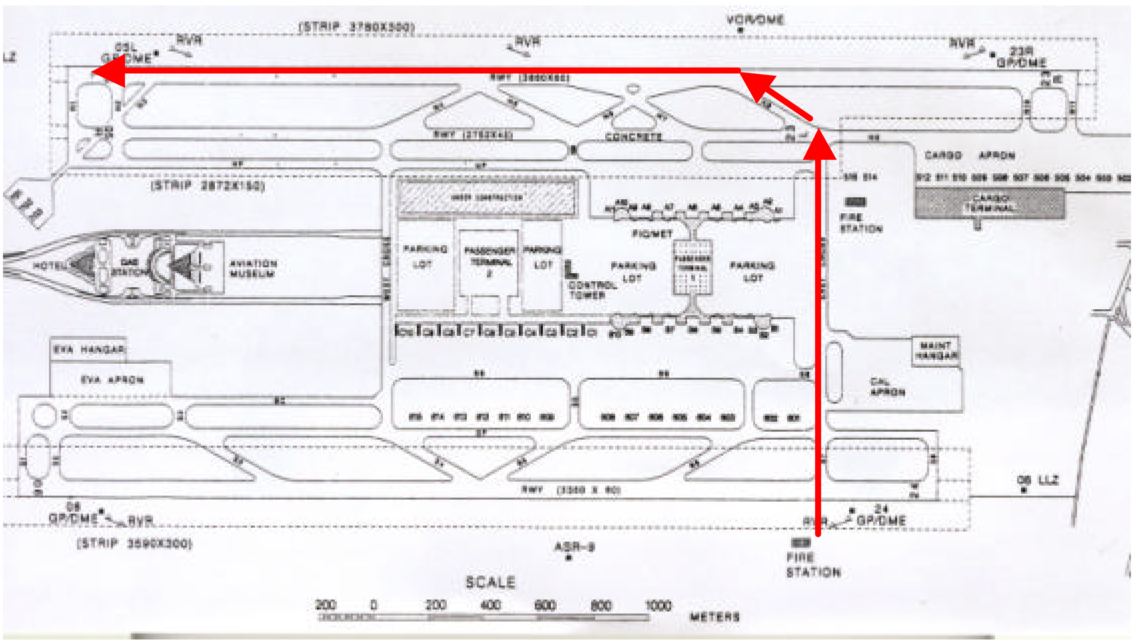
The No. 3 foam tender was chosen to participate in the test by ARFF, as it was the first responding fire vehicle to arrive at the scene on 31 Oct 2000. The results of the test were recorded as follow:

0 seconds	-	Crash Alarm
22 seconds	-	Vehicle leaves station
39 seconds	-	Cross RW 06/24
1 min35 seconds	-	Intersection of East Cross and RW 05R/23L
2 mins11 seconds-		Discharging Water at the intersection of N7 and RW 05R/23L.

From South Station to the start of runway 05L

Another test was conducted on 19 February 2001 at 1700 hours to determine the response time for the CKS Airport ARFF to respond to a crash alert. It was conducted at an optimum condition, i.e.good visibility and no rain.

Two fire tenders were involved in the test. Fire tender No.1 loaded with 6000 liters and No.3 with 12000-liter of water. The fire fighters were on standby in their rest area. ATC clearance to cross runway 06/24 was requested from the dispatching office after the alarm sounded. The fire tenders were cleared to cross the active runway by the tower. The route taken by the fire engines is highlighted in the chart below. No. 3 fire tender reached the runway end in 2 minutes 48 seconds followed closely by No. 1 fire tender.



Test Result

Fire Alarm Time	17:47:44

Vehicle leaved station 17:47:54

Cross Runway 06 on East cross 17:48:14

NP 17:49:04

05L 17:49:19

First shooting before 05L threshold 17:50:32

Elapsed Time 2 minutes and 48 seconds

ATC clearance was obtained before the fire tender reached the holding point of runway 06/24. As a result the fire tenders were able to cross 06/24 without having to stop at the holding point. Marshals were pre-deployed to control vehicular movements along the route taken by the test vehicles.

In January 2001, the CKS Fire Service has placed a 24 hours standby fire-fighting group at the Domestic Terminal.

1.16.2 Emergency Exit Lights Test

Four emergency lights battery packs were removed from E zone. These packs were located in the overdoor fairings at doors 4L, 4R, 5L, and 5R. The fifth pack was not recovered.

Battery locations, part number and serial numbers as listed Table 1.16-1.

Table 1.16-1 Battery part and serial number list

Location	Part Number	Serial Number
4L	2013-1A	20350
4R	2013-1A	20130
5L	2013-1A	31828
5R	2013-1A	9599

The battery packs were tested to determine their state of charge following the accident at China Airlines workshops at CKS airport. Each of the four packs was subjected to a 7 amp light load, as is used during functional testing of serviceable batteries. When each battery pack was connected to the load, the voltage across the terminals briefly rose to approximately 5.2 volts DC, and then dropped to less than 0.1 volts DC within 10 seconds. These readings are consistent with battery packs that are fully discharged. All four battery packs behaved the same way.

In the airplane, the control circuit wiring was checked to each of the four packs. Using a digital ohm meter, the resistance from pin 3 and pin 4 to pin 1 (airplane ground) was measured on the ship side wiring at each battery charger location. Pin 1 to pin 3 was an open circuit. Using the digital ohm meter, the measured resistance between pin 1 and pin 4 alternated between ~650 ohms and open circuit. The meter did not stabilize on a single reading. When this test was conducted, the remaining battery chargers were connected to the ships wiring. All four locations yielded the same results.

A serviceable and fully charged battery was obtained and used to sequentially test the emergency lights in E zone. The results are listed to be Table 16.2-1. Lights not mentioned were not visible in the wreckage or were not noticed.

Table 16.2-1 Emergency light test result

Location	Light	State
4L	Exit sign above and beside door	Off
	Floor light adjacent to attendant seat forward of door	Off
4R	Ceiling mounted emergency light in overdoor fairing	On
5L	Exit sign above and beside door	On
	Exit sign above aisle just forward of door 5L	On
	Floor prox lights on outboard side of left aisle	On from door 4L to 5L
5R	Exit sign above and beside door 5R	On
	Floor prox lights on outboard side of right aisle	On aft of seat row 57
	Exit sign above aisle just forward of door 5R	On

1.16.3 Evacuation slide/raft examination

The L1, L2 The L1,L2 and R4 slides were sent to manufacturer for inspection

and R4 slides were sent to manufacturer for further inspection on February 15,2001 .

1.16.3.1 Examination of the 1L Slide/Raft

The data on the upper ply of the girt was as follows:

Slide/Raft Assembly, Model 747

B.F. Goodrich

P/N 7A1467-21
S/N GH1651
Date of Manufacture 1/96
Boeing SCD P/N S416U001-113
TSO C69b

Examination of the 1L slide/raft was found burned through the slide/raft material on the aft pusher tube section that measured 20 inches long, 12" from the aft side of the girt bar and a 13 X 7 inch section of the aft lower pusher tube was melted. The aft left corner of the head end tube had melted material at 3 locations that were 4 inches apart and approximately 7 inches long. All of these burned sections of material would normally contact the fuselage when the slide/raft inflates.

There was no burn or fire damage to the red boarding strap adjacent to the melted aft pusher tube. The strap does not normally make contact with the side of the airplane. The forward ballast bag is melted and 2 small melted holes were found in the forward side of the bag ballast material.

The first main restraint (375 lot #2984, P/N 150125) from the top of the slide/raft did not release. The group removed the restraint and tested it on an Instron Load Tester. It released at 401 lbs. The release is rated for 375 lbs with a +- 6% tolerance (or 23 lbs)[2]. The 2 (70 lb.) aspirator restraints had released.

The regulator's (located on the inflation cylinder, S/N 1025) firing cable was fully extracted and the trigger levers were in the fired position, and the firing piston was in the up (fired) position. The manual inflation handle is in its stored position attached by velcro to the girt flap. The fusible plug was intact. The gage elbow was rotated about 10 degrees. The data stamp on the inflation bottle (S/N 411-9322) revealed that the last hydrostatic test was February 1999. The bottle had a long cut through its upper layer fibers, and the bottle had two areas where it was deformed inward (valleys), and its inflation hose had some abrasion damage. The inflation bottle had a rivet head imbedded in the lower side of the bottle just above the bottom hemisphere.

The forward aspirator flappers were found opened and its closure sleeve was found closed.

Small cuts were found in between the first and second canopy tubes on the

[2] It is not known how elevated temperatures will affect the performance of the restraint.

upper and lower main body inflation tubes along forward side of the slide/raft. There were also some jagged small holes on the upper main body inflation tube by the second canopy support tube. The slide/raft's center tube had a 3-inch section of melted material and a 20-inch torn section of center tube, adjacent to the third canopy support tube.

The forward sliding lane was torn and scraped adjacent to the 3rd and 4th canopy support. The slide/raft's toe end lifeline separated at the aft side of the slide. The intermediate tension strap attachment had separated from the slide/raft.

The aft lower main body tube had a 30-inch tear, a 12-inch tear, and a 8 X 6-inch "L" shaped tear between the 2nd and 3rd canopy support from the toe end of the slide. The tension strap was cut at the wrap around tube, and there were tears (10 x 9-inch "L" shape, and 12-inch) in the aft main body tube. There were tears (12 x 16 inch "L" shaped tear, and 2- 5-inch tears) between the 1st and 2nd canopy support. The upper main body tube had a 4-inch tear adjacent to the 2nd canopy support tube from the top of the slide/raft. The aft aspirator flappers were in the closed and locked position.

1.16.3.2 Examination of the 2L Slide/Raft

The data on the upper ply of the girt was as follows:

Slide/Raft Assembly, Model 747
B.F. Goodrich
P/N 7A1479-13, rev "R"
S/N G691
Date of Manufacture 7/93
Boeing SCD P/N S416U001-213
TSO C69a

The examination of the 2L slide/raft found that the girt material was consumed by fire had separated from the girt bar, but remained attached at the forward strap. The slide's main restraint had been manually detached at the lower clevis. Both of the upper 70 lb. restraints had released. The forward and aft aspirator flappers were open and the sleeves were closed.

The regulator's, (P/N 5A2851) firing cable was fully extracted and the trigger lever was in the fired position, and the firing piston was in the up (fired) position. The manual inflation handle is in its stored position attached by velcro to the girt flap. The fusible plug was intact.

There was a 30 x 60 –inch area of slide/raft lane and surrounding main body tubing that was consumed by fire (the edges were melted and charred) about 70 inches below the girt bar. There was a 4-5 –inch section of molten slide/raft material in the toe end of the main body tube. Both the lower 70 lb. restraints had released. There was a 12 x 18–inch section of slide/raft material that was consumed by fire (the edges of the hole were melted and charred), the Kevlar tension webbing was charred and melted, and there was an 8-inch tear above the forward aspirator.

1.16.3.3 Examination of the 4R Slide/Raft

The data on the upper ply of the girt was as follows:

Slide/Raft Assembly, Model 747
BFGoodrich P/N 7A1467-24 Rev "I"
S/N GH1426
Boeing SCD P/N S416U001-414
Date of Manufacture 1/94
TSO-C69b

The 4R slide/raft was rolled out for review. The inflation cylinder bottle was missing and the inflation hoses were cut adjacent to where the bottle had been. The manual inflation handle is in its stored position attached by velcro to the girt flap.

The aft aspirator had fabric ingested through one of its flappers. The other three flappers were closed. The fabric was removed from the aspirator and appears to be similar to the Singapore cabin crewmembers uniform fabric. The forward aspirator flappers were open, and the closure sleeve was closed. Soot was visible inside the aspirator. There was a 6 x 3-inch hole with molten edges on the aspirator tube, and several smaller holes near the aspirator area. The mooring line release pouch was slightly melted.

There was a long series of holes with molten edges, surrounded by blistered fabric along the upper main inflation tube on the forward side of the slide/raft. The first hole was 18 inches long, located near the second canopy support tube from the head end. The second hole was 32-inches long and located on the toe end side of the cross tube. The adjacent ballast bag walls were stuck together. The third hole was 7 inches long and located near the second canopy tube from the toe end of the slide/raft. There was one small tear in the forward cross tube next to the center tube.

The aft aspirator restraint remained connected (did not release.) The forward aspirator restraint had released. The main 375-pound restraint was found connected but the lower clevis was disconnected and the clevis pin was missing. The 70-pound restraint on the aft side of the lower slide/raft was found connected, and the forward restraint had released. The lower center frangible restraint was connected, the geometric release cord was fully extended, and the attached pin pulled free from the restraint. The inside of this restraint' s pouch was discolored (rusty).

IV. Appendices

Appendix 6-1 Tie Rods Test Result

Appendix 6-2: Survival Factor Aspect Interview Notes of Cockpit Crew

Appendix 6-3: Cabin Crew Interview Notes

Appendix 6-4: Cks Airport Flight Operation Reports and Interview Notes

Appendix 6-5: Slide Operating Limits

Appendix 6-6: Videotape Taken by Passenger Of CI 004

Appendix 6-7: Passenger Interview Notes

Appendix 6-8:The Questionnaire for Survival Passenger

Aviation Safety Council
Taipei, Taiwan

SQ006 Accident Investigation

Factual Data Collection

Group Report

Human Factors Group

February 21, 2001

ASC-FRP-01-01-007

I. Team Organization

Chairman:
Thomas Wang Aviation Safety Investigator, ASC
Members:
1. Prof. Y Y Yeh, Ph.D. Human Attention and Performance Specialist, NTU
2. Capt. David Liu China Airlines Boeing 747-400 Captain, ALPA
3. Randall Mumaw, Ph.D. Human Factors Specialist, Aviation System Safety, BCAG
4. Peter Renshaw Air Safety Investigator-Human Factors, ATSB
5. Dr Jarnail Singh Chairman Civil Aviation Medical Board, CAAS/MCIT
6. LTC (Dr.) Chew Peng Hoe Aviation Psychiatrist, RSAF
7. Long Foo Yee Head Department of Psychology/IMH
8. Delicia Ser Aviation Psychologist, RSAF
9. Capt. Kenneth E Toft Consultant/ Flight Operations Inspector, CAAS/MCIT
10. Capt. Anthony C K Tan Deputy Chief Pilot Boeing 747-400, SIA

II. History of Activities

Date	Activities
11/04/00	1. Research and discussion for Human Factors checklist and the Model for information collection.
11/05/00	1. Five new members from Boeing, NTSB, and MCIT joined the Human Factors team. 2. Brief the status regarding the investigation to new members. 3. Discuss the Models that may be helpful for the information collection. 4. Discuss the issues that might affect the pilots' decision making.
11/06/00	1. Five of the team members join the Flight Ops team for the taxi simulation. 2. Walk through the accident site in the morning. 3. Review ATC, dispatchers, and pilots' interview transcripts. 4. Plan and design the HF team' s next pilot interviews.
11/07/00	1. Listen to the CVR. 2. Discuss the questions for the pilots interview. 3. Interview SQ006 Cockpit Crew.
11/08/00	1. Organized the manuscripts of pilots' interviews.
11/09/00	1. Review the transcripts of pilots' interviews. 2. Arranged the ATC controllers' interview at CKS airport. 3. Plan the interview and prepare the questions for the interviews.
11/10/00	1. Interviewed ATC controller at CKS airport. 2. Write up the ATC interview transcript. 3. Prepare the group report.
11/11/00	1. Prepare the group report. 2. End of on-scene phase.
11/26/00 to 11/29/00	1. The Human Factors Group reconvened at the Singapore Airlines Training Center in Singapore. 2. Conduct interviews of SIA personnel.

01/02/01	1. Group chairman interviewed EVA Airways Flight Control Department' s managers and dispatchers.
01/08/01 to 01/10/01	1. Part of the Human Factors Group members reconvened at SIA Training Center in Singapore to visit SIA Flight Control Center. 2. Interview Flight Control Center managers and controllers. 3. The group members clarified certain outstanding issues with the accident crew.
01/15/01 to 01/19/01	1. Human Factors Group technical review meeting at ASC headquarter in Taipei. 2. Interview with ATC personnel on 18 January 2001.
01/06/01	1. Group chairman interviewed SIA Taipei Station Manager at CKS airport.

III. <u>Factual Description</u>

1.5 Personnel Information

1.5.1 The Captain CM-1

CM-1, a Malaysian national, is 41 years of age. He resides in Johore Bahru, West Malaysia, but is based in Singapore.

CM-1 joined Singapore Airlines as a cadet pilot on March 12, 1979. His flying training and progression was interrupted when he was redeployed as a flight steward on two occasions between August 1980 through April 1981 and again between February 1983 and May 1984. On resumption of his flying career, CM-1 progressed to the rank of First Officer on the Boeing 747-300 on April 11, 1986. He transitioned to the Boeing 747-400 fleet as a First Officer in July 1991. He was promoted to Captain on the A310-200/300 fleet on November 16, 1995 and later appointed as a Supervisory Captain in April 1997. He transitioned as Captain to the Boeing 747-400 fleet on April 13, 1998.

CM-1 was issued an Air Transport Pilot License (ATPL) on January 2, 1993 and holds ratings on the Boeing 747-200/300, the Airbus A310-200/300 and the Boeing 747-400 airplane types. His latest competency check was conducted on August 19, 2000. His last route check was on April 21, 2000. His latest Safety Equipment and Procedures check was done on June 20, 2000. CM-1 completed initial PVD training on March 8, 1998. He carried out PVD takeoffs as part of the currency requirements during a recurrent flight simulator session on June 4, 2000.

CM-1's first Aircrew Resource Management training (ARM 1) was conducted on July 7, 1985. His ARM 2 training was conducted on July 14, 1988 and ARM 3 was conducted on June 28, 1999.

To date he has accrued a total flying time of 11,235 hours, of which 2,017 hours is on the Boeing B747-400. His flying time over the last 12 months was 806 hrs 53 minutes, last 90 days was 164 hrs 11 minutes, last 60 days was 148 hrs 35 minutes, and last 30 days was 78 hrs 56 minutes. The rest period before the flight was 23 hrs 39 minutes.

1.5.1.1 Personal Factors

CM-1 reported that he has no difficulties working with colleagues and supervisors. During interviews, CM-1 commented that he had flown with CM-2 and CM-3 before. He reported a satisfactory working relationship with CM-2 and CM-3. CM-1 also mentioned during the interviews that he believes in maintaining open communication with his colleagues on the flight deck and he tries to promote a relatively relaxed but disciplined cockpit environment.

CM-1 reported that he had not been subject to any recent disciplinary incidents or warnings. His personal records indicate the company had sent him a note to be more mindful of his operational duties regarding a noise abatement departure out of Zurich 13 years ago.

CM-1's performance exceeded the minimum requirements during his initial training, recurrent (simulator) checks, line checks, and base checks on the B747-400. A summary review based on training records of his technical performance show that he was assessed to be an above average pilot.

During an interview with the Senior Instructor Pilot (SIP) who had conducted CM-1's most recent base check, the SIP stated that CM-1 received an average rating for the check (Appendix 7-1). The Instructor Pilot who had conducted CM-1's most recent line check and a pilot who was on a recent flight with CM-1 prior to the accident flight reported nothing unusual or significant regarding CM-1's performance (Appendix 7-5, 7-3).

CM-1 declared no financial or personal problems.

1.5.1.2 Medical factors

CM-1 held a valid Singapore ATPL Medical Examination (equivalent to the First Class Airman Medical Examination) dated 5 Sep, 2000. There were no restrictions. His height was 1.7 m and his weight was 65.7 kg. Distant vision was 6/6 (equal to 20/20) for both eyes without correction and his near vision was N5 (normal) for both eyes without correction. He had normal color perception as tested by Ishihara plates (See Appendix 7-4).

1.5.1.3 72 Hour History

Oct 27 CM-1 PF operated a flight from Singapore to Melbourne, Australia, departing at 2100 hrs Singapore time (UTC+8).

Oct 28 He arrived Melbourne at 0600hrs, Melbourne time (UTC+10). After checking in to the hotel about an hour later, he slept until 1700 hrs. He met the co-pilot for dinner. He then returned to his hotel room about 2 hours later.

Oct 29 He did not sleep until about 0300 hrs Melbourne time. He then slept until midday and joined the co-pilot for lunch at 1400 hrs. On returning to his room after lunch, he rested until call time. He departed Melbourne at 1730 hrs Melbourne time and arrived Singapore at around 2230 hrs Singapore time.

Oct 30 He went to sleep at around 0100 hrs and woke around 1100 hrs. After lunch at home, he left for the airport for the flight to Taipei at around 1730 hrs. The flight arrived in Taipei at around 2145 hrs Taipei time and he checked in to the hotel around midnight.

Oct 31 He went to sleep at 0100 hrs Taipei time and slept until 1100 hrs. During interviews, he commented that he had “good quality uninterrupted sleep”. He joined his crew for lunch at 1130 hrs. Lunch lasted about 2 hours. He rested for a while and slept again from 1600 hrs to 1900 hrs. He left the hotel at 2035 hrs and reported for duty at 2155 hrs.

In the 3 days prior to the accident, CM-1 reported that he had been eating, sleeping, and working as normal. The investigation did not find evidence of any physiological or medical condition that was likely to have impaired CM-1’s performance. See Appendix 7-5 for detail information.

Blood alcohol and toxicology tests had not been carried out on the pilots after the accident.

1.5.2 The First Officer CM-2

CM-2, a Singapore citizen, is 36 years of age. He resides and is based in Singapore.

He joined Singapore Airlines on June 6, 1994 as a cadet pilot. Previously, he was an officer in the Singapore Army. After successfully completing the cadet pilot phase of his training, he was appointed First Officer on the Airbus A310 200/300 fleet in January 1997. He transitioned to Boeing 777 200/300 in June 1998 and on to Boeing 747-400 in February 2000.

He was issued an Air Transport Pilot License on August 6, 1999 and holds ratings on Airbus A310-200/300, Boeing 777-200/300 and Boeing 747-400 airplane types. His latest competency check was conducted on October 19, 2000. His last route check was on February 16, 2000. His latest Safety Equipment and Procedures check was completed on July 20, 2000. CM-2 completed initial PVD training on December 12, 1999. He carried out PVD takeoffs as part of the currency requirements during a recurrent flight simulator session on September 24, 2000.

CM-2's first Aircrew Resource Management training (ARM 1) was conducted on June 12 1997. His ARM 2 training was conducted on October 18, 1999.

To date he has accrued a total flight time of 2,442 hours, of which 552 hours was on Boeing B747-400. His flying time over the last 12 months was 682 hrs 02 minutes, last 90 days was 201 hrs 11 minutes, last 60 days was 133 hrs 46 minutes, and last 30 days was 42 hrs 14 minutes. The rest period before the flight was 23 hrs 39 minutes.

1.5.2.1 Personal Factors

CM-2 reported that he has no difficulties relating to colleagues and supervisors. During interviews, CM-2 commented that he had flown with CM-1 before. He reported a satisfactory working relationship with CM-1. In particular, CM-2 commented that there were no cultural problems between the crewmembers.

A review of CM-2' s records revealed no disciplinary events.

CM-2' s performance exceeded the minimum requirements during his initial training, recurrent (simulator) checks, line checks, and base checks on the B747-400. A summary review based on training records of his technical performance show that he was assessed to be an average to above average pilot.

During an interview with the Senior Instructor Pilot (SIA) who had conducted CM-2' s most recent base check, the SIP rated CM-2 as average (Appendix 7-6). The Instructor Pilot who had conducted the most recent line check stated that CM-2 performed average during the check (Appendix 7-7). A pilot on a recent flight with CM-2 prior to the accident flight reported that CM-2 was an average to above average pilot (Appendix 7-8).

CM-2 declared no financial or personal problems.

1.5.2.2 Medical factors

CM-2 held a valid Singapore ATPL Medical Examination (equivalent to the First Class Airman Medical Examination) dated 26 July 2000. There were no restrictions. His height was 1.74 m and his weight was 76.3 kg. Distant vision was 6/6 (equal to 20/20) for both eyes without correction, and his near vision was N4.5 (normal) for both eyes without correction. He had normal color perception as tested by Ishihara plates (See Appendix 7-4).

1.5.2.3 72 Hour History

Oct 27 through Oct 29

CM-2 had operated a flight from San Francisco to Singapore on October 26. He was off duty between 27 October and 29 October. During this period, he spent most of his time at home with his family.

Oct 30 He woke up at 0615 hrs. Later in the morning, he drove to SIA to organize some financial maters. In the afternoon, he reported that he took a short nap until 1600 hrs. He was driven to the airport and arrived between 1630-1645 hrs for the SQ 006 flight (Singapore-Taipei, departing Singapore at 1730 hrs arriving Taipei at

2125 hrs). He checked into the hotel at Taipei at around midnight but he reported that he could not fall to sleep immediately.

Oct 31 He fell asleep towards the end of a television show. He woke up at 0800 hrs and went to the gym for a couple of hours. He jogged on the treadmill for about 30 minutes and did some stretching and weights for about an hour. He met the crew for lunch at 1130 hrs. Lunch lasted about 2 hours after which he returned to the hotel and went to sleep. He left the hotel at 2035 hrs for the airport and reported for duty at 2155 hrs.

In the 3 days prior to the accident, CM-2 reported that he had been eating and working as normal. The investigation did not find evidence of any physiological or medical condition that was likely to have impaired CM-2's performance. See Appendix 7-5 for detail information.

Blood alcohol and toxicology tests had not been carried out on the pilots after the accident.

1.5.3 The Relief Pilot CM-3

CM-3, a Singapore citizen, is 38 years of age. He resides and is based in Singapore.

He joined Singapore Airlines on March 9,1992 as a cadet pilot. After successfully completing the cadet pilot phase of his training, he was appointed a First Officer on Airbus A310 200/300 fleet in November 9, 1993. He transitioned onto Boeing 747-400 in June 1995.

He was issued an Air Transport Pilot License on January 7, 1997 and holds ratings on Airbus A310-200/300 and Boeing 747-400 airplane types. His latest competency check was on August 31, 2000. His last route check was on February 20, 2000. His latest Safety Equipment and Procedures check was on February 22, 2000. He underwent 'recency' training on the flight simulator on October 29, 2000 after returning from long leave for 28 days. CM-3 completed initial PVD training on April 28, 1996. He carried out PVD takeoffs as part of the currency requirements during a recurrent flight simulator session on July 18, 2000.

CM-3's first Aircrew Resource Management training (ARM 1) was conducted on July 30, 1993. His ARM 2 training was conducted on August 10, 1994.

To date he has accrued a total flight time of 5,508 hours, of which 4,518 hours was on Boeing B747-400. His flying time over the last 12 months was 823 hrs 57 minutes, last 90 days was 139 hrs 30 minutes, last 60 days was 92 hrs 19 minutes, and last 30 days was 4 hrs in the simulator for recency. The rest period before the flight was 23 hrs 39 minutes.

1.5.3.1 Personal Factors

CM-3 reported that he has no difficulties relating to colleagues and superiors. In particular, CM-2 commented that there were no cultural problems between the crewmembers.

During interviews, CM-3 commented that he has no record of disciplinary problems in the 8 years he has been with the company. A review of his records revealed no disciplinary events.

CM-3's performance exceeded the minimum requirements during his initial training, recurrent (simulator) checks, line checks, and base checks on the B747-400. A summary review based on training records of his technical performance show that he was assessed to be an above average pilot.

He declared that he does not have any financial or personal problems.

1.5.3.2 Medical factors

CM-3 held a valid Singapore ATPL Medical Examination (equivalent to the First Class Airman Medical Examination) dated 7 Sep 2000. His height was 1.77 m and his weight was 72 kg. Distant vision was 6/18 (equal to 20/60) for both eyes without correction and correctable to 6/6 with corrective lenses. His near vision was N5 (normal) for both eyes without correction. He was required to wear spectacles for distant vision and carry a spare pair whilst exercising the privileges of the license. There were no restrictions on his license. He had normal color perception as tested by Ishihara plates (See

Appendix 7-4).

1.5.3.3 72 Hour History

Oct 27 through Oct 28

CM-3 was on leave for 26 days until 28 October. He had spent a few days in Hong Kong. He indicated that he returned to Singapore for the last 3 days of his leave period. During interviews, he commented that he had rested well, sleeping for about 10 hours every day.

Oct 29 He flew the flight simulator on 29 October to regain his currency on the B747-400 after his leave break.

Oct 30 CM-3 was a passenger on SQ006. He was positioning to Taipei to be part of a three-pilot-crew for the next day' s flight from TPE-LAX. He arrived at the hotel about midnight and went to sleep shortly after that.

Oct 31 He woke up at about 1030 hrs for the lunch appointment at 1130 hrs with the rest of the crew. Another SIA pilot joined them for lunch that lasted about 2 hours. He returned to his hotel room, reviewed some charts and rested for another 2-3 hours. He reported for duty at the airport with the other crewmembers at around 2155 hrs.

In the 3 days prior to the accident, the relief First Officer reported that he had been eating and sleeping as normal. The investigation did not find evidence of any physiological or medical condition that was likely to have impaired the relief First Officer' s performance. See Appendix 7-5 for detail information.

Blood alcohol and toxicology tests had not been carried out on the pilots after the accident.

1.5.4 ATC Local Controller CKS Tower

1.5.4.1 72 Hour History

The Local Controller (LC)

Oct 29 LC was off duty.

Oct 30 During interviews with the controller, the LC reported that he awoke at 0700 hrs and read for a while. He had lunch at 12 noon before taking a nap at 1230 hrs until 1600 hrs. He arrived at the Tower at 1840 and started his shift at 1845. The Tower duty records indicated that the LC commenced his shift at 1845.

Oct 31 The controller reported that after he had finished work at 0900, he went home arrived at about 1030 hrs. He reported that he slept until 1200 hrs, woke up for lunch and then slept again until about 1500 hrs or 1600 hrs. He arrived for work at the Tower at 1840 hrs.

He declared that he had no problems with sleeping, personal difficulties or family difficulties in the 72 hrs before coming to work on the 31 Oct 2000 (See Appendix 7-9).

1.17 Organizational and Management Information

1.17.1 SIA Flight Operations Division

Flight Operations is one of the eight Divisions of Singapore Airlines Limited, the main company within the SIA Corporate Group. The other seven Divisions are Treasury, Finance, Corporate Affairs, Cabin Crew, Personnel, Engineering, and Commercial in the company. The Flight Operations Division is headed by a Senior Vice President and is divided into several Departments and Sections as per the Flight Administration Manual. The main departments within Flight Operations are Line Operations, Flight Crew Training, Safety, Security and Environment, Technical and Flight Control Center. All Divisions within SIA Flight Operations are managed by senior SIA management pilots. The prime duties and responsibilities of each of the departments are as follows.

Line Operations administers and manages the operation of the airplane fleets within SIA. The Acting Divisional Vice President (Line Operations) is responsible for line management issues. There are four Chief Pilots who manage the four airplane fleets.

The Flight Crew Training Department (FCTD) conducts all the training and proficiency checking of all pilots within the company. The FCTD is also responsible for training and the standards of Safety Equipment Procedures to be used by pilots and cabin crew operating flights on the line. Note: The administrative and other passenger service aspects are managed by the Cabin Crew Division, one of the eight SIA divisions mentioned previously. The Training Department is the responsibility of the Divisional Vice President (Training).

Safety, Security and Environment services the flight safety aspects of the airline, and when necessary, investigates major incidents and occurrences that arise from line operations. SSE is also responsible for the safety and security of company premises in Singapore and at all stations overseas throughout the SIA network. The Divisional Vice President SSE is a senior management pilot who is partly responsible for examining safety issues within the airline. This is achieved through various mechanisms such as the company incident reporting system, manages a confidential Flight Data Analysis Program (FDAP) which identifies occurrences when flight parameters are exceeded.

The Flight Control Center is the communication, information and coordinating arm of the company in general, and flight operations in particular. The FCC maintains a 24 hours flight watch and flight following for all services operated by SIA and other airlines that have purchased such services. FCC also performs flight dispatch, and the rescheduling of pilot rosters. The Documentation Section within FCC provides centralized updating of all documents used for line operations, for example, Airplane Operations Manuals, Jeppesen Route charts. The department head is the Senior Manager, FCC (SMFCC).

The third Divisional Vice President is a senior management pilot who is responsible for Projects. He is also the Chief Pilot B777 fleet. The DVP (Projects) has oversight of the SIA CRM (known as Aircrew Resource Management - ARM) training program.

The SVP Flight Operations stated in the interview that the prime objective of Flight Operations and throughout the company is Safety and Efficiency. See the notes on SVP' s interview for details (Appendix 7-10).

The Human Factors Group also conducted interviews with the Acting

Divisional Vice President (Line Operations) (Appendix 7-11), Chief Pilot B747-400 (Appendix 7-12), Divisional Vice President (Training) (Appendix 7-13), Senior Vice President SSE (Appendix 7-14), Divisional Vice President (Project) (Appendix 7-15) and Senior Manager, FCC (Appendix 7-16).

1.17.1.1 Flight Operations Training Department

The Flight Operations Training Department is responsible to the company through the Divisional Vice President (Training) and the SVP Flight Operations for:

All staff training and development in the division; managing the Flight Crew Training Center which is responsible for all pilot conversion crew courses through to license endorsement; the conduct of all proficiency testing (base checks, instrument ratings and line checks); the fidelity, approval and maintenance of the flight simulator; all safety equipment training, certification and continued proficiency for all pilots and cabin crew; selection, appointment and standards of all instructors (flight and ground training); overall welfare of the SIA Training Center staff; formulation of divisional policy on operational, training and other matters; and other duties assigned by the SVP Flight Operations.

1.17.1.2 Flight Operations Line Operations Department

The Flight Operations Line Operations Department is responsible to the company through the Acting Divisional Vice President (Line Operations) and the SVP Flight Operations for:

All technical and operational matters related to line operations of the company's airplane fleets; compliance with all Singapore and International regulations pertaining to line operations; liaison with the airplane manufacturers on operational matters; the performance, efficiency, conduct and discipline of all pilots on line; efficient assignment of pilots on all fleets; welfare of all staff in the Department; validity and currency of all operational documents; modernization of existing and crew management systems; formulation of procedures and line operations policy; and other duties assigned by the SVP Flight Operations.

1.17.1.3 Safety, Security and Environment Department

The Safety, Security and Environment Department is administered by the Flight Operations Division. It is headed by the Vice President, Safety, Security, and Environment (VPSSE) who reports to Senior Vice President, Flight Operations. The VPSSE may also report directly to the CEO on matters that the VP may deem necessary. The Safety, Security and Environment Department provides support services for flight safety, ground safety (e.g. ramp, engineering), industrial safety and fire fighting. The department develops procedures and training on safety equipment for technical and cabin crew. These procedures pertain to items such as emergency egress, ditching, fire, and disruptive passengers etc. The department does not conduct audits, or promote any specific risk management philosophy. They do not formulate policies for flight operations, as these are the responsibility of each fleet.

The SSE department is responsible for the mandatory incident reporting system. On minor matters such as bird and lightening strikes, no further action is necessary. Most operational matters however are investigated and the SSE generally has to refer to the relevant fleet management or other divisions such as engineering or cabin crew or marketing or the other support companies for further information verification or clarification. When the incident is considered major or substantive, the SSE may convene a full Incident Inquiry/Investigation committee. In such instances the person(s) involved and witnesses will be called ascertain the cause of the incident and a report is submitted to the appropriate Management level and division for remedial action.

The company informs the CAAS of all incidents and when requested for the outcome of investigations committee findings and remedial action taken.

All incident reports are reviewed every two months by a SIA Air Safety Committee. This committee, which is chaired by the SVP Flight Operations, consists of representatives from flight operations, cabin crew, engineering, and marketing. Committee members review the reports, and close cases as appropriate. The Committee may require further investigations if they deem that the investigative actions is incomplete or insufficient. The closed reports are then published and promulgated to all crew and relevant staff in the company's Flight Safety Review magazine. The Flight Safety Review magazine also contains, on the back page, an anonymous reporting form designed, to give crew who wish to report any safety related occurrences but who wish to remain anonymous.

The SSE also manages a confidential Flight Data Analysis Program (FDAP) which identifies occurrences when flight parameters are exceeded. A Committee comprising management and union pilots meet once a month to review and track exceedences that are recorded. The FDAP is conducted on aircraft that are suitably equipped for such monitoring. In SIA, this is 90% of all flights operated. If the program identifies a pilot with a history or tendency for such exeedences then he is spoken to privately by either the union representative on the Committee, (if he is a member of the union) or by the VPSSE if he is not a union member.

Fleet Management hold "Fleet Meetings" about twice a year to discuss operational matters. During such meetings, safety issues are highlighted and discussed as and when the need demands. In addition, day-to-day safety issues are made known to crew via the Flight Reporting and Messaging System (FRAMS) which crew access whenever departing from or arriving in Singapore. The FRAMS is an electronic system used by pilots to sign-in and off duty. It is also used as a medium to remind crew of the status of their license validity, as well as to provide crew with urgent operational information and other company matters, such as roster changes, latest documentation revisions, flight safety issues, as deemed necessary by management.

Interviews with senior SIA management pilots indicated that the Flight Operations Division currently does not have a dedicated unit for quality assurance and is working to establish a unit on Quality Assurance in the coming year. Among the systems being considered for adoption are the guidelines provided by the US Department of Transportation. As another safety enhancement, the company plans to implement a Confidential Human Factors Incident Reporting Program (CHIRP) that encourages crew to report human factor incidents. An interest group on operational safety is being formed by SIA pilot volunteers. This group intends to collect and share safety information, which, if not for the protection of anonymity, may go unreported.

1.17.1.4 Crew Resource Management

SIA developed its first Crew Resource Management course, Aircrew Resource Management (ARM 1) in 1984. This was followed by ARM 2 in 1987, and ARM 3 in 1998.

Interviews with senior SIA management pilots and instructor pilots indicated that ARM 1 focuses on crew behavioral styles, effective communication and teamwork by emphasizing synergism to address potential problems in multi-cultural cockpits. It also emphasized individual values and personal relationships. ARM 2 presents information on pilot decision-making, including topics on group decision-making, consensus decision-making and autocratic decision-making. It also includes a segment on the importance of spouse support. ARM 3 was developed solely for developing a commander's leadership capabilities with an emphasis on a commander's personal development and leadership qualities. Each ARM module is usually covered in three to four days.

According to Divisional Vice President (Project), the SIA ARM courses have not been updated to reflect the advances in CRM and HF research. During interviews with SIA management pilots, it became evident that Flight Operations management has been considering the development of ARM 4. This will focus on error management system. Details are yet to be worked out with expert consultants before further actions are taken to develop the course.

All ARM courses are conducted by an American Professor of Psychology outside of Singapore. A management pilot assists as a course facilitator. The courses are designed to cover concepts that crew should apply. Instructor Pilots look for application of these concepts during training and proficiency checking sessions on the flight simulator or the aircraft. They sometimes discuss the ATC principles and critique crew on the matter during debriefing. Apart from these observations by the Instructors, the company currently has no formal mechanisms to evaluate if crew has acquired such CRM skills (Appendix 7-15).

1.17.1.4.1 The Role of Relief Crewmembers

The B747-400 aircraft was designed to be operated by two pilots (captain and first officer). Depending on the length of the sectors on a trip, additional pilots may be carried to relieve captain and first officer during long sectors. On SIA operations, the relief crewmember fulfils this role on certain sectors. There are various crew complements that SIA aircraft may carry. For example, according to the SIA B747-400 Chief Pilot, the normal crew complement on the B747-400 is two-flight crew which includes one captain and one first officer. Some B747-400 operations may require one captain and two first officers, or two captains and one first officer, or two captains and two first officers. These crewing combinations depend on a number of factors including crew flight time and duty limitations.

The SIA B747-400 Chief Pilot stated that the role of relief crew will be subject to the discretion of the designated aircraft commander for the trip. For example, if the commander wants the relief crewmember in the cockpit during take-off and landing, he can ask for this. SIA have no clearly documented duties for relief crewmembers when they are not occupying a control seat. The investigation was unable to determine how effective or how much input a relief crewmember could realistically provide to crew decision-making. An interview with a senior company pilot indicated that the effective interaction and use of resources on the flight deck between relief crewmembers and the primary crew may depend upon the individual aircraft commanders (Appendix 7-8, 7-12).

1.17.1.5 Flight Control Center

According to Singapore Airlines Flight Administration Manual 2.1.1, the primary function of the Flight Control Center is to ensure that Singapore Airlines' services operate with the least possible disruption or delay, and that where services are disrupted or delayed, these services are rescheduled with the least possible inconvenience to passengers and at a minimal cost level consistent with safety, efficiency and service.

The Flight Control Center is responsible for the following decisions:

- Cancellation of flights;
- Re-scheduling flights due to weather, airport limitations, civil disturbance, crew duty time or sector limitations;

- Over-flights due to weather, airport limitations, crew duty time or sector limitations; and
- Other issues related to delay, aircraft diversions, re-routing, re-scheduling, and recalling of flights, re-allocation of aircraft, recalling flights and/or repositioning of crews.

In accordance with the Flight Administration Manual 2.1.2, to ensure effective operational decision-making, the Fight Control Center must be informed immediately by aircraft Commanders and SIA Station Managers if any event is likely to disrupt or delay scheduled or non-scheduled services. Information of this nature includes but is not limited to:

- Weather warnings;
- Airport closures or limitations; and
- Other information of possible delay or service disruption.

The FCC operates 24 hours and comprises about 94 staff. There are five FCC teams each consisting of 15 to 20 members depending on the time of shift. Larger teams man the center during peak daytime periods. Smaller teams man the FCC during off peak night shifts (generally defined as after midnight). Furthermore, the senior FCC duty controller works a 12-hour shift with breaks for meals.

The FCC is part of the SIA Flight Operations division. To fulfill its' functions, the FCC comprises 4 sections:

- Flight Control;
- Flight services/planning;
- Crew scheduling; and
- Aircraft documentation.

In addition, Interviews with staff from the SIA FCC indicated that the FCC liaises very closely with fleet, marketing and engineering divisions on the commercial and technical aspects of each major delay.

1.17.1.5.1 Briefing Package Preparation for Crew

EVA is the ground handling agents/contractors for SIA in Taipei. The ground handling service includes the dispatch function. The contractor's staff are experienced dispatchers who are trained in SIA's dispatch policies and procedures (P&P). The FCC indicated that the briefing service at Taipei was a full verbal brief provided by the dispatcher. The SIA flight crew and EVA dispatch service associated with the accident have stated that it was a self-briefing service with the dispatcher available for questioning by the crew if required before departure. According to the SIA Taipei Station Brief (SIA Nightstop Information-TPE, 1Mar2000, TPE-2-2, Appendix 7-17), the brief is to be conducted at the aircraft side. The pre-flight brief was conducted at the corridor leading to the holding area at the airplane's parking bay B5 on the evening of the accident (See Appendix 7-16, 7-18, 7-19, 7-20).

1.17.1.5.2 Aircraft Documentation

The FCC aircraft documentation section ensures that all SIA manuals and flight documentation are current and correct for the date of flight. Each crew are issued a current set of charts and documentation before each departure from Singapore. This documentation comprises a complete set of current charts and manuals pertaining to the actual flight, destination station, and specified alternates. If there is an amendment or revision to a chart or manual during the course of a flight, both forms of the document amendment will be included in the package provided to the crew before departure. With reference to the flight concerned, the crew was issued with the current CKS aerodrome chart, which indicated the presence of runway 05R and 05L.

1.17.1.5.3 Out-Station Audits

When queried about the auditing of out station dispatch services, the FCC indicated that the primary source of quality assurance information on out station dispatch services is provided by SIA crews through the Voyage Record system. The SMFCC indicated that the CAAS conducts regular audits of SIA ETOPS line out-stations. In particular, the CAAS conducts quarterly audits of flight documentation provided by dispatch (flight plans, INTAMS, NOTAMS, briefing packages). This documentation is kept for 3 months. This is essentially a paper work audit. Non-ETOPS out stations, such as Taipei, are audited on an ad-hoc basis. Finally, the FCC indicated that it was not aware of any problems reported by crews about the EVA dispatch service.

CAAS clarified the issue of Line Station audits. CAAS has an annual work plan and conducts regular audits/inspections on line stations, and not ad hoc as has apparently been perceived by the SMFCC. The target time interval to cover each station is at least once every three years. As for Taipei, CAAS conducted a flight operations inspection at the station on February 29, 2000 and an airworthiness audit on May 31, 2000. In addition, during the past year CAAS has also conducted inspections on some ETOP stations as part of the pre-certification requirements for such ETOP operations on the B777 fleet (Appendix 7-21)

1.17.1.5.4 Flight Delays

It became evident from interviews with management pilots, instructor pilots, the accident flight crew, and FCC staff that, in the case of poor weather at the departure aerodrome, the aircraft commander can decide on whether to delay a flight or not. In accordance with the SIA FAM, the Station Manager must, however, inform the FCC if there are flight delays or any problems affecting the proposed flight.

Management pilots and FCC staff commented that the aircraft commander has the option to call the FCC directly for consultations about the weather. The FCC can also transfer the commander to a management pilot if there is a technical issue that needs to be discussed. If the intentions of an aircraft commander are unclear with reference to a possible flight delay, the FCC may ask the commander to confirm his intentions.

When asked about the FCC procedure for flight cancellation, the B747-400 Chief Pilot stated that if a flight delay was to be considered excessive, the FCC will consult engineering and marketing. Fleet provides very little input into canceling a flight. However, fleet is informed if the reason for the delay revolves around aircraft unserviceability.

The aircraft commander did not contact the FCC or fleet Chief pilot prior to departure on October 31, 2000 nor was he required to do so.

See Appendix 7-16, 7-18, 7-19 for FCC detail information.

1.17.2 EVA Airways Flight Control Department

There are two divisions in the EVA Flight Control Department (FCD); one is Flight Dispatch, and the other is Flight Watch. The function of Flight Dispatch is to ensure all flights are following the CAA regulations and the company's policies, and operate in a safe, economic, and efficient way. The function of Flight Watch is to monitor all flights to ensure that they do not deviate from the original flight plans. The Flight Watch service is only provided to EVA's flights. EVA FCD does not follow the status of Singapore Airlines' flights.

The responsibilities of EVA FCD on handling SIA flights are mainly on the Flight Dispatch and Freighter Load Sheet operations. The detailed information regarding EVA's handling of SIA operations in Taipei is listed in the Operation and Training manual provided by the Chief Dispatcher FCD (Appendix 7-22).

It became evident from interviews with EVA FCD staff that EVA FCD usually communicates with SIA through telex (Code SINOFSQ). If there is a special condition, such as a need to use Island Reserve Fuel due to weather, FCD will contact FCC via telephone for SIA's approval.

EVA has a Typhoon Procedure in their operations manual. This Typhoon Procedure is only for EVA's flights; it does not apply to SIA's operations. During interviews, the FCD managers and dispatchers commented that they were not aware of SIA's Typhoon Procedures and they did not know the contents of SIA's Typhoon Procedures. The Chief Dispatcher also stated that SIA did not require EVA to report any typhoon information to FCC in any form. He indicated in the interview that when SIA came to Taiwan in 1995 to train EVA's dispatchers for SIA's operations, the SIA instructor did not mention anything related to typhoon procedure. Moreover, the SIA typhoon procedures have not been included in the training material provided to the SIA responsible ground-handling agent in Taipei (Appendix 7-23).

At 1821 local time, on Oct 31 2000, EVA FCD telexed to all the airlines (including SIA) that EVA represents at TPE airport regarding typhoon warning information. This information has been provided in the telex dated 311021 31 OCT 2000 (Appendix 7-24).

The EVA Operations Control Section (OCS) at CKS airport telexed SIA with the accident information at 2325 local time, Oct 31, 2000. (Telex dated 311525 31 OCT 2000, Appendix 7-24).

The Chief Dispatcher and the dispatcher on duty at the night of the accident stated that SIA did not communicate with FCD regarding the Typhoon information or Typhoon precaution on Oct 31, 2000 [note: during interview with the SMFCC, he stated that SIA FCC informed all affected stations including TPE by telex of typhoon condition II at 2155].

There have been no amendments to the EVA FCD operations procedures since the accident. . SIA did not discuss the issue of procedural changes with the SIA Taipei ground-handling agent after the accident.

See Appendix 7-20, 7-25, 7-26 for detail information on FCD.

1.17.3 SIA Taipei Station

According to the interview with the SIA Taipei Station Manager, the main responsibility of the SIA station manager is to make sure all flights depart punctually and safely, passengers are taken of and brought smoothly and safely to their destinations. On incoming flights, the station ensures that passengers get their baggage. In addition, SIA TPE station is responsible for all crews' accommodation, welfare, sickness, or other issues. TPE station will report to SIA in Singapore in cases of any emergency and on crew flight time issues, especially when it is necessary to replace crew.

There are a total of 86 staff in SIA TPE station. All passenger handling, cargo loading, catering service, gate checking are handled by SIA personnel. The flight operation aspects which include flight dispatch, flight planning, fuel, and freighter loading, are handled by EVA Airways. Engineering and maintenance are handled by China Airlines.

SIA TPE station needs to report all SIA flight movements through their station to SIA FCC. The "flight movement telex" includes information such as airplane registration and the flight arrival and departure times. The communication is usually done by phone, telex, or email. The telex code for station manager is KDSQ, for traffic office is KKSQ.

During interviews, the SIA Taipei Station Manager stated that when TPE station receives the typhoon information, the station will check all the hotels for room availability. The station also plans for tying down the aircraft, put as much fuel as possible to aircraft to increase the weight, and plan how to park the aircraft.

During interviews, the SIA Taipei Station Manager commented that TPE station will usually not inform the crew about the typhoon condition. The SIA Taipei Station Manager also mentioned that crew will be informed of the typhoon status by EVA during the pre-flight briefing. If the airport is closed due to the weather conditions, the Station Manager will call the crew to tell them not to come in to the airport. All flight operations logistics are the ground handling agent's (EVA's) responsibilities. TPE station is responsible for passengers and cargo. Therefore, when SIA TPE station received notification of the typhoon condition on Oct 31, 2000,from the FCC, the station's action was to check the hotel availability (Appendix 7-27).

1.17.4 Typhoon Procedures

According to the Singapore Airlines Flight Administration Manual section 3.41.1, the SIA typhoon warnings are categorized into four conditions. A specific typhoon condition is declared by the Flight Control Center after taking into account information from the affected station. Forecast or actual strong winds (22-33 kts and gusts which may exceed 60 kts) associated with an approaching typhoon and which may disrupt operations should be used as a trigger to declare typhoon conditions.

The out station and Singapore meteorology office normally informs the FCC if a typhoon is approaching a SIA station. The FCC will then inform all affected stations by telex of the typhoon condition. According to the SIA FAM section 3.41.2-5, the typhoon conditions are defined as follows:

Condition I	Typhoon within 48 hours away and deemed a potential threat to a station.
Condition II	Typhoon within 24 hours of a station.
Condition III	Typhoon within 12 hours of a station or imminent.
Condition IV	Winds have abated after passage or near passage of a typhoon. The onset of Condition IV can be taken as effective termination of typhoon conditions.

According to the SIA documentation pertaining to typhoon warnings (SIA FAM section 3.41.1), the risk of damage must be assumed to exist once

Condition III is declared. This declaration, however, does not preclude aircraft commanders and station staff from taking all the necessary precautions to protect facilities, installations and aircraft during Conditions I and II. All communications must be followed by telexes addressed URGENT and MUST be acknowledged.

According to the Typhoon Warning issued by Taipei Aeronautical Meteorological Center at Oct 31, 2100 local time, the civil airports warning status at TPE airport was W24 (typhoon within 24 hours of the station, see ATC/Weather Group report for detail). This would constitute a Condition II typhoon situation for SIA FCC.

The Condition II typhoon procedures in SIA' s Flight Administration Manual relevant to this accident are as follows:

- The responsible agent should ensure that relevant amendments and changes, whether favorable or adverse, are passed immediately to FCC as they become available;
- The responsible agent should ensure that the Commander of any aircraft on the ground is fully and immediately informed of the situation;
- FCC will inform the relevant fleet Chief Pilot(s), SIN station or Departure station, Destination station, Diversion station, Senior Manager Ground Services, Manager Schedules and SIA Engineering Co. that Condition II exists; and
- The Commander of a flight to/from an affected station is to be briefed on all available information regarding the typhoon, including ground handling plan at destination station and diversion plan. The briefing should be given before the Commander reports for duty. Where necessary, he shall consult FCC on all matters pertaining to the flight. In offering assistance, FCC must take into account Marketing and Engineering considerations.

When condition III is declared, the station and FCC shall prepare for delays, passenger logistic requirements at station and at alternates, and arrange for aircraft security and protection. Furthermore, the FCC tracks the progress of the typhoon in case there are any changes in its' intensity and/or direction of travel.

The FCC stated that the standard means for communicating with out stations is by telex. Telephone contact will only be initiated by the FCC if there is an urgent problem. FCC telexed Taipei SIA Station manager for typhoon Condition I at 1839 Taipei local time on the evening of the accident. EVA FCD was not informed by FCC of SIA's typhoon Condition I. At 2155 local time, all parties (include Taipei station and EVA FCD) were informed by telex of the typhoon Condition II (Appendix 7-28). [When a typhoon telex is distributed, it does not necessarily mean that certain parties will be able to immediately view the information.].

Under a condition II typhoon warning, the FCC will inform the Chief Pilot, ground services and engineering by telex. A Condition II typhoon warning is not sufficient to cancel a flight as long as the ambient conditions at the station are within the limits specified by the type specific (B747-400) SIA Flight Operations manual.

The FCC did not receive any responses from the effected stations after the Condition II telexes were sent. According to the FCC, an acknowledgement or response is not required from a station unless they are unprepared for the typhoon. On the night of the accident, the FCC did not receive an immediate response from Taipei, nor were they expecting an immediate response. However, the SIA FAM 3.41.1.6 states that all communications pertaining to typhoon procedures must be followed by telexes addressed urgent and must be acknowledged.

After the accident, Condition III was declared by the FCC at 0159 Nov 1, 2000 (Appendix 7-28).

During interviews, the SIA B747-400 Chief Pilot stated that the fleet does not actively involve itself in the decision-making of crews after a typhoon declaration. The aircraft commander makes the operational decisions pertaining to typhoons of all classifications. However, the option to consult the FCC and/or fleet Chief Pilot is available to the commander. The commander may delay a flight if unsure about the safety of the flight. However, flight cancellation is a commercial issue, which is decided by the fleet Chief Pilot, marketing, and engineering.

With reference to poor weather situations, the Chief Pilot stated that he left it to the aircraft commander to decide on the weather conditions been within the limits specified by SIA. If the operational situation contains uncertainty or ambiguity with reference to the severity of the weather, the Chief Pilot commented that the aircraft commander may consider delaying the flight to see how the weather evolves. Cancellation is a last resort. If the weather exceeds the limitations stipulated by SIA, the FCC, marketing and fleet Chief Pilot will make the decision concerning flight cancellation.

1.17.5 Voyage Record

According to Singapore Airlines Flight Administration Manual 3.28.1, a voyage record will be completed for every flight on the voyage record form. The commander will be responsible for the accuracy of the information in the voyage record.

When a delay occurs, circumstances giving rise to such delays must be entered in the voyage record, with sufficient relevant details for the causes to be clearly identified, e.g. details regarding weather, ATC, technical, ground handling, CIQ.

According to the interviews with SIA pilots, there is a requirement for aircraft commanders to submit a report if any delay is more than 3 minutes. However, captains are not questioned as to why the flight was delayed when good reasons are provided (Appendix 7-2, 7-3).

1.18 Additional Information

1.18.1 Pilot Interviews

1.18.1.1 The Captain, CM-1

During additional interviews with the SQ006 flight crew, CM-1 stated that during his dispatch briefing on the previous day at Singapore for his flight to Taipei, he knew that the typhoon "Xangsane" was approaching CKS airport. He also mentioned that SIA was tracking the path of the typhoon and noted that the typhoon would arrive at Taipei after the next day's scheduled flight. He read the NOTAM and INTAM on the partial closure of R/W 05 R between N4 and N5 and on the closure of the section of the northern ramp between and behind parking bays A1 and A2.

CM-1 reported that his focus was mainly on the strong cross winds and the low visibility. He wanted to know if these were within company limits. He worked on the calculations with the other two pilots. On ascertaining that these were within the company's departure limits, he proceeded to consider the Computer Flight Plan (CFP) and to determine the fuel required for the Los Angeles sector. The fuel uplift was passed to the EVA Operations Officer assisting in the dispatch.

During interviews, CM-1 commented that he had initially intended to give the TPE-LAX sector to CM-2 but because of the weather at Taipei, he decided to do the takeoff and to allow CM-2 to do the landing at LAX. He informed CM-2 about his decision and then the three pilots boarded the airplane.

CM-1 commented that CM-3 volunteered to do the external checks. CM-1 reported that he copied the latest ATIS and was working out the crosswind component. CM-1 stated that CM-2 performed the pilot flying preflight preparation so that CM-1 could concentrate on the weather conditions. CM-1 stated that he crosschecked the CM-2's preparation to ensure it was correct. CM-1 stated that both he and CM-2 loaded the FMS and checked the radio frequencies.

CM-1 stated that he continued to monitor the weather on the ATIS. He also heard the ATC giving weather information to two other flights (Cathay Pacific and China Airlines) that were departing around the same time. CM-1 stated that the visibility appeared to be improving and "better for us". The China Airlines flight was also using R/W 05L. Cathay was going to use R/W 06.

During interviews with the flight crew, CM-1 commented that SIA flights usually use R/W 06 as this runway was closer to the parking bays used by the company. However, CM-1 chose R/W 05L because its CAT II category permitted a lower visibility minimum especially when the RVR was declared. In addition, R/W 05L was longer and would therefore afford better margins for the prevailing wet runway conditions.

During the interview, CM-1 stated that he had experienced worse weather conditions than those that were present at CKS airport on the evening of the accident. He gave as an example a departure from Anchorage where he encountered strong crosswinds, blowing snow and icy runway conditions. He had last been in Taipei about 2 to3 weeks ago, but he reported that it had been between 2 to 3 years since he had used R/W 05L.

CM-1 conducted the procedural briefings inclusive but not limited to EGT limits, taxi and departure routings. He anticipated the taxi routing to proceed via SS, eastwards to East Cross, continuing East Cross to R/W 05R (because of the closure of a portion of the ramp between bays A1 and A2); backtrack on R/W 05R to N7, then taxi to the end of NP, turn onto N1 and then to R/W 05L.

The actual ATC taxi clearance that was issued to the crew was a different routing. CM-1 re-briefed the crew accordingly. The ATC clearance required the crew to taxi westwards on SS to West Cross; then to join NP; proceed to the end of NP to R/W 05L.

During interviews, CM-1 reported that he felt no time pressure on the evening of the accident. He commented that he had told the other pilots not to hurry, to "slow down" and to do their checks correctly. According to CM-1, the crew had sufficient time to complete the checklist and prepare for the departure. He was concerned about the weather because he knew the typhoon was inbound to Taiwan.

CM-1 stated the departure and pushback from the gate were normal. Shortly after taxiing, CM-1 called for Flaps 20. He checked the rudders and CM-2 checked the ailerons and elevators. He then called for the Before Take-off Checks. CM-2 went through the checklist.

CM-1 put the windshield wipers to LO [low speed] during taxiing. The wiper cleaned most of the windscreen and he could see through almost the whole windscreen.

CM-1 had asked CM-3 to monitor the ATIS and to check the wind component. Towards the end of the NP, CM-3 received the latest ATIS and using the relevant chart, he calculated the wind component to be 28.5 knots from the left. The crew were at the end of NP turning on to N1 at the time. This was still within the company crosswind limit of 30 knots. CM-1 reported that both the wind and visibility were not so bad and he could see where he was going.

CM-1 reported in the interviews that he told himself to be more alert than usual and to be especially aware of the situation.

CM-1 stated that during taxi, the crew discussed where they would go if they had to turn back after takeoff. CM-3 informed him that Kaoshiung and Hong Kong were closed. They could also return to Taipei as the weather was within the CAT II landing minima for R/W 05L. During the interviews, CM-1 commented that if winds had exceeded the company operating limits, he would have postponed the takeoff. He also mentioned that he was concerned that the weather over Taipei would get worse before it would get better.

As the airplane crossed the holding line on NP passing N2, prior to the completion of the Before-Takeoff-Checklist, CM-1 told CM-2 to inform Tower that they were ready. On receiving the call, the Tower cleared them into position and hold. At this point during the taxi sequence, CM-1 commented during the interviews that he expected the tower to have seen the aircraft before issuing the crew with the take-off clearance. CM-1 turned the airplane right to taxiway N1. During the interviews, CM-1 stated that he was focused on the image of the runway to his right, and he did not notice any further green lights ahead and along the extension of N1. He stated that he followed the curved centerline lights leading onto runway 05R. During the turn, he reported that he had a flash view of the piano keys [white stripes on the threshold]. He commented that he was attracted to the bright centerline lights leading onto the runway. As he turned, he did not recall seeing any runway identification signboard or the runway identification marking on the runway. On the runway, CM-1 engaged the parking brakes, activated all the landing lights and switched the wipers to HI. CM-1 indicated that he felt that his visibility was not impaired by the rain, even in the areas not swept by the wipers.

CM-1 recalled that as he turned right from N1 onto runway 05R, he remembered being very careful to maintain a taxi speed of 5 knots, so as not to skid on the painted piano keys.

CM-1 commented to the investigation team that as the airplane was lining up, he thought that the image before him was that of a runway. He reported that he could see the centerline light running down the runway, and was 80% sure that he also saw the runway edge lights. He later stated in a subsequent interview that he was not as sure about the status of the runway 05R edge lights as in the earlier interviews.

During interviews, CM-1 stated that he was convinced that he was on runway 05L. He reported that he did not see any objects obstructing the runway in the distance. During interviews, CM-1 said that the take-off clearance issued by ATC when the aircraft was approaching the runway threshold, reinforced his expectation that the Tower had him in sight. CM-1 stated that the airplane heading was around 050 degrees on line up, which was the expected direction for takeoff. CM-1 stated that from his perspective, the picture outside in the heavy rain and with the landing lights ON was that of a normal runway.

CM-1 stated that sometime during the turn to line up, CM-2, who was completing the Before Takeoff Checklist, remarked that the PVD had not activated. CM-3 stated that the PVD would arm only within 45 degrees of the runway heading. After lining up, the PVD was still shuttered. CM-1 stated that he believed the PVD is a most useful aid for low visibility takeoff. He said that he decided that there was no requirement to use PVD for centerline guidance during the takeoff because the visibility was sufficient to a visual takeoff.

See Appendix 7-5 for detail information.

1.18.1.2 The First Officer, CM-2

On the flight into Taipei the previous day, CM-2 had noted that the weather was poor. During interviews, CM-2 reported that aircraft broke through the clouds at 1,000ft, and the winds were strong, especially the headwind. CM-2 commented that the CM-1 performed a good landing. He said that CM-1 did not think the TPE-LAX flight would be cancelled, and he also remembered thanking CM-1 for offering him the next sector (TPE-LAX). The next day, prior to the TPE-LAX flight, CM-2 stated that he had reviewed the NOTAMS and weather in the hotel.

According to CM-2, the flight crew discussed the in-flight rest arrangements during transit from the hotel to the airport on the evening of the accident. CM-2 also mentioned that CM-1 had decided to perform the takeoff from TPE because of the strong winds associated with the inbound typhoon. CM-2 was instructed to fly the approach and landing into LAX. During the dispatch briefing, CM-1 and CM-3 reported that they calculated the crosswind components for take-off, and after checking the results, they decided to go ahead with the flight.

While walking to the cockpit, the flight crew noticed that the catering people were having some difficulty loading the catering on board due to the weather. During interviews, CM-2 reported that CM-1 had told them to slow down and take their time. CM-2 commented that he felt that CM-1 had set the tone for the crew about not rushing.

CM-2 stated that during the cockpit briefing, CM-1 briefed the flight crew on the taxi route he expected to take, which included backtracking on R/W 05R. CM-2 thought that R/W 05R was closed and CM-3 clarified that R/W 05R was only partially closed. CM-1 and CM-3 stated that they were concerned about the winds, whether the wind components were within limits, as well as the slippery runways. They also discussed the alternates for the departure airport and the visibility for a landing back at TPE if required.

CM-2 stated that CM-3 did the external checks. When CM-3 returned to the cockpit, his shoes were wet, and he asked permission to take them off and wear ‘sockettes’ instead. CM-2 completed the ‘bug card’ with some input from CM-3. CM-3 corrected the speeds for the wet takeoff. While CM-1 and CM-3 were looking at the crosswind calculation, CM-2 decided to set up the cockpit. He switched on the PVD. CM-2 stated that he felt good when he noticed that CM-1 had also turned on his PVD. CM-2 reported that he was acutely aware of how gusty the winds were, and that they were blowing hard and changing direction rapidly. CM-2 noted the effects of the wind on his speed trend vector as well as CM-1’s speed trend vector indication, which was different from his. CM-2 commented during interview that he was thinking of the speed trend vector system and the source of data contributing to this indication.

When ATC issued the crew with the taxi route, CM-1 briefed the crew on the new routing. During interviews, CM-2 expressed that he felt the taxi route was better than the anticipated route because it was an easier route to navigate. CM-2 stated that he had not been to TPE for quite some time. CM-2 was concerned about how he would support CM-1. He stated that if he had been asked to do the takeoff, he would have asked CM-1 to do the takeoff because he felt the more experienced pilot should do it.

CM-2 stated that he felt confident in CM-1 and CM-3, and that the crosswind components were within the limits for takeoff. After pushback and while taxiing along SS, he set flaps to 20, and checked the ailerons and elevators. He did it twice to be extra sure that the controls were free and was especially deliberate in his actions. He did the instrument checks and double-checked to ensure they were working properly. During this time, he stated that he was using his taxi chart to monitor taxi progress. He also said that he handled the radio communications throughout taxi.

While on West Cross, he was doing the first part of the Before Takeoff checklist, as well as the radio communication. During interviews, CM-2 reported that he did not notice lights in the distance in front of the aircraft. During the taxi along NP, he stated that he remembers waiting for the hand off to the tower controller for line up and takeoff clearances. Approaching the N2 turn, he said 'next right' and was prompted by CM-1 to say 'second right' instead. At this point, ATC calls came in for line up and takeoff.

CM-2 then commenced the 'below the line' Before Takeoff checklist. CM-2 reported that while going through the checklist, CM-1 was with him. CM-2 also mentioned that CM-1 was quick to respond to the checklist items. Going through the checklist, CM-2 noted that CM-1 had switched on the strobe and the landing lights. CM-2 stated that he was careful to make sure each checklist item was completed, but was also glancing out periodically to monitor CM-1's taxiing. CM-2 mentioned that he then checked the ground speed and that his attention was focused inside the cockpit at this time. He once again noted the CM-1's PFD speed trend vector indication was different from his and the difference caught his attention.

CM-2 stated that during line-up, he noticed that the PVD had not activated. CM-3 explained to the other pilots that the PVD would not be active until the aircraft was aligned within 45 degrees of runway heading. CM-2 stated in the interview that CM-1 decided the PVD would not be required for the takeoff because he was comfortable with the visibility along the runway. CM-2 was satisfied with CM-1's decision as he saw very bright centerline lights when he looked up at the runway ahead of him. He could not recall sighting any runway edge lights. He also commented that he saw the green lights leading onto the runway to the right [when airplane was turning into the runway]. He did not notice any other lights, but he saw the piano keys on the threshold and remembered they appeared ‘ scratchy’ .

During crew interviews, CM-2 reported that he did not notice any displacement of the localizer on the PFD. [It is noted that there is no requirement for this to be checked in either the SIA or the Boeing B747-400 operating procedures] He also mentioned that he has previously used the PVD in the simulator but he has not used the PVD for an actual take-off during line operations.

CM-2 turned on the weather radar and noticed that the entire area was painted green because of the rain. He also checked that the wipers were on “HI”, and noticed that CM-1 had already switched it on. The aircraft lights were working, but visibility was not as good as a clear conditions.

CM-2 reported that he was aware that only R/W 06 and R/W 05L were active and that R/W 05R was closed. When asked to describe his mental picture of a closed R/W 05R, he replied that a closed runway should be ‘ black’ and have no lights. Furthermore, he commented that any work in progress on the aerodrome should have warning lights.

CM-2 described the factors that made him think that he was on R/W 05L. He said the runway picture was ‘ correct’ . He recalled seeing lights down the middle of the runway and they were very bright. He reported that there were no visible obstructions ahead of the aircraft. He estimated that he could see a length of about 200 to 300 meters down the runway. The taxi lights led into the runway. Apart from the curved taxiway lights leading on to the runway, CM-2 reported that he did not notice any other lights. He did not see any runway identification signboard [box], or the runway identification markings. CM-2 stated that the visual cues indicated that the aircraft was on an active runway. There was no operational requirement to use the PVD for runway centerline guidance during a visual take-off. CM-2 indicated during interviews that he was prepared to tell CM-1 not to takeoff if the runway picture was not right. He also recalled that there were strong winds and very heavy rain from push back to takeoff. CM-2 recalled that apart from the portion that was cleared by the wiper, the rest of the windshield was obscured by rain.

See Appendix 7-5 for detail information.

1.18.1.3 The Relief Pilot, CM-3

Interviews with CM-3 revealed the following information. CM-3 was involved with the self-briefing of the flight documents at the gate. He also reported reading the NOTAM, INTAM, and the Fuel Flight Plan. He conducted the external checks that took about 15 minutes. This took slightly longer than usual because of weather conditions. CM-3 stated that CM-1 asked him to monitor the ATIS and keep a check on weather. CM-1 asked him to check the winds during taxi and to calculate the crosswind component. CM-3 also monitored CM-2 to ensure that all checklists and procedures were properly completed. CM-3 stated that he took out the spare copy of the Taipei Airport chart and was monitoring the taxi route. He stopped monitoring the taxi when he received the latest wind information from the ATIS. He then put the chart aside to calculate the crosswind component for takeoff.

CM-3 had experienced the weather conditions during the external airplane checks. He commented that he elected not to inform CM-1 of his assessment of the environmental conditions because he did not want to place additional pressure on CM-1. CM-3 stated that the crosswind for take-off was inside the limits. CM-3 stated that he knew the typhoon conditions would get worse the longer the flight was delayed. During interviews, he said he felt comfortable about the airplane taking off in those weather conditions. CM-3 thought that the CM-1's decision to do the take off was the correct one.

Interviews with the crew revealed that CM-3 felt his primary duty as the relief pilot was to be the third pair of eyes and to support CM-1 and CM-2 by monitoring their actions. He also mentioned that he felt comfortable about the manner in which CM-1 and CM-2 were managing the flight. He noted that CM-1's initial taxi briefing was different from what was given by ATC. In addition, he stated that he was aware that R/W 05R was to be used only for taxiing. CM-3 stated that his last operation from CKS R/W 05L was about 2 to 3 years ago. He stated that he had a good understanding of the CKS taxiways. If the winds or visibility exceeded operational limits, CM-3 commented that he was prepared to voice his concerns to CM-1. However, at that time the visibility was good. CM-3 stated that he could only see ahead of the aircraft because he was seated in the jump seat (first observers seat) behind and in between the two other pilots.

As the airplane taxied along NP, CM-3 recalled hearing a radio communication between the Tower and Cathay Pacific departing for HKG from R/W 06, and a radio communication with another carrier that winds were gusting up to 50 kts. CM-3 commented that he was worried by this wind gust information until he checked the crosswind component and found that it was still within company operational limits.

When the ATC clearance was issued to the crew to line up on runway 05L and hold, CM-3 commented that did not have an expectation that ATC were able to see the airplane.

As the airplane approached taxiways N1 and N2, CM-3 stated that he was concentrating on calculating the latest crosswind component for take-off. CM-3 indicated that his mental focus was inside the cockpit at this point in the taxi sequence. According to CM-3, the rain was very heavy but the wipers were able to clear the windshield. However, the visibility from the side windows was considered substantially degraded. The wind was very gusty. CM-3 said that CM-1 was in control of the situation.

As the aircraft began to turn into N1, CM-3 received another wind report from ATIS, and calculated the crosswind component again. During interviews, he reported that he then looked up and saw a very bright environment. He noticed the centerline lights, but did not notice the runway edge lights. He said that the visibility was sufficient and good enough for takeoff. He noticed that CM-2' s attention was drawn to the fluctuating speed trend vectors. CM-3 stated that he looked at the PFD and saw that the ILS frequency was correct.

When CM-2 mentioned that the PVD was not activated, CM-3 stated that he explained that the airplane alignment was not within 45 degrees of the runway heading. CM-3 stated that he was not concerned about the PVD indication because the visibility was sufficient for take-off, and the PVD is only required for Category III weather conditions. CM-3 noted that he felt CM-1 was comfortable about going ahead without the PVD. CM-3 also stated that he thought the airplane was sitting on the runway with bright lights. According to CM-3, the runway appeared to be like a typical runway with bright lights down the centerline of the runway. From where he was sitting, CM-3 reported that he could not see the piano keys, runway signboards or markings.

CM-3 was aware that only two runways were active. These were RW 06 and RW05L. He knew that runway 05R was closed but was available as a taxiway. When asked to describe his mental picture of a closed runway 05R, CM-3 said that the runway lights should not be illuminated. He further stated that there should also be obstruction lights and barricades for the work-in-progress area, and lit no-entry signs.

See Appendix 7-5 for detail information.

1.18.2 Air Traffic Interviews

1.18.2.1 Local Controller (LC)

During interviews, the Local Controller stated that he arrived for work at the Tower at 1840 hrs on 31 October 2000. He worked through cycling shifts of 40 minutes on duty and 20 minutes rest thereafter. At 2300 hrs, he took over the LC position after completing a rotation through the flight data/clearance delivery position. The LC managed only one airplane namely, SQ006. He checked that the taxi lights were already "On" (05L centerline and 05L edge lights were both already turned on with the intensity level set at 4). He remembered that the red sector (labeled N TW R) and yellow sector (labeled N TW Y) taxiway lights were also turned on [these were the Ground Controller's responsibility]. He also recalled seeing that the indicator lights at the red and yellow sectors of the airport were illuminated but he was unable to recall the intensity level of the lights.

There was a flight strip holder next to the lighting control panel to remind controllers that RWY 05R/23L was currently not in use. The strip had a white background with "RWY 05R/23L" in black letters and "currently not in use" (Chinese characters) in red.

There were four people working in the tower on the evening of the accident: the Aerodrome Controller (LC), the Ground Controller (GC), ATIS position and the Flight data/delivery clearance position. The LC recalled that the visibility was Runway Visual Range (RVR) 450 m when he took over SQ006. SQ006 had pushed back and was taxiing at the time. SQ006 was handed off to him at junction of taxiways West Cross and NP. The LC reported that he could not see the airplane shortly after it started to taxi along NP. The LC had issued the crew with an instruction to hold short 05L. The LC also provided the crew with the most recent wind velocity information. He asked the SQ006 crew for their intentions but he did not receive an immediate reply. A few seconds later, the SQ006 crew called to say that they were ready for takeoff. The LC subsequently cleared them for takeoff, because there were no other aircraft in the vicinity.

There were no ATC Tower equipment malfunctions, such as the radio communication controls, the runway lighting controls, the wind and weather displays and the radar display .

Shortly after the LC issued the takeoff clearance, he heard an explosion and saw fire in front of him, near NP and R/W 05R. He pushed the emergency alarm, while another controller contacted the fire department. Concurrently, the GC closed down 05L. Subsequently, the Airport Authority called the Tower and told them to close the airport. The LC closed the runways for arrivals and departures. The LC reported that he did not touch any of the runway lighting controls.

The LC recalled the visibility that night was poor. Prior to the crash, he could not see the centerline lights and the edge lights on runway 05R. Similarly, he could not see anything between him and 05L (inclusive of the construction area on 05R). The weather was poor with winds of such magnitude that they sent tremors along the suspension lights above him in Tower cab.

On a typical clear night, the LC reported that he would be able to see the end of the runways and even the runway sign boxes. However, he commented that he would not be able to read them. He stated that he was able to see the obstruction lighting on the works in progress on R/W 05R on clear night.

The tower had placed one tag over the 05R runway light switch since the middle of September 2000 to prevent inadvertent actions. A similar tag was placed the over 05L runway light switch after the SQ006 accident. Both tags were designed to remind the controller not to turn on these lights.

The LC was aware that Tower had already planned for a postponement of the NOTAM (see ATC group report for detail) with respect to the instruction on converting R/W 05R to taxiway NC. This postponement was for an indefinite period. Therefore, the operating instructions for the night of the accident were to remain the same.

1.18.2.2 Ground Controller (GC)

This interview was conducted with the GC to clarify the actions that ATC carried out in relation to the runway 05R centerline and edge lights after the Senior Flight Operation Officer (SFOO) had requested the closure of the RW 05L/R and thereafter (Appendix 7-29).

During interview, the GC stated that the lights for RW 05L/R were switched according to the following sequential events:

1. Immediately prior to the SQ006 accident, RW 05L edge and centerline lights were on and the RW05R edge lights were off. The RW 05R centerline lights were on.
2. After the SFOO called for the closure of RW 05 right after the SQ006 accident, the GC switched off all the edge and centerline lights for RW 05L, the centerline light for RW 05R, and all taxiway lights.
3. When the SFOO found that the RW 05R[accident site] was too dark for rescue operations, he asked for more lights. The GC then switched on all the edge and centerline lights on RW 05L and RW 05R, and all the taxiway lights.

1.18.3 ATC Low Visibility Procedure

During interviews with the Chief Tower controller, the investigation was informed that for low visibility operations, the primary consideration for ATC is to protect the active runway/s. In particular, ATC try to ensure that the aircraft are expedited from the active runway after landing and that taxiing aircraft do not enter active runways until cleared.

Second, the Chief Tower Controller commented that separation assurance is very important for aircraft during taxiing. If there are two or more aircraft on the movement area at one time, ATC will request aircraft to hold at various taxiway intersections to ensure separation. This process may involve asking flight crews to report their location on the airfield during taxi. If there are no other aircraft on the airfield during taxi, ATC does not have specific procedures or practices to assist crews' navigation. The Chief of CKS Tower stated that under these conditions, it is the flight crews' responsibility to ensure accurate navigation around the airfield. ATC will advise them about the low visibility and to taxi with caution.

In very poor weather, where ATC are unable to visually confirm the location of the aircraft, the only method that ATC has available to determine the aircraft's position is through radio transmission position reports from the crew (Appendix 7-30).

1.18.4 Runway Condition and Crosswind Limitation

ATC did not provide any information to the crew of SQ006 on the condition of the runway before or during taxi. According to interviews with ATC, CKS Airport does not have the equipment to measure the depth of standing water on the runway. Therefore, ATC does not have the capability to provide flight crews with accurate runway standing water information (Appendix 7-30).

When queried about the determination of a contaminated runway, the SIA B747-400 Chief Pilot stated that ATC should provide information to the crew on the condition of the runway. When asked if SIA had a procedure to assist pilots to assess the state of a wet runway when ATC did not provide such a service, the B747-400 Chief Pilot stated that crews rely upon ATC to provide this information. The Chief Pilot commented that the crews are not in a position to accurately assess whether a runway is contaminated. Furthermore, the Chief Pilot commented that most runways (unless defective) are designed with adequate drainage to prevent an excessive accumulation of water on the runway surface.

When asked about the crosswind limits for the B747-400, the Chief Pilot confirmed the following guidance stipulated by the SIA Flight Crew Training Manual. However, the SIA B747-400 Chief Pilot stated that these are training guidelines only;

- 30 knots dry runway;
- 25 knots wet runway; and
- 15 knots for a contaminated runway.

The SIA Operations Manual states that the crosswind limit is 30 knots, and does not differentiate between wet and dry runways. This is in accordance with the limit specified by the Boeing B747-400 flight manual (Appendix 7-31). SIA operates according to the Boeing procedures and performance limitations and has adopted the Boeing Operations Manual as its official operational document. SIA has added its own chapters on operational and fuel policy, and has modified the Boeing normal checklist to make it more compatible for airline use.

1.18.5 Field of View

CM-2 and CM-3 stated in the interview that, due to the rain on the cockpit windshield, they were unable to clearly see through the area not swept by the windscreen wipers. On behalf of the ASC, Boeing conducted a Field of View study which will be discussed in the analysis.

1.18.6 Para-visual Display (PVD)

1.18.6.1 Operational Concept

According to the Singapore Airlines B747-400 Flight Crew Training Manual (FCTM) (page 8.32), the PVD is a display that allows the pilot to receive director information from a peripherally located display whilst maintaining eyes forward and out the window looking for familiar visual cues. The two PVD elements are mounted on the coaming centrally in front of each pilot; one on the right side and one on the left side. Figure 7-1 shows the location of the PVD on CM-2's side. The inset in the lower left corner of this Figure shows a single PVD up close.

Para-Visual Display

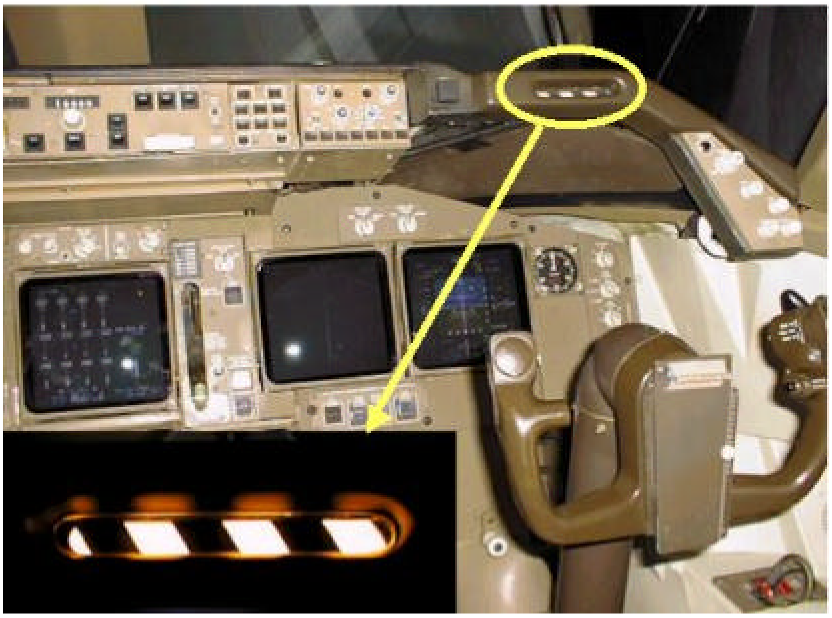


Figure 7-1 Para- Visual Display.

Each PVD unit is actually a mechanical device incorporating a rotating rod or pole that has black stripes on a white background (like a "barber pole"). Rotation of the pole gives the impression of lateral motion, or streaming, to the left or right.

The PVD becomes a valuable indication in the case that runway visibility is poor (less than 50 meters) during takeoff. The PVD is tuned to the takeoff runway's ILS signal. As long as the airplane is on the runway centerline, the "barber pole" indication is stationary. However, when the airplane diverges left or right of the centerline, the barber poles streams to guide the pilot's steering. For example, if the airplane is to the right of the centerline, the PVD will stream left to guide steering left toward the centerline.

The PVD is a high-reliability reversionary aid to runway steering—the primary aid being the pilot's normal visual cues from runway markings and lights. The PVD should unshutter and begin functioning correctly as the airplane is aligned with the runway centerline, and remain functioning as long as the controlling parameters remain valid. The PVD remains shuttered when it is not in use or when the ILS signal is not being picked up (e.g., out of range, signal blocked, system failure).

There is no procedure or requirement in the Boeing Operations Manual used by SIA that the PVD and the associated PFD indications are to be used as a means for identifying a runway.

1.18.6.2 Operational Procedure

According to the Singapore Airlines B747-400 FCTM (page 8.33), pilots should select the PVD on when they have taxied to the "hold." It is also necessary that the ILS localizer for the takeoff runway has been tuned. When the PVD is selected on, the computer will run pre-takeoff self-tests. These tests open the shutter and stream the display in each direction for 1.5 seconds. The crew should monitor this test for any anomalies. The crew should also adjust the brightness of the PVD display, if it is needed.

The memo messages PVD CAPT ON, PVD F/O ON, or PVD BOTH ON appear on the main EICAS display when either one or both PVDs have been selected on. If either PVD system fails during normal operation, the advisory message PVD SYS CAPT or PVD SYS F/O will appear on the main EICAS display.

1.18.6.3 Associated Indications

When the ILS is tuned for the takeoff runway (as required to use the PVD), two other indications appear on the Primary Flight Display (PFD). Figure 7-2 shows these PFD indications for two cases: on the left is the case when the airplane is aligned with the centerline, and on the right is when the airplane is not aligned with the centerline. The first indication is a localizer pointer and scale that appear on the bottom of the Attitude Indicator. The pointer is a solid pink diamond that shows the airplane's position relative to the localizer position.

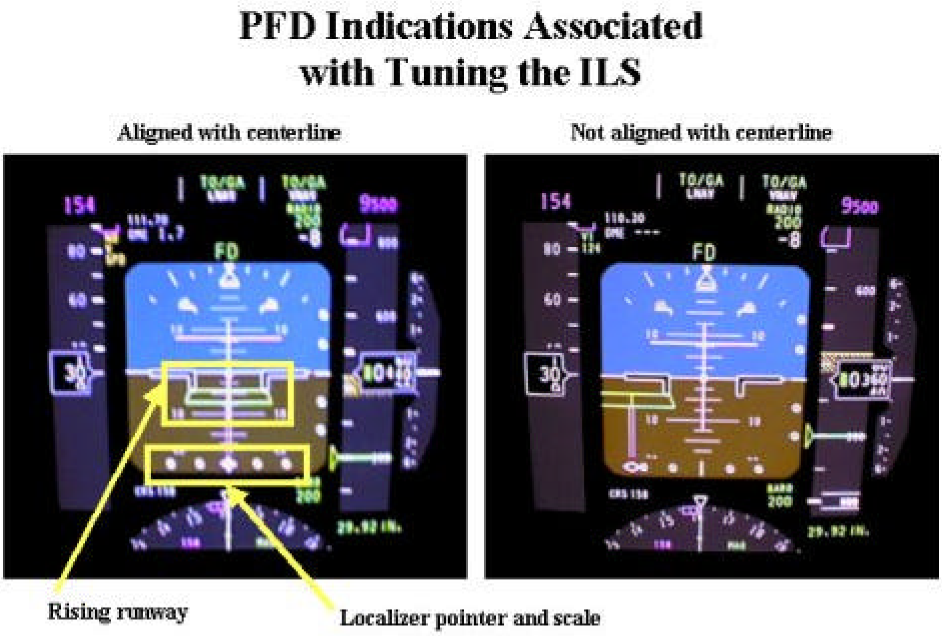


Figure 7-2 PFD Indications Associated with Tuning the ILS.

Note that when the airplane is not aligned with the centerline, the localizer diamond is shifted to the left side of the scale and is not filled in. The second indication is the rising runway symbol, which is a green trapezoid (a square with perspective) with parallel pink lines extending down from it. This runway symbol should appear just below the horizon and centered. Note that when the airplane is not aligned with the centerline, this rising runway is shifted off center.

1.18.6.4 Experience of SQ006 Crew with the PVD

From interviews with the CM-1 and CM-2, we learned that they had each selected the PVD on when parked at the gate. CM-2 also recalled seeing that CM-1 had turned his PVD on.

When the crew turned onto runway 05R, CM-2 noticed that the PVD did not unshutter as he expected it would [because it was tuned to 05L and, unknown to him, was out of the range in which it will unshutter]. Even when they were fully lined up on the runway, the PVD did not unshutter. At this point, CM-1 decided that visibility was satisfactory for takeoff, and he decided to begin the takeoff without the correct PVD indication.

1.18.6.5 PVD Training

According to the Singapore Airlines B747-400 FCTM (page 8.34), during initial training, all pilots are required to demonstrate proficiency in taking off with subsequent loss of sight of the centerline lights requiring reversion to PVD.

Initial technical knowledge of the PVD is part of the computer-based type transition (known as type conversion in SIA) course. Practical training is conducted during full flight simulator phase of conversion training.

To maintain PVD recency, pilots have to conduct at least four PVD assisted takeoffs each year. In order to ensure recency SIA roster pilots to do two PVD takeoffs during the two flight simulator "Recurrent Training" details within the year. The pilots are also required to ensure that the airplane system is also current by carrying out at least one PVD takeoff every 28 consecutive days. Each PVD takeoff must be recorded in the appropriate section of the airplane Technical Log.

1.18.6.6 PVD Reliability

Because the PVD is a reversionary (back-up) instrument, it needs to have a high reliability. The reliability information is from several sources: SIA 747-400 pilots, other air carriers using the PVD, and the PVD manufacturer, Smiths. Boeing itself does not maintain reliability information on this instrument.

During several interviews with SIA pilots (five SIA Captains and one First Officer, see Appendix 7-1, 7-2, 7-3, 7-6, 7-8, 7-12), the following information was obtained: Except for one interviewee who had heard of some pilots' having problems with the PVD, all the others were clear that the PVD is a reliable system if the runway is appropriately certified for PVD departures or as long as there is no shielding of the LLZ/ILS signal. They have not heard of any failures of the system. Even the one exception could not specify the type or nature of apparent problems with the PVD he had heard about.

When the investigation team contacted the air carrier who have purchased the PVD option for their 747-400s or 767s, there were no reported failures of the PVD system (Appendix 7-32).

The PVD manufacturer, Smiths Industries, provided repair data for 13 PVD computer units which were returned to them in the period from January 1998 to November 2000. During that period, one PVD unit was returned because it did not activate on takeoff. A second PVD was returned because it tripped off during takeoff with EICAS and status messages displayed. The remainder were returned for various status and maintenance messages, including seven returned to incorporate an upgrade. Smiths Industries was not able to find faults in any of the 13 returned units (Appendix 7-33).

Note: Appendices after 7-33 were currently not cited in the report. However, they may be use as future references for the investigation.

IV. Appendices

7-1	Interview note – Capt Bajerai
7-2	Interview note – Capt Ng
7-3	Interview note – FO Su
7-4	Pilots Medical Records
7-5	Pilots interview record
7-6	Interview note – Capt Teo
7-7	Interview note – Capt Chan
7-8	Interview note – Capt Teo
7-9	ATC interview record
7-10	Interview note – Capt de Vaz
7-11	Interview note – Capt Yong
7-12	Interview note – Capt Tan
7-13	Interview note – Capt McCully
7-14	Interview note – Capt De Silva
7-15	Interview note – Capt Koh
7-16	Interview note – Mohamed
7-17	SIA Taipei Nightstop Information
7-18	Interview note – Ting
7-19	Interview note – Lim
7-20	EVA FCD interview note
7-21	CAAS audit record on TPE
7-22	**長榮航空代理新加坡航空用航作業相關資料** (EVA handle SIA Ground Operations at TPE documentations)
7-23	EVA handle SIA flight dispatch training material, 1995
7-24	Telex record of FCD EVA
7-25	GSD Contract between SIA and EVA
7-26	ITAT Ground handling Agreements AHM810 April 1993
7-27	Interview note – SIA TPE Station Manager/Telex Record/Station Org. Chart
7-28	Telex records of FCC SIA

7-29	Interview note – Chen
7-30	Interview note – Lin
7-31	Interview note – Tan (2nd)
7-32	PVD information - Qantas
7-33	PVD information - Smiths
7-34	Crew Hotel records
7-35	Detailed taxi time line
7-36	Pilots' schedule for Oct. and Nov.
7-37	SIA FCC communication log
7-38	Crew Learjet training record
7-39	Interview note - Hock
7-40	Interview note - Huat
7-41	Interview note - Daws
7-42	Interview note – SQ6 crew
7-43	SQ006 Flight Package
7-44	SIA ' s reply to the request of UA audit report
7-45	Voyage Record Form
7-46	Interview note – Capt. Bauder
7-47	Boeing 747-400 PVD (SMITHS)
7-48	Crosswind Limit 747 Email (Boeing)

Aviation Safety Council
Taipei, Taiwan

SQ006 Accident Investigation

Factual Data Collection

Group Report

Recorders Group

February 21, 2001

ASC-FRP-01-01-008

I. <u>Team Organization</u>

A.CVR Group

CVR Group Chairman:

Steven Su
Engineer, Aviation Safety Council

Members:

1. Dennis R. Grossi
   National Resource Specialist
   National Transportation Safety Board

2. Joe MacDonald
   Captain, Chief Pilot 747
   The Boeing Company

3. Quek Tong Huat
   Airworthiness Manager
   Civil Aviation Authority of Singapore
   MCIT, Singapore

4. Edward Yeo Tin Ngiah
   Airworthiness Manager
   Civil Aviation Authority of Singapore
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5. Eugene C. Antoni
   Captain, 747-400
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6. Leong Kwok Hon
   Manager, Flight Safety
   Singapore Airlines
   MCIT, Singapore

7. Yeo Kern Yong
   Executive, Flight Data
   Singapore Airlines
   MCIT, Singapore

B.FDR Group

FDR Group Chairman:

Michael, Guan
Engineer, Aviation Safety Council

Members:

1. Dennis R. Grossi
   National Resource Specialist
   National Transportation Safety Board
2. Steven, Su
   Aviation Safety Council
3. Yeo Kern Yong
   Executive, Flight Data
   Singapore Airlines
   MCIT, Singapore

II. History of Activities

A. CVR Group Activities

Date	Activities
11/01/2000	1. CVR found at 1330 2. CVR back to ASC headquarter at 1600 3. Start readout of the CVR
11/02/2000	1. CVR readout and downloaded successfully
11/03/2000	1. Completed the last 4 minutes transcript.
11/04/2000	1. Finished the first 5 minutes and 30 seconds of CVR transcript.
11/06/2000	1. Flight Ops Group CVR listening 2. Draft transcript
11/07/2000	1. Human Factors Group CVR listening 2. CVR transcript refined
11/08/2000	1. Completed the CVR transcript verification.
11/09/2000	1. CVR final transcript available to all groups.
11/10/2000	1. Sent copy of CVR transcript for Dr.Barry Strauch, NTSB and Singapore Accredit Representative
01/30/2001 01/31/2001	1. CVR Group Factual Report Verification Meeting

. FDR Group Activities

Date	Activities
11/01/2000	1. The FDR was found at the tail section of the aircraft at 1330. It was brought back to the ASC lab about 1600. 2. The FDR was checked for damage 3. The raw data was downloaded with the recorder manufacturers standard hardware and software. 4. A B747-400 FDR database template obtained from EVA and engineering unit conversion was carried out.
11/02/2000	1. The AlliedSignal SSFDR RAW data was downloaded successfully. 2. The formal FDR database was obtained from Singapore Airlines and parameter validation process commenced. 3. In preparation for the progress meeting, the listing of 300 engineering parameters was compiled using Singapore Airlines database and ADRAS software.
11/03/2000	1. The FDR raw data was imported into RAPS for analysis (tabulating, plotting) and for the generation of animation. 2. The FDR data was double checked with ADRAS and RAPS database. 3. The CVR was synchronized with the FDR UTC time by using the microphone keying data recorded during the last 4 minutes of flight.
11/04/2000	1. The following three group FDR parameters were checked: A: General: Time, Airspeed, Ground Speed, Pitch, Roll, Heading, Vertical acceleration, VHF B: Flight Control: Aileron, Elevator, Rudder, Control Column Position and Control Wheel Position, Airspeed, Ground Speed. C: Engine Parameters: EGT, EPR, N1, N2, Ground Speed. 2. A 3D animation was created using FDR data on the RAPS. 3. The flight path was created by calculation using drift angles,

ground speeds and magnetic headings.

4. The CVR audio was incorporated into the 3D animation.

11/06/2000 1. Accomplished extracting data from FDR
2. Update the RAPS database for the parameters of EGT, EPR, N1 and N2, based on Boeing' s FDR system.
3. The accuracy of recorded ground speed was crosschecked by calculation using the recorded longitude acceleration data.
4. The satellite map, CVR, FDR and air-photography data were successfully integrated to produce the 3D animation of the flight.

11/07/2000 1. The last one-second' s FDR raw data was sent to AlliedSignal and ATSB for replay and verification.
2. The QAR box, was sent to Penny & Giles UK for data extraction.
3. The readout was accomplished and a plot of the localizer deviation, ground speed, and heading and vertical acceleration data was produced for the take-off phase.
4. The final draft version of the 3D animation was completed by integrating the CVR, FDR data with information obtained from the air-photo of CKS airport.

11/8/2000 1. The last four minutes 3D animation of SQ006 accident was finalized.

III. Factual Description.Recorders Group responsible for 1.11.

1.1-1.10(N/A to Recorders Group)

1.11 Flight recorders

1.11.1 Cockpit Voice Recorder

The airplane was equipped with a Fairchild model A200S CVR, SN 00744. The recording, which contained good quality audio information, consisted of four channels including the relief pilot's microphone, the first officer's microphone, and the captain's microphone. The fourth channel included the cockpit area microphone. The external surface and interior of the CVR was found without any damage or contamination. The CVR consists of 123 minutes of recording. Only 16 minutes and 30 seconds of information relevant to the accident flight were transcribed (see section 1.11.1.2). Timing of transcript was based on the ATC UTC that was correlated to microphone keying that are common to the CVR and FDR.

1.11.1.1. Description of Investigation

The recorder was properly seated in the rack when ASC personnel arrived at the crash site. There is no evidence of heat or impact damage on the exterior of CVR. There was also no contamination caused by rescue process.

The prosecutors viewed and recorded the model, part number and serial number of the CVR after the recorder was removed from aircraft. The recorder was released from the prosecutor officer to ASC on November 1, 2000.

The recorder arrived at the ASC Recorder Laboratory approximately 4:00 PM November 1, 2000 local time. Inspection of the CVR exterior was immediately conducted. There was no apparent damage found. The under water locator was attached to the CVR. CVR specialist then proceeded to open the CVR and inspected the inside of the CVR. The rear connector, pins, memory module and all circuit board were not damaged. There were no evidence of heat, impact damage or contamination on the circuit board and memory module.

The recording was downloaded successfully with the original recorder and standard equipment. This recorder had 123 minutes of recording. All recording were recorded on the digital audiotape with 44.1 kHz sampling rate. CVR was powered when number one engine was started. （see appendix 8A-1 Description of CVR ON/OFF logic）. Only the 16 minutes and 30 seconds of recording related to accident flight. All of the flight crews were using their hot microphone system. Advanced audio filtering and amplification techniques were applied to enhance readability of all data.

CVR time is correlated with the Solid State Flight Data Recorder (SSFDR) information and the Air Traffic Control (ATC) transcript（see appendix 3-11~3-13） developed by CAA.

Only the 16 minutes and 30 seconds of recording that related to accident flight was transcribed. The recording and transcript started ATC UTC 1500:53 as the flight pushed back from gate B5 at C.K.S. International Airport. The transcript continued uninterrupted until ATC UTC 1517:22, shortly after time of the first impact. The transcript contains push back, engines starting, taxi to runway zero five right via Sierra Sierra, West Cross, November Papa and N1. The recording ended shortly after the aircraft’ s first impact.

1.11.1.2. CVR Transcript

Transcript of Fairchild model A200S CVR, SN 00744, installed on a B-747-400, 9V-SPK, which was involved in a take off and crashed on a closed runway at Chiang Kai Shek (CKS) International Airport, Taiwan, on October 31, 2000.

Legend for SQ006 CVR Transcript

CM-1 PF	Channel 3 (Occupied left hand seat, Captain) Pilot flying
CM-2 PNF	Channel 2 (Occupied right hand seat, First Officer) Pilot non-flying
CM-3 OBS	Channel 1 (Occupied first observer seat, Relief Pilot) Observer
CAM	Channel 4 (Cockpit area microphone on P6 panel)
RDO-2	Radio transmission from CM-2 PNF
MAINT	Ground Maintenance interphone
TWR	Radio transmission from CKS Tower
GND	Radio transmission from CKS Ground Control
CI 004	Call sign of China Airlines flight CI 004（Dynasty zero zero four）
CX 2043	Call sign of Cathay Pacific Airlines flight CX 2043（Cathay two zero four three）
----	Unintelligible
△	Conversations between Ground/Tower and CI 004/CX 2043 that relate to ATC clearances
****	Expletives

ATC UTC	SOURCE	CONTENTS
15:00:53	CM-1 PF	Light up
15:00:54	CM-2 PNF	Check
15:01:12	CAM	(Sound similar to that of starter switch in)
15:01:12	CM-1 PF	Fifty percent N two
15:01:14	CM-2 PNF	Valve closed
15:01:16	CM-1 PF	Starting Engine two
15:01:18	MAINT	Roger, start two
15:01:18	CM-2 PNF	OK Starting two
15:01:19	CM-1 PF	See if you can get…what's the latest weather. Can you write it down What's the latest ... ATIS eh
15:01:23	CM-3 OBS	OK yah
15:01:25	ATIS	Taipei international Airport information Tango one four five four Zulu runway zero five left is in use. Runway zero six for departure only expect ILS runway zero five left category two approach wind zero two zero at three six gust five two visibility five hundred meters, runway zero five left RVR four hundred fifty meters runway zero six five hundred meters with heavy rain cloud broken two hundred feet overcast five hundred feet temperature two one dew point two zero QNH one zero zero one Hectopascal departure frequency one two five point one caution wind shear on runway zero five left final due to radio interference tower frequency change to one two nine point three caution taxiway November Sierra has been remarked aircraft using November Sierra advise taxi slowly with caution. Taxiway November Papa behind Alpha one and Alpha three closed, runway zero five right between November four and November five closed due to work in progress, taxiway November four and November five still available. Inform Taipei approach or tower initial contact you have tango.
15:01:29	CM-1 PF	Write up…write behind here
15:01:29	CAM	Write up
15:01:30	CM-3 OBS	I got it.
15:01:33	CAM	(Clicking sound -similar to the sound of chronometer resetting)

ATC UTC	SOURCE	CONTENTS
15:01:38	MAINT	Number two N one rotation
15:01:40	CM-1 PF	Thank you
15:01:41	CM-2 PNF	Oil pressure number two
15:01:43	CX 2043	Ground Cathay two zero four three request the wind and RVR of runway zero six
15:01:49	CM-1 PF	Light up
15:01:49	CM-2 PNF	Check
15:01:51	GND	Cathay two zero four three runway zero six RVR five hundred fifty meters and wind zero two zero at three eight gust five one
15:02:04	CM-1 PF	Ok lah, this is better still, Fifty percent N two
15:02:04	CAM	(Sound similar to that of starter switch in)
15:02:06	CX 2043	Cathay two zero four three
15:02:07	CM-2 PNF	Valve closed
15:02:09	CM-1 PF	Ok starting three
15:02:11	MAINT	Roger start three
15:02:12	CM-1 PF	Zero two zero better for us
15:02:13	CM-2 PNF	Ya
15:02:14	CM-1 PF	Starting three please
15:02:16	CM-1 PF	So resolved already it become less
15:02:21	CAM	(Clicking sound -similar to the sound of chronometer resetting)
15:02:31	CM-2 PNF	Oil pressure number three
15:02:31	CAM	(Clicking sound -similar to the sound of chronometer resetting)
15:02:33	CM-1 PF	Roger N one
15:02:38	MAINT	Number three N one rotation and set the brake
15:02:42	CM-1 PF	Confirm set parking brakes
15:02:44	MAINT	Yes
15:02:46	CAM	(Sound similar to that of parking brake being set)
15:02:47	CM-1 PF	OK light up
15:02:48	CM-1 PF	Check, parking brake set
15:02:49	MAINT	Roger
15:03:01	CAM	(Sound similar to that of starter switch in)
15:03:01	CM-1 PF	Fifty percent N two
15:03:03	CM-2 PNF	Valve closed
15:03:04	CM-1 PF	Ya
15:03:05	CM-1 PF	Starting four

ATC UTC	SOURCE	CONTENTS
15:03:08	MAINT	Roger, starting four
15:03:09	CM-1 PF	Ok start first, four
15:03:24	CAM	(Clicking sound -similar to the sound of chronometer resetting)
15:03:27	CM-2 PNF	N one and oil pressure
15:03:30	CM-1 PF	Fuel on
15:03:34	MAINT	Number four N one rotation
15:03:35	CM-1 PF	Thank you
15:03:37	CM-1 PF	Light up
15:03:38	CM-2 PNF	Check
15:03:55	CM-1 PF	Zero two zero is better
15:03:55	CAM	(Sound similar to that of starter switch in)
15:03:56	CM-1 PF	Fifty percent N two
15:03:58	CM-2 PNF	Valve closed
15:04:00	CI 004	(Dynasty Zero zero four conversation with ground control)△
15:04:04	GND	(Ground control conversation with Dynasty zero zero four)△
15:04:06	CI 004	(Dynasty zero zero four with conversation Ground control)△
15:04:14	GND	(Ground control conversation with Dynasty zero zero four)△
15:04:17	CI 004	(Dynasty zero zero four with conversation Ground control)△
15:04:18	CAM	(Clicking sound similar to that of chronometer resetting)
15:04:21	CAM	(Sound similar to that of seat motor)
15:04:26	CM-1 PF	Today can put on
15:04:33	CM-1 PF	Wait first huh
15:04:34	CM-2 PNF	Ok
15:04:35	CM-1 PF	Ok cockpit to ground we normal start, remove ground equipment hand signal thank you bye bye
15:04:39	MAINT	Roger all equipment removed standby left bye bye
15:04:42	CM-1 PF	Ok
15:04:43	CM-1 PF	What's the trim you got there, seven point…
15:04:45	CM-2 PNF	Seven point six…
15:04:48	CAM	(Unknown click sound)
15:04:51	CM-1 PF	Seven point..., Waa pretty high huh today

ATC UTC	SOURCE	CONTENTS
15:04:54	CM-2 PNF	Point six
15:04:56	CM-1 PF	Ok thanks
15:04:57	CM-1 PF	What's the.. ok.. ok
15:04:58	CM-3 OBS	…..t his is the latest zero two zero three six gust fifty two lah still within limit
15:05:02	CM-1 PF	Yah, zero two zero better
15:05:02	CM-3 OBS	Yah
15:05:02	CM-1 PF	More, more on head wind side
15:05:03	CM-3 OBS	The rest no significant change
15:05:03	CM-1 PF	Ok,
15:05:07	GND	(Cathay two zero four three conversation with ground control)△
15:05:08	CM-3 OBS	Visibility and RVR still the same four fifty meters
15:05:09	GND	(Ground control conversation with Cathay 2043)△
15:05:12	CX 2043	(Cathay 2043 conversation with ground control)△
15:05:15	GND	(Ground control conversation with Cathay 2043)△
15:05:21	CM-1 PF	Ha ha Ok
15:05:22	CM-1 PF	Ok after start check list
15:05:24	CM-2 PNF	After start check, APU
15:05:25	CM-1 PF	Off
15:05:26	CM-2 PNF	Number four demand pump
15:05:27	CM-1 PF	Auto
15:05:28	CM-2 PNF	Anti-ice
15:05:29	CM-1 PF	Off
15:05:29	CX 2043	(Cathay 2043 conversation with ground control)△
15:05:30	CM-2 PNF	Aft cargo heat
15:05:31	CM-1 PF	On
15:05:32	CM-2 PNF	Packs
15:05:32	CM-1 PF	Normal
15:05:33	CM-2 PNF	Recall check huh
15:05:34	CM-1 PF	Check
15:05:34	CM-2 PNF	Check
15:05:35	CM-2 PNF	Trims
15:05:36	CM-1 PF	So we got seven point eight, err seven point six units, zero zero set.
15:05:42	CM-2 PNF	Auto brake
15:05:43	CM-1 PF	Ok RTO
15:05:44	CM-2 PNF	Ground equipment

ATC UTC	SOURCE	CONTENTS
15:05:45	CM-1 PF	Ok, your side gone already ah
15:05:47	CM-1 PF	Is he there, ok alright ok huh gone away
15:05:48	CM-2 PNF	This guy that guy out this side on the right side
15:05:50	CM-1 PF	Ok huh
15:05:50	CM-2 PNF	Ok, wah "terok" (terrible) man
15:05:51	CM-1 PF	Ok lights cabin going off
15:05:52	CAM	(Click)
15:05:53	CM-2 PNF	Ok
15:05:55	RDO-2	Singapore six request taxi.
15:05:57	GND	Singapore six taxi to runway zero six via taxiway.., correction runway zero five left via taxi way Sierra Sierra, West Cross and November Papa.
15:06:08	CM-2 PNF	I missed that man, what is it
15:06:09	CM-1 PF	Sierra Sierra West Cross and November Papa
15:06:12	RDO-2	Taxi via Sierra Sierra
15:06:14	CM-1 PF	West Cross
15:06:14	RDO-2	West Cross
15:06:15	CM-1 PF	And November Papa
15:06:15	RDO-2	And November Papa for runway zero five left Singapore six
15:06:21	CM-2 PNF	Sierra Sierra West Cross November Papa
15:06:25	CM-1 PF	Yah, so you go straight down.
15:06:26	CM-2 PNF	Roger that
15:06:26	CM-1 PF	Hit West Cross, go across the West Cross then November Papa all the way down ok
15:06:26	CM-2 PNF	Ok
15:06:29	CM-2 PNF	Then come down further south ah
15:06:29	CM-1 PF	Ok, alright
15:06:30	CM-2 PNF	Ok, yes sir zero five..-----
15:06:34	GND	(Ground conversation with Dynasty Zero zero four) △
15:06:35	CI 004	(Dynasty Zero zero four conversation with Ground) △
15:06:36	GND	(Ground conversation with Dynasty Zero zero four) △
15:06:36	CM-1 PF	Ok, left is clear ah
15:06:38	CM-2 PNF	Ok right side is.. clear, except for this vehicle-lah down here

ATC UTC	SOURCE	CONTENTS
15:06:42	CM-1 PF	Ok
15:06:49	CI 004	(Dynasty Zero zero four conversation with Ground) △
15:07:00	GND	(Ground conversation with Dynasty Zero zero four) △
15:07:05	CM-1 PF	Taxi slowly
15:07:10	CAM	(Sound similar to that of parking brake release)
15:07:10	CI 004	Taipei ground from Dynasty Zero zero four, can we check out your wind and RVR please.
15:07:13	CM-1 PF	OK turn left skidding right passing heading about zero two four zero now
15:07:13	CM-2 PNF	Checked
15:07:16	GND	Dynasty Zero zero four runway zero five left RVR is four hundred fifty meters and wind zero two zero at two five and gust four one
15:07:21	CM-3 OBS	Actually we have to nominate a return alternate because below landing minimum
15:07:25	CM-1 PF	Landing mim…
15:07:25	CM-2 PNF	Below landing minimum
15:07:27	CM-1 PF	Ah, because er Kaohsiung CAT two we still can go CAT two, no problem.
15:07:28	CM-2 PNF	CAT two lah, CAT two…
15:07:33	CI 004	(Dynasty zero zero four conversation with Ground) △
15:07:38	CM-2 PNF	Still ok lah, CAT two
15:07:40	CM-1 PF	CAT two yah, you can look yah ...five left huh
15:07:40	GND	(Ground conversation with Dynasty zero zero four) △
15:07:43	CI 004	(Dynasty zero zero four conversation with Ground) △
15:07:47	CM-1 PF	Can still take Kaohsiung you see
15:07:49	CM-2 PNF	Kaohsiung is closed...the airport
15:07:49	CM-1 PF	Kaohsiung I think, is closed is it
15:07:52	CM-2 PNF	We can take Naha or, yah I think CAT two..
15:07:53	CM-1 PF	But we are CAT two, we can still come back, we can still come back
15:07:55	CM-2 PNF	Yah, yah
15:07:56	CM-1 PF	Ok, flaps twenty please.

ATC UTC	SOURCE	CONTENTS
15:07:56	CAM	(Sound similar to that of flap lever through the detent positions)
15:08:04	CM-1 PF	Ok checking rudder er
15:08:06	CM-1 PF	Full left
15:08:07	CM-2 PNF	Full left
15:08:08	CM-1 PF	Center
15:08:09	CM-2 PNF	Center
15:08:10	CM-1 PF	Ok full right
15:08:11	CM-2 PNF	Full right
15:08:12	CM-1 PF	Center
15:08:13	CM-2 PNF	Center
15:08:14	CM-2 PNF	My controls checks ah
15:08:24	CM-1 PF	Hongkong is closed man, ha ha... worse
15:08:27	CM-3 OBS	Hongkong closed ah
15:08:27	CM-1 PF	That' s what he said not accepting any
15:08:29	CM-2 PNF	I see
15:08:30	CM-1 PF	I think some people might have diverted there lah I think
15:08:40	CM-2 PNF	Ok column coming back
15:08:47	CM-1 PF	If the RVR five left was two hundred right just now we checked
15:08:50	CM-3 OBS	RVR yah two hundred
15:08:50	CM-1 PF	Correct, yah two hundred meters ah, ok lah
15:08:54	CAM	(Sound similar to that of seat motor)
15:08:55	CM-1 PF	Ok man before take off checklist
15:08:56	CM-2 PNF	Roger sir
15:08:58	CM-2 PNF	Before..take off checks, flaps
15:09:02	CM-1 PF	Twenty green
15:09:03	CM-2 PNF	Twenty green
15:09:06	CM-2 PNF	Flight control
15:09:07	CM-1 PF	Check
15:09:07	CM-2 PNF	Check
15:09:08	CM-2 PNF	EPR and speeds
15:09:09	CM-1 PF	Ok, EPR one point five two ah, Vee one, one forty two, Vee R one five six and Vee two, one six nine set
15:09:15	CM-2 PNF	EPR one point five two ah, Vee one, one forty two, rotate one five six and Vee two, one six nine

ATC UTC	SOURCE	CONTENTS
15:09:19	CX 2043	(Cathay two zero four three conversation with ground control)△
15:09:22	CM-2 PNF	Speed set
15:09:24	CM-2 PNF	Departure routing
15:09:25	CM-1 PF	Ok ah Taipei runway zero six left huh
15:09:27	CM-2 PNF	Zero five left
15:09:28	GND	(Ground control conversation with Cathay two zero four three)△
15:09:29	CM-1 PF	Zero five left
15:09:29	CM-3 OBS	Zero five left
15:09:31	CM-1 PF	And er we got Anpu three departure Kikit transition huh
15:09:32	CX 2043	(Cathay 2043 conversation with ground control)△
15:09:34	GND	(Ground control conversation with Cathay 2043)△
15:09:35	CX 2043	(Cathay 2043 conversation with ground control)△
15:09:38	CM-1 PF	Looks like I got to go..
15:09:40	CM-2 PNF	Next one got to go right is it
15:09:41	CM-1 PF	Yah, go right turn right here, all the way to West Cross lah right turn here
15:09:46	CM-2 PNF	Runway is zero five left..Kikit transition initially two hundred ah level alpha one squawk two six five seven, will be two nine zero by Bulan
15:09:58	CM-1 PF	A lot of rudder work man here.. really ah
15:10:01	CM-3 OBS	Cross wind ah..
15:10:02	CM-1 PF	Yah
15:10:03	CM-2 PNF	Transponder TA RA, set, checks down to the line
15:10:06	CM-1 PF	Ok, thanks.
15:10:08	CM-2 PNF	West Cross correct, Sierra Sierra West Cross
15:10:14	CM-1 PF	Everybody waiting for each other for take off you see haha
15:10:18	CM-1 PF	The bugger heard us…er going…that fellow also
15:10:21	CM-3 OBS	Yah, it is coming in ah, the longer they delay the worse it is lah
15:10:23	CM-1 PF	Yah, worse if we are going to get out, if don't take off ah……I am going to go very slow here, ok, because you going get skid
15:10:24	CM-2 PNF	Ok nine knots
15:10:33	CM-3 OBS	Ok, to catch the wind

ATC UTC	SOURCE	CONTENTS
15:10:35	CM-2 PNF	That's all the moisture
15:10:41	CM-2 PNF	Turning left skidding er turning right err skidding left two seven zero
15:10:42	CM-3 OBS	The weather radar will be all red ha ha
15:10:43	CM-1 PF	Ok, passing ah two eight zero now, ah needles tracking and turn right skidding left now ah, past heading of about two.. three hundred now ah
15:10:45	CM-2 PNF	Yah that's right ah
15:10:56	CAM	(Sound of clicks)
15:11:00	CM-2 PNF	My speed excursion is more than the left side, because the wind is coming from here
15:11:03	CM-1 PF	Ah, yah
15:11:03	CM-3 OBS	Your pitot on the other side ah ..just pick up
15:11:10	CM-2 PNF	Roger that
15:11:12	CM-1 PF	For the take off use autopilot better
15:11:22	CM-1 PF	Typhoon man, ok tomorrow the guys coming in will be "terok" (terrible) man
15:11:28	CM-3 OBS	Yah, tomorrow morning Singapore five
15:11:29	GND	(Ground control conversation with Cathay two zero four three)△
15:11:36	CX 2043	(Cathay two zero four three conversation with ground control)△
15:11:38	GND	(Ground control conversation with Cathay two zero four three)△
15:11:42	CX 2043	(Cathay two zero four three conversation with ground control)△
15:11:47	CX 2043	(Cathay two zero four three conversation with ground control)△
15:11:49	CM-1 PF	The five left also imp..imp.. improve already the visibility to five hundred fifty meters
15:11:52	GND	(Ground control conversation with Cathay two zero four three)△
15:11:54	CX 2043	(Cathay two zero four three conversation with ground control)△
15:11:55	CM-3 OBS	Five left..wait ah
15:11:56	CM-1 PF	Ya, the guys said improved already went up
15:11:59	CM-3 OBS	Now is four fifty
15:12:00	CM-1 PF	Just now the guys ask him over the tower

ATC UTC	SOURCE	CONTENTS
15:12:01	CM-2 PNF	Yah
15:12:02	ATIS	Taipei Chiang Kai Shek International Airport information uniform one five zero zero zulu runway zero six for departure only runway zero five left for category two approach and departure wind zero two zero at three six gust five six visibility six hundred meters runway zero five RVR four hundred fifty meters downward runway zero six RVR five hundred fifty meters downward with heavy rain cloud broken two hundred feet overcast five hundred feet temperature two one dew point two zero QNH one zero zero one Hectopascal
15:12:06	CM-2 PNF	Coming up er.. November Papa eh..
15:12:07	CM-1 PF	Ok, all the way down left turn all the way down
15:12:10	CM-2 PNF	Left ah
15:12:10	CM-1 PF	Yah
15:12:17	CM-2 PNF	One two five one departure
15:12:20	GND	(Ground control conversation with Cathay 2043)△
15:12:21	CAM	(Sound similar to that of radio frequency selection)
15:12:22	CM-1 PF	Ok, first left
15:12:23	CX 2043	(Cathay 2043 conversation with ground control)△
15:12:23	CM-2 PNF	Affirm first left
15:12:24	CM-1 PF	Left
15:12:25	CM-2 PNF	Left
15:12:26	GND	(Ground control conversation with Cathay 2043)△
15:12:33	CAM	(Sound similar to that of seat motor)
15:12:38	CX 2043	(Cathay 2043 conversation with ground control)△
15:12:41	CAM	(Sound similar to that of nose gear scrubbing)
15:12:47	CAM	(Sound similar to that of nose gear scrubbing)
15:12:47	GND	(Ground control conversation with Cathay 2043)△
15:12:56	CM-3 OBS	The latest QNH is one zero zero one
15:12:56	CM-2 PNF	Clearing that huh
15:12:58	GND	Singapore six contact tower one two nine point three, good day.
15:13:02	RDO-2	One two nine point three good day sir, Singapore six.
15:13:13	CM-2 PNF	One zero zero one one two nine point.. one two nine point three ah.....ok ah

ATC UTC	SOURCE	CONTENTS
15:13:25	RDO-2	Taipei Tower, good evening, Singapore six.
15:13:28	TWR	Singapore six, good evening, Taipei Tower hold short runway zero five left.
15:13:33	RDO-2	Hold short runway zero five left, Singapore six.
15:13:38	TWR	Singapore six, for information now surface wind zero two zero at two four, gust four three, say intention.
15:13:44	CM-1 PF	Gusting four three ah
15:13:46	RDO-2	Thank you sir, Singapore six.
15:13:47	CM-1 PF	Ok, ok better less
15:13:48	CM-3 OBS	Less, less gust already
15:13:54	CM-1 PF	Zero two zero it's from left lah
15:13:56	CM-3 OBS	Two four gust four three
15:14:05	CM-2 PNF	Zero two zero
15:14:08	CM-1 PF	Ok this one will be here ah
15:14:18	CM-1 PF	Zero two zero
15:14:20	CM-3 OBS	Ya, left lah
15:14:21	CM-1 PF	Go right to the end of the runway, end of the runway then turn, ok.
15:14:31	CM-3 OBS	Quite a bit of aileron for the take off
15:14:35	CM-2 PNF	OK
15:14:40	CM-2 PNF	The next one
15:14:41	CM-2 PNF	Next one is November one
15:14:42	CM-1 PF	Ok second right
15:14:44	CM-2 PNF	Second right, that' s right
15:14:47	CM-1 PF	In Australia, to them, next one is this, first one you know
15:14:50	CM-2 PNF	Next one this one
15:14:51	CM-1 PF	Yah..ha ha
15:14:52	CM-1 PF	Australian
15:14:53	CM-1 PF	I think the best is to say second right ah first right second right ah
15:14:55	CM-2 PNF	Clearing that Satvoice
15:14:58	CM-1 PF	Tell them we are ready lah
15:15:02	RDO-2	Singapore six ready.
15:15:04	TWR	Singapore six roger, runway zero five left, taxi into position and hold.
15:15:08	RDO-2	Taxi into position and hold, Singapore six

ATC UTC	SOURCE	CONTENTS
15:15:12	CM-2 PNF	I get them seated ah
15:15:12	CM-1 PF	Ok below the line please ..yah
15:15:15	CM-2 PNF	Cabin crew to your takeoff station thanks
15:15:20	CAM	(Sound similar to that of door closing)
15:15:21	CAM	(Sound of chime)
15:15:22	TWR	Singapore six, runway zero five left, wind zero two zero at two eight, gust to five zero, cleared for take off.
15:15:30	RDO-2	Cleared for take off, Runway zero five left Singapore six.
15:15:31	CM-1 PF	OK man
15:15:34	CM-2 PNF	OK checks below the line, cabin announcement complete
15:15:37	CM-2 PNF	Packs
15:15:38	CM-1 PF	Ok norm eh
15:15:39	CM-2 PNF	Norm
15:15:40	CM-2 PNF	Strobes on, landing lights all on
15:15:44	CM-2 PNF	Take off clearance
15:15:45	CM-1 PF	Obtained hah
15:15:46	CM-2 PNF	Obtained sir
15:15:47	CM-1 PF	OK thanks
15:15:48	CM-2 PNF	Before take off checklist completed
15:15:50	CAM	(Sound of click)
15:15:50	CM-2 PNF	OK green lights are here
15:15:52	CM-1 PF	It going to be very slippery I am going to slow down a bit, slow turn here
15:15:53	CM-2 PNF	Turning that
15:16:07	CM-2 PNF	And the PVD hasn't lined up ah
15:16:10	CM-1 PF	Yeah we gotta line up first
15:16:12	CM-3 OBS	We need forty five degrees
15:16:15	CM-2 PNF	I see, excellent man
15:16:16	CM-1 PF	Yah
15:16:23	CM-1 PF	Not on yet er PVD huh never mind we can see the runway, not so bad. Ok, I am going to put it to high first. OK ready eh, so zero one zero is from the left lah Ok
15:16:27	CM-2 PNF	Ok
15:16:30	CAM	(Sound similar to that of wipers going to high speed)

ATC UTC	SOURCE	CONTENTS
15:16:31	CM-2 PNF	Ready sir zero two zero check ok
15:16:33	CM-1 PF	Left wing into aileron, left aileron into wind. Huh OK Cabin reported eh.
15:16:37	CM-3 OBS	Yah cabin is ready.
15:16:37	CM-1 PF	Ok thanks
15:16:37	CM-2 PNF	Yup thanks
15:16:43	CM-3 OBS	Ok –thrust ref toga toga
15:16:43	CM-2 PNF	Thrust ref toga toga
15:16:44	CM-1 PF	Ok –thrust ref toga toga
15:16:44	CAM	(Sound similar to that of engines spooling up)
15:16:54	CM-3 OBS	Hold
15:16:54	CM-2 PNF	Hold
15:16:54	CM-1 PF	Roger
15:16:55	CM-3 OBS	Eighty knots
15:16:55	CM-2 PNF	Eighty knots
15:16:56	CM-1 PF	Ok my control
15:17:13	CM-2 PNF	Vee one
15:17:13	CM-3 OBS	Vee one
15:17:16	CM-1 PF	**** something there
15:17:17	CAM	Sound of the first impact
15:17:18	CAM	****waaah****
15:17:18	CAM	Sound of a series of impacts
15:17:22		End of Recording

1.11.2 Flight Data Recorder

The accident airplane's flight data recorder (FDR) is an AlliedSignal Solid-State flight data recorder (SSFDR), part number 980-4700-033, and serial number 1634. Investigator found the FDR at the tail section, and carried it back to ASC Lab in Taipei, Taiwan.

Readout of the FDR was accomplished using the laboratory's standard hardware and software, these systems including the AlliedSignal hand-Held download unit (HHDLU), ADRAS and RAPS.

Data plots and tabular listings of each data parameter for the entire accident flight are included in this report. Penny & Giles Aerospace Ltd. has finished the OQAR NVM data readout on November 22, they have confirmed that the OQAR NAM data stopped at UTC 15:16:40 (before start takeoff). According to FDR readout data, the FDR stopped at UTC 15:17:12.16, both existing FDR and QAR data are consistent.

The time synchronization between cockpit voice recorder (CVR) timing was compared to the FDR VHF microphone keying and a time correction developed.

1.11.2.1. FDR Information

FDR Manufacturer: AlliedSignal Solid State Flight Data Recorder (SSFDR)

Part No.: 980-4700-033 （2X, 128 Words/sec）

Serial No.: 1634

Boeing P/N: S283T003-1

Data Size: 52.14 hour (187706 sec)

DFDAC: Boeing, P/N 285U0071-203

1.11.2.2. FDR Parameters

Database Source: Singapore Airlines

Recorded Parameters: 318

Database List: Appendix 8B-1

1.11.2.3. Readout Findings:

1. Flight ID: SIA006

2. Start recording: UTC15:00:00
3. B5 gate position: N25.0777, E121.2377 (UTC 15:00:00)
4. Aircraft stayed on NP for taxi: UTC 15:13:47 ~15:15:25
5. Start acceleration: UTC15:16:34, Magnetic heading 50.6 deg
6. FDR stop condition: UTC 15:17:12; Magnet heading 48.0 deg, CAS 158 Knots, Ground speed 130.8 Knots, Radio Alt –8 ft, pitch attitude 0.53 deg, roll attitude 0.0 deg.
7. 15:17:13 unsynchronized FDR data: Magnetic heading 48.7 deg, CAS 158 Knots, Ground speed 130.8 Knots, Radio Alt –8 ft, pitch attitude CAS 18 Knots, Ground speed 272.5 Knots, Radio Alt –2 ft, pitch attitude 2.99 deg, roll attitude 0.7 deg.
8. Gross weight at first impact time: 755840 Lbs
9. According to AIP (RCTP 2-3) the recorded the gate B5 position of CKS airport is N25^{o}04' 50.38", E121^{o}14' 22.37"。 The relative position difference between the AIP gate B5 position and FDR recorded at UTC 15:00:00 is 10.7 meters (delta North) and 6.2 meters (delta East).

1.11.2.4. Time synchronization between CVR and FDR

The CVR local time reference was established through the correlation of the last three VHF radio transmissions made by SQ006 which event recorded by the FDR, CVR and ATC transcript. The following table displays the time coordination among FDR UTC, ATC UTC and CVR time. There is 4 seconds difference between FDR UTC and ATC UTC. Timing used on FDR recording description, plots and tables is base on FDR UTC.

CVR Time	FDR UTC	ATC UTC
00:28:24	15:14:58	15:15:02
00:28:30	15:15:04	15:15:08
00:28:52	15:15:26	15:15:30

1.11.2.5. Data Printout

Table 1（Table 1 to Table 4 referred to appendix 8B-2） contains a tabular printout of generic parameters from 15:00:00 to the end of data recorded for flight SQ006:

UTC Time	Altitude	Airspeed	Ground Speed
Roll Attitude	Pitch Attitude	Mag. Heading	TAT（total air temp.）
Wind direction	Wind Speed	Drift	Longitude Acc.

Lateral Acc.	Vertical Acc.	Longitude Pos.	Latitude Pos.
Localizer Dev			

Table 2 contains a tabular printout of flight control parameters from 15:00:00 to the end of data recorded for flight SQ006:

UTC Time	Aileron-LIB	Aileron-LOB	Aileron-RIB
Aileron-ROB	Air/Ground	Control Column	Control Wheel
Elevator-RIB	Elevator-ROB	Rudder Pedal	Rudder-DWR
Rudder-UPR			

Table 3 contains a tabular printout of engine parameters from 15:00:00 to the end of data recorded for flight SQ006:

UTC Time	EPR1	EPR2	EPR3
EPR4	N1-1	N1-2	N1-3
N2-4	N2-1	N2-2	N2-3
EGT1	EGT2	EGT3	EGT4

Last two columns of Table 1, 2 and 3 at UTC 15:17:13 are unsynchronized data. AlliedSignal is working with FDR group to readout the last second data.

1.11.2.6. Data Plots

Fig. 1 （Fig.1 to Fig.6 referred to appendix 8B-3）shows the seven generic parameters plotted as a function of UTC time, from 15:14:18 to the end of data recorded at 15:17:13。 These parameters are listed as follows:

VHF Keying	Pitch	Mag. Heading	Longitude Acceleration
EPRs	Computed Airspeed	Ground Speed	

Fig. 2 shows the several flight control parameters plotted as a function of UTC time, from 15:14:18 to the end of data recorded at 15:17:13。 These parameters are listed as follows:

Aileron	Elevator	Rudder	Rudder Pedal
Pitch	Mag. Heading	Control Column	Control Wheel

Fig. 3 shows the four engine parameters plotted as a function of UTC time, from 15:14:18 to the end of data recorded at 15:17:13。 These parameters are list as follows:

EGT	N1	N2	Fuel Flow
Mag. Heading			

Fig. 4 shows the last 40 seconds' FDR parameters plotted as a function of UTC time。 These parameters are listed as follows:

VHF Keying	Vertical Acceleration	Longitude Acceleration	Localizer Dev
Mag. Heading	Computed Airspeed	Ground Speed	
Integrated Ground Speed			

1.11.2.7. OQAR data

After SQ006 accident, FDR group received the QAR from ground operation group on November 5. There were no damage to the optical disk. We copied the original disk raw data for backup, and then sent the OQAR raw data to Singapore airlines and Penny & Giles Aerospace Ltd. FDR group received the QAR engineering parameters on November 8. The data showed that the OQAR data stopped at UTC 15:16:23 (before takeoff). Both existing FDR and QAR data are consistent. (Appendix 2: SQ006 Technical Inspection Report-SQ006 OQAR).

Penny & Giles Aerospace Ltd. has finished the OQAR NVM data readout on November 22, they have confirmed that the OQAR NAM data stopped at UTC 15:16:40 (before takeoff). Both existing FDR and QAR data are consistent. Table 4 contains a tabular printout of OQAR parameters from 15:15:05 to the end of data recorded for flight SQ006:

PALT	PTCH	RALT	ROLL
RUDDL	RUDDU	SPLL	SPLR
SYNC	THDG	UTC	VHF1

1.11.2.8. FDR Flight Path and Sat. Map

Fig 5. Shows the smoothed latitude and longitude position of FDR data (yellow line), based on the related satellite image with taxiways, and runways. Fig 5 also shows the ground scars of the SQ006 and wreckage distributions.

FDR group combined the satellite map, CVR audio and FDR data for 3D animation in RAPS. Due to limitation of recorded latitude and longitude position, we apply the ground speed, magnetic heading, and drift angle to calculate the flight path. We also used the air-photography data to correct the position of the A/C' s flight path (ref. Fig 6).

1.11.2.9. CVR, FDR and OQAR Power Source

CVR Power Source: 115VAC from Bus #1; 28VDC from bus #1
FDR Power Source: 115VAC from Bus #3; 28VDC from bus #3
OQAR Power Source: 115VAC from Bus #3

1.12-1.18 (N/A to Recorders Group)

IV. Appendices

8A-1 Description of CVR ON/OFF logic

8B-1 FDR Parameters Listing

8B-2 SQ006 FDR and QAR Parameters Tabular Listings

- Table1 Singapore Airline flight SQ006 B747-412, FDR Generic Parameter Listings
- Table2 Singapore Airline flight SQ006 B747-412, FDR flight Control Parameter Listings
- Table3 Singapore Airline flight SQ006 B747-412, FDR Engine Parameter Listings
- Table 4 Singapore Airline flight SQ006 B747-412, OQAR Generic Parameter Listings [readout from NVM memory chip]

8B-3 SQ006 FDR Parameters Plots

- Fig 1 FDR generic parameters Plot and Related CVR transcripts
- Fig 2 FDR flight control parameters plot and related CVR transcripts
- Fig 3 FDR four engine parameters plot and related CVR transcripts
- Fig 4 FDR last 40 seconds parameters plot and related CVR transcripts
- Fig 5 Singapore SQ006 accident: Flight path Vs. Sat. Map with ground scars, and wreckage distribution
- Fig 6 3D animation with air-photography, flight path and generic panels

8B-4 SQ006 Technical Inspection Report-SQ006 OQAR

Aviation Safety Council
Taipei, Taiwan

SQ006 Accident Investigation Factual Data Collection Group Report

Weather Group

February 21, 2001

ASC-FRP-01-01-009

I. Team Organization

Chairman:
Walter Chang Engineer, ASC
Members:
1. James Skeen Senior Meteorologist, NTSB
2. Chin-Wan Lee Chief of Taipei Aeronautical Meteorological Center, CAA

II. History of Activities

Date	Activities
NOV 1	1. Obtained METARs, 1-min mean data of meteorological sensors, Doppler and ASR-9 radar graphical printouts.
NOV 2	1. Discussed the relationship between RVR, extinction coefficient, runway light setting and background light intensity with maintenance personnel and chief of Tower. 2. Obtained radar data printouts.
NOV 3	1. Data validation of meteorological sensors.
NOV 4	1. Checked the maintenance and calibration records of meteorological sensors. 2. Data validation with personnel of CKS weather station.
NOV 6	1. Contacted the manufacturer of AWA system to calculate RVR from 1-min mean. 2. Interviewed on-duty observers at the time of accident. 3. Calibrated RVR sensor of RWY05.
NOV 7	1. Data collection completed.

III. <u>Factual Description</u>

1.7 Meteorological Information

1.7.1 General Weather Information

Taiwan was affected by northeast monsoon flow and Typhoon "Xangsane", centered at approximately 360 kilometers south of Chiang Kai Shek (CKS) International Airport around the time of the accident (appendix 9-1). Maximum wind speed of the storm was 75 knots gusting 90 knots, pressure of the storm center was 965 hPa.

The Taipei Aeronautical Meteorological Center in Taipei City issued a significant meteorological information (SIGMET) for cumulonimbus (CB), which was applicable for CKS International Airport at the time of the accident. Additionally, the Taipei Aeronautical Meteorological Center issued several gale warnings and typhoon warnings, which were applicable for CKS International Airport about the time of the accident. The SIGMET and warnings are included in appendix 9-2,9-3 and 9-4.

1.7.2 Surface Weather Observations

The following surface weather observations were taken by the CKS Weather Station before and after the accident (appendix 9-5):

1440: Type—special; Wind—020 degrees at 38 knots gusting 58 knots; Visibility—800 meters; Runway Visual Range—RWY05/800 meters, RWY06/800 meters; Present Weather-heavy rain; Clouds—broken 200 feet overcast 500 feet; Temperature—21 degrees Celsius; Dew Point—20 degrees Celsius; Altimeter Setting—1002 hPa (A29.60 inches Hg); Wind shear RWY05[1]; Trend Forecast—no significant change=

1454: Type—special; Wind—020 degrees at 36 knots gusting 52 knots;

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[1] The wind shear remark was obtained from a pilot report at 1327. The aircraft encountered wind shear 500 feet height at final approach.

Visibility—500 meters; Runway Visual Range—RWY05/450 meters, RWY06/500 meters; Present Weather-heavy rain; Clouds—broken 200 feet overcast 500 feet; Temperature—21 degrees Celsius; Dew Point—20 degrees Celsius; Altimeter Setting—1001 hPa (A29.58 inches Hg); Wind shear RWY05; Trend Forecast—no significant change=

1500: Type—record; Wind—020 degrees at 36 knots gusting 56 knots; Visibility—600 meters; Runway Visual Range—RWY05/450 meters, RWY06/550 meters; Present Weather-heavy rain; Clouds—broken 200 feet overcast 500 feet; Temperature—21 degrees Celsius; Dew Point—20 degrees Celsius; Altimeter Setting—1001 hPa (A29.58 inches Hg); Wind shear RWY05; Trend Forecast—no significant change; Remark rain amount 22.50 millimeters=

1520: Type—extra; Wind—020 degrees at 30 knots gusting 61 knots; Visibility—600 meters; Runway Visual Range—RWY05/550 meters, RWY06/800 meters; Present Weather-heavy rain; Clouds—broken 200 feet overcast 500 feet; Temperature—21 degrees Celsius; Dew Point—21 degrees Celsius; Altimeter Setting—1002 hPa (A29.59 inches Hg); Wind shear RWY05=

The automated weather observation system for CKS International Airport is called Airport Weather Advisor (AWA). The AWA is comprised of anemometers, forward scatter sensors (RVR sensors), ceilometers, barometers and temperature/dew point sensors. The anemometers were located at the approach ends (05, 23, 06, 24) and midpoints of the two runways, and the RVR sensors were located in the vicinity of each anemometer with the exception of the midpoint of runway 06-24. The following conditions were obtained by runway 05 and mid-point 05/23 sensors around the time of the accident[2] (appendix 9-6):

[2] Data recorded by AWA were 1-minute mean values.

Time (UTC)	RWY 05 Wind Direction and Magnitude (degree/knot)	RWY 05 Cross wind Magnitude from Left Hand side (knot)	RWY 05 Visibility[3] (meter)	Mid-point 05/23 Visibility (meter)
1512	358/14.5	11.3	518	475
1513	023/43.2	18.9	504	604
1514	018/28.2	14.5	923	420
1515	029/29.6	10.1	450	236
1516	013/29.3	17.2	360	168
1517	360/20.5	15.5	444	192

1.7.3 Weather Information Provided to the Flight Crew by ATC

According to the ATC and CVR transcripts, the following weather information was provided during the airplane taxi and before takeoff:

1513:38 UTC – SQ006, for information now surface wind 020 at 24, gust 43, say intention.

1515:22 UTC – SQ006, runway 05L, wind 020 at 28, gust 50, cleared for take off.

[3] The visibilities were calculated by the manufacturer.

IV. Appendices

9-1	A GMS-5 infrared satellite image received by CWB at 1500 Z
9-2	A SIGMET 04 Valid 311300/311700.
9-3	Gale warnings at 1300 and 1430Z.
9-4	Typhoon warnings at 1300, 1600Z.
9-5	METARs of RCTP at 1440, 1454, 1500, 1520.
9-6	1-min mean data of meteorological sensors.