Runway excursion after landing, involving a Boeing 747SP, B-18253, at Chiang Kai-shek International Airport on September 2, 1999

Micro-summary: **High-speed exit maneuver off a runway involving a Boeing 747SP results in a runway excursion.**

Event Date: **1999-09-02 at 1148 Taipei time**

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

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

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Aviation Safety Council

Aircraft Incident Report

Number: ASC/AIR-2000/01

Flight Number: China Airlines, Dynasty Training Two (DT-2)
Occurrence: Runway excursion after landing
Registration: B-18253
Type: Boeing 747SP
Location: Chiang Kai-shek International Airport
Date: 2 September 1999

Summary

On 2 September 1999, a China Airlines Boeing 747SP (B-18253) Flight Dynasty Training 2 landed on Runway 06 at the Taoyuan Chiang Kai-shek International Airport (CKS Airport) after a type check flight of two first officers undertaking transition training. During the landing roll with half of the runway remaining, the pilot-in-command attempted to depart the runway by steering left into Taxiway S5 at 76.8 knots. The aircraft, however, failed to make the turn. At 11.48 local time, its left body gear and nose gear collided with a protruding concrete manhole approximately 11 meters from the edge of the runway on the grass strip adjacent Taxiway S5, snapping the front and rear axles of the left body gear truck, separating #5 and #6 wheels, and damaging the belly's skin and structure, while #1 engine came into contact with the ground.

In conjunction with the Civil Aeronautics Administration (CAA) and China Airlines (CAL), the Aviation Safety Council (ASC) collected evidence and records, played back and analyzed data from the Flight Data Recorder and Cockpit Voice Recorder, sketched marks and tracks made by tires on the runway, and conducted tests on the nose gear and its steering system. The probable causal factors of the occurrence were identified jointly by members participating in the investigation.

The probable causal factors are as follows: (a) the pilot-in-command failed to select before touchdown a point to depart the runway based on the aircraft's braking

characteristics; (b) reverse thrust, brakes and body gear steering were not applied at a desired speed; and (c) nose gear steering was applied before reaching a desired rolling speed; (d) light weight and an aft center of gravity towards the rear increased the aircraft's tendency to pitch up, causing the nose wheel to slip laterally despite the actuation of nose gear steering, and (e) the aircraft veered to the side of the runway onto the grass strip rather than turning into Taxiway S5.

The protruding manhole to the left of Runway 06 is an indirect cause of the occurrence. The location, structure and construction of the manhole failed to meet both domestic specifications, as well as those recommended by the International Civil Aviation Organization (ICAO), causing serious damages to the deviated aircraft when its landing gear collided with the manhole.

In order to prevent similar incidents, the following safety recommendations based on the probable causes identified by the investigation were made:

Recommendations to China Airlines

1. The CAL should require its flight crews to operate all aircraft in strict accordance with flight manuals and relevant standard operating procedures;
2. The CAL should set rolling speeds for various flight conditions in the Boeing 747 SP Flight Manual, so that the flight crews can operate safely when taxing and rolling;

Recommendations to CAA

3. The CAA should examine if the location, design, construction and structure of all fixed structures (including concrete manholes) around the runway strips at CKS Airport are in compliance with international standards, so as to protect the safety of any deviated aircraft; and
4. The CAA should assess whether the transverse slopes of the runway strips at CKS Airport are in compliance with specifications recommended by the ICAO, so as to protect the safety of any deviated aircraft.

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CHAPTER 1 Factual Information

1.1 History of Flight

On 2 September 1999, a China Airlines Boeing 747SP (B-18253) Flight Dynasty Training 2 (DT2) departed Chiang Kai-shek International Airport (CKS Airport), Taoyuan, at 1006 hrs Taipei Time for a type check flight of two first officers undertaking transition training. CM1 (left seat), the examiner, who is a CAA Designated Examiner (DE), was the pilot-in-command. As dictated by the nature of the flight, no passengers or cargoes were on board except for five flight crew, one examiner, two first officers undertaking training, one line first officer and one flight engineer. The crew had flown ten traffic patterns at CKS AIRPORT in according with Instrument Flight Rules flight plan, and this training had proceeded smoothly. During the last final approach, the first officer (right seat) executed a full stop landing as required by the training program, and landed the aircraft at 1148:02. The examiner (left seat) called out “I HAVE CONTROL!” 8 seconds after touchdown, then took over the control with minimum autobrakes rolling, and activated reverse thrust for approximately 8 seconds. The flight engineer called out “80 KNOTS!” 23 seconds after touchdown. At 76.8 knots, the pilot-in-command attempted to depart the runway by steering left into Taxiway S5. The aircraft, however, failed to make the turn. The sound of vibration and collision with the manhole was heard 3 seconds later, and the aircraft veered to the left onto the grass strip adjoining Runway 06 and Taxiway S5. The nose gear struck the right side of the manhole, causing the right nose wheel tire to deflate. The left body gear then collided with a protruding concrete manhole approximately 10.8 meters from the left edge of the runway (excluding shoulder), snapping the front and rear axles of the left body gear truck, separating #5 and #6 wheels, and damaging the belly’s skin and structure. The cowl of #1 engine also came into contact with the ground before the aircraft skidded another 220 meters. The dark black nose gear track, as well as those lighter main gear tracks appeared on the runway surface approximately 200 meters to Taxiway S5. Visual meteorological conditions and a surface wind of 090°/16~26 knots were reported at the time of occurrence.

1.2 Injuries to Persons

No crew members were injured in the accident.

1.3 Damage to Aircraft

A 26ft x 10ft lower fuselage skin immediately adjacent to the left body gear,including the hydraulic lines, were damaged (Fig. 1-1). Some parts of the nose gear assembly and both nose tires were damaged (Fig. 1-2). The axles of the front and rear trucks of the left body gear were snapped (Fig. 1-3 & 1-4). Scrubbed marks were found at the bottom of #1 engine cowling. Please refer to Fig. 1-5 & 1-6 for the outlook of the aircraft and gear locations.

Fig. 1-1 Damage to Fuselage

Fig. 1-2 Damage to Nose Wheels

Fig. 1-3 Damage to Front Truck of Left Body Gear

Fig. 1-4 Damage to Rear Truck of Left Body Gear

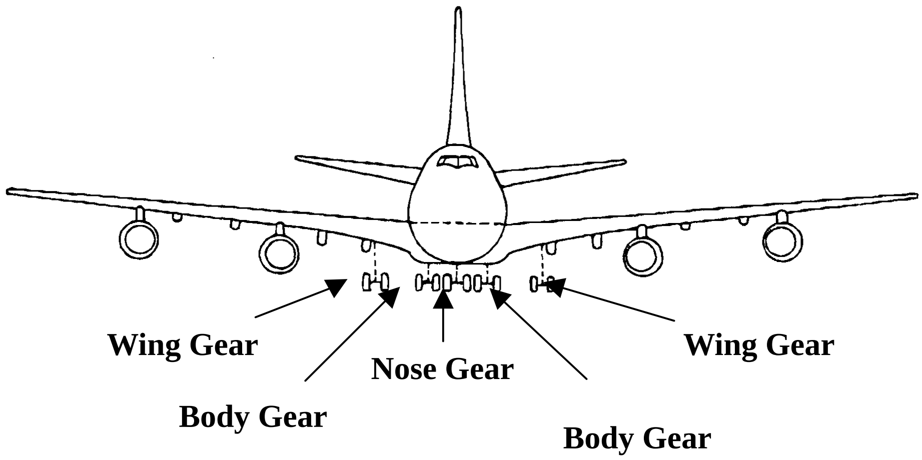


Fig. 1-5 Aircraft Outlook and Gear Locations

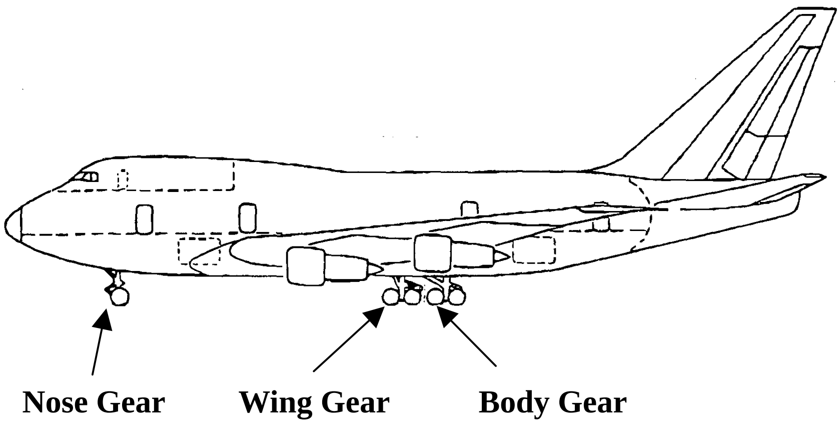


Fig. 1-6 Aircraft Outlook and Gear Locations

1.3.1 Damage to Fuselage

1. Bulkhead at left lower fuselage STA 1480 was torn or deformed;
2. Fairing panel support at lower fuselage STA 1480 was cracked and deformed;
3. Skin between #38 and #41 frames at left fuselage from STA 1480 to STA 1740 was cracked, wrinkled or dented in varying sizes, while the frames and stringers were also snapped, dented and deformed in varying degrees;
4. Skin between #42 and #45 frames at left fuselage from STA 1740 to STA 1800 was cracked, wrinkled or dented in varying sizes, while the frames and stringers were also snapped, dented or deformed in varying degrees;
5. Stringers were dented or deformed between #38 and #41 frames at left fuselage STA 1700;
6. Stringers between #39 and #46 frames at left fuselage STA 1760 were snapped, dented or deformed;
7. Stringers between #35 and #45 frames at left fuselage STA 1780 were dented and deformed;
8. Pressurized deck between #84 and #90 centerlines at left fuselage from STA 1460 to STA 1475 was punctured or penetrated, while the surrounding structure was also creased, dented or deformed at various places;
9. Fairing panel at left lower fuselage from STA 1460 to STA 1820 was punctured or dented, with its support snapped, displaced, dented or deformed; and
10. Hydraulic lines above the bulkhead at left lower fuselage STA 1480 were

pulled or wrinkled by the detached gear truck.

1.3.2 Damage to Landing Gear

1.3.2.1 Nose Gear

1. Nose gear: No visible damage to the structure and shock strut. The landing light was separated, while the squat switch was deformed and displaced (Fig. 1-7).

Fig. 1-7 Landing Light Separated

2. Left nose wheel hub: Spot-like abrasion marks were found on both left and right flanges at about the same height (Fig. 1-8). Spots where both flanges (Fig. 1-9 & Fig. 1-10) were impacted were dented and deformed. The right side of the hub was covered with mud (Fig. 1-11).

Fig. 1-8 Spot-like Abrasion Marks (circled areas)

Fig. 1-9 Left Flange Dented and Deformed (circled area)

Fig. 1-10　　　Right Flange Dented and Deformed (circled area)

Fig. 1-11　　　Left Wheel Hub Covered with Mud (pointed area)

3. Left nose tire: Cracks on the right sidewall was straightly parallel with the cords. A 45° cut by foreign objects inclined from the sidewall to the entire tread, forming a 32” scratch. The dismounted right sidewall slipped to the left, and the tire is deflated (Fig. 1-12). A ring of white marks were observed on the left sidewall near the rim line (Fig. 1-13), while the entire tread was covered with abrasion marks vertical to the grooves (Fig. 1-14). A ring of

abrasion marks 3/4” in width were also observed on the right tread shoulder. The 2nd and 5th grooves from the outer shoulder were approximately 1/8” in depth, and tread rubber to the right of both grooves rose approximately 1/16” for the entire circumference, while the 3rd and 4th grooves were completely worn out. (Fig. 1-15).。

Fig. 1-12 Left Tire Damage and Tread Abrasion

Fig. 1-13 White Marks on Left Sidewall

Fig. 1-14 Tread Covered with Abrasion Vertical to Grooves

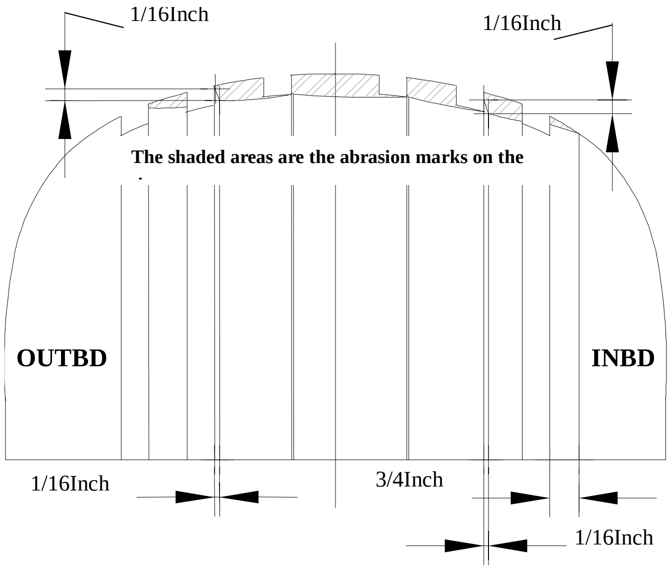


Fig. 1-15 Wear on Left Tire Tread

4. Right nose wheel hub: Scratch marks were found on the deformed right flange (Fig. 1-16). The hub was covered with mud (Fig. 1-17).

Fig. 1-16 Deformed Flange

Fig. 1-17 Hub’s Right Side Covered with Mud

5. Right nose tire: Bulged, delaminated tire surface and 6” to 12” cuts caused by foreign objects were found on the right sidewall which slipped off the nose gear hub to the left. Abrasion marks covered the entire right tread shoulder, and extended to the right sidewall. A 24” kite-shaped tread was ripped off the tire, creating an 18” hole (Fig. 1-18) where white marks were found on the right-hand side edge. Immediately in front of the hole on the tread was a fan-shaped abrasion mark, the depth of which decreased as it extended from right to left (Fig. 1-19). Similar to those seen on the right wheel, abrasion marks vertical to the grooves covered the ripped off tire casing (Fig. 1-20), which was found between the manhole and where the aircraft came to stop. The 2nd groove from the outer shoulder was approximately 1/8” in depth, and part of the tread rubber to the right of the groove rose approximately 3/16”, while the 3rd and 4th grooves were completely worn out. (Fig. 1-21).

Fig. 1-18 Damaged Right Tire and Tread Abrasion

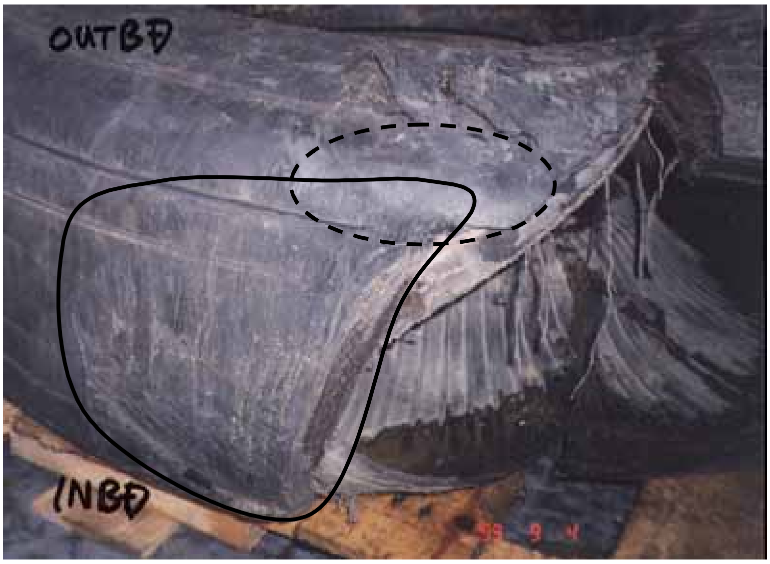


Fig. 1-19 Fan-shaped Abrasion and White Marks

(abrasion is enclosed by full line; marks are enclosed by dotted line)

Fig. 1-20 Abrasion Vertical to Grooves

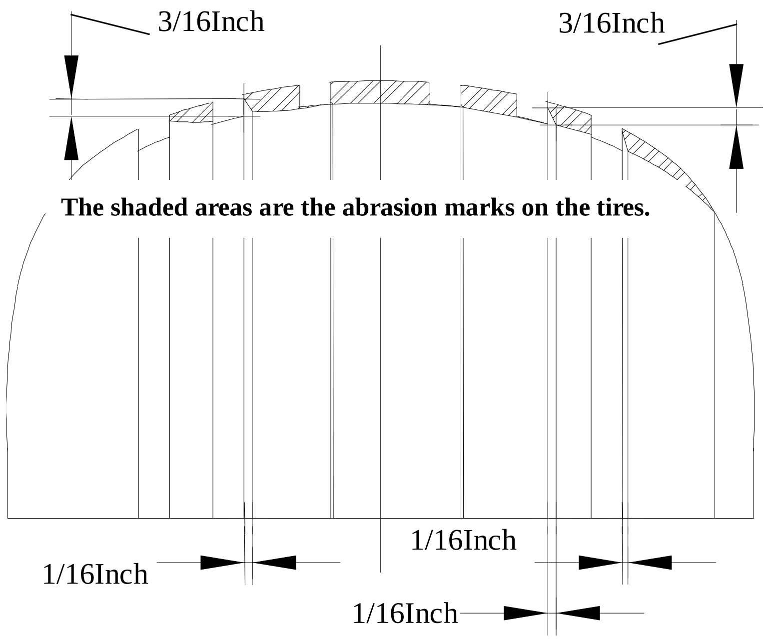


Fig. 1-21 Abrasion on Right Sidewall

1.3.2.2 Left Body Gear

1. Front truck: The front truck was separated from the gear, and found 5 meters to the left of the manhole. The axle snapped at a 45°angle, severing the cables and hydraulic lines (Fig. 1-22).

- Left front wheel (#5) : The flange was separated from the hub, and the brakes were squeezed as a result. The inner tire bead was broken and blow off from it's seat, while the outer tire bead was push off it's seat and shifted inward. A 45°gash was found to run across the tread, from the inner sidewall to outer sidewall, causing the tire to deflate.
- Right front wheel (#6) ：The inner hub was slightly deformed. The brakes appeared to be normal. Cut at a oblique angle, the tire was deflated.

Fig. 1-22 Damage to Front Body Gear Truck

● Rear truck: The axle snapped at a 45°angle (Fig. 1-23).

The hub, brakes and tire of #7 and #8 wheels appeared to be intact.

Tire pressure was normal (Fig. 1-24) .

Fig. 1-23 Rear Truck Snapped at 45°Angle

Fig. 1-24 Damage to Rear Body Gear Truck

1.4 Other Damage

The protruding concrete manhole located on the grass strip adjoining Runway 06 and Taxiway S5 can be seen on Fig. 1-25. Collision marks caused by foreign objects and a band of black rubber deposits were found on the side of the manhole facing Taxiway S5 (Fig. 1-26). Two taxiway lights were damaged by the wheels.

Fig 1-25 Concrete Manhole

Fig. 1-26 Abrasion Marks and Rubber Deposits

1.5 Personnel Information

1.5.1 Pilot-in-Command (CM1, left seat)

- Age: 53
- Employed by CAL since 1 July 1985
- License:

  Airline Transport Pilot's (issued on 21 August 1987 with certificate number 100831)

- Aviation ratings:

  (a) B747-200 (valid from 30 March 1999 to 29 March 2000)

  (b) operating as Captain of B767 on 19 August 1988

  (c) operating as Captain of B747-200 since 18 July 1990 to present

  (d) serving as B747-200 Instructor Pilot since 18 November 1994 to present

  (e) served as Chief Pilot for CAL's B747-200 fleet from September 1996 to

January 1999

(f) operating as CAA's Designated Examiner for B747-200 since 1 January 1999 to present

- Medical Certificate:

  Class One, valid to 31 December 1999, with the limitation that the holder shall wear glasses that correct for near vision when operating a type qualified aircraft

- Flying time (till 2 September 1999):

  Total flying: 13,446 hours

  B747 flying: 7,943 hours

  Last 90 days: 117 hours

  Last 30 days: 48 hours

- Activities during last 72 hours:

  (a) attended an aviation safety improvement conference in CAL on 30 and 31 August

  (b) rested at home in the morning of 1 September

  (c) executed a 747-200 type check flight (B-18160) at CKS AIRPORT from 1400 hrs to 1600 hrs on 1 September 1999

  (d) was picked up to CAL at 0748 hrs on 2 September 1999, then to CKS AIRPORT for the flight in question

  (e) well rested during last 72 hours, no clear signs of fatigue

Before joining CAL, the Pilot-in-Command served in the Air Force as a transport aircraft pilot, and commander of air transport unit.

1.5.2 First Officer (CM2, right seat, undertaking training)

- Age: 47
- Was employed by CAL on 2 September 1996
- License:

  Airline Commercial Pilot's License (issued on 28 October 1997)
- Aircraft ratings:

  A300-600R F/O (License/Certificate Number: 301481, valid from 22 October 1998 to 21 October 1999)
- Medical Certificate:

  Class One, valid to 31 December 1999, with the limitation that the holder shall wear glasses that correct for near vision when operating a type qualified aircraft
- Flying time (until 2 September 1999):

  Total flying: 3,812 hours

  B747 flying: 9 hours (B747 training not yet completed)

  Last 90 days: 9 hours

  Last 30 days: 9 hours (B747 local training)
- Operated as first officer for A300-600R from January 1998 to May 1999, and started training on first officer for B747-200 on 1 June 1999

Activities during last 72 hours:

(a) undertook type transition local training for 6.52 hours on 29 and 30 August

(b) prepared for flight, well rested on 31 August and 1 September

1.5.3 Flight Engineer (CM3)

- Age: 59
- was employed by CAL on 5 February 1969
- Airline Transport Flight Engineer's License〈issued on 24 October 1972〉
- Aircraft ratings:

  B747 (License/Certificate Number: 900122, valid from 29 April 1999 to 28 April 2000)
- Medical Certificate:

  Class Two, valid to 30 September 1999, with the limitation that the holder shall wear glasses that correct for near vision when operating a type qualified aircraft
- Flying time (until 2 September 1999):

  Total flying: 24,908 hours

  On type: 19,446 hours

  Last 90 days: 154 hours

  Last 30 days: 43 hours
- Activities during last 72 hours:

(a) had a flight from Jakarta on 29 August, well rested and no flight on 30, 31 August and 1 September 1999.

1.5.4 First Officer (CM4, supporting first officer)

- Age: 36
- was employed by CAL on 31 June 1992
- Airline Transport Pilot's License〈issued on 9 February 1999〉
- Aircraft ratings:

  B747 F/O (License/Certificate Number: 101714, valid from 26 January 1999 to 25 January 2000)
- Medical Certificate:

  Class One, valid to 29 February 2000, with no limitations
- Flying time (until 2 September 1999)：

  Total flying: 3,984 hours

  On type: 997 hours

  Last 90 days: 184 hours

  Last 30 days: 59 hours
- Operated as A300-B4 first officer from March 1994 to October 1997, and operating as B747-200 first officer since 14 October 1997

Activities during last 72 hours:

Flew from Anchorage to Taipei on 30 August, and no flight was scheduled for the following 2 days. Reported to CAL at 0730 hours on the day of incident.

1.5.5 Other Information

- The personal information of the other first officer, who was not operating the aircraft at the time of incident, is not provided in the report.
- Based on the interviews with the crew on the day of incident, as well as data recorded by the CVR, the training program proceeded as planned, and the cockpit tasks were well coordinated in a friendly atmosphere.

1.6 Aircraft Information

1.6.1 Fundamental Information

1. Type: transport aircraft
2. Aircraft type: B747-SP
3. Constructor's serial number: 22298
4. Registration number: B18253
5. Manufacturer: BOEING
6. Date of manufacture: 17 April 1991
7. Owner: China Airlines
8. Operator: China Airlines
9. Date of Delivery: 4 May 1991
10. Certificate of Airworthiness: valid to 30 April 2000

11. Total flying hours: 73127:04 hours

12. Total landing times: 14147 times

13. Last overhaul: Type C

14. Completion Date of Last overhaul: 5 August 1999

15. Engines:

- Number: 4
- Manufacture: PRATT＆WHITNEY
- Type: JT9D-7A

Other information: Table 1-1

Table 1-1 Engine Data

Position	＃1	＃2	＃3	＃4
Serial Number	695726	695794	695747	695814
Total Used Hours	69250	48578	60304	51750
Hours in Used After Overhaul	16213	5677	6435	8894

1.6.2 Maintenance Records

The aircraft's flight log and maintenance records showed no operational defects, and carried forward defects were all corrected before the flight. The Certificate of Airworthiness was valid at the time of flight.

1.6.3 Systems Tests

- Objective: To confirm whether the braking and nose gear steering system functioned normally.

- Date: 3 and 4 September 1999

  Participants: ASC investigators and CAL maintenance personnel

1.6.3.1 Tire Pressure Measurement

The measurements were taken in accordance with Boeing Maintenance Manual AMM 12-15-06 (p.301). The results are listed in Table 1-2.

Table 1-2 Tire Pressure Readings

Locations	#1	#2	#3	#4	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
Readings	200 PSI	205 PSI	200 PSI	210 PSI	195 PSI	190 PSI	190 PSI	200 PSI	195 PSI	195 PSI	200 PSI	190 PSI	190 PSI	205 PSI

- Tire pressure measurements for both nose wheels, #5 and #6 main wheels, which were deflated or ruptured, were not possible.
- No melting was found on any fuse plugs.

All measurements, with the exception of the failure tires, were normal.

1.6.3.2 Inspection on Nose Wheel Bearings

The four inner and outer bearing were taken down, and dismantled in a landing gear shop. Test results were found to be normal.

1.6.3.3 Nose Gear Steering Test

The nose gear steering test was conducted in accordance with Boeing Maintenance

Manual AMM 32-51-00 (p. 509). The results, as listed in Table 1-3, were found to be normal.

Table 1-3 Results of Nose Gear Steering Test

Test Items	Standard Values	Results
Control Wheel (full left)	65°+2/-3	64°
Control Wheel (middle)	±1°	±1°
Control Wheel (full right)	65°+2/-3	64°
Rudder Paddles (full left rudder)	7°±1°	6°
Rudder Paddles (full right rudder)	7°±1°	6°

1.6.3.4 Braking System Test

The test was conducted in accordance with Boeing Maintenance Manual AMM 32-41-00 (p.501). The damaged hydraulic lines to #5, 6 and 7 wheels were temporarily connected via soft high pressure hoses to the brakes' serviceable parts, while those to #8 wheel were externally connected to a pressure gauge (Fig. 1-27). The aircraft's electrical power system was then turned on to pressurize, and the gauge indicated 3000PSI when braking paddles were applied (Fig. 1-28). All wheel braking functioned normally. The brakes for #6, 7 and 8 wheels also functioned normally when tested with manual hydraulic pumps. The brakes for #5 wheel were not tested due to damage upon impact.

Fig. 1-27　　Soft High Pressure Tubes Connected to Useable Parts

Fig. 1-28　　External Pressure Gauge Indicated 3000PSI

1.6.3.5 Weight and Balance

According to DT-2's Weight and Balance Table on the day of occurrence, the total take off weight was 400,000 pounds, of which 88,000 pounds were fuel at the time of take off, with no payloads or passengers aboard. The Center of Gravity was calculated as 22.4% MAC.

After the occurrence, with the engines shut down and auxiliary power system turned on, the remaining fuel weighed 51,000 pounds. The amount of fuel used by each engine indicated no imbalance. The Center of Gravity was calculated as 22.5% MAC based on the amount of remaining fuel.

According to CAL's weight and balance records of recent passenger flights of B747SP with loads under normal fuel consumption: (1) while the total take off weight was approximately 450,000 to 483,000 pounds; (2) the Center of Gravity at the time of take off was 19.4% to 19.7% MAC; (3) while the landing weight was approximately 404,000 to 426,000 pounds; (4) the Center of Gravity at the time of landing was 19.1% to 20% MAC.

1.7 Meteorological Information

The actual and forecast weather before take off was observed and reported to be visual meteorological conditions (VMC). The weather observations at 1130 hours were 100°/21 knots, visibility greater than 6 miles, 2,500 feet few clouds, temperature 34℃, dew point 22℃, altimeter setting 1009hPa（hectopascals）. Weather observation from the tower at 1141:52 hours was 090°/16~26 knots, good visibility.

1.8 Aids to Navigation

Aids to navigation on Runway 06 were normal on the day of occurrence. No effective NOTAM was applicable to the occurrence.

1.9 Communications

All radio communications between DT2 to CKS Approach Control, CKS Tower and CAL's Asia Dispatch Center were normal at the time occurrence.

1.10 Airport Information

1.10.1 Station and Runways

Chiang Kai-shek International Airport (Fig. 1-29), elevation 107 feet, latitude 25° 04' 48.6" North, longitude 12° 13'56.0" East, is 16.7 miles south west of Taipei City. The airport is served by North Runway 05L/23R and 05R/23L, and South Runway 06/24, on which DT2 touched down. Runway 06 is a concrete runway, 3350 meters long and 60 meters wide, with a buffer zone 120 meters long and 73 meters wide, and a clearing zone 300 meters long and 300 meters wide. The approach threshold elevation is 106 feet.

Runway 06 has 8 taxiways, namely EW (S1), SF (S2), SP (S3), SH (S4), SN (S5), SJ (S6), SK (S7) and Ee (S8), all taxi ways are 35 meters wide with concrete shoulders 10.5 meters in width. Taxiway S4 and S5 intersect Runway 06’s midsection at a 30 degree angle, forming a V-shaped intersection which is 5,500 feet from the threshold. Runway 06 is equipped with navigation aids such as left and right locators, glideslope, distance measurement equipment and middle marker, all of which functioned normally at the time of incident.

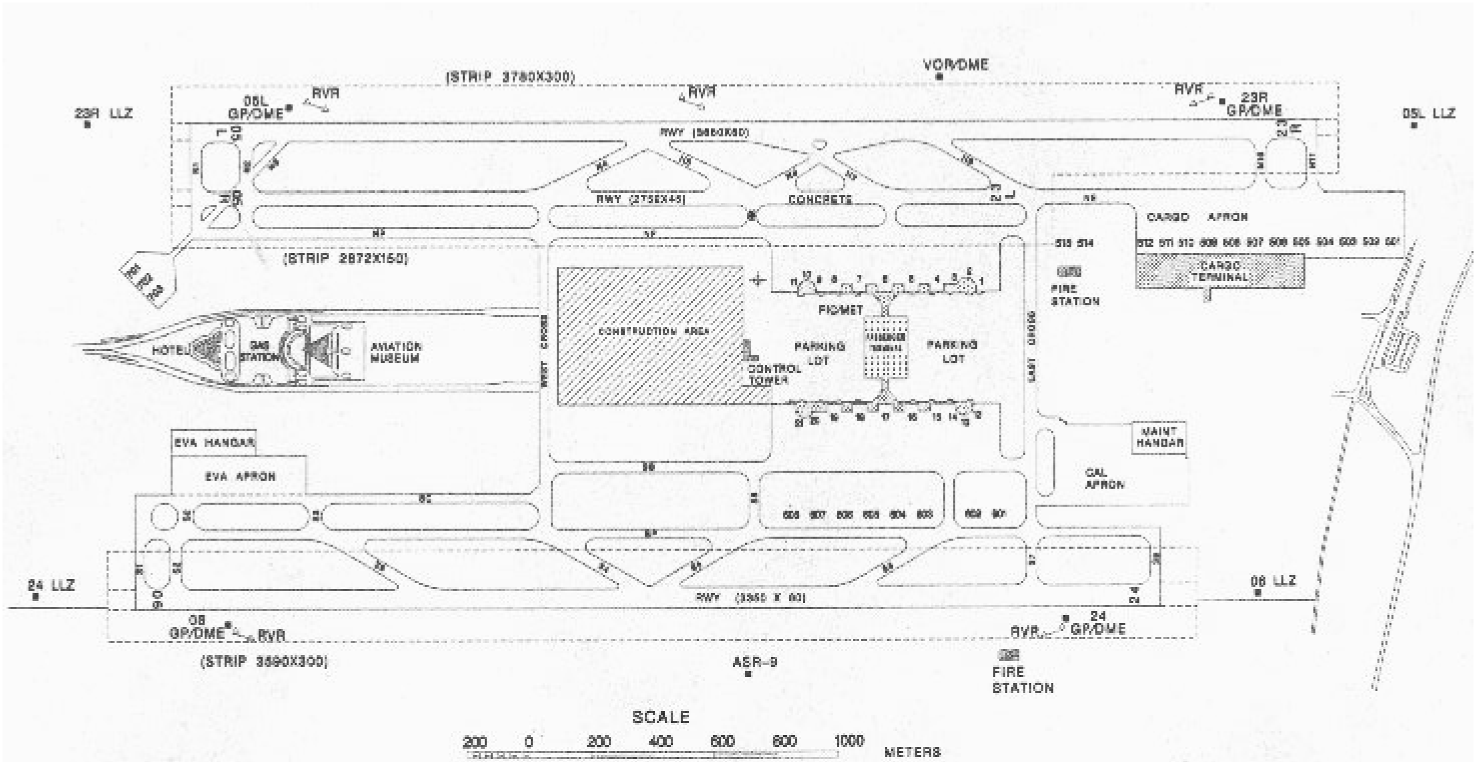


Fig. 1-29 CKS International Airport

1.10.2 Manhole Structure

As part of the navigation lighting system, the protruding concrete manhole (Fig. 1-30) struck by DT2's nose gear is located 11 meters to the side of the runway between Runway 06 and Taxiway S5.

Parallel to the runway, the manhole's base is a 2.4 x 2.4 square structure without bevel. The hole is covered, 1.5 meters in diameter, and 35 centimeters in height, while the base is approximately 29 centimeters above the ground. Thus, the height of the manhole is 69 centimeters in total (Fig. 1-31).

Grassed areas around the manhole slope at a 10° to 12° angle.

The manhole was designed and constructed on 5 September 1990 as Contract MD-2-35 under Bid CK-24, Phase II CKS Runway/Taxiway. Approximately 227 similar manholes were constructed under the same contract.

Fig. 1-30 Manhole Struck by Nose Gear

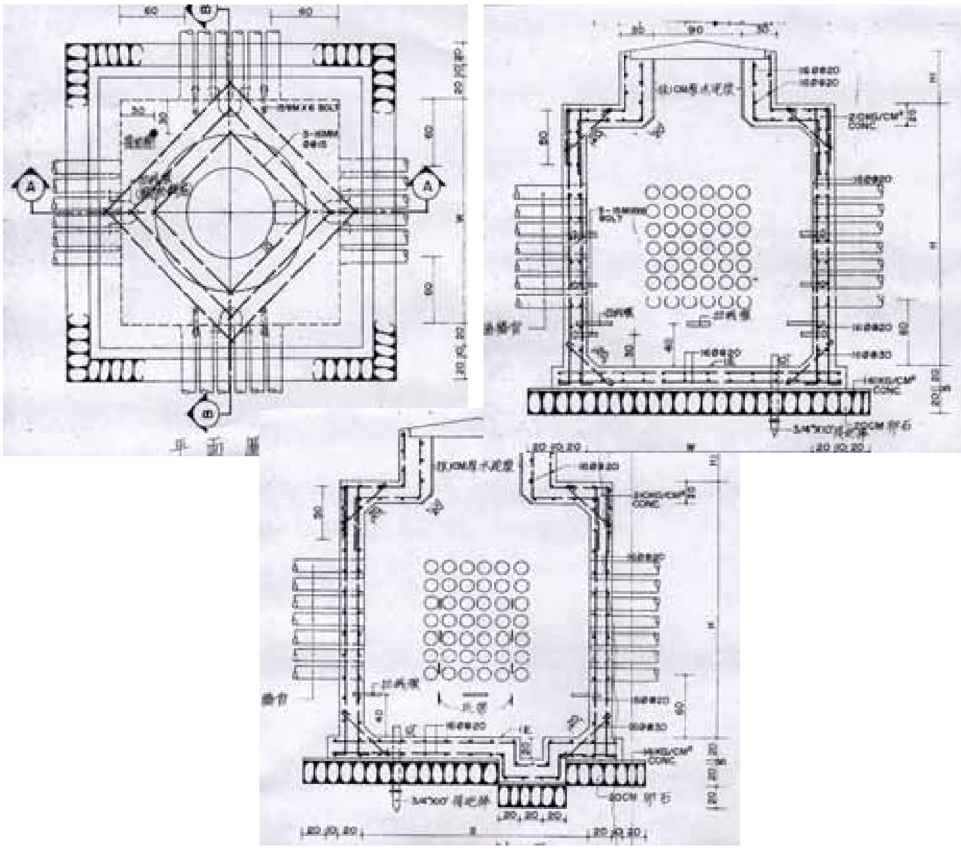


Fig. 1-31 Manhole Design

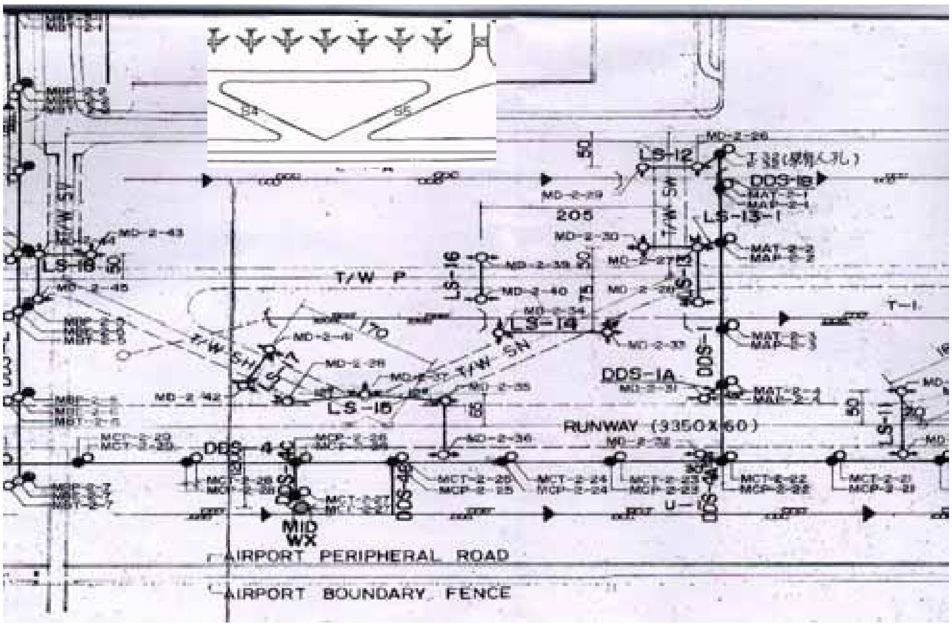


Fig. 1-32 Manhole Locations

1.11 Flight Recorders

A Loral A100 cockpit voice recorder (CVR) was installed on B-18253. The CVR is capable of recording communications by the captain, first officer and flight engineer, and other noises picked up by the cockpit area microphones. The recording contained high quality audio information from the crew, which started with final approach, continued through standstill, and ended when the crew left the cockpit. The recording was readout, with audio information pertinent to the occurrence transcribed as Attachment 3.

The FDR was a magnetic recorder (MN209, SN733, PN10077A500-103) manufactured by Lockheed Aircraft Service Company, capable of recording 25 hours of data covering 42 variables. Both the FDR and CVR were obtained on 2 September, and all readout were completed the next day. However, 15 seconds of data (03:48:21~03:48:22 and 03:48:28~03:48:40) was lost between the time DT2 veered off the runway and struck the manhole, and the time DT2 came to the stop. Data recorded during final approach and landing roll can be seen on Attachment 4.

1.12 Site Surveying

1.12.1 Ground Marks

According to the descriptions of the crew members after the occurrence, the aircraft touched down at approximately 1,500-2,000 feet from the threshold. The point of touch down was slightly to the left of the runway's centerline. As the aircraft taxied to approximately 3,500 feet, slightly visible nosewheel tracks (unable to be recorded on video) were left on the runway, and the tracks gradually deviated to the left of the runway's centerline. The aircraft deviated away from the runway's centerline approximately 1,300 feet ahead of Taxiway S5, where the nosewheel tracks became more apparent thereafter. Description of the evident runway marks, starting from the aircraft deviated from the centerline, are as follows:

- Mainwheel Tracks (Appendix I)

  The figure shows the tracks left by the four main gears and the nose gear, starting from when the aircraft deviated from the centerline, till the aircraft came to a complete stop after running off the runway.

- Nosewheel Tracks (Appendix II)

  The figure shows the tracks left by the nose gear, starting from when the aircraft deviated from the centerline, till the aircraft came to a complete stop after running off the runway. The figure also shows the ground contact surface of both nosewheels, as well as the changes in the distance between the tracks left by both nosewheels.

1.12.2 Changes in the Wheel Tracks

(Refer to the x-axis of Appendix I and II for the distance and placement.)

1. 0-150 meters (Fig. 1-33)

- Nosewheel: Two strips of dark nosewheel tracks were discovered after the aircraft deviated from the runway's centerline. The track left behind by the right wheel was visibly darker and wider.
- Mainwheel: No tracks were discovered at this time.

Fig. 1-33 Ground track between 0-150 meters.

2. 150-180 meters (Fig. 1-34)

- Nosewheel: The right nosewheel track was widened and became darker in color; the right half side of the track started to become less visible. The track distance between the two nosewheels was narrower gradually.
- Mainwheel:
  - ◻ Right Body Gear: Two traces of lightly visible wheel tracks started to appear.
  - ◻ Right Wing Gear: No tracks were discovered.
  - ◻ Left Body Gear: Two traces of lightly visible wheel tracks started to appear.
  - Left Wing Gear: No tracks were discovered.

Fig. 1-34 Ground track between 150-180 meters.

3. 180-250 meters (Fig. 1-35)

- Nosewheel: The left nosewheel track was darker and wider. The right nosewheel track was wider than the left nosewheel track. The track distance between the two wheels was narrower gradually.
- Mainwheel:
  - Right Body Gear: The two tracks became darker in color, with alternating dark and light strips in the tracks.
  - Right Wing Gear: Two strips of wheel tracks started to become visible and evident.
  - Left Body Gear: The two strips of wheel tracks started to form into four strips of smooth wheel tracks.

  Left Wing Gear: No tracks were discovered.

Fig. 1-35 Ground track between 180-250 meters.

4. 250-325 meters (Fig. 1-36)

- Nosewheel: The left and right nosewheel tracks continued to be wider and become darker. The gap continued to become smaller.
- Mainwheel:
  - Right Body Gear: The two strips of wheel tracks were overlapped by another two strips of wheel tracks, and their colors became darker.
  - Right Wing Gear: Two strips of wheel tracks were clearly visible as was before.
  - Left Body Gear: The four strips of wheel tracks were smooth and the distance between them widened.

  Left Wing Gear: No tracks were discovered.

Fig. 1-36 Ground track between 250-325 meters.

5. 325-450 meters (Fig. 1-37)

- Nosewheel: The left and right tire marks had slippery traces of liquid, especially on the edge of the white line on the runway, where there were traces of liquid being run over and spread to the sides.
- Mainwheel:
  - Right Body Gear: The four tracks were wider than before, with alternating dark and light strips in the tracks. Starting from the outer edge, the gaps between the first and second, as well as that between the third and fourth tracks, widened.
  - Right Wing Gear: The two strips of wheel tracks were overlapped by another two strips of wheel tracks, their colors visible, and had alternating dark and light strips in the tracks.
  - Left Body Gear: The four strips of wheel tracks were visible. Starting from the outer edge, the gaps between the first and second, as well as that between the third and fourth tracks, continued to widen.

  Left Wing Gear: Two tracks started to become visible.

Fig. 1-37 Ground track between 325-400 meters.

1.12.3 Nosewheel Tracks on the Grass Area

After running off the runway, the nosewheel left a 111-cm wide track on the grass area, and scrapped a protruded concrete manhole. The nosewheel left a 71-cm wide track (Fig. 1-38) on the grass area after it cleared off the protruding manhole.

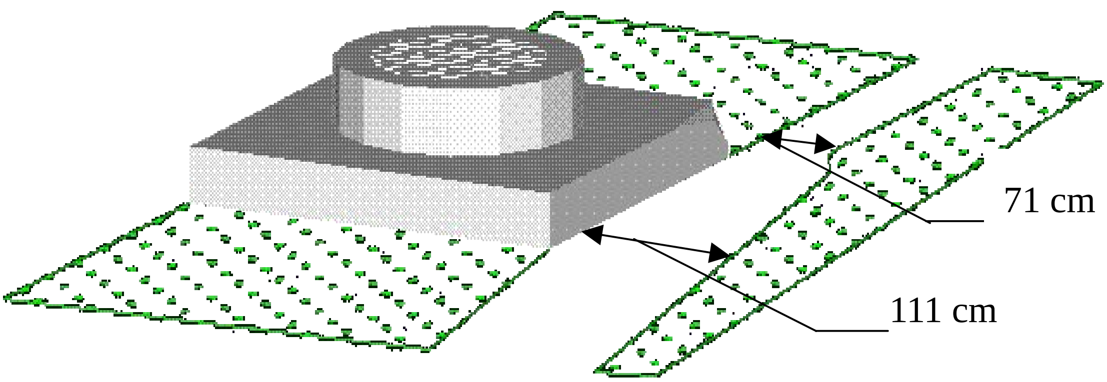


Fig. 1-38 Nosewheel tracks on the grass area.

1.12.4 Nosewheel Contact Area with the Ground Surface

While a B-747SP was parked in a hangar, the aircraft's nosewheel contact area with the ground surface was measured as shown in Fig. 1-39.

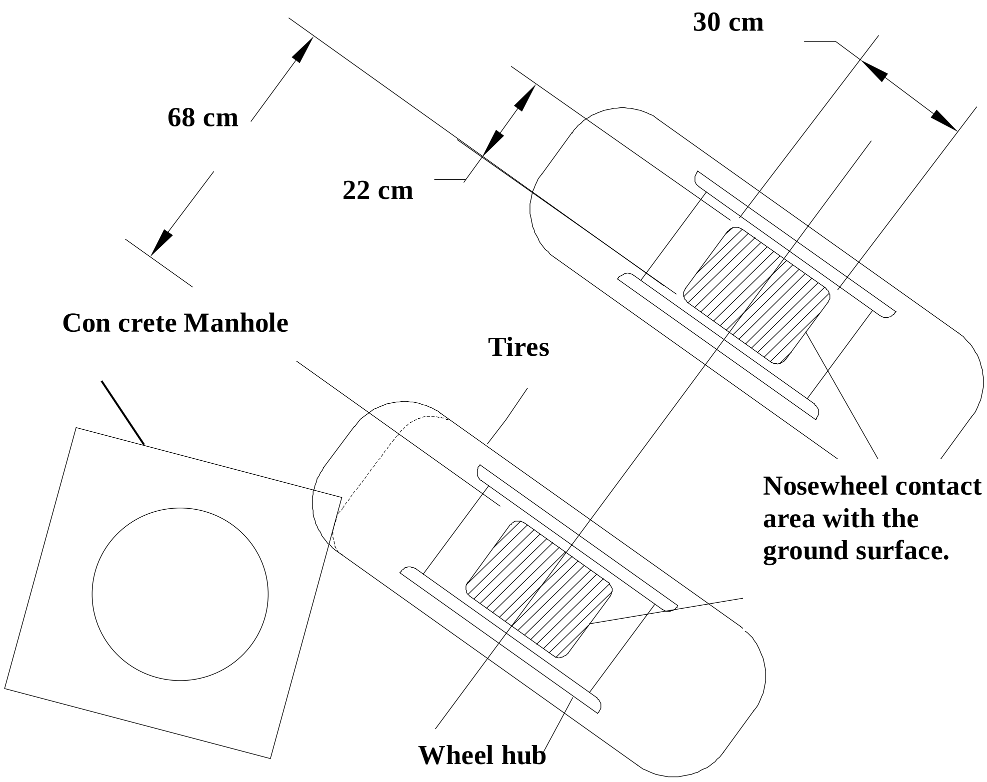


Fig.1-39 Nosewheel Contact area with the ground surface.

1.13 Medical and Pathological Information

Physical examination records of the DT-2 aircraft crew members showed no evidence of physiological and health abnormalities. After the occurrence, aviation personnel of the CKS immediately conducted alcohol level testing on the crew members. The results were negative.

1.14 Fire

There was no fire resulting from the occurrence. After the occurrence, the control tower immediately activated the emergency alarm. Fire vehicles and fire fighters arrived on site at 1151.

1.15 Survival Aspects

Since there was no fire or emergency situations after the occurrence, the flight crew members did not undertake any emergency measures for life saving. The flight crew left the airplane via the electronic equipment compartment door after the ground crew members entered the cabin through the electronic equipment compartment door.

1.16 Tests and Research

There was no need for tests and researches for this occurrence.。

1.17 Organizational and Management Information

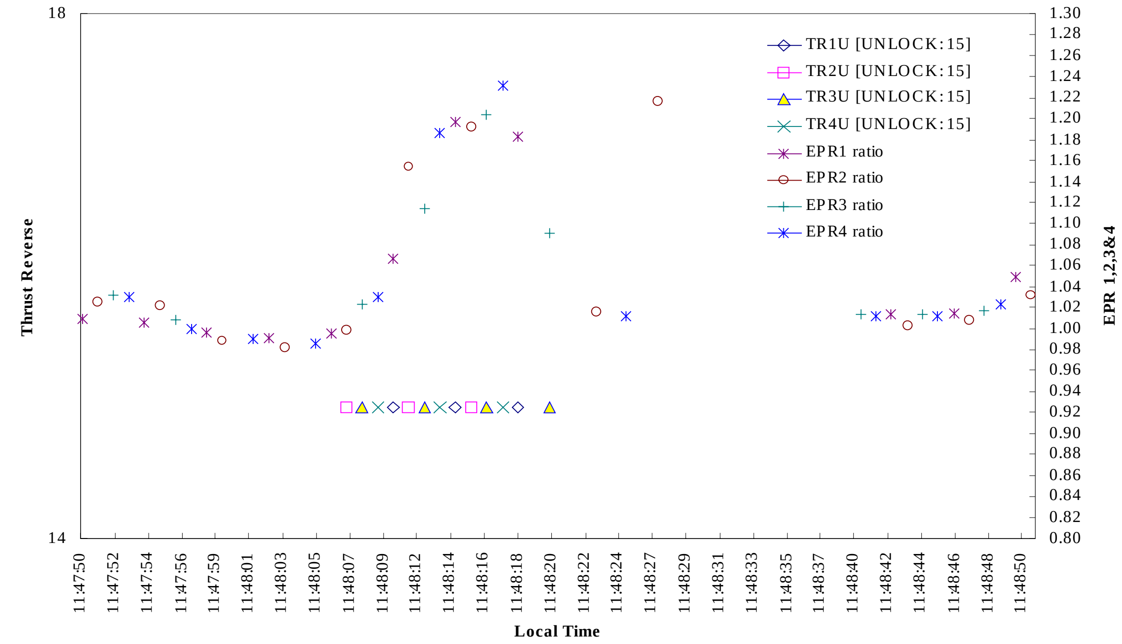
No mismanagement or negligence in personnel dispatch, certification of personnel qualifications, personnel training, and aviation planning were evident in the aviation occurrence.

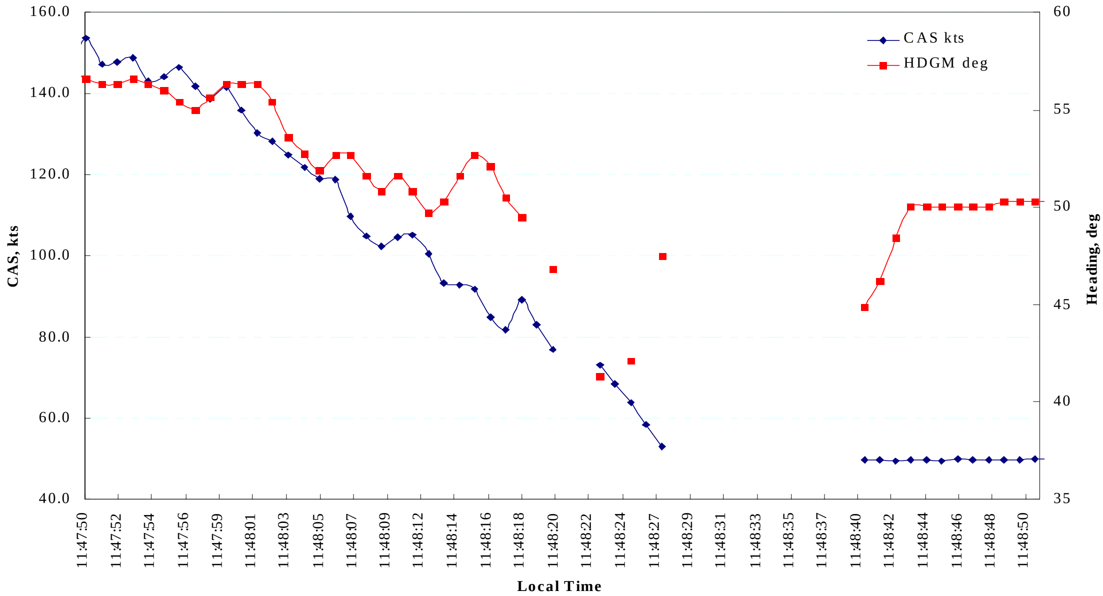
CHAPTER 2 Analysis

2.1 Landing Deceleration and Steering

The first officer was in command during the Dynasty Training 2 (DT-2) last full stop landing, The last stage of this final sortie commenced with a runway 06 ILS approach with manual flight and manual throttle control. The air speed during final approach was approximately 146 Kts; both the approach and touchdown were normal. The aircraft touched down at 1148:05 at a speed of 128 Kts. The flight crew described the point of touchdown as being 1,500 to 2,000 feet from the threshold. The spoilers were deployed normally and the first officer pulled the Reverse Thrust levers. Eight seconds after touchdown, the pilot-in-command called out “I HAVE CONTROL!,” after which he took over control. Four seconds later, the sound of the reverse thrust became louder, which continued for approximately eight seconds. After another three seconds, the flight engineer called out "80 KNOTS!" and the sound of vibration and collision was heard four seconds later.

The flight data recorder indicated that the path of the DT2 during its landing roll was approximately 052 degrees, but shifted to 047 degrees 16 seconds after touchdown (for a duration of approximately four seconds). Two seconds thereafter, the path shifted rapidly to 041 degrees, and information on the flight data recorder disappeared in these two seconds. The shift in direction during this period, verified by of the uneven dark nosewheel tracks and the bodywheel tracks indicated that the pilot-in-command had started using the tiller to steer the aircraft toward Taxiway S5. Before the drastic change in the aircraft direction, the FDR recorded the air speed as 76.8 Kts, and the reverse thrust was not stowed. The relevant records are shown in Fig. 2-1.





當地時間	FDR Time	人員	內容
11:48:05	03:48:02	A/C	Wu~ (Speed brake raising)
11:48:13	03:46:10	CM 1	OK! I have control!
11:48:16	03:48:13	CM 2	You control! (Reverse聲音)
11:48:28	03:48:25	CM 3	80 knots
11:48:32	03:48:29	CM 1	碰撞聲

Fig. 2-1 CVR and FDR records.

According to the statements of the flight crew, the pilot-in-command set Auto Brake to OFF prior to steering the aircraft toward Taxiway S5; the Body Gear Steering was set to ARM. In accordance with the Landing Roll Procedure under Normal Procedures of the B747-SP Flight Crew Operation Manual of China Airlines, operations of the Brake and Body Gear Steering are as follows:

- Brake … Check

When the airplane reaches desired taxi speed, release autobrakes by applying brake pedal force as required.

- Body Gear Steering … ARM

When taxi speed is reached, place body gear steering switch to ARM.

Although each of the different aviation manuals of China Airlines did not clearly specify the taxi speed, Chapter 3 of the Aircraft Operations Manual of Boeing 747-200 (SP), Procedures and Techniques, 3.20.4 Taxi, states that:

> Body gear steering has been designed to minimize thrust and tire scrubbing as well as to prevent wheels and tires from excessive stress in tight turns, but it is not intended for speeds above 20 Kts.

In 3.20.8 Landing, the manual states that:

> If autobrake was used transition to manual braking depends on stopping requirements. For normal runway conditions transition should be made near 60 Kts.

Therefore, under normal runway conditions, aircraft that uses autobrake during landing should release the autobrake below 60; body gear steering should be used only for speeds of less than 20 Kts. Prior to the DT-2 aircraft's sudden turn, the air speed was 76.8 Kts. The flight crew had started using manual brake and had activated Body Gear Steering.

During the day of the occurrence, the DT2 was on a type check flight of two first officers undertaking transition training. Since there were no passengers or cargoes on board, the aircraft landing weight was approximately 40,000 pounds less than that of a passenger flight. The center of gravity was 22.5% of MAC, which was further aft compared to the 19.4% to 20% MAC passenger flight. The center of gravity limits are 12% to 26% at landing configuration.

In section 3.20.5, Turn Radius: In the Boeing operations manual, the note to the figure on B747-SP turn radius states that:

> Note: Taxi speed, G.W, C.G, Runway conditions and nose wheel steering will affect turn radius and location of turn center.
>
> Use maximum width available. Use of minimum width will cause excessive tire slippage and scrubbing.

Section 3.20.8 Landing of the Boeing 747-200 operations manual states that:

> Note: When operating without auto-brakes the airplane requires a forward stick pressure to counter the pitch up effects from spoiler extension and reverse thrust.

When the DT-2 reduced speed to 76 Kts and prior to executing the large turn, the aircraft had a lighter weight, its center of gravity was toward the rear, spoiler was deployed, reverse thrust was not yet released, the auto-brake was released, body gear steering was deployed, and the aircraft was experiencing a pitch up effect. Due to the aircraft's light weight and center of gravity, the lift forces applied to the control surface before the aircraft reached its taxi speed decreased the friction between the nosewheel and the ground surface. As a result, the steering became less effective, resulting in scrubbing and slippage.

2.2 Wheel Tracks

According to the facts gathered on site, the analyses of the occurrence were as follows (Table 2-1):

Table 2-1 Analysis of the events of the occurrence.

Facts		Analysis
0-150 meters		
Nosewheel	Two strips of dark nosewheel tracks were discovered after the aircraft deviated from the runway's centerline. The track left behind by the right wheel was visibly darker and wider.	The tracks indicated that the physical appearances of the two nosewheels remained intact, and rotation remained smooth. The apparent shift of the center of gravity toward the left should be caused by the centrifugal force resulting from the aircraft's left turn. Since the friction between the ground surface and the nosewheel, which controlled the aircraft steering, was greater than the forward moving inertia of the aircraft, the steering angle of the nosewheel was not too large; thus the aircraft was still moving forward under control.
Mainwheel	No tracks were discovered.	The physical appearance of the mainwheels remained intact; wheel rotation remained smooth.

150-180 meters		
Nosewheel	The right nosewheel track widened and became darker in color; the right side of the track started to become less visible. The distance between the tracks was narrower than the previous.	The tracks indicated that the center of gravity had shifted way to the right, which should be a result of the sudden increase in centrifugal force due to a wide-angle left turn at high speed. The right wheel showed signs of scrubbing and slippage, which should be a result of the forward moving inertia of the aircraft being greater than the friction between the ground surface and the nosewheel; consequently, lateral slippage occurred on the nosewheel despite the steering angle. The nosewheel steering angle at this point should be greater than 21 degrees.
Right Body Gear	Two traces of lightly visible wheel tracks begun to appear.	The tacks indicated that scrubbing and slippage had occurred on this gear, a result not of breaking because there were no traces of brakes on the wing gear. The scrubbing and slippage should be a result of the forward moving inertia of the aircraft being greater than the friction between the ground surface and the steering wheel, resulting in lateral slippage in the direction of forward movement despite that the wheels were at their steering angle. The nosewheel left steering angle at this point should be greater than 21 degrees. The body gear steering will start to function after the nosewheel steering angle exceeds 21 degrees.
Right Wing Gear	No tracks were discovered.	The physical appearance of the mainwheels remained intact; wheel rotation remained smooth. No brakes were applied.

Left Body Gear	Two traces of lightly visible wheel tracks begun to appear.	The tracks indicated that scrubbing and slippage had occurred on this tire, not as of a result braking because there were no traces of brakes on the wing gear. The scrubbing and slippage should be a result of the forward moving inertia of the aircraft being greater than the friction between the ground surface and the steering wheel, resulting in lateral slippage in the direction of forward movement despite that the wheels were at their steering angle. The nosewheel left steering angle at this point should be greater than 21 degrees.
Left Wing Gear	No tracks were discovered.	The physical appearance of the mainwheels remained intact; wheel rotation remained smooth. No brakes were applied.
180-250 meters		
Nosewheel	The left nosewheel track started to become darker and wider. The right nosewheel track was wider than the left nosewheel track. The distance between the two wheels was narrower than the previous.	The center of gravity appeared to be restored somewhat, thus increasing the contact pressure between the left wheel and the ground surface. The aircraft forward moving inertia was not reduced, lateral slippage continue to occur on the nosewheel despite its steering angle. The nosewheel steering angle continued to increase.
Right Body Gear	The two tracks became darker in color, with alternating dark and light strips in the tracks.	The tracks showed that the steering of the body gear was normal, and continued to increase slowly. The brake system was applied and the brake functions were normal.
Right Wing Gear	Two strips of wheel tracks started to become visible and evident.	The tracks showed that the brake system was applied and the brake functions were normal.

Left Body Gear	The two strips of wheel tracks started to form into four strips of smooth wheel tracks.	The tracks showed that the steering of the right wing gear was normal. The steering angle was greater than that of the right body gear, indicating that the body gear steering was normal. However the brake functions were not as evident as that in the right body gear. This might be due to the centrifugal force, which resulted in insufficient pressure required to leave evident track marks.
Left Wing Gear	No tracks were discovered.	The physical appearance of the left body gear remained intact and its rotation remained smooth. However the brake functions were not as evident as that in the right wing gear. This might be due to the centrifugal force, which resulted in insufficient pressure on the ground surface.
250-325 meters		
Nosewheel	The left and right nosewheel tracks continued to widen and become darker. The gap continued to become smaller.	The tracks showed that the nosewheel steering angle continued to increase, and the forward moving inertia was not decreased.
Right Body Gear	The two strips of wheel tracks were overlapped by another two strips of wheel tracks, and their colors became darker.	The tracks showed that the steering of the right body gear was normal, and the steering angle continued to increase slowly. The brake was applied and the brake functions were normal.
Right Wing Gear	Two strips of wheel tracks were clearly visible as was before.	The tracks showed that the brakes were continually applied and that the brake functions were normal.

Left Body Gear	The four strips of wheel tracks were smooth and the distance between them widened.	The tracks showed that the steering of the right body gear was normal, and the steering angle continued to increase. There was evidence of braking, but the results were not as evident as that on the right body gear. This might be due to centrifugal force, which resulted in insufficient pressure on the ground surface.
Left Wing Gear	No tracks were discovered.	The physical appearance of the mainwheel of the left wing gear remained intact and its' rotation remained smooth. There were no traces of brake applied. This might be due to the leftward shift of the center of gravity, which resulted in insufficient pressure on the ground surface required to leave evident track marks.
325-450 meters		
Nosewheel	The left and right tire marks showed traces of melted rubber, especially on the edge of the white line on the runway, where there were traces on liquid being run over and spread to the sides. The gap continued to narrow.	The tracks showed that after more than 300 meters of contact and friction with the cement ground surface, the rubber tires started to melt as a result of the generated heat. (The melting point of the rubber tire is approximately 200^{o}C.) The steering angle of the nosewheel continued to increase, and prior to the aircraft entering the grass area, the nosewheel steering angle was over 54 degrees.
Right Body Gear	The four tracks were wider than before, with alternating dark and light strips in the tracks. Starting from the outer edge, the gaps between the first and second, as well as that between the third and fourth tracks, widened.	The tracks showed that the steering of the right body gear was normal, and the steering angle continued to increase slowly. The brake functions were normal.

Right Wing Gear	The two strips of wheel tracks were overlapped by another two strips of wheel tracks, their colors visible, and had alternating dark and light strips in the tracks.	The tracks showed that the brakes were continually applied, brake functions were normal, and that the brake and anti-slippage functions of the right wing gear were normal.
Left Body Gear	The four strips of wheel tracks were visible. Starting from the outer edge, the gaps between the first and second, as well as that between the third and fourth tracks, continued to widen.	The tracks showed that the steering of the left body gear was normal, and the steering angle continued to increase slowly. There was evidence of braking, but the results were not as evident as that on the right body gear. This might be due to centrifugal force, which resulted in insufficient pressure on the ground surface.
Left Wing Gear	Two tracks started to become visible.	The tracks showed that the center of gravity was shifting back to normal, the braking system of the left wing gear continued to be operational, and that the brake and anti-slippage functions were normal.

2.3 Analysis of the Tracks on the Grass Area

Calculating the turn angle of the aircraft based on the tracks left by the aircraft prior to its running off the runway, and verifying the calculation with the tracks left on the grass area, the time of rupture of the tire and events during that period can be determined.

2.3.1 Tracks on the Grass Area

The data measured on site were as follows (Fig. 2-2):

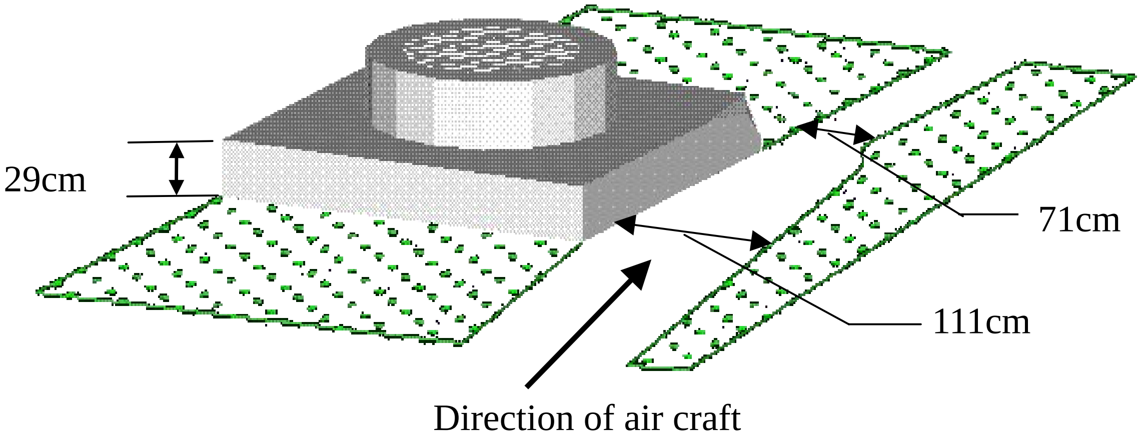


Fig. 2-2 Tracks on the grass area.

2.3.2 Wheel Contact Area with the Ground Surface

The data obtained at the China Airlines hanger were as follows (Fig. 2-3):

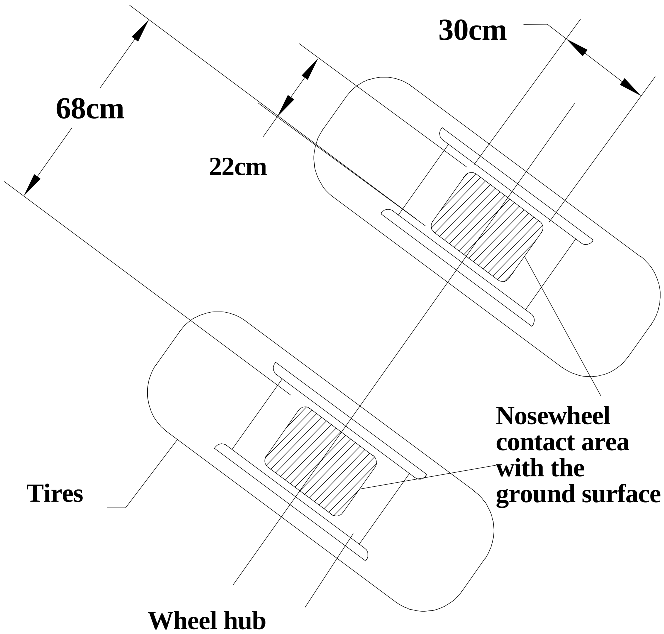


Fig. 2-3 Contact area with the ground surface.

2.3.3 Nosewheel Steering Angle Prior to Entering the Grass Area

From the gap between the nosewheels prior to their entering the grass area, the steering angle at that time was calculated to be at 45 degrees.

From the steering angle at that time, the track width was calculated to be 101 centimeters.

The steering angle of the nosewheel prior to entering the grass area is as shown in Fig. 2-4. The method of calculation is shown in Fig. 2-5.

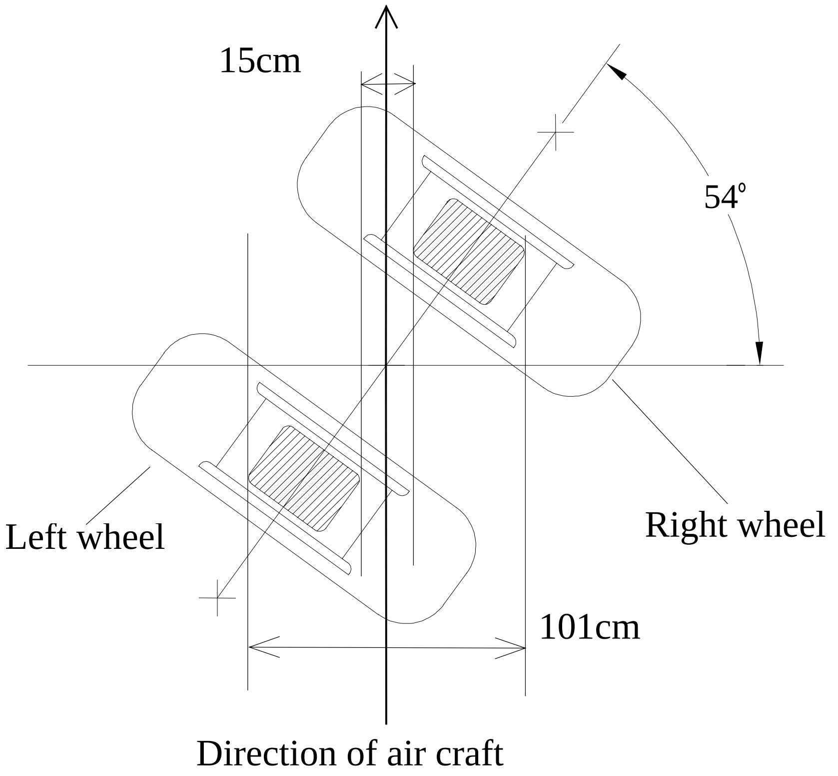


Fig. 2-4 The steering angle of the nosewheel prior to entering the grass area.

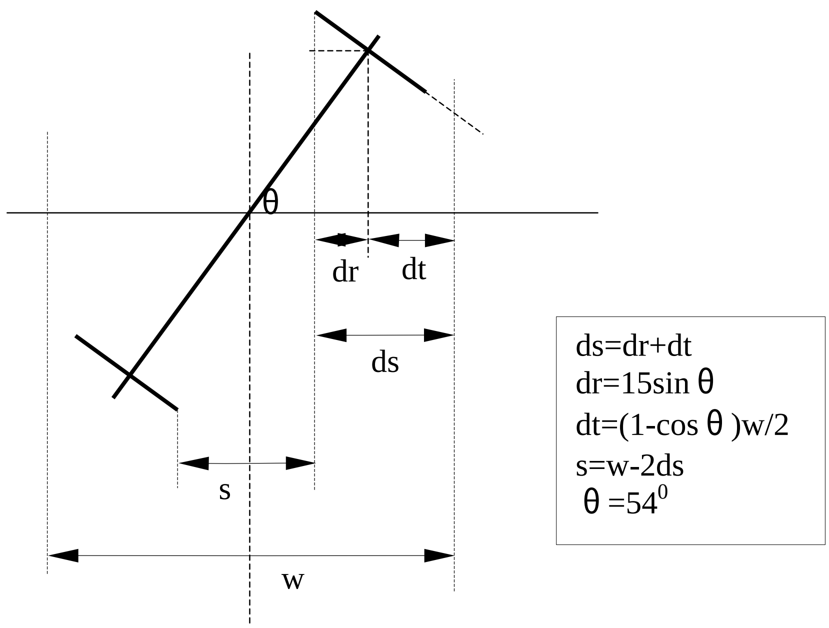


Fig. 2-5 Calculation of the steering angle of the nosewheel prior to entering the grass area.

2.3.4 The Contact of Nosewheels to Runway Surface and Ground Area

Comparing the calculated track width (101 centimeters) with the track width measured on the grass area (111 centimeters), the track width on the grass area was 10 centimeters wider. If the track width on the grass area were overlaid on the track width on the ground surface, with the centerlines of both tracks coinciding, the track width of the grass area would extend five centimeters beyond each side of the ground surface track width. This could be due to the softer grass area, which resulted in a sag leading to the wider track width.

2.3.5 Collision of the Nosewheel and the Concrete Manhole

While simulating the travel path of the aircraft using the above track marks, the three points of collision of the left and right wheels, as well as the left wheel hub, with the concrete manhole were as follows.

2.3.5.1 Collision of the Left Nosewheel and the Concrete Manhole

As shown in Figures 2-6 and 2-7, the right side of the left wheel came into collision with the concrete manhole. From the wreckage, a rupture of the right sidewall due to collision with a foreign object was discovered, where the cut was parallel to the base of the concrete manhole. After the collision with the base of the manhole, the left tire continued to roll and slip forward until the right wheel came into collision with the manhole base. From the wreckage, a hub of white marks was discovered on the right sidewall of the left tire, and black tire marks were discovered on the base of the manhole. The marks should be the result of the right sidewall scrubbing against the manhole after the left tire has ruptured.

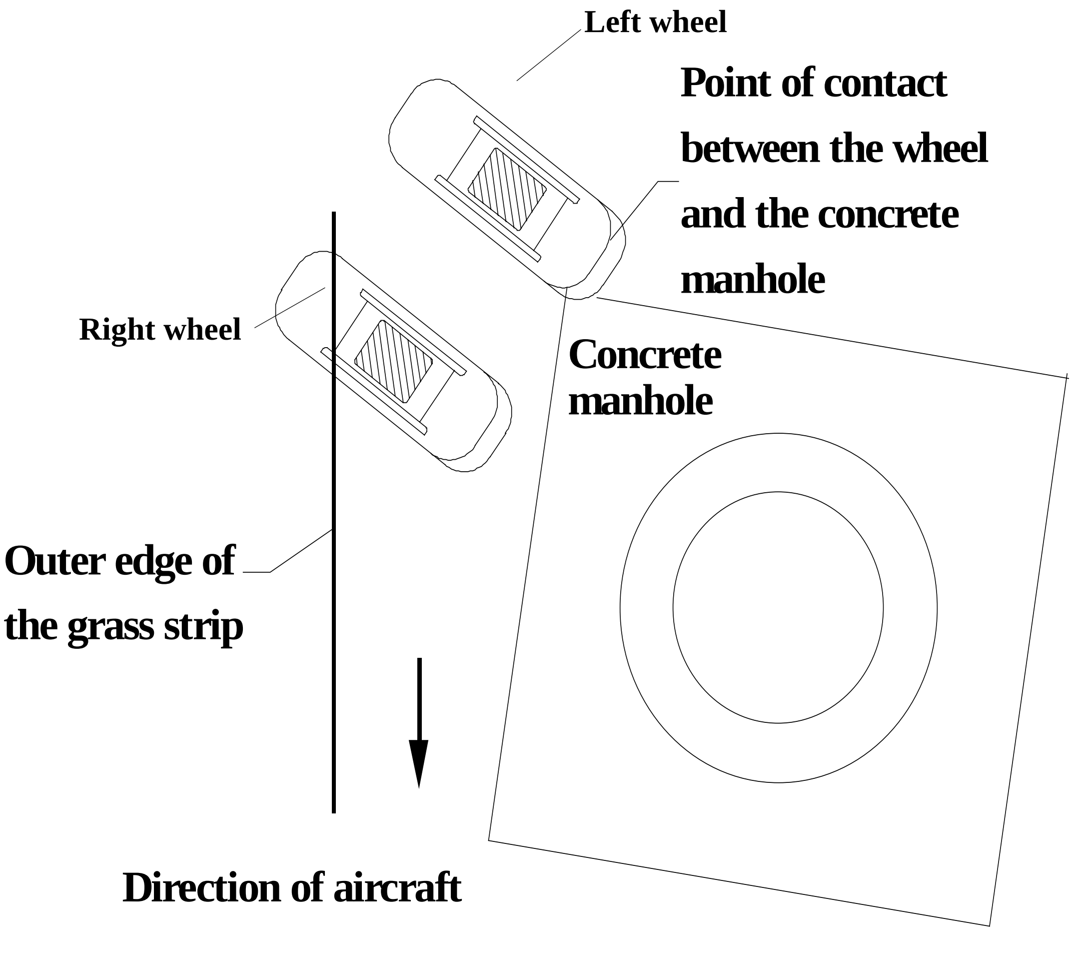


Fig. 2-6 Top view of the collision between the left wheel and the concrete manhole.

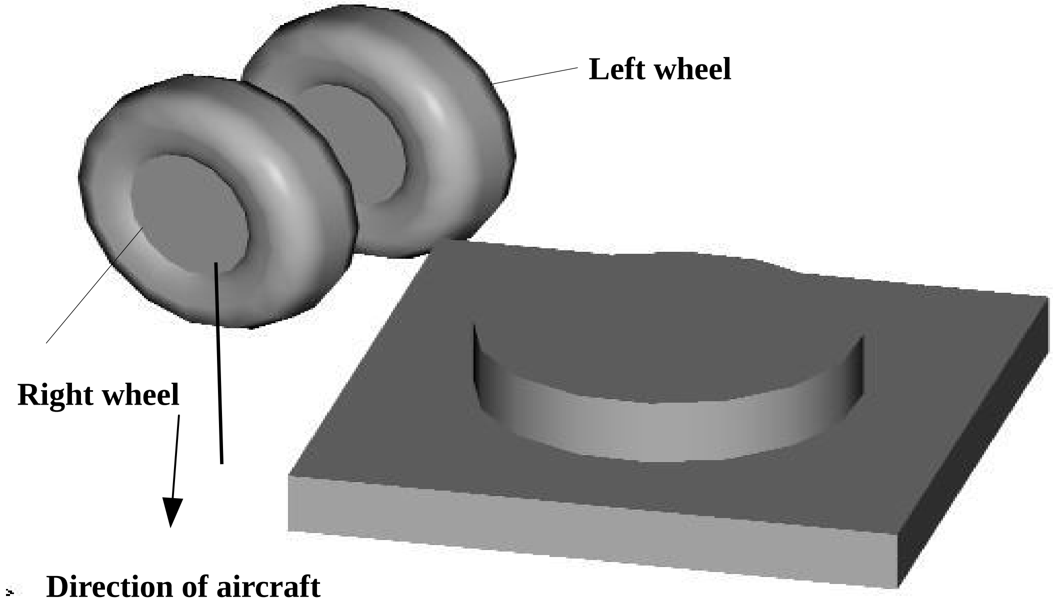


Fig. 2-7 Three-dimensional view of the collision between the left wheel and the concrete manhole.

2.3.5.2 Collision of the Right Nosewheel and the Concrete Manhole After the Rupture of the Left Nosewheel

As shown in Figures 2-8 and 2-9, the right wheel left shoulder came into contact with the outer edge of the base of the manhole first; thus the remaining travel distance would only damage the tread and the left sidewall. From the wreckage, white marks were discovered on the right wheel left shoulder, which might have resulted from the collision with the base of the manhole. The fan-shaped scratch marks on the tread should be the result of the short contact between the cylindrical-shaped tread and the flat-surfaced manhole base. Since the left wheel hub was elevated due to the height of the right wheel, it was higher than the cement manhole base and therefore did not came into contact with cement base.

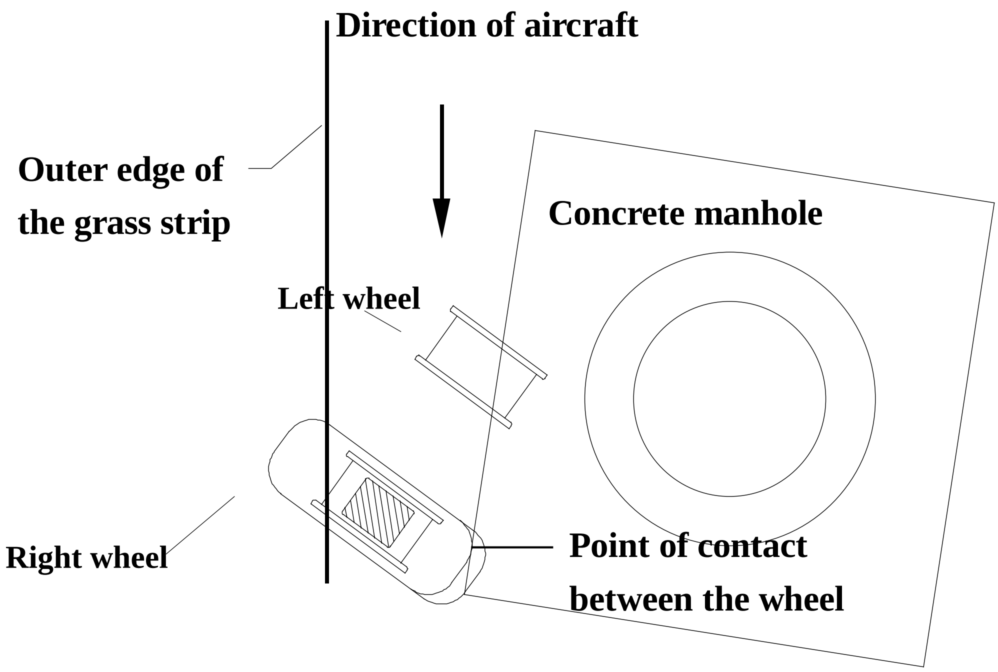


Fig. 2-8 Top view of the collision between the right wheel and the concrete manhole after the left tire had ruptured.

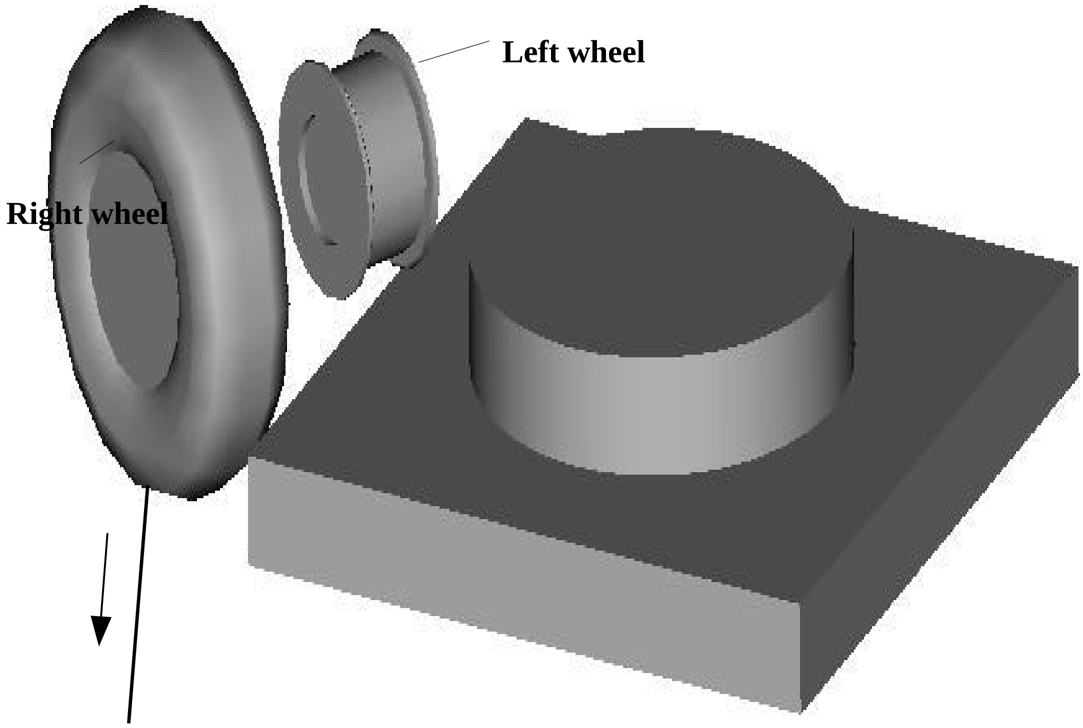


Fig. 2-9 Three-dimensional view of the collision between the right wheel and the concrete manhole after the left tire had ruptured.

2.3.5.3 Collision of the Left Nosewheel Hub and the Concrete Manhole After the Rupture of the Right Nosewheel

As shown in Figures 2-10 and 2-11, the height of the cement base was 29 centimeters. Since the height of the tire was 33 centimeters (according to the tire manual), the left wheel hub was supported by the right tire and did not came into contact with the cement base after the left tire had ruptured. When the right tire ruptured, the left wheel hub lowered due to the weight of the aircraft and ultimately came into collision with the cement base. This was evidenced from the dents found on the lateral flanges of the left wheel hub, and on the broken corners found at the edge of the cement base.

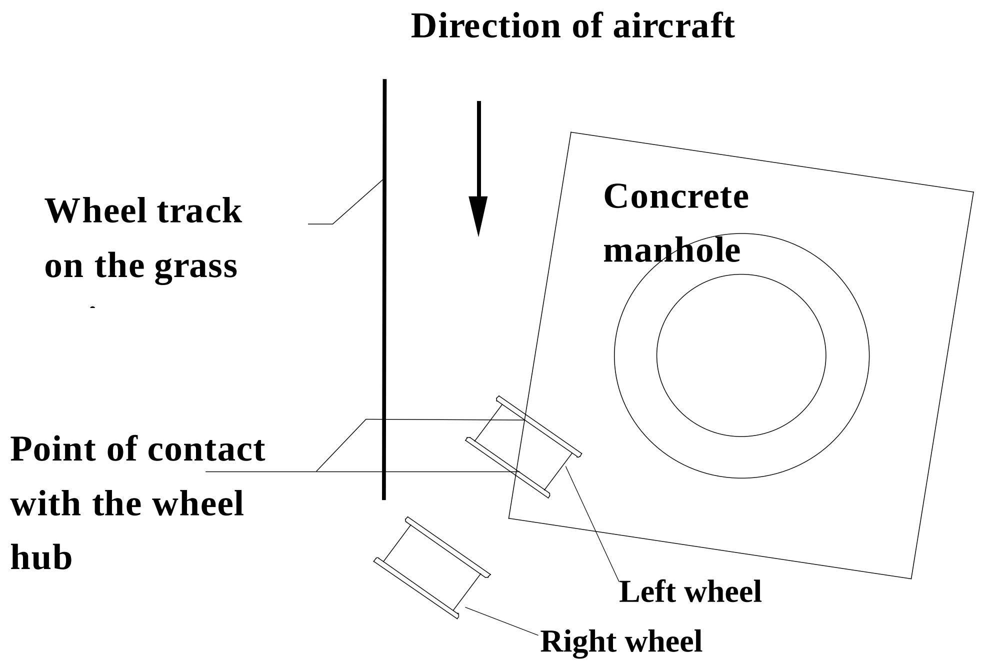


Fig. 2-10 Top view of the collision between the left wheel hub and the concrete manhole after the right tire had ruptured.

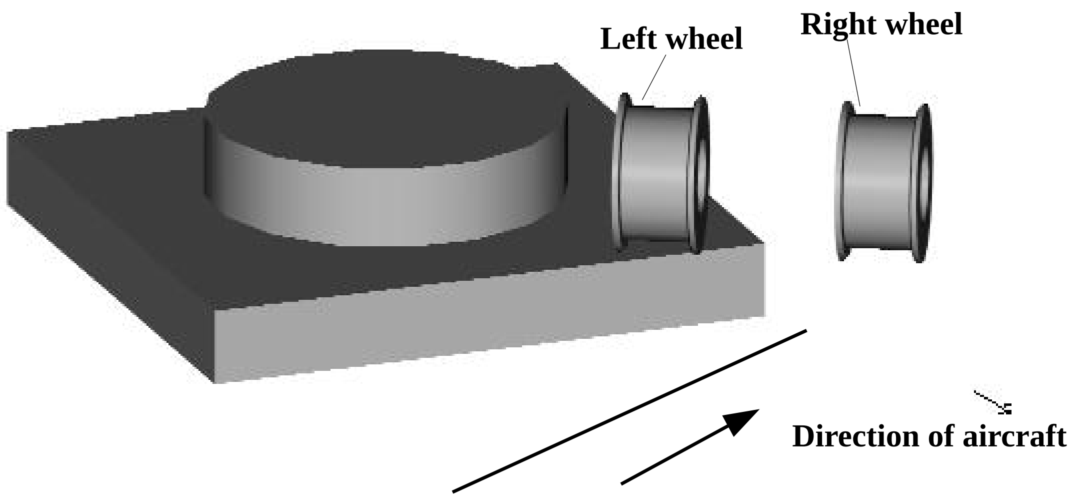


Fig. 2-11 Three-dimensional view of the collision between the left wheel hub and the concrete manhole after the right tire had ruptured

2.4 Analysis of the Nosewheels

According to the facts gathered on site and analysis of the occurrence, the probable events of the occurrence were as follows (Table 2-2):

Table 2-2 Probable events of the occurrence according to the facts gathered on site and analysis of the occurrence.

Wreckage	Facts	Analysis
Left Nosewheel		
Wheel Hub	Spot-like abrasion marks were found on both left and right flanges at about the same height. Spots where both flanges were impacted were dented and deformed. The dent on the left hub was more severe than that on the right hub.	Should be caused by collision with the edge of the concrete manhole after the left and right wheels were ruptured in succession. The left wheel hub scrubbed the concrete base for a longer distance thus resulting in a deeper dent.
	The right side of the left wheel hub was covered with mud.	The wheels ruptured in succession after the aircraft ran into the grass area. The wheel rims came into contact with the grass surface. Due to the nosewheel's wide leftward steering angle and the aircraft's continued forward movement due to its' inertia, the right tire sidewall scrubbed against the ground surface. As a result, the right sidewall slid to the left, and large amounts of mud were accumulated at the right side of the hub.
Wheels	Left tire: Cracks on the right sidewall was clean and parallel with the casing plies. A 45° cut by foreign objects extended from the sidewall to the entire tread, forming a 32" gash when joined with the cracks.	The crack on the right sidewall should be the place where collision with the concrete manhole started. The other 45 degree diagonal cut should be the result of the tire ripping from its plies due to the sustained inner and external pressures when the tire ruptured. The tire care and maintenance manual regard this type of rupture as impact brake caused by penetration of foreign object.

	The dismounted right sidewall slipped to the left, and the tire was deflated.	The left and right wheels ruptured in succession after the aircraft ran into the grass area and collided with the concrete manhole. Due to the nosewheel's wide leftward steering angle and the aircraft's continued forward movement from its' inertia, the right tire sidewall scrubbed against the ground surface. The friction of between the right sidewall and the ground surface caused the right sidewall to slip to the left.
	A ring of white marks were observed on the left sidewall near the rim line.	Should be due to the scrubbing against the concrete manhole.
	The entire tread was covered with abrasion marks vertical to the grooves.	The marks were results of movements in two directions and two forces of friction: the tires rolling and scrubbing against the ground surface at the steering angle, and the slippage due to the aircraft's continued forward movement due to its inertia. From the calculated nosewheel steering angle of 54 degrees, it was known that the ratio between the slipping and rolling speed was 1:0.58.
	A ring of abrasion marks 3/4 inches in width were also observed on the right tread shoulder.	Due to the nosewheel's wide steering angle and the aircraft's continued forward movement due to its inertia, the tires were deformed and the left tire shoulder scrubbed against the ground surface.

	The second grooves from the left and right outer shoulders were approximately 1/8" in depth. The tread rubber to the right of both these grooves rose approximately 1/16" for the entire circumference, while middle grooves were completely worn out.	Due to the wheel's wide steering angle and the aircraft's continued forward movement from its' inertia, massive and even abrasion occurred over the entire tread. Since the massive abrasion caused the middle grooves to be completely worn out while the outer grooves still remained, tire pressure of the aircraft during slipping should be normal and the physical appearance of the tires should still be intact.
Right Nosewheel		
Wheel Hub	Scratch marks were found on the distorted right flange.	Should be caused by collision with the edge of the concrete manhole after the left and right wheels were ruptured in succession.
	The hub's right side was covered with mud.	The left and right wheels ruptured in succession after the aircraft ran into the grass area. The wheel rims came into contact with the grass surface. Due to the nosewheel's wide leftward steering angle and the aircraft's continued forward movement from its' inertia, large amounts of mud were accumulated at the right side of the hub.
Wheels	The right sidewall slipped towards the left.	The left and right wheels ruptured in succession after the aircraft ran into the grass area. Due to the nosewheel's wide leftward steering angle and the aircraft's continued forward movement due to its' inertia, the right tire sidewall scrubbed against the ground surface and slid to the left as a result.

Several bulges and 6 to 12-inch cuts caused by foreign objects were found on the right sidewall.	The left and right wheels ruptured in succession after the aircraft ran into the grass area. Due to the nosewheel's wide leftward steering angle and the aircraft's continued forward movement from its' inertia, the right tire sidewall scrubbed against the ground surface.
Abrasion marks covered the entire right tread shoulder, and extended to the right sidewall.	Due to the nosewheel's wide steering angle and the aircraft's continued forward movement from its' inertia, the tires were deformed and the left tire shoulder scrubbed against the ground surface. Since the aircraft's center of gravity was leaning to the right, the right tire was more severely deformed than the left.
A 24-inch kite-shaped casing was ripped from the tire, creating an 18-inch hole.	The cut should be the result of the tire ripping from its plies due to the sustained inner and external pressures when the tire ruptured. The tire care and maintenance manual regard this type of rupture as impact brake caused by penetration of foreign object.
White marks found on the right-hand side edges of the hole.	Should be the scrubbing against the concrete manhole.
Immediately in front of the hole on the tread was a fan-shaped abrasion mark, the depth of which decreased as it extended from right to left.	Should be the result of the short contact between the cylindrical-shaped tread and the flat-surfaced manhole base.

	The abrasion on the tire casing ripped off from the hole was the same as the abrasion on the tire; the ripped-off casing was found between the manhole and where the aircraft came to a standstill.	Since the abrasion on the tire casing ripped off from the hole was the same as the abrasion on the tire, the tire might have ruptured after the collision with the concrete manhole.
	Abrasion marks vertical to the grooves covered the ripped off tire casing.	The marks were results of movements in two directions and two forces of friction: the tires rolling and scrubbing against the ground surface at the steering angle, and the slippage due to the aircraft's continued forward movement from its' inertia. From the calculated nosewheel steering angle of 54 degrees, it was known that the ratio between the slipping and rolling speed was 1:0.58.
	The outer groove from the shoulder was approximately 1/8-inch deep, and part of the tread rubber to the right of the groove rose approximately 3/16 inches, while the middle grooves were approximately 1/32 inches deep.	Due to the wheel's wide steering angle and the aircraft's continued forward movement due to its' inertia, massive and even abrasion occurred over the entire tread. Since the massive abrasion caused the middle grooves to be completely worn out while the outer grooves still remained, tire pressure of the aircraft during slipping should be normal and the physical appearance of the tires should still be intact.

2.5 Placement and Design of the Runway Manhole

2.5.1 Guidelines to Manhole Placements on Runway Strips

Compared the ICAO Annex 14 Aerodromes guidelines, the domestic guidelines have the same basic concepts as the ICAO guidelines.

Section 3 (Basic and Ancillary Facilities), paragraph 3.3, of the Construction Standards of Civilian Airports (document number 76-Ke Chi-1 (3) dated September 30, 1987) of the Aviation Transportation Technology Guidelines issued by the Civil Aeronautics Administration contained the following statements on the runway strips:

3.3.1 General Principles

For the safety of aircraft take-off and landing, a rectangular runway strip, normally a grass area, shall be provided surrounding the runway.

3.3.2 Importance of Runway Strips

1. When the aircraft runs off the runway, the placement of the runway strip will be able to minimize the damage to the aircraft.
2. The runway strip and its' transition surface make up a free and open space to ensure a safe air space.
3. Due to the placement of the runway strip, navigational aids such as instrument landing systems will have access to open ground surface and air space to ensure normal functions.
4. During emergency situations, the strips surrounding the runway will

ensure the speedy arrival of fire vehicles and medical equipment on site.

3.3.3 Width of Runway Strips

3.3.3.1 The width of the runway strip is as detailed in Table 2-3, with the centerline of the runway strip coinciding with the runway's centerline.

Table 2-3 Width of Runway Strips.

Aerodrome Reference Code	Distance on each side of the centerline of the runway and its extended centerline throughout the length of the strip.	
	Precision-approach Runway	Non-instrument Runway
More than 1200m.	≥ 150 meters	≥ 75 meters
Airplane reference field length 800m up to but not including 1200 m.	≥ 75 meters	≥ 40 meters
Airplane reference field length 800m.	≥ 75 meters	≥ 30 meters

3.3.3.2 The width of the instrument landing runway strip shall be further divided into inner and outer strip areas. The inner strip width shall be the same that the width of the non-instrument runway strips of corresponding reference runways; the remaining width shall belong to the outer strip area, as shown in Fig. 2-12.

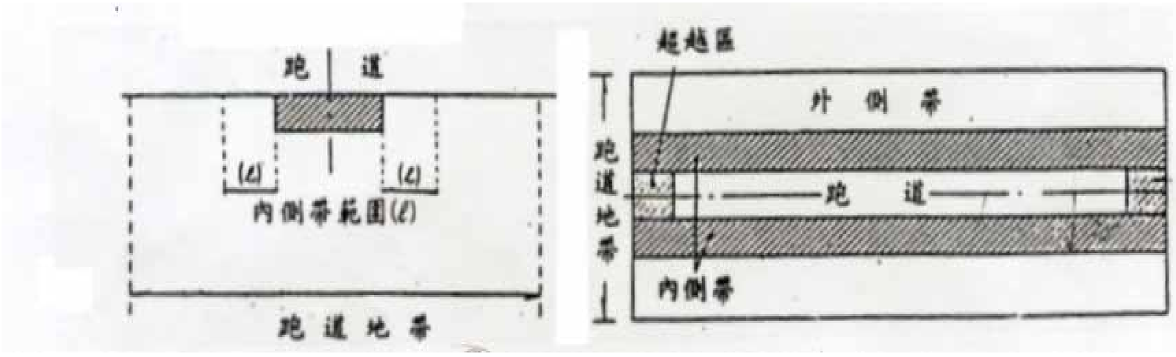


Fig. 2-12 Definition of the different areas of the runway strip.

3.5.6.2 In principle, no access roads, deflectors, and objects protruding from the ground surface that may affect aviation safety shall be located around the taxiway (jet 30.0m).

The manhole (number MD-2-35) that was hit and run over by the B18253 aircraft nosewheel is only 40.8 meters away from the runway's centerline. Since the runway width is 60 meters, the manhole is less than 11 meters from the edge of the runway. The manhole is located within the limits (minimum 75m) of the runway strip having length of more than 1200m.

The manhole (number MD-2-35) run over by the B18253 aircraft nosewheel is only 25 meters away from the taxiway. Since the taxiway width is 35 meters, the manhole is less than eight meters from the edge of the taxiway.

Based on the purpose of installing a runway strip, the manhole should be able to minimize damage persons and aircraft, provide a clear zone, and ensure the speedy arrival of fire vehicles and medical equipment on site when the aircraft enters this area by chance.

In addition, the standard guidelines also stipulated that the runway strip should be clear of all obstructions:

> Apart from the necessary facilities directly related to aviation, such as lighting, communications, and weather equipment, no other objects, in principle, should be located within the runway strip.

Therefore, to ensure normal functional operations and to maintain a clear zone for aviation, it is appropriate that no objects be installed within this area, so as to provide a safety buffer in the event that an aircraft runs off the runway.

There are 227 manholes and electrical manhole structures that were installed during the same period, most of which are located at the inner strip of this runway.

2.5.2 Adequacy of the Manhole Design Structure

Section 3 (Basic and Ancillary Facilities), paragraph 3.3.6.3, of the Construction Standards of Civilian Airports (document number 76-Ke Chi-1 (3) dated September 30, 1987) of the Aviation Transportation Technology Guidelines issued by the Civil Aeronautics Administration stipulates the following:

“Within the non-instrument and instrument landing runway strips, structures should be buried at least 30 centimeters under the ground surface as much as possible to ensure uniform strength along the entire runway strip. If it becomes necessary to locate a structure such as manhole above ground surface, the structure can be constructed in accordance with Fig. 2-13. The structure surrounding should be protected by concrete, with a 30 centimeter tapering leading to top of the structure.”

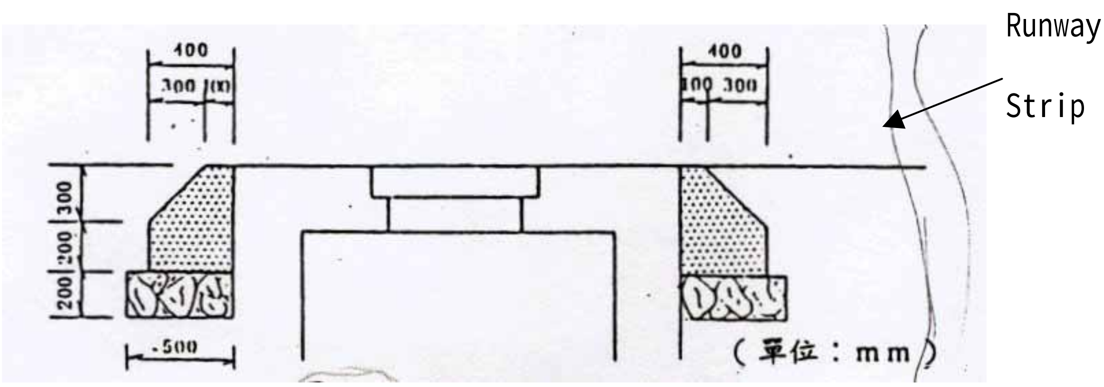


Fig. 2-13 Design of the manhole protective structure.

The essence of the guideline is that when a aircraft runs over a soft ground surface, the aircraft wheel will still be protected by the tapered surface when it sags to the safety limit of 30 centimeters; as such, the tire will not break off or rupture due to forceful collision.

The MD-2-35 manhole was not buried at least 30 centimeters under the ground surface as stipulated by the guideline. Since it was protruding from the ground surface, it was likewise not protected by a concrete structure with a 30 centimeter tapering toward the top. Although the design plan was completed in January 1981 before the promulgation of the Construction Standards of Civilian Airports in 1987, the current manholes at the CKS airport need to be modified due to safety concerns.

2.5.3 Adequacy of the Design of Slopes on Runway Strips

Section 3 (Basic and Ancillary Facilities), paragraph 3.3.5, of the Construction Standards of Civilian Airports (document number 76-Ke Chi-1 (3) dated September 30, 1987) of the Aviation Transportation Technology Guidelines issued by the Civil Aeronautics Administration stipulates the following:

> "The traverse slope limits of non-instrument or instrument landing runway inner strips shall be 2.5% (where the width is 150m) and 3.0% (where the width is 80m or 60m)."

According to the guidelines, the traverse slope of the runway inner strip should be ±2.5%, which is within ±1.432 degrees angle of elevation. Thus the angle of elevation of any point within the runway inner strip should be within ±1.432 degrees (Fig. 2-14).

The angle of elevation of the grass area as measured was -10 degrees.

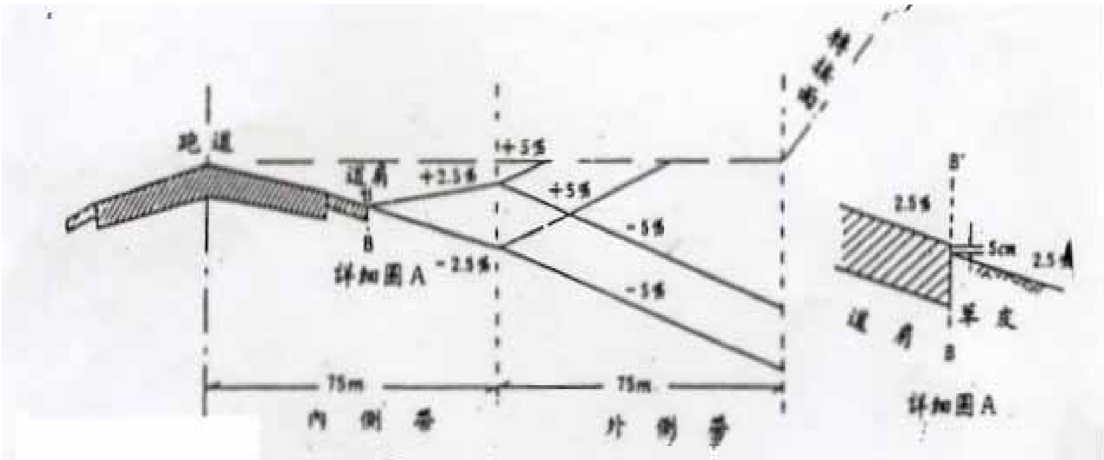


Fig. 2-14　　　Traverse slope of the runway strip.

The cowl of #1 engine of China Airlines B18253 came into contact with the grass surface after the aircraft ran off the runway. Thus from the physical appearance of the aircraft (Fig. 2-15) and assuming that the left wing gear ran into a grass area with the same slope, the angle of elevation of the runway’s inner strip exceeded 6.9 degrees, that is, the grass areas ran over by the left and right wing gear had a difference in elevation of 134 centimeters. The traverse slope exceeded 12.1%, which does not comply with the above guideline.

Analyzing the breakage of the left body gear, and assuming that the left wing gear ran into a grass area with a different slope, the angle of elevation of the runway’s inner strip exceeded 5.13 degrees based on calculation using the aircraft’s centerline. The traverse slope exceeded 8.99%, which does not comply with the above guideline.

Therefore, due to safety concerns, the traverse slopes of the runway strips at the CKS airport should be appropriately modified.

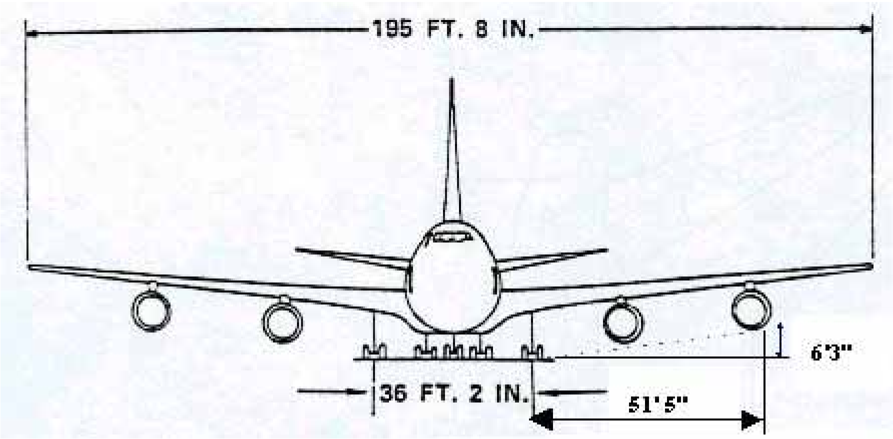


Fig. 2-15 Physical dimension of the Boeing 747SP.

CHAPTER 3 Conclusion

3.1 Findings

The crew and flight operations:

1、Approximately 18 seconds after touchdown, the aircraft was veered to the left rapidly; the air speed at this instant was 76.8 Kts. The pilot-in-command chose manual brake prior to the steering and activated body gear steering.

2、After the landing, the deceleration operation till the excursion, the flight crew were CM1 (left seat), the pilot-in-command; CM2 (right seat), was the first officer; CM3, the flight engineer; CM4, the co-pilot. The pilot flying was CM1.

3、All the five crew members held valid civil transport pilot licenses. CM1, CM2, and CM4 are holding valid B747-200 ratings. The flight crew members were all in good physical and mental condition. Prior to the occurrence, the atmosphere in the cabin was fine, and crew coordination was normal.

4、The aircraft landing weight was approximately 364,000 pounds, and its' center of gravity was 22.5% of the MAC. The landing weight of the occurrence was less than that of the schedule passenger flight, and landing center of gravity was a rear c.g. condition.

5、Visual meteorological conditions and a surface wind of 090°/16~26 knots were reported at the time of occurrence. The prevailing conditions had no evident effect on the landing roll operations.

The aircraft:

6、Inspection and testing after the occurrence showed that all the landing gears and tires were normal; the tire pressure of the different tires were normal, the steering of the nosewheel and body gears were normal, and all components and brake functions of the wheels were normal.

7、The aircraft nosewheel and mainwheel left tracks of uneven depth approximately 220 meters long on the runway ground surface near Taxiway S5. From the tracks on the ground surface, it was evident that the aircraft, while rolling at high speed, attempted to steer left using nosewheel steering, and the nosewheel steering angle was in excess of 54 degrees. The tracks left by the nosewheel on the ground surface showed evidence of lateral slippage. After the aircraft deviated away from the runway, it collided with the manhole, rupturing the nosewheel tire, snapping the left body gear, and damaging the aircraft's belly skin and structure.

The airport facilities:

8、The CKS airport runway has a total of 227 concrete manholes, the location, structural design, and construction of which are not in compliance with International Civil Aviation Organization (ICAO) and domestic technical specifications. As a result, the landing gear came into collision when it deviated from the runway, leading to serious damages.

9、The transverse slope of the runway grass area close to the boundary between

Runway 06 and Taxiway S5 was too steep, causing the outer casing of the aircraft's outer left engine to come into contact with the ground surface when the aircraft deviated from the runway.

3.2 Probable Cause

The probable causal factors are as follows: the pilot-in-command failed to select before touchdown a point to depart the runway based on the aircraft's braking characteristics; reverse thrust, brakes and body gear steering were not applied at the desired speed; and the nose gear steering was applied before reaching the desired rolling speed. In addition, the aircraft's light weight and center of gravity which was toward the rear increased the aircraft's pitch up tendency, causing the nose wheel to slip laterally despite the actuation of nose gear steering, and the aircraft veered off to the side of the runway onto the grass strip rather than turning into Taxiway S5.

The protruding manhole to the left of Runway 06 is an indirect cause of the occurrence. The location, structure and construction of the manhole fail to meet both domestic specifications, as well as those recommended by ICAO, causing serious damage to the deviated aircraft when its' landing gear collided with the manhole.

CHAPTER 4 Safety Recommendations

To China Airlines:

1. Should require flight crew to operate all aircrafts strictly accordance with flight manuals and relevant standard operating procedures;
2. Should stipulate the rolling speeds for various flight conditions in the Boeing 747 SP Flight Manual, so that flight crews can operate safely when taxing and rolling;

To the Civil Aeronautics Administration, Ministry of Transportation and Communications:

1. Should ensure that the location, design, construction and structure of all fixed structures (including concrete manholes) around the runway strips at the CKS airport are in compliance with international standards, so as to ensure the protection and safety of any deviated aircraft; (ASC-ASR-9909-03)
2. Should ensure that the transverse slopes of the runway strips at CKS are in compliance with specifications recommended by the ICAO, so as to protect the safety of any deviated aircraft. (ASC-ASR-9909-04)

Appendix 1 Ground Track of DT-2

Appendix 2 Track of DT-2 Nose Gear

Appendix 3 FDR Parameters

Local Time	Comp_Airspeed (CAS)	Control Column Position(CCP)	Control Wheel Position(CWP)	Pressure Altitude
hh:mm:ss	kts	deg	deg	ft
11:47:50	153.6	14.6	1.0	325
11:47:51	147.2	-14.8	-1.0	321
11:47:52	147.6	15.6	-15.2	291
11:47:53	148.7	12.5	3.0	298
11:47:54	143.2	13.6	4.0	284
11:47:55	144.1	15.3	3.0	264
11:47:56	146.4	13.4	0.0	258
11:47:57	141.7	13.8	1.0	253
11:47:58	138.6	14.0	-6.0	262
11:47:59	141.5	15.0	4.0	258
11:48:00	135.9	0.3	0.5	251.5
11:48:01	130.2	-14.5	-3.0	245
11:48:02	128.1	14.2	-19.2	262
11:48:03	124.9	-15.0	-5.0	254
11:48:04	121.9	-14.6	-5.0	252.5
11:48:05	118.9	-14.2	-5.0	251
11:48:06	118.8	-13.4	4.0	253
11:48:07	109.8	-13.7	4.0	243
11:48:08	105.0	-15.5	1.0	243
11:48:09	102.3	-15.4	1.0	238
11:48:10	104.6	-15.4	3.0	245
11:48:11	105.1	15.9	3.0	242
11:48:12	100.5	-15.8	-4.0	236
11:48:13	93.3	16.0	-1.0	225
11:48:14	92.9	15.9	3.0	225
11:48:15	91.8	16.0	3.0	231
11:48:16	84.9	-16.0	3.0	231
11:48:17	81.9	-15.8	3.0	234
11:48:18	89.3	16.0	3.0	228
11:48:19	83.1	16.0	3.0	233.5
11:48:20	76.8	16.0	3.0	239
11:48:21	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:22	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:23	73.0	-15.7	3.0	0
11:48:24	68.5	-15.8	3.5	0
11:48:25	63.9	-15.8	4.0	0
11:48:26	242.6 [Error]	-6.4	4.0	0
11:48:27	300.0 [Error]	3.1	4.0	0
11:48:28	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:29	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
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11:48:38	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:39	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:40	49.8	-15.2	4.0	240
11:48:41	49.7	-15.3	4.0	245

11:48:42	49.6	-15.5	4.0	254
11:48:43	49.7	16.0	4.0	261
11:48:44	49.8	15.9	4.0	245
11:48:45	49.5	15.9	4.0	255
11:48:46	50.0	15.9	4.0	237
11:48:47	49.7	15.9	4.0	251
11:48:48	49.8	15.9	4.0	248
11:48:49	49.8	15.9	4.0	248
11:48:50	49.8	15.9	4.0	243

Local Time	Vertical Acc. 1 (VAcc1)	Vertical Acc. 2 (VAcc2)	Vertical Acc. 3 (VAcc3)	Vertical Acc. 4 (VAcc4)
hh:mm:ss	**g**	**g**	**g**	**g**
11:47:50	1.04	1.03	1.07	1.07
11:47:51	1.14	1.18	1.16	1.10
11:47:52	1.05	0.97	1.00	0.97
11:47:53	0.96	0.95	0.88	0.94
11:47:54	1.07	1.11	1.07	1.12
11:47:55	1.18	1.11	1.08	1.07
11:47:56	1.02	0.97	0.99	0.99
11:47:57	1.00	1.01	1.02	1.04
11:47:58	0.99	0.98	1.04	1.02
11:47:59	1.07	1.05	0.98	0.96
11:48:00	1.01	1.04	0.95	0.95
11:48:01	0.94	1.02	0.91	0.94
11:48:02	0.95	0.95	1.04	1.10
11:48:03	0.99	0.95	0.93	1.00
11:48:04	1.00	0.96	0.99	0.98
11:48:05	1.00	0.97	1.04	0.96
11:48:06	0.99	0.97	1.04	0.98
11:48:07	0.96	1.01	0.98	0.97
11:48:08	0.99	0.96	1.01	0.98
11:48:09	1.00	0.94	0.99	1.02
11:48:10	1.03	1.00	1.01	1.02
11:48:11	0.97	1.05	0.96	0.99
11:48:12	1.00	0.99	0.96	0.99
11:48:13	1.03	0.93	0.96	0.97
11:48:14	1.01	1.03	0.96	0.96
11:48:15	0.98	1.01	1.04	0.96
11:48:16	0.99	0.95	0.98	0.99
11:48:17	1.04	0.95	0.96	0.99
11:48:18	1.03	1.00	0.97	1.00
11:48:19	1.02	0.98	0.98	0.99
11:48:20	1.00	0.96	0.98	0.98
11:48:21	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:22	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:23	1.01	1.03	0.95	0.96
11:48:24	1.01	0.97	0.96	0.98
11:48:25	1.00	0.90	0.96	0.99
11:48:26	3.02	2.78	3.46	-1.08
11:48:27	5.03	4.66	5.96	-3.15
11:48:28	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**

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11:48:39	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:40	0.90	0.97	0.97	0.97
11:48:41	0.96	0.97	0.98	1.02
11:48:42	0.97	0.97	0.97	1.00
11:48:43	0.99	0.97	1.00	1.00
11:48:44	1.00	0.97	0.98	1.00
11:48:45	0.99	1.00	0.98	1.00
11:48:46	0.99	0.99	0.99	0.99
11:48:47	0.99	0.99	0.99	0.99
11:48:48	0.99	0.99	0.99	0.99
11:48:49	0.99	0.99	0.99	0.98
11:48:50	1.00	0.99	0.99	0.99

Local Time	**EPR1**	**EPR2**	**EPR3**	EPR4	**TR1U Thrust Reverse**	**TR2U Thrust Reverse**	**TR3U Thrust Reverse**	**TR4U Thrust Reverse**
hh:mm:ss	**ratio**	**ratio**	**ratio**	**ratio**	**[Active:**	**[Active: 15]**	**[Active: 15]**	**[Active: 15]**
11:47:50	1.01							
11:47:51		1.03						
11:47:52			1.03					
11:47:53				1.03				
11:47:54	1.01							
11:47:55		1.02						
11:47:56			1.01					
11:47:57				1.00				
11:47:58	1.00							
11:47:59		0.99						
11:48:00			**DATA LOSS**					
11:48:01				0.99				
11:48:02	0.99							
11:48:03		0.98						
11:48:04			**DATA LOSS**					
11:48:05				0.99				
11:48:06	1.00							
11:48:07		1.00				15		
11:48:08			1.02				15	
11:48:09				1.03				15
11:48:10	1.07				15			
11:48:11		1.16				15		
11:48:12			1.12				15	
11:48:13				1.19				15
11:48:14	1.20				15			
11:48:15		1.19				15		
11:48:16			1.20				15	

11:48:17				1.23				15
11:48:18	1.18				15			
11:48:19		**DATA LOSS**						
11:48:20			1.09				15	
11:48:21	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**				
11:48:22	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**				
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11:48:27		1.22						
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11:48:35	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**		**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:36	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**		**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:37	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**		**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:38	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**		**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:39	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**		**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:40			1.01					
11:48:41				1.01				
11:48:42	1.01							
11:48:43		1.00						
11:48:44			1.01					
11:48:45				1.01				
11:48:46	1.02							
11:48:47		1.01						
11:48:48			1.02					
11:48:49				1.02				
11:48:50	1.05							

Local Time	**Later Acc. 1 (LATG1)**	**Later Acc. 2 (LATG2)**	**Later Acc. 3 (LATG3)**	**Later Acc. 4 (LATG4)**
hh:mm:ss	**g**	**g**	**g**	**g**
11:47:50	-0.025	-0.031	-0.013	-0.019
11:47:51	0.006	-0.001	-0.019	-0.027
11:47:52	-0.031	-0.021	-0.001	0.024
11:47:53	0.054	0.034	-0.019	0.004
11:47:54	-0.007	0.018	0.018	-0.005
11:47:55	-0.017	-0.011	-0.025	-0.033
11:47:56	-0.023	-0.047	0.004	0.004
11:47:57	-0.013	-0.003	0.026	-0.015
11:47:58	0.016	0.014	0.004	0.044
11:47:59	0.042	0.028	0.016	-0.009
11:48:00	0.094	0.080	0.088	0.078
11:48:01	0.146	0.132	0.160	0.164
11:48:02	0.134	0.134	0.050	-0.009

11:48:03	-0.055	-0.135	-0.133	-0.178
11:48:04	-0.036	-0.056	-0.048	-0.056
11:48:05	-0.017	0.024	0.038	0.067
11:48:06	0.042	0.044	0.063	0.004
11:48:07	0.016	0.028	-0.013	-0.072
11:48:08	-0.098	-0.094	-0.104	-0.057
11:48:09	-0.041	0.018	0.040	0.065
11:48:10	0.052	0.026	0.014	-0.043
11:48:11	-0.060	-0.092	-0.090	-0.094
11:48:12	-0.049	-0.068	-0.001	-0.019
11:48:13	0.030	0.061	0.048	0.124
11:48:14	0.101	0.093	0.115	0.103
11:48:15	0.042	0.069	0.018	0.020
11:48:16	-0.017	-0.055	-0.066	-0.041
11:48:17	-0.092	-0.064	-0.070	-0.037
11:48:18	-0.045	-0.098	-0.033	-0.094
11:48:19	-0.060	-0.081	-0.031	-0.061
11:48:20	-0.074	-0.064	-0.029	-0.027
11:48:21	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:22	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:23	-0.074	-0.033	-0.057	-0.015
11:48:24	0.955	0.975	0.955	0.975
11:48:25	0.099	0.071	0.126	0.156
11:48:26	0.955	0.975	0.955	0.975
11:48:27	-0.182	0.575	0.935	-1.050
11:48:28	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:29	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:30	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:31	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:32	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:33	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:34	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:35	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:36	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:37	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:38	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:39	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:40	0.124	0.077	0.117	0.089
11:48:41	0.122	0.136	0.113	0.115
11:48:42	0.063	0.071	0.067	0.065
11:48:43	0.071	0.065	0.061	0.036
11:48:44	0.046	0.091	0.028	0.044
11:48:45	0.050	0.058	0.048	0.063
11:48:46	0.044	0.058	0.050	0.054
11:48:47	0.050	0.050	0.054	0.050
11:48:48	0.056	0.052	0.054	0.050
11:48:49	0.058	0.048	0.056	0.056
11:48:50	0.048	0.050	0.061	0.050

Local Time	Magnetic Heading	PITCH	ROLL	RUDDER POS. LEFT	RUDDER POS. RIGHT
hh:mm:ss	deg	deg	deg	deg	deg
11:47:50	56.6	0.4	0.7	0.0	-0.8
11:47:51	56.3	1.1	-0.7	-1.3	-1.5
11:47:52	56.3	0.4	-2.1	-1.6	-2.1
11:47:53	56.6	0.4	-0.7	-2.1	-1.5
11:47:54	56.3	1.8	0.0	-1.6	-1.3
11:47:55	56	1.8	0.0	-1.4	-1.1
11:47:56	55.4	1.1	-0.4	-1.1	-1.3
11:47:57	55	1.8	-1.1	-1.0	0.8
11:47:58	55.6	2.1	-2.1	0.9	-0.2
11:47:59	56.3	2.1	-1.1	-0.6	-0.7
11:48:00	56.3	1.6	-1.8	-2.9	-3.6
11:48:01	56.3	1.1	-2.5	-5.2	-6.4
11:48:02	55.4	-0.4	-2.1	-7.4	-7.5
11:48:03	53.6	-0.4	-0.4	-4.3	-2.5
11:48:04	52.75	-0.6	-0.4	-5.2	-4.6
11:48:05	51.9	-0.7	-0.4	-6.0	-6.7
11:48:06	52.7	-0.7	-0.7	-7.5	-7.9
11:48:07	52.7	-0.7	-0.7	-11.9	-6.4
11:48:08	51.6	-0.4	-0.4	-3.3	-5.3
11:48:09	50.8	-0.4	-0.4	-7.7	-4.7
11:48:10	51.6	-0.4	-0.7	2.4	-3.9
11:48:11	50.8	-0.4	-0.4	-1.5	-0.9
11:48:12	49.7	-0.4	-0.7	-1.1	-1.2
11:48:13	50.3	-0.4	-1.1	-1.5	-2.1
11:48:14	51.6	-0.4	-2.1	-2.4	-2.4
11:48:15	52.7	-0.4	-2.1	-2.2	-1.9
11:48:16	52.1	-0.7	-1.1	-1.7	-1.7
11:48:17	50.5	-0.7	-1.1	-1.7	-1.9
11:48:18	49.5	-0.7	-2.1	-1.9	-1.7
11:48:19		-0.7	-1.8	-2.0	-1.9
11:48:20	46.8	-0.7	-1.4	-2.0	-2.1
11:48:21	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:22	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:23	41.3	-1.1	-2.1	1.4	4.3
11:48:24		1.0	1.0	1.0	1.0
11:48:25	42.1	-1.1	-2.5	6.4	7.8
11:48:26		1.0	1.0	1.0	1.0
11:48:27	47.5	1.0	-13.0	-25.7	26.2
11:48:28	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:29	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:30	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:31	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:32	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:33	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:34	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:35	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:36	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:37	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:38	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:39	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**	**DATA LOSS**
11:48:40	44.9	-2.1	-3.9	-0.2	-0.2
11:48:41	46.2	-1.4	-3.9	-0.5	-0.8
11:48:42	48.4	-1.4	-3.5	-0.9	-0.8
11:48:43	50	-1.1	-3.5	-0.8	-0.9
11:48:44	50	-1.1	-3.5	-1.0	-1.1
11:48:45	50	-0.7	-2.8	-0.8	-0.5
11:48:46	50	-0.7	-2.8	0.6	-0.2
11:48:47	50	-0.7	-2.8	-1.0	-1.0

11:48:48	50	-0.7	-2.8	-0.9	-0.6
11:48:49	50.3	-0.7	-2.8	-0.7	-0.9
11:48:50	50.3	-0.7	-2.8	-0.9	-0.8

Appendix 4 DT-2 (CVR Transcript)

1. The following is a transcript of the communications between the cockpit Area Mic and ATC after the DT-2 radio was switched over to the CKS Control Tower.
2. Conversations not relevant to the occurrence were not included in the transcript.

Local Time	FDR Time	CVR Time	Personnel	Contents
11:41:10	03:41:07	0:10:54	CM1	Tower good morning, Dynasty training 2, ILS/DME 06, 16 miles on final.
11:41:19	03:41:16	0:11:03	TWR	Dynasty training 2, Taipei Tower, runway 06, continue approach, wind 090 at 15 maximum wind 24, QNH 1009.
11:41:29	03:41:26	0:11:13	CM1	1009, continue approach runway 06
11:41:52	03:41:49	0:11:36	TWR	Dynasty training 2, runway 06, wind 090 at 16 gust 26, clear to land.
11:41:59	03:41:56	0:11:43	CM1	Clear to land, runway 06, Dynasty training 2
11:42:05	03:42:02	0:11:49	CM3	Our final location after stopping is 604
11:42:15	03:42:12	0:11:59	CM2	Flap 20
11:42:24	03:42:21	0:12:08	CM3	20,20
11:42:25	03:42:22	0:12:09	CM2	20,20
11:42:36	03:42:33	0:12:20	CM2	Gear down
11:42:38	03:42:35	0:12:22	CM1	Gear down
11:42:58	03:42:55	0:12:42	CM3	Gear lights green
11:43:10	03:43:07	0:12:54	CM2	We'll fly at this speed.
11:43:19	03:43:16	0:13:03	CM3	30,30
11:43:26	03:43:23	0:13:10	CM1	Final check list
11:43:27	03:43:24	0:13:11	CM3	Final check list, fuel heat system OFF, Autobrake
11:43:30	03:43:27	0:13:14	CM1	Minimum
11:43:32	03:43:29	0:13:16	CM3	Ignition flight start, speed brake
11:43:34	03:43:31	0:13:18	CM1	Arm
11:43:36	03:43:33	0:13:20	CM3	Gear
11:43:37	03:43:34	0:13:21	CM1	Down Green
11:43:38	03:43:35	0:13:22	CM3	Flaps

11:43:39	03:43:36	0:13:23	CM1	30 , 30 Green
11:43:40	03:43:37	0:13:24	CM2	30 , 30 Green
11:43:41	03:43:38	0:13:25	CM3	30 , 30 Green
11:43:42	03:43:39	0:13:26	CM3	HYD SYS CK. Landing checklist complete.
11:43:48	03:43:45	0:13:32	CM2	Final speed we'll fly 146, Manual thrust
11:44:21	03:44:18	0:14:05	CM2	Manual flight
11:44:23	03:44:20	0:14:07		(Alarm from disengaging the "Autopilot") Sound of from the rotation of the Stabilizer Trim
11:45:57	03:45:54	0:15:41	CM1	1500
11:45:59	03:45:56	0:15:43	CM2	Check!
11:47:47	03:47:44	0:17:31	A/C	200 (Auto Alt call)
11:47:49	03:47:46	0:17:33	CM1	Clear to Land,
11:47:26	03:47:23	0:17:10	CM2	Clear……, Sir,
11:47:53	03:47:50	0:17:37	A/C	100
11:47:57	03:47:54	0:17:41	A/C	50,40,30,20, tic… tic,10
11:48:05	03:48:02	0:17:49	A/C	Wu ~ (Speed brake raising)
11:48:08	03:48:05	0:17:52	A/C	Vibration sound
11:48:11	03:48:08	0:17:55	CM2	Oh!
11:48:13	03:48:10	0:17:57	CM1	OK! I have control !
11:48:16	03:48:13	0:18:00	CM2	You control ! (Sound from the Reverse)
11:48:28	03:48:25	0:18:12	CM3	80 knots
11:48:31	03:48:28	0:18:15	A/C	NNNN···. (Unknown sound)
11:48:32	03:48:29	0:18:16	A/C	Sounds of vibration and collision
11:48:39	03:48:36	0:18:23	CM1	Why is it like this?
11:48:48	03:48:45	0:18:32	CM1	What's happened?
11:48:53	03:48:50	0:18:37	CM2	Checking the engine.
11:48:56	03:48:53	0:18:40	CM3	Let me see the engine.
11:49:05	03:49:02	0:18:49	CM3	Still there. Didn't touch anything.
11:49:18	03:49:15	0:19:02	CM3	Contact Operation.
11:49:20	03:49:17	0:19:04	CM1	OK. Calling Operation.
11:49:31	03:49:28	0:19:15	CM3	TR-2 we are now leaving the runway. Need backup.
11:49:34	03:49:31	0:19:18	CM2	Do we have to shut of engine?
11:49:39	03:49:36	0:19:23	CM1	APU is not turned on. Wait a moment.
11:49:56	03:49:53	0:19:40	CM1	How come? Why won't it move?
11:49:59	03:49:56	0:19:43	CM3	Maybe too much speed. Too much speed.
11:50:06	03:50:03	0:19:50	CM1	Is the APU switched on?
11:50:07	03:50:04	0:19:51	CM3	Switching to on.
11:50:38	03:50:35	0:20:22	CM1	Turn off another one.

11:50:39	03:50:36	0:20:23	CM3	Wait. #3 turned off.
11:50:42	03:50:39	0:20:26	CM1	What?
11:50:43	03:50:40	0:20:27	CM3	Turned off #3.
11:50:52	03:50:49	0:20:36		(Sound of alarm)

Appendix 5　ICAO ANNEX14

AERODROMES 3.3

Aerodome reference code

Code 1	Airplane reference field length	less than 800m
Code 2	Airplane reference field length	800m up to butnot including 1200m
Code 3	1200m up to but not including 1800m	
Code 4	1800m and over	

3.3　Runway strips

General

3.3.1　A runway and any associated stopways shall be included in a strip.

Length of runway strips

3.3.2　**Recommendation.**－A strip should extend before the threshold and beyond the end of the runway or stopway for a distance of at least:

--60 m where the code number is 2,3 or 4;

--60 m where the code number is 1 and the runway is an instrument one; and

--30 m where the code number is 1 and the runway is a non-instrument one.

Width of runway strips

3.3.3 A strip including a precision approach runway shall, wherever practicable, extend laterally to a distance of at least:

--150 m where the code number is 3 or 4; and

--75 m where the code number is 1 or 2;

on each side of the centre line of the runway and its extended centre line throughout the length of the strip.

3.3.4 ***Recommendation.*** *—A strip including a non-precision approach runway should extend laterally to a distance of at least:*

--150 m where the code number is 3 or 4; and

--75 m where the code number is 1 or 2;

on each side of the centre line of the runway and its extended centre line throughout the length of the strip.

3.3.5 ***Recommendation.*** *-- A strip including a non-instrument runway should extend on each side of the centre line of the runway and its extended centre line throughout the length of the strip, to a distance of at least:*

-- 75 m where the code number is 3 or 4;

-- 40 m where the code number is 2; and

-- 30 m where the code number is 1.

Objects on runway strips

Note. -- See 8.7 for information regarding siting and construction of equipment and installations on runway strips.

3.3.6 ***Recommendation.*** -- *An object situated on a runway strip which may endanger aeroplanes should be regarded as an obstacle and should, as far as practicable, be removed.*

3.3.7 No fixed object, other than visual aids required for air navigation purposes and satisfying the relevant frangibility requirement in Chapter 5, shall be permitted on a runway strip:

a) within 60 m of the runway centre line of a precision approach runway category I, II or III where the code number is 3 or 4; or

b) within 45 m of the runway centre line of a precision approach runway category I where the code number is 1 or 2.

No mobile object shall be permitted on this part of the runway strip during the use of the runway for landing or take-off.

Grading of runway strips

3.3.8 ***Recommendation.*** *-- That portion of a strip of an instrument runway within a distance of at least:*

-- 75 m where the code number is 3 or 4; and

-- 40 m where the code number is 1 or 2;

from the centre line of the runway and its extended centre line should provide a graded area for aeroplanes which the runway is intended to serve in the event of an aeroplane running off the runway.

Note. -- Guidance on grading of a greater area of a strip including a precision approach runway where the code number is 3 or 4 is given in Attachment A, Section 8.

3.3.9 ***Recommendation.*** *-- That portion of a strip of a non-instrument runway within a distance of at least:*

-- 75 m where the code number is 3 or 4;

-- 40 m where the code number is 2; and

-- 30 m where the code number is 1;

from the centre line of the runway and its extended centre line should provide a graded area for aeroplanes which the runway is intended to serve in the event of an aeroplane running off the runway.

3.3.10 The surface of that portion of a strip that abuts a runway, shoulder or stopway shall be flush with the surface of the runway, shoulder or stopway.

3.3.11 ***Recommendation.*** *-- That portion of a strip to at least 30 m before a threshold should be prepared against blast erosion in order to protect a landing aeroplane from the danger of an exposed edge.*

Slopes on runway strips

3.3.12 Longitudinal slopes

Recommendation. *-- A longitudinal slope along that portion of a strip to be graded should not exceed:*

-- 1.5 per cent where the code number is 4;

-- 1.75 per cent where the code number is 3; and

-- 2 per cent where the code number is 1 or 2.

3.3.13 Longitudinal slope changes

Recommendation. *-- Slope changes on that portion of a strip to be graded should be as gradual as practicable and abrupt changes or sudden reversals of slopes avoided.*

3.3.14 Transverse slopes

Recommendation*. -- Transverse slopes on that portion of a strip to be graded should be adequate to prevent the accumulation of water on the surface but should not exceed:*

-- 2.5 per cent where the code number is 3 or 4; and

-- 3 per cent where the code number is 1 or 2;

except that to facilitate drainage the slope for the first 3 m outward from the runway, shoulder or stopway edge should be negative as measured in the direction away from the runway and may be as great as 5 per cent.

3.3.15 ***Recommendation.*** *-- The transverse slopes of any portion of a strip beyond that to be graded should not exceed an upward slope of 5 per cent as measured in the direction away from the runway.*

Strength of runway strips

3.3.16 ***Recommendation.*** *-- That portion of a strip of an instrument runway within a distance of at least:*

-- 75 m where the code number is 3 or 4; and

-- 40 m where the code number is 1 or 2;

from the centre line of the runway and its extended centre line should be so prepared or constructed as to minimize hazards arising from differences in load bearing capacity to aeroplanes which the runway is intended to serve in the event of an aeroplane running off the runway.

3.3.17 ***Recommendation.*** *-- That portion of a strip containing a* *non-instrument runway within a distance of at least:*

-- 75 m where the code number is 3 or 4;

-- 40 m where the code number is 2; and

-- 30 m where the code number is 1;

from the centre line of the runway and its extended centre line should be so prepared or constructed as to minimize hazards arising from differences in load bearing capacity to aeroplanes which the runway is intended to serve in the event of an aeroplane running off the runway.