Hard landing, Report on the accident to Boeing MD11 B-150 at Hong Kong International Airport on 22 August 1999

Micro-summary: **A hard landing during foul weather results in the failure of the main landing gear and right wing.**

Event Date: **1999-08-22 at 1043 UTC (1843 local)**

Investigative Body: **Civil Aviation Department Hong Kong, Accident Investigation Division, Hong Kong**

Investigative Body's Web Site: **http://www.cad.gov.hk/**

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AIRCRAFT ACCIDENT REPORT 1/2004

ACCIDENT INVESTIGATION DIVISION

Civil Aviation Department
Hong Kong

Report on the accident to
Boeing MD11 B-150
at Hong Kong International Airport
on 22 August 1999

Hong Kong
December 2004

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GLOSSARY

AAIB	Air Accident Investigation Branch (UK)
ACARS	Aircraft Communications Addressing and Reporting System
AFC	Airport Fire Contingent
AGL	Airfield Ground Lighting
AIP	Aeronautical Information Publication
AND	Airplane Nose Down
ANU	Airplane Nose Up
APT	Automatic Pitch Trim
APV	Airport Passenger Vehicle
ASC	Aviation Safety Council, Taiwan, China
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATS	Auto Throttle System
CAM	Cockpit Area Microphone
CAWS	Central Aural Warning System
CRM	Cockpit Resource Management
CVR	Cockpit Voice Recorder
°	degree(s)
DFDR	Digital Flight Data Recorder
EEC	Electronic Engine Control(s)
EEPROM	Electrically Erasable Programmable Read Only Memory
EEROM	Electrically Erasable Read Only Memory
ETA	Estimated Time of Arrival
EPR	Engine Pressure Ratio
FCC	Flight Control Computer(s)
FCOM	Flight Crew Operations Manual
FOM	Flight Operations Manual
ft	feet
fpm	feet per minute
fps	feet per second

GP	Glide Path
GSD	Geographic Situation Display(s)
HKIA	Hong Kong International Airport
HKO	Hong Kong Observatory
hpa	hectopascal(s)
hr	hour(s)
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
kg	kilogram(s)
km	kilometre(s)
kN	kilonewton
kt	knot(s)
L1, L2, L3, L4	Identification of left-side aircraft cabin doors from forward (L1) to rear (L4)
lb	pound(s)
L/D	Let Down
LMLG	Left Main Landing Gear
LSAS	Longitudinal Stability Augmentation System
m	metre(s)
mm	millimeter(s)
m	Magnetic
MAC	Mean Aerodynamic Chord
METAR	Meteorological Actual Report
MLW	Maximum Landing Weight
MN	meganewton
MSA	Minimum Safe Altitude
nm	nautical mile(s)
no.	number
NVM	Non Volatile Memory
NTSB	National Transportation Safety Board (USA)
PA	Passenger Address
PFD	Primary Flight Display
PAPI	Precision Approach Path Indicator

PNF	Pilot Not Flying
PTB	Passenger Terminal Building
QAR	Quick Access Recorder
QFE	Pressure setting related to touchdown elevation
QNH	Pressure setting related to mean sea level
R1, R2, R3, R4	Identification of right-side aircraft cabin doors from forward (R1) to rear (R4)
RA	Radio Altitude
RMLG	Right Main Landing Gear
RTF	Radio telephony
RVR	Runway Visual Range
RW	Runway
S-B-F-T-T-P	Side-Brace-Fitting-To-Trapezoidal –Panel
SCC	Stress Corrosion Cracking
SCT	Scattered
SIGMET	Significant Meteorological warning
SOP	Standard Operational Procedure
SPECI	Special Meteorological Report
SSCVR	Solid State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder
STS	Severe Tropical Storm
TAF	Terminal Area Forecast
Taiwan	Taiwan, China
TDZ	Touchdown Zone
TDWR	Terminal Doppler Weather Radar
TEMPO	Temporarily
TRA	Throttle Resolver Angle(s)
UTC	Universal Time co-ordinated
VHF	Very High Frequency
Vref	Landing reference speed
WAGS	Windshear Alert and Guidance System
WTWS	Windshear and Turbulence Warning System

ACCIDENT INVESTIGATION DIVISION

CIVIL AVIATION DEPARTMENT

Aircraft Accident Report 1/2004

Registered Owner	:	Civil Aeronautics Administration, Taiwan, China
Operator	:	China Airlines
Aircraft Type	:	Boeing MD11
Nationality and Registration Mark	:	B-150
Place of Accident	:	Hong Kong International Airport Hong Kong Special Administrative Region China
Date and time	:	22 August 1999 at 1043 hr (1843 hr local time)

All times in this report are UTC and are based on the Hong Kong Air Traffic Control Master Clock System, except where otherwise specified.

SYNOPSIS

At the time of the accident, Hong Kong International Airport (HKIA) was affected by weather associated with a tropical cyclone centred approximately 50 kilometres to the north east. At the airport there was a strong gusting wind from the northwest with heavy rain, resulting in a wet runway. The Automatic Terminal Information Service (ATIS) included a warning to pilots to expect significant windshear and severe turbulence on the approach.

The aeroplane carried out an Instrument Landing System approach to Runway 25 Left (RW 25L). After becoming visual with the runway at approximately 700 feet, the commander then disconnected the autopilot but left the autothrottle system engaged. The aeroplane continued to track the extended runway centreline, but descended and stabilised slightly low on the glide-slope until the normal flare height was reached. Although an attempt was made to flare the aeroplane, this did not arrest the rate of descent and resulted in an extremely hard impact with the runway in a slightly right wing-down attitude, at an estimated landing weight of 443 lbs (201 kg) below maximum landing weight. This was followed by collapse of the right main landing gear, separation of the right wing, an outbreak of fire and an uncontrollable roll and yaw to the right. The aeroplane ended up in an inverted, reversed position on a grass area just to the right of the runway.

Rescue vehicles quickly arrived on the scene and suppressed the fire on and in the vicinity of the aeroplane, allowing rescue of the passengers and crew to progress in very difficult conditions. Two passengers rescued from the wreckage were certified dead on arrival at hospital and one passenger died five days later in hospital. A total of 219 persons, including crewmembers, were admitted to hospital, of whom 50 were seriously injured and 153 sustained minor injuries.

The investigation team identified the cause of the accident as the commander's inability to arrest the high rate of descent existing at 50 ft Radio Altitude (RA).

Other probable and possible contributory causes are listed at paragraphs 3.2.2 and 3.2.3 of the report.

During the course of the investigation, ten safety recommendations were made and are summarised at paragraph 4 of the report.

1. FACTUAL INFORMATION

1.1. History of the flight

China Airline’s flight CI642 was scheduled to operate from Bangkok to Taipei with an intermediate stop in Hong Kong. The crew had carried out the sector from Taipei to Bangkok, passing through Hong Kong on the previous day. On that flight, the crew were aware of the Severe Tropical Storm (STS) ‘Sam’ approaching Hong Kong and the possibility that it would be in the vicinity of Hong Kong at about the scheduled time of arrival on the following evening. Weather information provided at the preflight briefing for the return flight indicated the continuing presence of STS ‘Sam’ with its associated strong winds and heavy precipitation.

The flight departed from Bangkok on schedule with 300 passengers and 15 crew on board, with an estimated time of arrival (ETA) of 1038 hour (hr) in Hong Kong. The commander had elected to carry sufficient fuel to permit a variety of options on arrival – to hold, to make an approach, or to divert. If an immediate approach was attempted, the aircraft would be close to its Maximum Landing Weight (MLW) involving, in consequence, a relatively high speed for the approach and landing.

Throughout the initial stages of the flight and during the cruise, the commander was aware of the crosswind component to be expected in Hong Kong and reviewed the values of wind direction and speed which would bring it within the company’s crosswind limit as applicable to wet runways of 24 kt.

In the latter stage of the cruise, the crew obtained information ‘Whisky’ from the Automatic Terminal Information Service (ATIS) timed at 0940 hr, which gave a mean surface wind of 320 degrees (º) / 30 knots (kt) maximum 45 kt in heavy rain, and a warning to expect significant windshear and severe turbulence on the approach. Although this gave a crosswind component of 26 kt which was in excess of the company's wet runway limit of 24 kt, the commander was monitoring the gradual change in wind direction as the storm progressed, which indicated that the wind direction would possibly shift sufficiently to reduce the component and thus permit a landing. Hong Kong Area Radar Control issued a descent clearance to the aircraft at 1014 hr and, following receipt of ATIS information 'X-ray' one minute later, which included a mean surface wind of 300º at 35 kt, descent was commenced at 1017 hr. Copies of the information sheets used by Air Traffic Control (ATC) as the basis for ATIS broadcasts 'Whisky' and 'X-ray' are at Appendix 1.

The approach briefing was initiated by the commander just after commencing descent. The briefing was given for an Instrument Landing System (ILS) approach to Runway 25 Right (RW 25R) at HKIA. However, the active runway, as confirmed by the ATIS was RW 25L. Despite the inclusion in the ATIS broadcasts of severe turbulence and possible windshear warnings, no mention was made in the briefing of the commander's intentions relating to these weather phenomena nor for any course of action in the event that a landing could not be made, other than a cursory reference to the published missed approach procedure.

The descent otherwise continued uneventfully and a routine handover was made at 1025 hr to Hong Kong Approach Control which instituted radar vectoring for an ILS approach to what the crew still believed was RW 25R.

At 1036 hr, after having been vectored through the RW 25L localiser for spacing, CI642 was given a heading of 230º to intercept the localiser from the right and cleared for ILS to RW 25L. The co-pilot acknowledged the clearance for ILS 25L but queried the RVR (runway visual ranges); these were passed by the controller, the lowest being 1300 m at the touchdown point. The commander then quickly re-briefed the minimums and go-around procedure for RW 25L.

At 1038 hr, about 14 nautical miles (nm) to touchdown, the aircraft was transferred to Hong Kong Tower and told to continue the approach. At 1041 hr, the crew were given a visibility at touchdown of 1600 metres (m) and touchdown wind of 320º at 25 kt gusting 33 kt, and cleared to land.

The crew of flight CI642 followed China Airline's standard procedures during the approach. Using the autoflight modes of the aircraft, involving full use of autopilot and autothrottle systems, the flight progressed along the ILS approach until 700 ft where the crew became visual with the runway and approach lights of RW 25L. Shortly after this point the commander disconnected the autopilot and flew the aircraft manually, leaving the autothrottle system engaged to control the aircraft's speed.

After autopilot disconnect, the aircraft continued to track the runway centreline but descended and stabilised slightly low (one dot) on the glideslope. Despite the gustiness of the wind, the flight continued relatively normally for the conditions until approximately 250 ft above the ground at which point the co-pilot noticed a significant decrease in indicated airspeed. Thrust was applied as the co-pilot called 'Speed' and, as a consequence, the indicated airspeed rose to a peak of 175 kt. In response to this speed in excess of the target approach speed, thrust was reduced and, in the process of accomplishing this, the aircraft passed the point (50 ft RA) at which the autothrottle system commands the thrust to idle for landing.

Coincidentally with this, the speed decreased from 175 kt and the rate of descent began to increase in excess of the previous 750-800 feet per minute (fpm). Although an attempt was made to flare the aircraft, the high rate of descent was not arrested, resulting in an extremely hard impact with the runway in a slightly right wing down attitude (less than 4º), prior to the normal touchdown zone. The right mainwheels contacted the runway first, followed by the underside of the right engine cowling. The right main landing gear collapsed outward, causing damage to the right wing assembly, resulting in its failure. As the right wing separated, spilled fuel was ignited and the aircraft rolled inverted and came to rest upside-down alongside the runway facing in the direction of the approach.

The cockpit crew were disorientated by the inverted position of the aircraft and found difficulty in locating the engine controls to carry out engine shut down drills. After extricating themselves, they went through the cockpit door into the cabin and exited the aircraft through L1 door and began helping passengers from the aircraft through a hole in the fuselage. Airport fire and rescue services were quickly on the scene, extinguishing the fuel fire and evacuating the passengers through the available aircraft exits and ruptures in the fuselage.

As a result of the accident, two passengers were found dead on arrival at hospital, and six crew members and 45 passengers were seriously injured. One of the seriously injured passengers died five days later in hospital.

1.2. Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	0	3	0
Serious	6	44	0
Minor/None	9	253	-

1.3. Damage to aircraft

The aircraft came to rest inverted with severe impact and some fire damage. The crown of the fuselage in contact with the grass area was crushed downward for its entire length, and some of the forward crown skin was torn away.

The right wing was fractured between the number (no.) 3 engine nacelle and the right side of the fuselage. The right wing structure outboard of the fracture was in one section and was found on a taxiway about 90 m from the nose of the aeroplane. The left wing remained attached to the fuselage and was found together with the main wreckage. The inboard section of the left wing exhibited evidence of sooting.

The right main landing gear had separated from its mount. All four tyres remained attached to the truck beam. The left main landing gear remained attached to the wing and fuselage at its attachment points. There was no evidence of any impact or fire damage to the left main landing gear. The centre landing gear was fractured at the bottom of the cylinder near the axle. Its wheel truck with tyres was found on the runway near the wreckage. The nose landing gear remained attached to the front section of the fuselage with minimal structural damage, although the right hand nosewheel had separated from the hub.

All three engines were found at the crash site. No. 1 engine (mounted on the left wing) remained attached to its pylon structure. No. 2 engine (mounted at the rear) remained attached to the inlet and engine mounting structure but the whole assembly was detached from the rear fuselage. No. 3 engine (mounted on the right wing) remained attached to its pylon structure; however, the whole assembly was separated from, but lay close to, the wing on the taxiway.

1.4. Other damage

Scratch marks were found on the runway pavement surface starting as a light skid mark about 250 m to the west of the threshold and 12 m to the north of the centre line. This mark was almost continuous along the track of the aircraft, with multiple scratched marks developed on its sides starting from about 300 m west of the threshold. At around that distance, intermittent scratch marks were observed close to the centre line. All the scratch marks ranged from a few centimetres to over one metre wide and from surface scratches to a maximum depth of 25 millimetres (mm). These marks were seen deviating to the right from about 450 m west of the threshold extending to the grass area where the aircraft came to rest.

An area of the runway pavement of about 120 m long and 10 m wide starting from about 470 m west of the threshold was contaminated by burning fuel.

Similar contamination was found on the pavement at taxiway J7 over an area of about 50 m x 40 m adjacent to the grass area to the east. Burn marks were also apparent on the grass areas along the path of the aircraft.

A number of inset airfield light fittings including adapter rings, upper cans and lenses had been damaged by the aircraft. These damaged light fittings consisted of 10 touchdown zone lights, four runway centre line lights, two stop bar lights and four exit taxiway centre line lights. In addition, a total of 26 elevated lights including six runway edge lights, 19 taxiway lights and one runway guard light, plus two movement area guidance signs, were damaged.

However, it is believed that while the aircraft had caused damage to a few of these lights and to the guidance signs, most of the damage was caused by vehicles during the rescue operation.

A survey map showing the scratched and burn marks is at Appendix 2.

1.5. Personnel information

1.5.1. Flight crew qualifications

Commander	:	Male, aged 57 years
Licence	:	Airline Transport Pilot's Licence valid to 14 July 2000
Type rating	:	MD-11 valid to 10 August 2000
Instrument rating	:	Valid to 10 August 2000

Medical certificate	:	Valid to 30 November 1999 Limitation : Spectacles required for near vision
Date of last proficiency check	:	2 July 1999
Date of last line check	:	4 March 1999
Date of last emergency drills check	:	12 February 1998
Flying experience		
Total all types	:	17,900 hours
Total on type	:	3,260 hours
Total in last 30 days	:	80 hours 8 minutes
Total in last 7 days	:	22 hours 41 minutes
Duty time		
Day of the accident	:	2 hours 55 minutes
Day prior to accident	:	6 hours 18 minutes
Co-pilot	:	Male, aged 36 years
Licence	:	Airline Transport Pilot's Licence issued on 19 November 1997
Type rating	:	MD-11 valid to 13 November 1999
Instrument rating	:	Valid to 13 November 1999
Medical certificate	:	Valid to 30 September 1999 with no limitations

Date of last proficiency check	:	4 March 1999
Date of last line check	:	30 May 1999
Date of last emergency drills check	:	7 April 1999
Flying experience		
Total all types	:	4,630 hours
Total on type	:	2,780 hours
Total in last 30 days	:	83 hours 49 minutes
Total in last 7 days	:	14 hours 11 minutes
Duty time		
On day of the accident	:	2 hours 55 minutes
On day before the accident	:	6 hours 18 minutes

1.5.2. Flight crew histories

The commander joined China Airlines in May 1997 as a MD-11 line captain following his retirement from a major European national airline, where he had been an instructor pilot on MD-11 aircraft. He had a total of 2,300 hours as commander on the MD-11 aircraft.

Following a simulator course and an abridged line training course, the commander was cleared to fly the MD-11 as a fully qualified line captain. After two years in this capacity, he underwent a simulator training course to qualify as a line instructor on the MD-11 and satisfactorily completed this training at the end of May 1999.

Throughout his periodic sessions of training and checking, only minor comments were made on his ability and he was generally awarded an ‘average’ grading. Earlier in August 1999, the commander underwent annual training in Cockpit Resource Management (CRM).

The co-pilot joined China Airlines as an ab initio entrant in May 1989. Following three years of training in the United States, he graduated as a commercial pilot and commenced a training course with China Airlines as a co-pilot on B737 aircraft. This was successfully completed in September 1992. In November 1994, he commenced a transition course on the MD-11 at the manufacturer’s facility in Long Beach, California and qualified as a co-pilot in March 1995. More recently, in November 1998, he qualified as an in-flight relief captain enabling him to act as relief commander whilst in the cruise on long haul flights.

The co-pilot’s ability was classed as ‘average’ throughout his career with China Airlines, with no adverse comments on his training records. Approximately one month prior to the accident, the co-pilot also underwent annual CRM training.

Both pilots underwent windshear training in the course of recurrent simulator training/checking.

1.5.3. Cabin crew

The cabin crew consisted of one purser and twelve flight attendants.

All were medically fit and were qualified to carry out their duties in accordance with the regulatory requirements of Taiwan, China. All had completed safety and emergency procedure training, and had been checked by the company, within the 12 months prior to the accident.

1.6. Aircraft information

1.6.1. Aircraft particulars

Model No.	: MD-11, serial no. 48468
Manufacturer	: McDonnell Douglas Corporation (now Boeing Company)
Registered Owner	: Civil Aeronautics Administration, Taiwan, China
Registration No.	: B-150
Operator	: China Airlines
Date of Manufacture	: 30 October 1992
Engines	: Three Pratt and Whitney PW4460 turbofans
Maximum Landing Weight	: 430,000 lbs (195,454 kg)
Estimated Landing Weight	: 429,557 lbs (195,253 kg)
Zero Fuel Weight	: 388,757 lbs (176,707 kg)
Certificate of Airworthiness	: No. 87-09-127, valid from 30 September 1998 – 30 September 1999
Certificate of Registration	: No. 81-497, issued on 30 October1992
Total Flying Hours	: 30721:32 hours
Total Cycles	: 5824

1.6.2. Maintenance history

The aircraft was maintained under a China Airlines MD11 Maintenance Programme approved by Civil Aeronautics Administration, Taiwan, China. The last major checks accomplished were as follows:

Check Type	Date	Flying Hours
1A	31 July 1999	30450
7C	28 August 1998	26773
5-year Structural Inspection	18 November 1997	23467

The last weight check was carried out on 12 April 1998. Aircraft basic weight was 282,400 lbs (128,400 kg); centre of gravity was 32.31% Mean Aerodynamic Chord (MAC).

The aircraft had previously experienced two hard landings. The first one was on 25 February 1995. Both nose wheels and steering actuator pressure line were damaged and replaced and the nose landing gear was removed for detailed inspection. Structural repair was carried out on wrinkled fuselage skin just aft of the nose landing gear wheel well. The second hard landing was on 8 August 1997. The ‘hard landing’ inspection was accomplished and no damage was found.

Maintenance log pages from November 1997 to August 1999 were inspected. No significant discrepancy was found.

1.6.3. Automatic Flight System

The MD11 is designed to be operated most efficiently through its automatic flight system. This system is comprised of multiple autopilots and an autothrottle system which together direct and control the aircraft in virtually all regimes of flight as required either by the pilot when utilising basic autoflight modes, or by the Flight Management System (FMS) when using computer controlled modes.

In the approach mode, given correct information inserted into the FMS, the autothrottle controls the aircraft's airspeed as demanded by the FMS target. The speed is calculated by the FMS from the aircraft's current all-up weight, which provides a basic landing reference speed (Vref) to which a factor for wind must be added. This factor makes allowance for the effect of the wind expected on the approach and is able to account for gusts. In conditions of light winds, a constant factor of 5 kt is added to the Vref; in stronger winds, a calculated factor of up to a maximum of 20 kt is added, and the higher of these two resulting speeds is used for the approach. Vref + 5 kt is automatically generated by the FMS and this is the speed on the approach to which the autothrottle will control unless the speed is modified by the crew. The approach speed may be modified through the FMS which would normally be done in the course of the approach briefing, or the current speed target may be instantly changed by selection and insertion on the mode control panel in order to cater for wind conditions not foreseen earlier. For

CI642's approach, the crew were using an approach speed of 170 kt, which had been programmed into the FMS early in the descent. This is further discussed at paragraph 2.6.2.

The programme for the autothrottle in the final stages of the approach is designed to ensure that the aircraft crosses the runway threshold at Vref + 5 kt and touches down at Vref. To accomplish this, the system receives a radio altitude signal as the aircraft passes 50 ft, at which point the thrust levers are commanded to idle with a consequent decrease in thrust. This will occur irrespective of the aircraft's speed or environmental conditions, unless the autothrottle is overridden by the handling pilot or the go-around switch is pressed. Once reverse thrust is selected, autothrottle is disengaged.

1.6.4. Windshear Alert and Guidance System

The MD11 is equipped with a sophisticated Windshear Alert and Guidance System (WAGS) which provides detection, alerting and guidance through windshear. Wind and inertia information is detected by the aircraft's Central Air Data Computers and by the Inertial Reference Systems and transmitted to the Flight Control Computers (FCCs) for windshear detection, warning and guidance. On approach, the aircraft enters the protection envelope on passing 1500 ft RA and exits on descending below 50 ft RA. Visible warning of windshear is provided on the pilots' Primary Flight Displays (PFDs) and, at the same time, audio warnings are also generated. Windshear pitch guidance, which is provided to the flight directors and dual autopilots, is only available on the approach when either the go-around switch is pressed or the thrust is manually or automatically increased to 95% or more of the go-around thrust value. Below 50 ft RA, windshear alerting and guidance are not available and automatic increase in thrust is not provided. In the course of CI642's approach, WAGS did not trigger any windshear warnings.

1.6.5. Longitudinal Stability Augmentation System

The aircraft is equipped with a Longitudinal Stability Augmentation System (LSAS) which provides pitch attitude hold and limiting pitch rate damping, automatic pitch trim, speed protection and stall protection. LSAS is not provided when the autopilot is engaged. Below 100 ft RA, and transparent to the pilot, LSAS is progressively removed from the pitch control system.

LSAS holds the aircraft's current pitch attitude if there is no force on the control column and the bank angle is less than 30º. If the pilot manually changes pitch attitude and then removes the control column force, the aircraft will hold the new pitch attitude.

LSAS holds pitch attitude by deflecting the elevators up to 5º, and the stabiliser is then automatically adjusted to relieve sustained elevator deflection and maintain a full 5º of elevator authority. LSAS also limits pitch attitude to less than 10º of aircraft nose down (AND) or 30º of aircraft nose up (ANU). Below 15,000 ft, if there is more than approximately two pounds (lb) (0.9 kilogram) of force on the control column, LSAS is inoperative: once the pilot applies about four lb (1.8 kg) of control column force, the elevators respond to the pilot's commands. Above 20,000 feet, LSAS provides pitch rate damping when force is applied to the control column. This damping is gradually reduced to zero between 20,000 and 15,000 feet.

Automatic Pitch Trim (APT) is available when LSAS is in operation. APT positions the horizontal stabiliser to off-load any steady state elevator deflections, and varies the trim rate with airspeed for best performance in all flight conditions. On a manual approach, APT is inhibited if more than two lb (0.9 kg) force is applied to the control column, or bank angle exceeds 5º.

1.6.6. Rain clearance

A separate wiper system is installed for the left and right windshields, each system being independently controlled by a selector on the forward overhead panel. When the wipers are selected off, the wiper assembly is designed to move to a parked position below its windshield and out of the airstream.

Each wiper system contains two protecting circuit breakers, one rated at five amperes for control and the other rated at 15 amperes for the motor.

The optional rain repellent system was not fitted to the accident aircraft.

1.6.7. Radio altitude voice warnings

The aircraft is equipped with a Central Aural Warning System (CAWS) which monitors the aircraft's two radio altimeters. Included in the automatic voice callouts, which are triggered by the system, are callouts of '*50/40/30/20/10*' ft on the approach. These callouts, and their cadence, assist pilots in initiating and controlling the flare immediately prior to touchdown.

1.7. Meteorological information

1.7.1. Airport meteorological office

Forecasts and observations issued by the Hong Kong Observatory's (HKO) Airport Meteorological Office (AMO) at Hong Kong International Airport (HKIA) were disseminated in real time by video monitor, by point-to-point dedicated circuits and by scheduled broadcasts, with additional meteorological information available on request. Routine, special and extra meteorological reports, trend-type landing forecasts, aerodrome forecasts, SIGMET information, current RVRs, aerodrome warnings and other relevant supplementary information were provided to air traffic services units. Meteorological information transmitted by local data network to displays at the various ATC positions comprised half-hourly reports, special reports, aerodrome forecasts, surface wind information and windshear warnings for HKIA. The locations of the meteorological sensors for surface wind and RVR measurement at HKIA are shown on the plan at Appendix 3.

1.7.2. General weather situation

The weather on 22 August 1999 was influenced by STS 'Sam' which had formed over the Pacific Ocean and was approaching Hong Kong on a northwesterly track.

A tropical cyclone bulletin issued by the HKO at 0945 hr on 22 August 1999 advised that 'Sam' was then centred about 25 kilometres (km) east-northeast of the Observatory (51 km or 27 nm east-northeast of HKIA), and was forecast to move northwest at about 15 km per hour (8 kt). The 'Number 8 Northwest Gale or Storm Signal' was hoisted, which meant that winds with sustained speeds of 63 – 117 km per hour (34 - 63 kt) could be expected from the northwest quarter, with the possibility of gusts exceeding 180 km per hour (97 kt).

The weather in Hong Kong was overcast with occasional heavy showers and squalls. The cloud base was generally about 1,000 ft with visibility falling below 1,000 m at times in rain. Gale force northwesterly winds prevailed as 'Sam' approached the region.

1.7.3. Weather forecasts for Hong Kong International Airport

Before leaving Bangkok, both pilots were aware that weather conditions at Hong Kong were being influenced by a tropical cyclone. They were in possession of the relevant significant weather chart, winds at altitude, terminal approach forecasts and recent weather reports. The pictorial significant weather chart, valid for 0300 hr on 22 August, showed that an extensive area of cumulonimbus clouds associated with 'Sam' was covering the Hong Kong area.

The Terminal Area Forecast (TAF) passed to the crew before departure from Bangkok was issued by HKO at 0400 hr on 22 August and covered the 24 hr period from 0600 hr that day. For the aircraft's ETA, the relevant contents can be summarised as follows:

Wind 320º/30 kt gusting 42 kt; visibility 9,000 m; cloud base - few 1,200 ft, scattered 2,500 ft, broken 10,000 ft.

TEMPO between 0600 - 1200 hr : wind 310º/42 kt gusting 55 kt; 0600 - 0600 hr : visibility 3,000 m; heavy shower or thunderstorm with moderate rain; cloud - few 800 ft, scattered cumulonimbus 1,400 ft, broken 8,000 ft.

Routine updates to the forecasts were issued by the AMO at 0654 hr and 0751 hr and were available to the crew via the aircraft's Aircraft Communications Addressing and Reporting System (ACARS). However there were no significant changes from the TAF passed to the crew before departure.

1.7.4. Actual weather conditions at Hong Kong International Airport

The most recent Meteorological Actual Report (METAR) for HKIA passed to the crew before departure from Bangkok was issued at 0600 hr on 22 August. The observation included the following relevant details:

Wind 320º/35 kt gusting 47 kt; visibility 6,000 m in light rain showers; cloud base - few 2,000 ft, scattered 3,000 ft, broken 8,000 ft.

TEMPO: 340º/35 kt gusting 57 kt; 3,000 m; heavy rain shower; cloud - few cumulonimbus 1,000 ft, scattered 2,000 ft, broken 8,000 ft.

This report was followed by updates at approximately 30-minute intervals which were available to the crew via ACARS. The updates did not suggest any significant changes other than temporary fluctuations in visibility in the heavy showers.

An 'EXTRA' observation taken at 1044 hr immediately following the accident included the following relevant details:

Wind 310º/33 kt maximum 47 kt; visibility 1,400 m; present weather moderate rain shower; cloud base - few 1,000 ft, scattered 1,600 ft, broken 8,000 ft; temperature 25º Celsius; dew point 24º Celsius; QNH 987 hPa; QFE 986 hPa; turbulence warning: moderate to severe turbulence in vicinity of cumulonimbus on approach and departure.

TEMPO: wind 330º/38 kt gusting 58 kt; visibility 600 m in heavy rain shower or thunderstorm with moderate rain; cloud base - few cumulonimbus 1,000 ft, scattered 2,000 ft, broken 8,000 ft.

Note: The turbulence warning had been in effect from 0735 hr until 1732 hr on 22 August 1999 and was included in all ATIS broadcasts during that period - see paragraph 1.7.5.

1.7.5. Automatic Terminal Information Service

Shortly after commencing descent, the flight crew listened to the ATIS weather broadcast by VHF radio. A transcript of the broadcast follows:

'This is Hong Kong International Airport. Information X-ray at time one zero zero six. Runway in use two five left, runway two five right available on request. Expect ILS/DME approach. Runway surface wet. Braking action reported as good. Surface wind three zero zero degrees three five knots. Visibility eight hundred metres in heavy rain. Runway visual range two five left six five zero metres. Cloud few at one thousand feet, scattered at one thousand six hundred feet. Temperature two five, dew point two four. QNH nine eight six hectopascals. Expect significant windshear and severe turbulence on approach and departure. Acknowledge information X-ray on frequency one one nine decimal three five for arrival and one two nine nine for departure.'

1.7.6. Runway visual range

A system for measuring RVR was operating at the time of the accident, and consisted of three transmissometers for each runway. Those for RW 07L/25R were situated approximately 80 m north of that runway and those for RW 07R/25L some 90 m south of this runway, with one transmissometer abeam each touchdown zone and one abeam the midpoint of each runway. The one-minute mean touchdown RVR recorded at the time of the accident (1043 hr) was 1900 m for RW 25L and 900 m for RW 25R as shown on the record for the period 1025-1045 hr at Appendix 4.

1.7.7. Surface wind measurement

Surface wind at HKIA was measured by six sets of anemometers located abeam the touchdown zones and also abeam the midpoints of each runway, 10 m above the ground. For RW 25L, the touchdown zone anemometer was located 330 m west of the threshold and 120 m north of the runway centre line i.e. between the runway and the Passenger Terminal Building (PTB), while the other two anemometers for RW 07R/25L were a similar distance to the south of the runway; all three anemometers for RW 07L/25R were located 120 m to the north of that runway (see Appendix 3). The midpoint wind information from RW 07R/25L site was taken as the official wind for weather observations, while the information from all six sites were fed into the windshear and turbulence warning system for the airport. The surface wind passed to an aircraft with its landing clearance was taken from the appropriate runway touchdown zone anemometer.

At each anemometer location, there were two anemometers on the mast, one designated as operating and the other as stand-by.

Consistency checks were performed by the maintenance staff by comparing the two-minute mean wind readings between the operating and stand-by anemometers at about 0215 hr on 21 August. Another consistency check was accomplished at about 0544 hr on 23 August. On both occasions, the differences in readings between the operating and stand-by anemometers were less than one kt in speed and 10º in wind direction (directions rounded to nearest 10º) for all six anemometer locations. The HKO stated that all anemometers were considered to be operating properly.

Appendix 5-1 shows the two-minute mean wind direction, speed, and gust values recorded every 10 seconds for the period from 1025 hr to 1045 hr at the six anemometer locations. These values are utilised, as recommended by the International Civil Aviation Organisation (ICAO), for reports used for take off and landing and for wind indicators in air traffic services units.

Appendix 5-2 shows the 10-second mean wind direction and speed values also recorded every 10 seconds for the same six anemometers over the same period.

Appendix 5-3 shows the 1-second mean wind direction and speed values also recorded every 1-second for the same six anemometers.

1.7.8. Cloud base measurement

Cloud base at HKIA was measured by one ceilometer located at the meteorological enclosure near the ATC tower.

Appendix 6 records the one-minute mean cloud base height (ft above mean sea level) at 10-second intervals from 1041 hr to 1044 hr, and these values indicate a cloud base varying between 781 ft and 2281 ft above aerodrome elevation.

1.7.9. Rainfall

A rain gauge, also located at the meteorological enclosure recorded 5-minute cumulative rainfall data in millimetres.

Appendix 7 shows the 5-minute cumulative values taken at 10-second intervals for the period 1041 hr - 1044 hr and these values indicate a light to moderate rainfall.

1.7.10. Local wind effects at Hong Kong International Airport

The Aeronautical Information Publication (AIP) Section VHHH AD 2.23 for Hong Kong, dated October 1998 contained the following text concerning the local effects of northerly winds.

'Northwesterly Through Northeasterly Winds

When winds are from the north with speeds in excess of 15 kt, significant low-level windshear and moderate turbulence is expected to occur along the final approach due to the disturbance by the hills to the north. Severe turbulence may be expected should the wind speeds exceed 30 knots. Turbulence level is however less severe near touchdown than at around 1,000 ft – 2,000 ft. Pilots should be well prepared for significant crosswind at touchdown.'

1.7.11. Windshear and Turbulence Warning System

A Windshear and Turbulence Warning System (WTWS) was installed at HKIA. Components of the WTWS included anemometers on and off the airport, wind profilers, and a Terminal Doppler Weather Radar (TDWR) installed at Tai Lam Chung, about 12 kilometres northeast of HKIA.

The WTWS and TDWR continuously monitor low level windshear and turbulence induced by terrain and caused by convection within three nm of the runway thresholds. Alerts from TDWR are integrated with those from WTWS to provide comprehensive windshear and turbulence alerts in the vicinity of the airport.

Alerts are given as microburst, windshear, and turbulence, with associated intensity and location. For windshear and microburst alerts, the intensity is given as headwind loss or gain in kt, 15 kt or greater in the case of windshear and 30 kt or greater for microbursts. For turbulence alerts, the intensity is given as moderate or severe.

Windshear alerts generated by the TDWR or WTWS are based on the highest priority, the maximum intensity and the location of the first encounter with any occurrence for that runway. When both loss and gain events impact the same area, loss events would have higher priority over gain events. Event locations for windshear alerts are given as one, two or three nautical miles on approach or departure, or on the runway. Event locations for turbulence alerts are given as departure or approach.

WTWS alerts are displayed as alphanumeric messages on dedicated terminals for use by air traffic controllers. In addition, WTWS Geographic Situation Displays (GSD) are located in the ATC tower for use by ATC supervisors and in the AMO for use by HKO personnel. The GSD shows the horizontal profile of the various hazardous weather areas as well as the text alert messages.

Appendix 8 shows the WTWS alerts generated between 1005 hr and 1045 hr, which includes the time when CI642 was on its approach to HKIA. While the system warned of moderate or severe turbulence throughout the quoted period, the last windshear warning occurred at 1017 hr, some 26 minutes before the accident.

1.7.12. Pilot reports of weather

Although pilots making approaches to HKIA prior to the accident did confirm some aspects of the prevailing weather conditions, ATC did not receive any reports of windshear alerts generated by their aircraft's onboard windshear warning systems.

The commander of a B747 aircraft which landed at 1036 hr reported later that, after passing 1,000 ft, the turbulence was moderate in a steady crosswind of 35 kt. The commander was fully visual by 400 ft, and his visibility was unobscured to touchdown. At 250 ft, he experienced moderate to severe mechanical turbulence which decreased at 150 ft, as did the crosswind which he estimated as

20-25 kt in the flare.

The commander of a B777 aircraft which landed on RW 25L some four minutes before CI642 stated later that he became fully visual by 400 ft, although in driving rain. Between 200 and 100 ft, the aircraft encountered some violent gusts which resulted in speed fluctuations of 10 – 15 kt, and ‘a large speed reduction’ on entering the flare, which was successfully countered by a rapid, manual, application of power.

1.8. Aids to navigation

All relevant navigational aids were serviceable during the period of the accident flight.

1.8.1. Approach aids

The approach aid in use at the time of the accident was the Category II instrument landing system (ILS) to RW 25L. The localiser centre line was aligned to 253°M and the glide-path (GP) was set at 3°. A distance measuring equipment was co-located with the GP. Copies of the RW 25L and 25R ILS approach charts are at Appendix 9.

The ILS was calibrated at quarterly intervals. At the time of the accident, a calibration aircraft was stationed in Hong Kong for the periodic calibration. The post accident flight check carried out by the calibration aircraft confirmed that the ILS was operating normally.

1.9. Communications

The radio callsign for the accident flight was 'Dynasty 642'. At 1025 hr, Dynasty 642 established radio communication with Hong Kong Approach Control on 119.35 MHz, and continued on this frequency until 1038 hr when the aircraft was passed to Hong Kong Tower on frequency 118.4 MHz. Continuous speech recording equipment was in operation on both frequencies and a satisfactory transcript of the communications exchanged between Dynasty 642 and ATC was obtained and correlated with cockpit voice recordings (see paragraph 1.11.3). The transcript shows that radiotelephony (RTF) conversations on both frequencies 119.35 MHz and 118.4 MHz were conducted in English and proceeded normally. No difficulties in transmission or reception were evident.

The transcript of relevant RTF messages is included at Appendix 10.

1.10. Aerodrome information

1.10.1. General

HKIA is situated primarily on reclaimed land on the western side of the Hong Kong Special Administrative Region and is managed by the Airport Authority Hong Kong. Open seas surround the airport on three sides. A narrow channel separates the southern side of the airport and Lantau Island on which high ground rises to a height of 933 m above mean sea level.

The HKIA had two parallel runways, namely runway 07R/25L and runway 07L/25R, separated by a distance of 1540 m between the centre lines of the two runways. The PTB and the passenger aprons were located in between the runways on the eastern side of the airport. Runway 25L was the runway in use at the time of the accident. It had the following physical characteristics:

Direction	:	253°M
Length	:	3800 m
Width	:	60 m
Shoulders	:	7.5 m either side
Surface	:	Asphalt
		Central 54 m grooved (6mm x 6mm) at 32 mm spacing for a length of 3400 m

Landing Distance Available	:	3800 m
Takeoff Run Available	:	3800 m
Accelerated Stop Distance Available	:	3800 m
Takeoff Distance Available	:	4100 m
Runway markings	:	Runway designation, threshold, touchdown zone, centre line, fixed distance markers, side stripe and runway exits.

A plan of HKIA is at Appendix 3.

1.10.2. Lighting aids

The Airfield Ground Lighting (AGL) system at the HKIA was in compliance with the ICAO Standards and Recommended Practices for precision approach Category II/III operations. The lighting was available 24 hours a day and controlled by ATC. The AGL consisted of both elevated and inset lights. Generally, edge lights were elevated fixtures with frangible supporting structures and low enough in height to clear aircraft engine pods and propellers. All centre line lights were inset fixtures, capable of withstanding aircraft weight. All lighting had independent intensity variance control to suit the operational conditions. The AGL comprised the following lighting systems:

i) Approach lighting consisting of centre line barrettes, side barrettes, inner crossbar, outer crossbar and sequenced flashing lights;

ii) Runway lighting consisting of threshold lights, centre line lights, touchdown zone lights, edge lights and end lights;

iii) Taxiway and taxilane lights consisting of centre line lights, edge lights, exit taxiway centre line lights, taxiway intersection lights and hold bars;

iv) Stop bars and runway guard lights at every taxiway entrance to the runways.

v) Precision Approach Path Indicators (PAPIs) installed on both sides of Runway 25L at a distance of 497 m from the threshold, with the nominal glide path set at 3° giving a minimum eye height of 22 m over the threshold.

The daily lighting inspection conducted between 0838 and 0920 on the day of 22 August 1999 found that all lights were serviceable. At the time of the accident, the approach lighting and PAPI for RW 25L and the runway lighting were at 100% brightness. Post accident flight calibration confirmed that the PAPI indication was coincidental with the ILS glide-path angle.

A plan of the AGL system is at Appendix 11.

In addition, movement area guidance signs were located with distances from the runway and taxiway pavements, and with heights in accordance with the ICAO requirements. These signs were supported by frangible structures.

1.10.3. Air traffic services

The air traffic services at HKIA were provided by the Air Traffic Management Division of the Civil Aviation Department which was responsible for the control of air traffic within the Hong Kong Flight Information Region (FIR) and the additional Area of Responsibility (AOR).

The Air Traffic Control Centre, which provided Approach Radar Control, Terminal Radar Control, Area Radar Control and Area

Control services, was located at the ATC Complex in the mid-field area of the airport. This complex also included the ATC Tower, which provided Air Movement Control, Ground Movement Control, Zone Control and Clearance Delivery Control services.

1.10.4. Meteorological services

The meteorological services at HKIA were provided by the Airport Meteorological Office (AMO) of the Hong Kong Observatory. The AMO was situated in the ATC Complex and performed the following functions:

a) Aeronautical Meteorological Station

b) Aerodrome Meteorological Office

c) Meteorological Watch Office.

A Meteorological Briefing Area was available in the PTB from which flight crew members and airline operators could obtain relevant meteorological information.

1.10.5. Airport fire services

The HKIA had two fire stations and two sea rescue berths. The main fire station was located south of RW 07R/25L and the sub fire station was located in between the two runways north of the ATC complex. The sea rescue berths were located on the north-eastern and south-western shores of the airport island. The locations of the fire stations and sea rescue berths are shown in Appendix 12.

The fire stations and rescue berths were manned 24 hours a day in accordance with established procedures. The fire services personnel were at immediate readiness due to the prevailing adverse weather conditions. Each fire station had seven rescue and fire fighting vehicles and one ambulance. The rescue and fire fighting vehicles consisted of two Rapid Intervention Vehicles (RIV), two Major Foam Tenders (MFT), two Hose Foam Carriers (HFC) and one Jackless Snorkel (JS). A total amount of 84,800 litres of water and 22,080 litres of foam compound meeting the ICAO performance level B was carried by these vehicles. Additionally, fire hydrants were installed along the runway shoulders at intervals of 150 m.

The sea rescue berths provided berthing facilities for two command boats. The command boats were supported by six speed boats.

1.11. Flight recorders

1.11.1. General

All flight recording equipment was recovered from the wreckage by members of the investigating team shortly after the accident, and transported to the UK Air Accident Investigation Branch (AAIB) for replay. The equipment comprised a Digital Flight Data Recorder (DFDR), Cockpit Voice Recorder (CVR) and a Quick Access Recorder (QAR). All three units were found to be undamaged on recovery.

Two members of the US National Transportation Safety Board

(NTSB) were present during the replays, and copies of all recovered information were made available to NTSB and the Air Safety Council of Taiwan, China.

1.11.2. Flight data recorder

The aircraft was fitted with a Fairchild model F1000 solid-state flight data recorder (SSFDR). The F1000 stores flight data in a compressed form in electrically erasable programmable read only memory (EEPROM).

Almost 350 parameters were recorded on the SSFDR. The compressed data was downloaded into computer memory via the SSFDR serial data link, and then decompressed and reduced to engineering values. In order to ensure all the data pertaining to the accident flight was recovered, the last bytes of compressed data were decompressed manually. The SSFDR status information was also downloaded and confirmed that the equipment 'BITE' had detected no faults.

The recording of longitudinal acceleration was found to be defective, but all other recorded parameters pertinent to the understanding of the accident were operational. The lack of longitudinal acceleration data did make subsequent calculation of the winds experienced by the aircraft on its final approach more complicated and potentially less precise than would have been the case with a fully serviceable SSFDR.

1.11.3. Cockpit voice recorder

The CVR installed in the aircraft was a Fairchild Aviation Recorder Model A200S solid-state cockpit voice recorder (SSCVR).

The SSCVR stores two hours of cockpit audio using EEPROM recording medium. The recording consisted of four channels of full bandwidth audio and an additional two hours of reduced bandwidth audio. During the most recent 30 minutes of recording, both full bandwidth and reduced bandwidth audio recordings were available.

The channels allocated to the 30-minute recording were:

Channel 1: Passenger Address (PA) and FDR synchronisation signal

Channel 2: Co-pilot (P2) live microphone and Radiotelephony (RTF)

Channel 3: Captain (P1) live microphone and RTF,

Channel 4: Cockpit area microphone (CAM).

The channels allocated to two hour reduced quality recording were:

Channel 1: Reduced quality CAM, channel 4

Channel 2: Reduced quality voice, channel 1, 2 & 3 combined.

The stored information was copied on to audiotapes and the SSCVR status information was also downloaded. This confirmed that the equipment ‘BITE’ had detected no faults.

A transcript of the relevant CVR extracts during the descent and final approach produced by the Aviation Safety Council, is included at Appendix 10.

1.11.4. Quick access recorder

The QAR fitted to the aircraft was a Penny & Giles Type D51434-1.

Documentation obtained from the QAR manufacturer confirmed that the data was buffered in volatile memory before it was written on tape. The block structure of the recorded data would result in about 39 seconds of data being lost if the recorder was switched off in a non-standard way e.g. through interruption of the power supply, as was the case in the accident flight. As a consequence, data pertaining to the final 500 feet of the aircraft's approach was lost due to interruption of the power supply at impact which caused loss of the data in the volatile buffer storage.

Data that was available was recovered by the UK AAIB utilising modified data reduction software which enables recovered data to be reduced to engineering values.

1.11.5. Data presentation

Time synchronisation of the data obtained from the SSFDR and SSCVR was achieved by use of a frequency shift keying code, generated by the flight data acquisition unit, and recorded every four seconds on the CVR.

Graphs of relevant flight data are at Appendix 13 and show the following parameters:

Appendix 13-1: Tabulated FDR data from 500 ft RA to touchdown.

Appendix 13-2: Graphical FDR data from 700 ft RA to touchdown.

1.11.6. Interpretation of the data

According to the DFDR, the aircraft was following a relatively stabilised approach in the landing configuration in turbulent and gusty wind conditions. The airspeed varied about a mean of 165 kt by approximately +7 and –4 kt and followed the ILS glide slope at a vertical speed of 750 to 800 feet per minute (fpm). Mean pitch attitude was about 2.5º airplane nose up (ANU) with some variations in pitch, possibly in response to wind gusts. The Auto Throttle System (ATS) remained engaged throughout the approach and the Throttle Resolver Angles (TRAs) varied generally between 44 and 50 º.

From the point on the approach at which manual control was established at about 480 ft RA, considerable flight control activity took place which resulted in vertical accelerations varying between 0.7 and 1.3g.

At 300 ft RA, there was a rapid decrease in indicated air speed from 166 kt to 157 kt, the pitch attitude reduced to less than 2º ANU, the descent rate increased to approximately 1,100 fpm and the flight deviated progressively below the ILS glide slope to in excess of one dot low. The thrust levers then advanced to TRAs between 59 and 62º at a rate of some 3º per second for five seconds, with engine thrust consequently increasing to 1.3 EPR. Indicated airspeed increased to 175 kt, accompanied by an increase in the angle of attack to 9º and in pitch to 5º ANU. This stabilised the aircraft at one dot low on the glide slope and re-established the rate of descent associated with a normal 3º approach, albeit with the aircraft below the glideslope.

As the aircraft passed 135 ft, the indicated airspeed approached 175 kt and TRA began to decrease, achieving an angle of approximately 38º as the aircraft passed 60 ft RA. Engine thrust simultaneously decreased towards flight idle, where it remained until touchdown. At the same time, the pitch attitude rapidly decreased to 2º ANU and the angle of attack reduced to a mean of 4º.

Entering the final one hundred feet of the approach, the angle of attack, as sensed by the two angle of attack (AoA) sensors, fluctuated with increasing divergence between 3º and 8º, consistent with significant wind gustiness, these variations oscillating about a one second period. At the same time, pitch attitudes varied with a slower periodicity, probably in response to the angle of attack variations and, possibly, without pilot input.

As the aircraft approached 45 ft RA, elevator angle was quickly increased to 12º up, then rapidly reversed to 8.5º down, and maintained at a negative angle of around 5º until approaching 21 ft RA; during this period, the pitch angle increased from around 3º ANU to just over 4º then returned to about 3.5º ANU, while the airspeed decreased from 172 kt to 166 kt.

At 21 ft RA, the elevator angle was reversed and was progressively increased to reach 15.7º up just before touchdown, the pitch angle simultaneously reached 4.9º ANU and the speed further reduced to 152 kt at touchdown.

During this last 45 ft, the roll angle varied between approximately wings level and 3º to 4º right wing down, consistent with a wing-down approach manoeuvre in the prevailing gusting crosswind conditions, and resulted in the aircraft touching down some 3.5° - 4° right wing low.

RA data from the FDR indicated an average rate of descent of approximately 16 feet per second (fps), or 960 fpm, over the last 300 feet of the approach, while The Boeing Company later calculated the actual rate at the right main landing gear at touchdown as 18 fps, or 1080 fpm.

The methodology used in these calculations has been verified by the NTSB, and is shown at Appendix 14.

1.12. Wreckage and impact information

After the accident, survey photographs were taken to record the final position of the main wreckage, the wreckage parts and the skid marks evident on RW 25L and adjacent landscape areas. Based on the information from these photographs, a wreckage plot was produced which is shown on the survey map at Appendix 2.

The inverted fuselage wreckage was found on the landscaped area between Taxiway J6 and J7, with the nose pointing in an approximately easterly direction. Wreckage parts were also found scattered on the runway and Taxiways J, J7 and J8. Photographs of the wreckage are included in Appendix 15.

The broken right wing was found on Taxiway J7 at a location of about 75 m from the nose of the main wreckage and 30 m from the edge of the runway. The vertical stabilizer and rudder assembly were found on Taxiway J7 at a location of approximately 60 m from the nose of the main wreckage and 30 m from the edge of the runway. Both left-hand and right-hand horizontal stabilizers and their associate elevators remained attached to the main fuselage.

The left main landing gear remained attached to the left wing attachment points. The right main landing gear was detached from the right wing and rested next to the right-hand horizontal stabilizer of the inverted main wreckage. The centre landing gear truck bogie had broken off from the shock strut and was found on the runway. The shock strut remained attached to the fuselage attachment points. The nose landing gear remained attached to the fuselage attachment points though its left-hand wheel was detached from the axle.

No. 1 engine remained attached to the left wing of the main wreckage. No. 2 engine was detached from the main fuselage and was found at approximately 15 m behind the left wing of the main wreckage. No. 3 engine was detached from the right wing and was found on the edge of Taxiway J7 at a location of approximately 120 m from the nose of the main wreckage and 30 m from the edge of the runway.

From the wreckage plot, there were three main burn mark areas noted indicative of post-accident fire. The first one was at the landscape area between Taxiways J6 and J7 where the main wreckage was located, and took the shape of a rectangle (90 m x 15 m) together with a triangle (base 45 m x 15 m height). The second one was in the form of a triangle (base 180 m x 45 m height) spreading across Taxiway J7 and the landscape area between Taxiway J7 and J8. The third one was in the form of a rectangle (120 m x 10 m) on the runway commencing at a point some 450 m from the runway threshold.

Scrape marks were first noted at a point some 250 m from the runway threshold. They were initially parallel to the centre line of the runway for a distance of approximately 380 m where their path started to curve towards the landscape area between Taxiway J7 and J8, and entered that area at a point approximately 820 m from the runway threshold. Their path then continued across Taxiway J7 and into the landscape area between J6 and J7 where the inverted wreckage finally settled.

1.13. Medical and pathological information

A total of 212 persons, including passengers and crew members, were admitted to six local hospitals for treatment immediately after the accident. This figure included two passengers who were certified dead on admission, and one who died five days later from injuries received in the accident. Within seven days of the accident, seven more passengers from this flight reported at various hospitals requesting medical assistance for injuries apparently sustained in the accident.

Urine samples were obtained from the commander and co-pilot about five hours after the accident, and sent to the Hong Kong Government Laboratory for testing. Medical examinations of both pilots were conducted some 15 hours after the accident by an aeromedically-qualifed examiner approved by the Hong Kong Government. There was no evidence of any pre-existing medical or physical conditions which might have contributed to the accident.

Autopsies of the three fatal passengers were carried out by Medical and Health Officers from the Forensic Pathology Service of the Department of Health. The causes of death of the three fatalities were found to be different and were as follows:

i) The cause of death of the deceased on seat 1K was determined to be drowning. However, traces of sand and grass were also found in his trachea, which suggested that he was knocked unconscious at the time of the accident, but continued to breathe in a mixture of water, sand and grass.

ii) The passenger who occupied seat 37B had visible bruises to her face and back. Investigators found that seat 37B seat belt functioned as required and exhibited no evidence of malfunction. In addition, the passenger's autopsy report revealed that there were no marks on her abdomen associated with seatbelt use, and that she died as a result of multiple injuries.

iii) The passenger who was on seat 25J died five days later in hospital, having suffered extensive second degree burns to approximately 55% of his total body area.

The injuries to those admitted to hospital were classified as follows:

- ♦ 45 burn or scald injuries, of which the majority of the wounds were located on the limbs, especially on lower limbs;
- ♦ 45 head injuries;
- ♦ 31 limb injuries other than burn, scald, contusion, abrasion or laceration;
- ♦ 22 abrasions or lacerations;
- ♦ 19 contusions;
- ♦ 16 neck injuries;
- ♦ 15 inhalations of smoke or fuel/engine fluid vapor;
- ♦ 12 back injuries;
- ♦ 11 chest or rib injuries;
- ♦ 9 injuries at the waist, hip, pelvic or buttock area; and
- ♦ 7 shoulder injuries

Some passengers suffered more than one type of injury as classified above. Some passengers also sustained other minor injuries such as abdominal pain or soft tissue damage.

A diagram showing the seats occupied by those persons who suffered fatal or serious injury is at Appendix 16.

1.14. Fire

As the starboard wing of the aircraft began to detach from the fuselage, fire broke out at the point of failure between the fuselage and the wing, leaving a trail of fire along the tracks of the aircraft and the starboard wing to their final resting places on the grass area to the right of the runway and on taxiway J7 respectively.

The Duty Air Movement Controller activated the crash alarm to call out the Airport Fire Contingent (AFC) before the aircraft had come to rest. A total of 14 AFC appliances arrived at the scene within one minute and immediately commenced fire fighting at the following locations:

i) detached starboard wing and no. 3 engine on taxiway J7, together with a trail of spilt fuel pointing to the east covering an area of about 100 m x 20 m;

ii) rear portion of the aircraft fuselage;

iii) no. 2 engine detached and lying about 20 m to the south of the tail of the overturned aircraft; and

iv) port wing and no. 1 engine.

It was also apparent that flashes of fire had gone through the R3 door into the cabin.

The fire on the aircraft fuselage was brought under control within two minutes and suppressed within five minutes. The fires at the other locations were completely extinguished within 15 minutes.

1.15. Survival aspects

1.15.1. The occurrence

Prior to landing, the cabin attendants conducted a visual inspection to check that passengers had fastened their seatbelts. After that, they returned to their respective seats and strapped in for the landing.

According to statements from surviving passengers, the approach to land was turbulent and the landing was heavy. Some felt that the aircraft had tilted to the right and touched down on only the starboard undercarriage, followed by bumpy movements before the aircraft overturned. During the sequence, a short flash of fire entered the cabin from the right wing area near door R3, possibly prior to or during the overturning of the aircraft. After the aircraft rolled upside down and yawed through 180° to the right, the forward section of the fuselage impacted the ground first followed by the aft section and the fuselage then slid backwards due to its inertia. During the sequence, the flight attendant seated next to door R1 was thrown outside the aircraft. The crown of the fuselage was crushed downwards resulting in head injuries to many of the persons onboard. The aircraft came to rest to the right of RW 25L at a distance of 1,110 m from the runway threshold - see photograph of main wreckage in Appendix 17.

The entire cabin was in comparative darkness, except where illuminated dimly from light sources outside the aircraft, and from some emergency lights in the aircraft ceiling (which was now effectively, the cabin floor) which had automatically illuminated on loss of main aircraft power. Some passengers later commented on the presence of what they described as these ‘dim lights’.

1.15.2. Damage to the cabin

During the crash sequence, the forward fuselage skin was torn and crushed just aft of the R1 and L1 doors, corresponding to business class seats 1A and 1K through 5A and 5K, along the left and right sides of the cabin. A passenger seated on 1K was rendered unconscious and subsequently drowned. A picture of seats 1J and 1K taken after the accident is included in Appendix 17. The cabin wall on the right fuselage next to seats 1K through 5K was deformed inboard, with seats 1J and 1K separated from their respective seat tracks. The cabin floor and lower seat structures surrounding seat 25J, located in front of the R3 exit, were scorched and burned. The flight attendant seat adjacent to door R3 was also burned and heavily sooted, and the flight attendant at this seat suffered serious burn injuries. The lavatory forward wall immediately aft of door R3 was burned and blistered. A large section of the left side of the fuselage was torn forward and aft of door L2 and parallel with the window belt, corresponding to seats in rows 4A/4B through 17A/17B.

The back of the seats 25J and 25K were burned, and passenger windows were severely crazed between seats 20K and 32K. This was consistent with the statements of survivors that the short flash of fire entered the cabin via the R3 door. A picture of the burned and blistered lavatory wall is included in Appendix 17. Many passengers seated on the starboard side in the mid-section of the cabin suffered burns varying from minor to severe to the leg, back and/or right side of the body. The passenger on seat 25J sustained extensive second degree burns and died five days later in hospital.

Doors L1, R2, R3, L4 and R4 were jammed either closed or partially open due to damage sustained to the crown of the fuselage, while doors R1, L2 and L3 were separated from the aircraft.

During the crash sequence, rainwater lying on the grass surface of the airport to the right of RW25L entered the cabin through the gaps and cracks which opened in the fuselage just aft of the R1 and L1 doors. The cabin also became quickly contaminated with fuel and hydraulic fluid.

1.15.3. The evacuation

Immediately after the aircraft came to a halt, the flight attendants began to look for torches to assist them in the evacuation. The task of locating torches was complicated by the aircraft being inverted and the fact that the aircraft ceiling (now floor) was cluttered with debris.

Statements given by surviving passengers confirmed that their seatbelts had been fastened for the landing. However, some passengers stated that they unbuckled their seatbelts immediately after the first touchdown; one passenger confirmed that she had unfastened her seatbelt just before the aircraft rolled inverted, and was then thrown around inside the cabin until the aircraft came to a halt. Some passengers dropped down and were injured on releasing their seatbelts, while others had difficulty in releasing their seatbelts and had to be assisted by companions or by rescue crew. The restraining effect of the seatbelts, and of unfastening them and falling to the ceiling from the inverted position, appears to be consistent with the reports of persons suffering from injuries to the neck, shoulder, back, chest, ribs, waist, hip, pelvis or buttocks.

Sensing the emergency, many of the passengers commenced evacuation on their own initiative. The cabin crew also started to direct passengers to the available exits. After completion of the emergency checklist, the flight crew also assisted in directing passengers to the nearest exit. Some passengers also elected to stay inside the cabin to assist in the evacuation of other passengers.

During the initial stage of the evacuation, several passengers were struck by objects falling from the cabin floor above, possibly damaged cabin furnishings or passengers' personal belongings. They were also subjected to dripping water and a liquid which smelt like fuel. The clothing of most passengers became soaked. Some passengers commented that their evacuation was slowed by the debris inside the cabin, and also by other passengers who were trying to recover their hand luggage. The presence of debris and of belongings of other passengers lying on the aircraft ceiling therefore became a distinct hindrance to the evacuation. As a result, many persons sustained lower limb injuries during the evacuation. Pictures of the business and economy class sections after the accident are included in Appendix 17.

In the early stage of the evacuation, some passengers and crew members attempted to open doors L1, R2, R3, L4 and R4 without success, and they subsequently followed other passengers to leave the aircraft via the available exits. These exits were doors L3 and R1, and the cracked hole that was torn open by the impact in the fuselage aft of door L2. Pictures of these exit areas are shown in Appendix 17.

Once outside, the passengers began to spread out in all directions to distance themselves from the aircraft, which was still burning around the area where the right wing had detached. Considerable efforts were required by the rescue crew to re-direct evacuees away from the aircraft, and to avoid some other fires which were still burning on the ground.

1.15.4. The search and rescue operation

The fire-fighting and rescue operations were conducted concurrently by the rescue services upon their arrival at the scene shortly after 1045 hr. Initially two ambulances from the AFC arrived together with the fire appliances. More rescue services in terms of firemen, ambulance crews and medical practitioners were called from areas outside the airport to assist in the search and rescue operations. The ambulance crew who arrived at the scene shortly after 1045 hr set up a first casualty clearing station at taxiway J6 to provide immediate medical treatment to the casualties.

The first fireman who entered the cabin via door R1 at around

1048 hr described later that there was smoke and a smell of jet fuel but no fire inside the cabin. More firemen wearing breathing apparatus began to enter the cabin to release passengers who were still strapped onto their seats in the inverted position, or to assist persons who were not able to evacuate by themselves. The search and rescue operation inside the aircraft was constrained by the narrow space and the absence of a clear gangway. The entire cabin was in comparative darkness and flooded with water to about 0.6 m high.

Some passengers were assisted to evacuate the aircraft by firemen through the fuselage skin that was torn open by the impact in the area aft of door L2, and through doors L3 and R1 respectively. The AFC had attempted to further open the cracked hole but they had limited success and only managed to extend the opening by two to three inches. The AFC also made considerable efforts to force open other closed doors, and subsequently managed to fully open door R2 and partially open door R4 after the various fires were extinguished. After the passengers were assisted from the aircraft, they were led to safety at temporary collection points on RW 07R/25L, taxiway J and taxiway J6.

Firemen found a passenger who had occupied seat 37B lying on the cabin ceiling near seat 37B. She was certified dead on arrival at hospital.

By 1053 hr, some 200 passengers had been rescued and led to safety at the temporary collection points. The remaining passengers left the aircraft in the early stages of the evacuation either unassisted or assisted by other passengers or crew members. At 1111 hr, the first ambulance conveying five casualties departed for hospital. A second casualty clearing station was established at taxiway J7 at 1145 hr. A temporary mortuary was also established at the scene utilising an ambulance. A triage point was set up at the South Airport Passenger Vehicle (APV) lounge on the ground floor of the PTB. Eleven transport vehicles from an airport service provider were sent to the scene for transporting crew members and passengers to the South APV lounge. As all occupants in the aircraft had not been accounted for, the search for occupants continued in comparative darkness. At 1300 hr, the AFC reported that a seat unit, which was later confirmed to be seat 1J and K, was found to be separated from the seat tracks and was lying on the ground immediately beside door R1 partly immersed in water. A passenger, who was certified dead on arrival at hospital, was restrained in seat 1K. The fireman who found the deceased stated that water had accumulated up to knee level in and around the fuselage in that area.

At 1350 hr, all known casualties had been treated and/or conveyed to various hospitals for further treatment. Search operations continued until 1935 hr when confirmation was received from the Police that all persons had been accounted for.

Some passengers who suffered burn injuries developed skin infections later and required further treatment in hospital. Medical teams from the Department of Health and from the airport private clinic were called to assist in the treatment of casualties at the scene and at the South APV lounge.

1.16. Tests and analysis

The objective of this section of the report is to provide a brief account of the tests and analysis completed on these wreckage parts by the Engineering Group. There is no intention to describe any details of a particular test, which are covered in the original reports.

After the accident, the Engineering Group had some mechanical parts and on-board computers removed from the wreckage and sent to Boeing, Long Beach for metallurgical and non-volatile memory (NVM) data analysis. The three Electronic Engine Controls (EEC) were sent to Pratt & Whitney for data analysis, and components of the windshield wiper system were tested for serviceability in Hong Kong. The seat belt from seat 37B was forwarded to NTSB for confirmation of its functioning capability.

The Engineering Group met twice in September and November 1999 at Boeing, Long Beach to discuss the scope of the metallurgical analysis required and witnessed some of the testing. The Engineering Group also agreed with Boeing to send parts to the original equipment manufacturer (OEM) for analysis if required.

Subsequent to the analysis, Boeing has produced three reports to consolidate the findings. These reports are:

a) Material and Process Engineering Report on China Airlines MD11 Fuselage Number 518 Accident at Hong Kong International Airport, Hong Kong, China.

b) Sequence and Characteristics of the Structural Failure of the China Airlines MD11 Fuselage Number 518 – August 22, 1999 Accident at Hong Kong International Airport, Hong Kong, China.

c) NVM Summary – China Airlines Accident, Flight 642 MD11 Fulselage 518, August 22, 1999.

Also, Pratt & Whitney has produced evaluation reports of the three EECs examined. The title of these reports is 'Evaluation of Data Recovered from China Airlines MD11 Flight 642 Electronic Engine Control – Engine #1/2/3'.

1.16.1. Material and process engineering report

The report details the metallurgical examination and analysis of selected structural parts sent to Boeing, Long Beach. Each part was analysed for failure modes, failure origin areas and abnormalities. Hardness and conductivity measurements, chemical analysis, tensile, and dimensional inspection were performed only on selected parts.

The report subdivides the various parts into eight major categories:

i) Wing rear spar and support structure

ii) Wing front spar and support structure (inboard of no. 3 pylon)

iii) Trapezoidal panel and support structure

iv) Right main landing gear (RMLG) and support structure

v) Left main landing gear (LMLG) and support structure

vi) Centre landing gear and support structure

vii) No. 3 engine pylon and support structure

viii) Passenger's seat 1 J/K and seat track (1^{st} class section)

1.16.1.1. Testing and examination

With the concurrence and participation of the Engineering Group, all the wreckage parts sent to Boeing, Long Beach underwent the following tests and examinations, where appropriate, to determine the failure characteristics.

a) Visual Inspection

b) Dimensional Inspection

c) Macroscopic Examination

d) Hardness Test

e) Tensile Test

f) Conductivity Test

g) Scanning Electron Microscope Analysis

h) Chemical Analysis

1.16.1.2. Discussion on result of testing and analysis

All the primary fractures of the failed assemblies and components that were analyzed, evaluated, and/or tested by Boeing, Long Beach occurred by ductile overload. There was no evidence found that associated the initiation of any of the primary fractures to brittle failure mechanism (stress corrosion cracking (SCC), fatigue, etc.). Also, there was no evidence to associate the cause of the fractures to other than the accident at HKIA.

The overall fracture characteristics and directions of deformation of the RMLG forward trunnion bolt indicated that the forward portion of the failed trunnion bolt had been pushed forward and had rotated. The inboard position of the lubrication (zirk) fitting appeared to indicate that the aft sleeve and most likely the aft forward RMLG fractured trunnion bolt had not rotated. These observations appeared to suggest that the forward RMLG trunnion bolt had moved upward relative to the wing attachment support (support fitting/attachment fitting). The oblique region found on the fracture surface of the RMLG trunnion bolt, which extended outside of the zero-margin groove, appeared to be the terminal portion of the fracture.

Evidence on the aft axle of the RMLG showed that it was deformed (bent) upwards at the inboard and outboard ends, due to the accident sequence.

Some of the components analysed exhibited secondary intergranular and quasi-cleavage fractures, indicating brittle failure mechanisms. These secondary brittle failures are the result of SCC, which is supported by the following facts:

a) They appeared to be associated with mechanical damaged regions or adjacent to primary fracture surfaces which are sources of high sustained residual stresses.

b) The parts were exposed to harsh and hostile environments (moisture, fire, extinguisher chemicals, water, etc.) after the accident, which could also include the transportation to Long Beach by ocean shipment.

The analysis of the seat tracks and seat did indicate that the seat separated from its tracks when the seat tracks failed by ductile overload.

There are differences in the acid number and particle count found between the results of the analysis performed on the fluid from RMLG and LMLG and that of the requirements of Douglas Process Manual Specification DPM 6176 and DPM 6177 and/or Military Specification MIL-H-5056. Such differences cannot be explained completely. However, the possibility of contamination, testing techniques, the accident sequence, post-accident conditions (including the transport of the landing gears to Long Beach) can be considered to be contributing factors in the lack of correspondence.

1.16.1.3. Conclusion

The primary fractures of all the failed parts occurred by ductile overload failure.

All the parts/components and assemblies analysed, evaluated and/or tested met the applicable engineering drawings and specifications.

All secondary cracks were due to stress corrosion cracking.

There was no evidence to associate the cause of the fractures to other than the accident at HKIA.

1.16.2. Sequence and characteristics of structural failure

After the accident, Boeing conducted a structural failure sequence analysis on the accident and produced a report, which details the analysis techniques applied to determine the structural failure sequence of the accident, based on the information obtained from site investigation and metallurgical analysis of wreckage parts.

The following is a summary of the report, which is reproduced in full at Appendix 18.

1.16.2.1. Analysis techniques

When the wreckage parts were examined and analysed at Boeing, Long Beach, it was found that the structural failure observed from this accident aircraft was very similar to that from the FedEx MD-11 involved in an accident at Newark, New Jersey on 31 July 1997, particularly that of the right wing rear spar.

During the investigation of the FedEx MD-11 accident, a significant amount of analysis was conducted to simulate the accident and estimate structural loads on the RMLG, the RMLG-to-wing attachment fitting, the right wing rear spar, and the right landing gear side-brace-fitting-to-trapezoidal-panel (S-B-F-T-T-P) joint. This analysis was conducted using an in-house aircraft dynamic landing program (B7DC), a commercially available finite element program (MSC NASTRAN), and a commercially available nonlinear kinematics code (ADAMS).

Based on knowledge and experience gained from the FedEx accident, a simplified analysis technique was developed for studying the effects of very high sink rate landings on aircraft structure. The crash landing analysis performed for this accident utilized MSC NASTRAN. A transient nonlinear solution was run using a detailed finite element model of the MD-11 inboard wing and center fuselage, combined with a coarser idealization of the remaining structure. The main landing gear was idealized by using a nonlinear spring and damper element (BUSH1D), which allowed the gear characteristics to be input in table form. The results from this model were compared and correlated with certification analysis (for cases within the design limits of the aircraft) and with the FedEx ADAMS analysis and were shown to be satisfactory.

The most significant difference in the structural loads applied to the aircraft during the FedEx and the China Airlines accidents lay in the drag loads applied to the right main landing gear, which in the FedEx case was minimal. To cater for this difference, an adjustment to the simplified MSC NASTRAN was made. Spin-up and spring-back loads were estimated using B7DC and the time history was manually input into the MSC NASTRAN solution. The peak load from the B7DC time history was phased to correspond with the peak right main landing gear vertical load.

1.16.2.2. Landing conditions and simulation

The attitude of the accident aircraft, along with the velocity and acceleration components, were estimated from the data obtained from the flight data recorder. The sink rate was estimated to be in the vicinity of 18 fps. The roll attitude was estimated to be approximately 3.5-4º right-wing-down and the pitch attitude was estimated to be 4.5º nose-up.

1.16.2.3. Loads experienced by the structures

By applying the simulation techniques mentioned, the peak loads experienced by the RMLG strut and the RMLG forward trunnion bolt at the time of the accident was estimated to be 1.4 million lb (6.23 MN) and 1.2 million lb (5.34 MN) respectively. Also, the peak rear spar shear flow was estimated to be 35,000 lb per inch (6,129 kN per m). The rear spar shear flow is well in excess of what is required to fail the rear spar shear web and the forward trunnion bolt load is roughly that required to fail it.

1.16.2.4. Structural failure sequence analysis

The result of the analysis confirms that loads high enough to fail the RMLG forward trunnion bolt and the rear spar web were feasible, and that the failure sequence described in the following subparagraphs is reasonable.

- Due to the combination of a high sink rate and a right-wing-low rolled attitude, the right main landing gear shock strut bottomed and the vertical load on the right main gear ‘spiked’.

- The forward trunnion bolt on the right main landing gear sheared upwards as a result of a very high vertical gear load combined with a large ‘springback’ moment.

- The forward trunnion of the right main landing gear was driven upwards and contacted the MLG-to-wing attachment fitting, damaging the fitting.

- The rear spar web and caps inboard of the MLG-to-wing attachment fitting of the right wing fractured.

- The inboard upper wing panel of the right wing began to collapse from back to front.

- The outboard (right) wing twisted significantly nose down, which caused the MLG-to-wing attachment fitting to move up and the main landing gear tires to move aft and outboard.

- The track attached to the inboard flap on the right wing was pried off the rollers that support it at the fuselage side-of-body.

- The inboard flap on the right wing twisted off its outboard hinge support fitting and separated from the aircraft.

- Excessive movement of the right main landing gear and its wing attachment fitting imparted large 'prying' loads on the S-B-F-T-T-P joint.

- The right main landing gear fixed brace failed near the S-B-F-T-T-P joint.

- With the side brace failed, large sideloads were introduced to the S-B-F-T-T-P joint by the folding side brace.

- The S-B-F-T-T-P joint failed; first the inboard attachment bolt fractured, then an outboard section of the outboard trapezoidal panel ‘split off’ releasing the outboard attachment bolt and its barrel nut.

- The right main landing gear strut, now released from the fuselage (trap panel), pivoted outboard; the trunnion arms contacted the MLG-to-wing attachment fitting. The resulting ‘short couple’ (prying) loads completed the separation of the landing gear from the attachment fitting.

- The right nacelle contacted the runway (at about the same time as the inboard flap was separating and the S-B-F-T-T-P joint was failing) and the right wing engine/pylon assembly was twisted off. The pylon-wing separation appears to have been dominated by side loads applied to the nacelle rather than vertical loads.

- The aircraft began to roll clockwise having lost the integrity of the right wing, yet still carrying enough speed to generate meaningful lift on the left hand wing.

- Failures beyond this point were consequential, are not considered particularly relevant, and were not studied in detail.

1.16.3. Summary of Non-volatile Memory data analysis

The following avionics components were sent to Boeing for Non-volatile Memory (NVM) data retrieval and analysis:

a) Brake Temperature Monitor / Tyre Pressure Indicator

b) Electrical Power Control Unit

c) Three Generator Control Units

d) Auxiliary Data Acquisition System / Data Management Unit

e) Flight Control Computers

On conclusion of the analysis, none of the NVM in the components that were sent to Boeing provided any information or evidence that may have contributed to the cause of the accident.

1.16.4. Summary of analysis of Electronic Engine Control data

This summary provides a description of the Electrically Erasable Read Only Memory (EEROM) data that was recovered from each channel of the three Electronic Engine Control (EEC) units of the CI642 wreckage.

1.16.4.1. No. 1 Electronic Engine Control

The EEROM data from the EEC mounted on no. 1 Engine were successfully recovered. A review of these data has revealed that channel A contained diagnostic messages that spanned the last 573 flight hours and 293 flight cycles while channel B contained messages that spanned the last 400 flight hours and 293 flight cycles. Neither channel A nor channel B had recorded any messages for 28 flights prior to the terminal flight. On the terminal flight, 11 messages involving channel A and 10 messages involving channel B were recorded.

On channel A, three of the messages are consistent with interruptions on circuits between engine and aircraft. Five of the messages provide troubleshooting guidance, but do not identify a specific system or component. The remaining three messages identify anomalies with the engine inlet pressure/temperature sense system and the execution of the compressor Stall Recovery Logic. These recorded messages are consistent with either the dynamics of the aircraft during the accident or the observed engine damage from the accident.

On channel B, three of the messages are consistent with interruptions on circuits between engine and aircraft. Four of the messages provide troubleshooting guidance, but do not point to a specific system or component. The remaining three messages identify anomalies with the engine inlet pressure/temperature sense system and the execution of the compressor Stall Recovery Logic. These recorded messages are consistent with either the dynamics of the aircraft during the accident or the observed engine damage from the accident.

1.16.4.2. No. 2 Electronic Engine Control

The EEROM data from the EEC mounted on no. 2 Engine were successfully recovered. A review of these data has revealed that both channel A and channel B contained diagnostic messages that spanned the last 315 flight hours and 232 flight cycles. Neither channel A nor channel B had recorded any messages for 137 flights prior to the terminal flight. On the terminal flight, 16 messages involving channel A were recorded and 11 messages involving channel B were recorded.

On channel A, three of the messages are consistent with interruptions on circuits between engine and aircraft. Nine of the messages provide troubleshooting guidance, but do not identify a specific system or component. The remaining four messages identify anomalies with the engine inlet pressure/temperature sense system and the execution of the compressor Stall Recovery Logic. These recorded messages are consistent with either the dynamics of the aircraft during the accident or the observed engine damage from the accident.

On channel B, three of the messages are consistent with interruptions on circuits between engine and aircraft.

Five of the messages provide troubleshooting guidance, but do not point to a specific system or component. The remaining three messages identify anomalies with the engine inlet pressure/temperature sense system and the execution of the compressor Stall Recovery Logic. These recorded messages are consistent with either the dynamics of the aircraft during the accident or the observed engine damage from the accident.

1.16.4.3. No. 3 Electronic Engine Control

The EEROM data from the EEC mounted on no. 3 Engine were successfully recovered. A review of these data has revealed that both channel A and channel B contained diagnostic messages that spanned the last 203 flight hours and 150 flight cycles. Neither channel A nor channel B had recorded any messages for two flights prior to the terminal flight. On the terminal flight, 15 messages involving channel A and nine messages involving channel B were recorded.

On channel A, five of the messages are consistent with interruptions on circuits between engine and aircraft. Five of the messages provide troubleshooting guidance, but do not identify a specific system or component. The remaining five messages identify anomalies with the engine inlet pressure/temperature sense system, the torque motor circuits for the fuel metering unit and stator vane actuator, and the thrust reverser system. These recorded messages are consistent with either the dynamics of the aircraft during the accident or the observed engine damage from the accident.

On channel B, one of the messages is consistent with interruptions on circuits between engine and aircraft. Seven of the messages provide troubleshooting guidance, but do not point to a specific system or component. The remaining message identifies anomalies with the engine inlet pressure/temperature sense system. These recorded messages are consistent with either the dynamics of the aircraft during the accident or the observed engine damage from the accident.

1.16.5. Tests of fluid samples

After the accident, fluid samples were collected from all three engine oil systems, all three hydraulic systems and the no. 1 inboard fuel tank for laboratory tests. Fuel samples from other tank locations were not available due to the damage sustained by both wings during the accident. The laboratory tests did not indicate any abnormal conditions.

1.16.6. Tests of windshield wiper systems

On examination of the cockpit controls and switches immediately following the accident, the position of the left windshield wiper selector was found to be OFF and the circuit breaker protecting the left wiper motor tripped. In addition, the left wiper was out of its parked position. As a result of these anomalies, the related components were removed for testing.

The tests were carried out by a local aircraft engineering company under the direct supervision of a member of the Engineering Group of the accident investigation team. The tests did not reveal any reasons why the system should not have been operating normally at the time of the accident, nor for the inconsistencies between the positions of the components referred to above.

A report on the tests carried out is at Appendix 19.

1.16.7. Test of seat belt at seat 37B

As the passenger on seat 37B suffered fatal injuries consistent with lack of restraint, the seat belt from that seat was sent to NTSB for testing. NTSB confirmed that the seat belt had normal functioning capability.

1.17. Organisational and management information

Pertinent information concerning organisations and their management involved in influencing the operation of the aircraft is included in relevant parts of this report.

1.18. Additional information

1.18.1. Flight crew manuals

The flight manual and operations manuals used by China Airlines MD11 fleet were prepared and issued by the Boeing Company, Long Beach Division (previously McDonnell Douglas Corporation). The Airplane Flight Manual (AFM) was Boeing document no. MDC–K0041, last revised 16 March 1999. The Flight Crew Operations Manual (FCOM) consisted of four relevant volumes. Volume 1, 'Flight Handbook', containing Emergency and Abnormal procedures extracted from Volume II for 'quick reference', was Boeing document CI MD-11, applicable to aircraft 'DEU 910 and Subs', and last revised 15 April 1999. Volume II, 'Operating Procedures', was Boeing document CI-L53-VAC/995/0005 last revised 15 April 1999; a later revision dated 13 August 1999 had not been incorporated in the accident aircraft copy of the manual but the subject matter did not affect the circumstances of the accident. Volume III covered systems descriptions, and Volume V contained performance data for Pratt and Whitney-engined aircraft. (Volume IV was for the General Electric-engined aircraft, and therefore not applicable to the accident aircraft).

China Airlines made no changes or additions to these manuals other than the incorporation of frontispiece pages in each manual for company administrative purposes, and of routine textual revisions supplied by the Boeing Company. Copies of the AFM and relevant volumes of the FCOM were carried on the flight deck.

Additional instructions from the airline to its flight crew were contained in China Airlines Flight Operations Manual (FOM) last revised November 1998, and in MD11 Standard Operation Procedure (SOP) manual, last revised 25 January 1996. The FOM contained general company organisation, regulations and procedures applicable to all fleets. The SOP manual contained MD-11 type-specific standard operating procedures. Copies of both documents were carried on the flight deck. China Airlines also provided plastic-covered normal aircraft checklists copied from FCOM Volume 2-1, and a briefing reminder for use by the crew when briefing before take off or landing. These cards were both carried and stowed in a readily accessible position on the flight deck.

China Airlines IP (Instructor Pilot) Manual Vol. 1, documentation no. OZ-OT-01, published on 5 May 1999, contained general, non type-specific information on company training requirements. The Training Manual for the MD11 fleet was a China Airlines produced document, originally dated 1 April 1996, and last revised on 15 June 1999. This was essentially a structural document, containing syllabuses to be followed and equipment available for use for various aspects of MD11 training. It did not contain advice to training staff on techniques to be followed in such areas of aircraft operation as in crosswind landings, or as in control of aircraft in the flare. It was therefore recommended to China Airlines that they consider the introduction of a 'Flight Instructor Guide' of a type used by other MD11 operators, which does contain such advice.

Study of the published manuals did reveal contradictions in the figures quoted as crosswind limitations. The FOM lists the limits for the MD11 as 35 kt dry and 24 kt wet, while the MD11 SOP quotes comparable figures of 30 kt and 25 kt respectively. While these contradictions did not have any direct bearing on the accident, it was recommended to China Airlines that they should be resolved.

Other inconsistencies between some of these documents in one area of aircraft operation pertinent to the accident (use of autothrottle) are discussed in paragraph 2.6.3 of the report.

1.18.2. En-route and approach charts

The en-route and approach charts used by China Airlines were supplied by the Jeppesen company. The airline made no changes or additions to the Jeppesen manuals other than incorporating routine revisions supplied by Jeppesen.

1.18.3. Approaches by other aircraft

ATC recorded all missed approaches (or 'go-arounds') and landings at HKIA. During the early afternoon, when a crosswind of 35-45 kt prevailed and RW 07R was in use, ATC reported that there had been many go-arounds because of the weather conditions, and only occasional successful landings. Following go-arounds by three successive aircraft between 0727 hr and 0742 hr, and with the wind observed as backing to northwesterly, the runway was changed to 25L. Two further go-arounds followed, but the successful landing rate then improved so that in the period between 0947 hr and the accident at 1043 hr, six aircraft landed and only one had to go-around, the latter occurring at 1034 hr.

A tabular summary of all approaches during the period 0657 hr – 1043 hr showing the times of landing or go-around is at Appendix 20.

1.18.4. Additional flight data

Data was recovered from the QAR of a B777 aircraft which landed on RW 25L some four minutes before the accident i.e. at 1039 hr. The data was analysed to provide a comparison of the wind conditions at that time to those prevalent during the final approach of CI642. As the QAR data for CI642 could not be recovered (see paragraph 1.11.4), the winds for the accident flight had to be derived from a combination of FDR data and performance calculations. These latter calculations were undertaken by the Boeing Company whose methodology was verified by NTSB.

The comparison of the data for the two aircraft, which concentrated on the last 200 ft of flight in each case, indicated that down to 50 feet RA, the wind speed experienced by both aircraft were essentially similar. According to the Boeing study below 50 feet RA, both aircraft experienced dissimilar winds which varied in direction and magnitude (see Appendix 21-1/2). However the lack of longitudinal acceleration data did make subsequent calculation of the winds experienced by the aircraft on its final approach more complicated and potentially less precise than would have been the case with a fully serviceable SSFDR (paragraph 1.11.2).

In the absence of QAR data from CI642, the derived data was included in the wind model used in the flight simulations described in paragraph 1.18.7. However as a result of a Boeing review of these winds (hereinafter referred to as the 2000 winds) the Boeing Company produced a further wind study in 2003 (hereinafter referred to as the 2003 winds) which indicated an error in the application of the 2000 winds during these simulator trials.

It is therefore recommended that the Boeing Company and the equipment vendor should conduct a study to examine methods for preventing the loss of QAR data in the event the equipment is switched off in a non standard way such as by an interruption to the power supply.

1.18.5. Eyewitness accounts

Accounts were obtained from several pilots shortly after the accident.

An off-duty pilot sitting in a car parked on a service road at the airport, at a location estimated to be approximately 100 m north of the RW 25L approach centre line and 400 m from the threshold, observed the aircraft for its last 25-30 seconds of flight. He estimated the cloud base at about 500 ft and visibility in excess of 1,000 m. He described the final approach as generally stable, with the aircraft noticeably crabbing into wind, and making some centreline adjustments. The aircraft appeared to descend but then stabilise 'slightly low, perhaps about one degree below the glidepath'. He described the rate of descent near touchdown as high, in a slightly right wing low attitude and with no flare. A flash occurred at touchdown, which he thought was a pod strike, followed by a major explosion upwards and along the right side of the aircraft. The left wing was then seen to rise up through the vertical as the aircraft banked 90 º to the right and then disappeared from his view.

Accounts were received from the pilots of an aircraft at the J10 holding point, which was cleared by ATC to 'line-up after the MD11 on short final'. The commander thought that the MD11 appeared to be somewhat low from around 200 ft with considerable crab (15-20º) as it passed the threshold but close to the centre line of the runway, but otherwise stable in both pitch and roll. He noted that it appeared to touch down somewhat short of the normal touchdown point. His attention was immediately focused on fire erupting from the area of the MD11's right engine/gear area, in what appeared to be a 10º right wing low touchdown, consistent with the strong crosswinds. The MD11 immediately started to veer to the right, with increasing and spreading fire intensity around the right hand engine/gear area, and a tightening of the turn radius. The left wing then appeared to rise very slowly into the air and the aircraft rolled completely on to its back. His co-pilot also thought that the aircraft appeared low as it came over the approach lights and that it crossed the threshold no more than 30 ft above the ground descending at a very rapid rate. The aircraft appeared to hit the runway in a nose up attitude with the right wing slightly low, first on the right main gear, but then with the centre and left wheels. The co-pilot's description of the aircraft's subsequent behaviour closely followed that of his commander.

The co-pilot of a B777 aircraft which landed four minutes before the accident aircraft and was taxiing east bound on 'Juliet' confirmed that after the MD11 landed, he observed sparks which appeared to be coming from under the right engine. He thought that these must have been from the engine pod scraping along the runway. After about a second, the aircraft appeared to come down on the main gear, followed by separation of the right wing. The left wing then started rising causing the aircraft to roll and turn to the right, after which the tail of the aircraft rose and the aircraft somersaulted.

The controllers on duty in the ATC tower were interviewed shortly after the accident. From their positions, those controllers who did view the aircraft's final approach and landing regarded them as normal until the aircraft was seen to catch fire and veered to the right off the runway.

Therefore to facilitate the monitoring of the touch down zones, it is recommended that CAD give consideration to the installation of equipment, such as video recorders, to monitor the touch down zones of Runways 25 R/L and 07 R/L.

1.18.6. Interviews with the pilots

Both pilots were interviewed on a preliminary basis by members of the accident investigation team about four hours after the accident. The basis for the interview was to allow the pilots to provide their recollection of the aircraft's descent and final approach while it was still fresh in their memory, and with minimal involvement by the investigators.

Arrangements were made to interview both pilots again, on a more structured basis, on 24 August 1999. On arrival, the commander was accompanied by members of the Hong Kong Aircrew Officers Association and one of their nominated lawyers, and declined to be interviewed except in the presence of one of these representatives. The interview was therefore deferred whilst this was being considered, and during which time, on or about 26 August 1999, the commander left Hong Kong. This action was taken without reference to the accident investigators or to his company. All further attempts to interview him have been frustrated. However, he did answer certain queries put to him by telefax on 4 September 1999, and later forwarded a prepared statement dated 2 February 2000 of his recollections of the final approach and landing. The content of the latter is not entirely consistent with some of the statements previously made either by himself or his co-pilot.

The co-pilot was further interviewed as planned on 24 August 1999, and again on 2 September 1999.

1.18.7. Wind Analysis and Flight Simulations

The weather conditions and operating parameters associated with the accident were replicated in full flight simulators in Taipei and Long Beach in an attempt to gain a better understanding of the pilot tasks and difficulties.

The simulations in Taipei involved the use of a China Airline's MD11 training simulator. As the simulator could not be programmed with variable windspeeds and gusts, the results of these simulations, during which successful landings could be achieved, were considered to be inconclusive.

Further simulations were therefore carried out in Boeing's (Long Beach Division) MD11 engineering development simulator, which is also used for crew training. The three-dimensional wind model used was the 2000 wind developed from the accident FDR data by Boeing performance engineers, verified by NTSB, and included both horizontal and vertical wind variations. Due to simulator programming limitations, it was not possible to replicate the varying gusts to which the aircraft would have been subjected in the final stages of its approach, and a standard training turbulence programme had to be utilised instead. The simulator FCC was initially loaded with the standard – 907 model FCC software used in the accident aircraft, and a series of approaches were flown by a number of Boeing and China Airline pilots, and by a HKCAD accident investigator type-qualified on the MD11. During these approaches, ability to flare the simulator below 50 ft using the technique recommended in the China Airlines Operations Manual and achieve a normal touchdown at a low rate of descent proved unsuccessful on the majority of approaches flown; if power was manually applied late in the flare, the rate of descent could be reduced but was still high at touchdown. By comparison, and although the crosswind exceeded the published limits for autolanding, successful autolandings could be completed but involved an exaggerated pitch up to nearly 10°, well beyond that which would normally be expected.

The China Airline's co-pilot involved in the accident observed the latter simulations. He subjectively assessed the simulated conditions as realistic, except that he recalled the turbulence level below about 150 ft as being greater on the accident approach than even the highest level which could be set in the simulator.

However, as stated at paragraph 1.18.4, during the review of the 2000 winds using processes that had been recently enhanced, Boeing identified that the sign convention for rudder deflection was inadvertently reversed when calculating sideslip angle. In addition, the calculation of the angle of attack parameter was revised. These changes affected the calculated horizontal winds and the previously derived vertical winds shown at A21-1 and A21-2.

As stated above, the winds used in Boeing's (Long Beach Division) simulator demonstration were based on the 2000 derived winds. However, as a result of the re-evaluation of the 2000 winds (paragraph 1.18.4), Boeing elected to complete a comparison between the 2000 winds and the 2003 winds using a desktop simulation and a simplified pilot model to control the landing task. Boeing confirmed that the pilot model was able to land the aircraft successfully. NTSB has verified the following table.

Case	**Descent Rate at Touchdown (ft/sec)**	**Normal Load Factor at Touchdown (g's)**
No wind	-5	1.4
Steady 25 kt Crosswind	-5	1.3
July 2000 Simulator Winds	-7	1.5
Corrected 2003 Winds	-10	1.9
Flight 642	Between -18 and -20	2.6

The table shows the descent rate and normal load factor at touchdown are higher for the accident wind cases than for zero wind or a steady 25 kt crosswind, indicating that the aircraft was harder to control under the accident wind conditions. Furthermore, the descent rate and normal load factor at touchdown are higher for the corrected 2003 winds case than for the 2000 winds case, suggesting that the landing task with the 2003 winds is more difficult than with the 2000 winds. Nonetheless, the descent rate at touchdown with the 2003 winds is about half that of the actual touchdown descent rate on the accident flight, and is still within the design parameters of the landing gear. [Federal Aviation Regulations (FARs) 25.473

requires a descent rate of 10 ft/sec to be used in the analysis of touchdown ground loads at the design landing weight.] Consequently, the simulations show that, even with the corrected 2003 winds, there does exist a set of flight control inputs that will land the aircraft safely, and that the weather conditions were not beyond the performance or control capabilities of the MD11. This is the same determination reached after the July 2000 simulator exercise. It will be noted from A21-6 (Segments 1 through 4) that the Boeing 2003 wind study verified by NTSB* indicates the following:

- From 55 ft RA (4½ seconds before impact) to 22 ft RA (2 seconds before impact) the Rate of Descent (ROD) of CI 642 varied between 1080 ft/min and 900 ft/min, reducing momentarily to 840 ft/min passing 35 ft RA. From 35 ft RA to 5ft RA the ROD progressively increased to 1200 ft/min with the elevator deflection changing from 8 degrees elevator down at 35 ft RA to 1 degree elevator up passing through 22 ft RA and increasing to 9 degrees elevator up at 5 ft RA. The time span between 22 ft RA and 5 ft RA was 1½ seconds.

- Commensurate with the aforementioned elevator movement, spoiler movement on the right wing varied between 10 degrees up and 25- 30 degrees up, with the majority of the latter figures being prevalent from 25 ft RA to impact.

* The NTSB reviewed and concurred with the theory and method used by Boeing to perform the 2003 wind calculations and desktop simulations, but did not attempt to duplicate the numerical results of these computations.

- From 55ft RA to impact the thrust levers were at idle, with the engine thrust reducing from 1.02 EPR to 1.0 EPR at 30 ft RA.

- The comparisons of 2000 winds and the 2003 winds are shown at A21-3, A21-4 and individual details of the 2003 winds are shown at A21-5 to A21-10.

1.18.8. MD11 landing accident – Newark International Airport, USA

On 31 July 1997, a MD11 freighter aircraft was involved in an accident with similar consequences when landing at Newark International Airport, New Jersey, USA. In that accident, which occurred in good weather conditions, the aircraft also suffered structural failure of the RMLG and right wing rear spar, and came to rest inverted.

The US National Transportation Safety Board (NTSB) investigation concluded that the probable cause of the accident was overcontrol of the aircraft during landing. This involved elevator deflections varying from 26º ANU to 18º AND, and resulted in an initial touchdown that become airborne again followed by a heavy second touchdown during which the structural failure occurred. The second touchdown was in a 9.5º right wing down attitude with a rate of descent at the RMLG calculated as 13.5 feet per second.

2. ANALYSIS

2.1. Scope

The combined wealth of eye witness reports, recorded data, crew interviews and wreckage analysis enabled a detailed reconstruction of the process which led to the accident. The reconstruction draws upon all the available evidence to define what happened and the order in which significant events occurred. The serviceability of the aircraft was not in question leading to the deduction that the causal factors were probably aspects of the weather, and the performance of the flight crew. Relevant aspects of the weather, the design of the aircraft, and the airport are identified and analysed before the human factors are examined in detail. Possible changes and additions to crew procedures and use of the aircraft systems are reviewed. Throughout the analysis, factors which may have contributed to the accident are identified and where applicable, safety recommendations are made. The analysis concludes with a list of the findings and a summary of the safety recommendations.

2.2. Reconstruction of the accident

2.2.1. Descent and intermediate approach

Flight CI642 appears to have been a routine operation until approaching top of descent into HKIA. The crew were aware of the proximity of STS ‘Sam’ to the airport and of its associated weather conditions. The commander had uplifted extra fuel prior to departure from Bangkok to allow himself operational flexibility in terms of either initiating an approach to land, holding, or diverting to one of several available alternate airports in the region. In consequence, the loadsheet estimated that the aircraft would only be 443 lbs (201 kg) below its MLW if a landing was attempted in Hong Kong, which would result in a relatively high approach speed. The commander was also monitoring the surface winds from the regular ATIS broadcasts for HKIA, and comparing these with the company's crosswind limits for the type. The crew were therefore well aware that an approach to land at HKIA would necessarily involve demanding and near limiting conditions.

Just after commencing descent, the commander commenced briefing for an approach to RW 25L but was interrupted by the co-pilot who was sure that the runway in use was 25R. This mistaken impression may have been due to the co-pilot hearing another aircraft ahead requesting an approach to RW 25R, which was later withdrawn because of a deterioration in visibility on that runway. After questioning this, the commander continued his briefing but now referred to RW 25R. Playback of the CVR indicates that the briefing was diminished by discussion, radio call interruptions and misunderstanding, and that the description of the approach procedure appeared to be only a recitation, with the attention of both pilots being focussed elsewhere. No mention was made of the warnings on successive ATIS broadcasts of severe turbulence and significant windshear, or of the commander's intentions in relation to such conditions, or his intentions if a landing could not be made other than a cursory reference to the published missed approach procedure.

As the arrival progressed, the crew continued with their mistaken impression of the runway in use. It was not until Hong Kong Approach, who had radar vectored the aircraft through the ILS localiser for RW 25L to the north for spacing, gave the aircraft a heading of 230° and cleared it for an ILS approach to 25L that the pilots realised their mistake. The commander later referred, briefly, to the minimums for an ILS approach to RW 25L and the relevant missed approach procedure. Relevant extracts from the CVR transcript are at Appendix 10.

While the late and sporadic crew briefings for the approach, including reference to the wrong runway, are not considered to have contributed directly to the accident, they do have human factors aspects which are further discussed at paragraph 2.7.2.1.

2.2.2. Final approach

With the autopilot and autothrottle systems engaged, the aircraft captured the ILS localiser beam and then the glide path. The approach continued relatively normally for the conditions, the autoflight system coping adequately with the gusty winds.

At approximately 13 nm on the approach, air traffic control passed the current surface wind as 330°/26 kt gusting 36 kt which the commander judged to be in excess of the crosswind limit, but continued the approach with the intention of rechecking the surface wind as the aircraft descended below 1,000 ft.

Because of the late realisation of which runway was in use and the fact that the missed approach procedure for runway 25L differs significantly from that of 25R, the commander then correctly reviewed the initial missed approach procedure altitude for runway 25L as ‘*2000*’. The co-pilot mistakenly interjected ‘*actually 4500*’, but then agreed with the commander’s insistence that the figure was ‘*2000 until 3 mile*’.

Prior to reaching 1,000 ft, ATC passed the current surface wind as 320°/25 kt gusting 33 kt, and cleared the aircraft to land. The commander elected to continue with the intention of requesting a final wind check below 1,000 ft.

At about 700 ft RA, visual contact with the approach lights was established and ATC passed a final surface wind check of 320°/28 kt gusting 36 kt, which indicated a small increase in the steady state speed and put the crosswind component at 26 kt, 2 kt in excess of the required limit. Shortly after this, the commander disconnected the autopilot to fly the aircraft manually but kept the autothrottle system engaged, in accordance with normal MD11 operating philosophy. The FDR indicates that the approach continued within reasonable tolerances, though control activity, particularly aileron, increased considerably by comparison to that with the autopilot engaged. The commander later confirmed that his windshield wiper was selected to the ‘FAST’ position at this stage and that visibility through the windshield was ‘moderate’.

The autothrottle controlled the speed adequately within a four or five kt tolerance either side of a mean speed of 165 kt until just below 300 ft RA when the indicated airspeed fell to 157 kt. The co-pilot called ‘*Speed*’ and claimed to have moved the thrust levers forward when there was no apparent response from the commander; however, in a later statement the commander claimed that he had moved the thrust levers forward. The thrust then increased significantly from a previous average of 1.05 EPR to almost 1.3 EPR, with a consequential increase in speed to 175 kt. In response to this excessive speed the thrust levers were at the fully closed position by about 70 ft RA, and the thrust decayed to an average of 1.0 EPR by 50 ft RA (the altitude at which the autothrottle would normally commence thrust lever retard), and to idle thrust by 35 ft AGL. The commander used the basic crosswind approach technique described in the MD11 SOP Part 2 page 4. Runway alignment was maintained by crabbing into wind until approximately 130 ft RA. After this point, the aircraft’s heading was progressively aligned with the runway direction of 253°, which was achieved by 50 ft RA, and sideslip used as recommended to maintain runway alignment. The commander’s crosswind approach technique is therefore not considered to be contributory to the accident.

Under *'Landing Techniques'*, the MD11 SOP states at Part 1 page 117 that:

'The recommended landing procedure for the MD11 calls for reducing the sink rate at approximately 30 feet radio altitude. Only a 2° attitude change is required to reduce (but not stop) the rate of descent. As this attitude is being held, power should be slowly reduced'.

On the actual approach, the attempt made to flare the aircraft after it passed 50 ft RA, with thrust levers already retarded and descending increasingly below the GP from its previous one dot low perspective, was not effective. This involved an initial up elevator input of 12º at about 45 ft RA, immediately followed by a reversal to 8.5º down, which only succeeded in achieving a momentary increase in pitch attitude from about 3.5º ANU to 4.2º, then returning to 3.2º. As the aircraft passed 21 ft RA, up elevator was again applied, reaching almost 16º immediately before touchdown. While this did increase the pitch attitude to 4.5º ANU, it did not succeed in reducing the high rate of descent, which was calculated to be approximately 18 feet per second at the RMLG as it impacted the runway. This continuing high rate of descent is evident from playback of the CVR tape recording, which does not indicate any slowing in the cadence of the CAWS readouts of *'50/40/30/20/10'* as would normally occur in the flare.

While the first attempt to flare the aircraft may have been slightly early, and may have led to some minor overcontrol in pitch, this could have been prompted by the gusting, turbulent conditions which prevailed. The aircraft's loss of 20 kt indicated airspeed below 50 ft RA, consequent upon a loss of headwind component due to the varying wind conditions and the early retardation of the thrust levers, would have resulted in a significant decrease in lift at a critical stage of the approach; this could only be compensated for by a marked increase in pitch attitude (as was demonstrated in the flight simulations described in paragraph 1.18.7) or by an increase in thrust, or a combination of both. In the event, the commander's attempt to flare the aircraft by limited use of elevator alone, and without the application of thrust, was inadequate and proved unsuccessful in the conditions with which he was contending. Not only was the recommended change in pitch attitude of 2° not achieved and then held, but the flight simulations described in paragraph 1.18.7 indicated that a much greater change would have been required to successfully flare the aircraft from its increasingly high rate of descent.

It was therefore recommended to China Airlines that, in association with the Boeing Company, they amend the recommended landing procedures in the MD11 SOP to include procedures for approaches and landings in more demanding weather conditions.

2.2.3. The landing and after landing

The first tyre marks identified as possibly having been made by CI642 were from the right main gear impacting at about 140m (460 ft) from the RW 25L threshold, and some 11m (35 ft) to the right of the runway centre line. This was followed by the body gear apparently impacting about 180m (600 ft) from the threshold but only 1.5m (4-5 ft) right of the centre line, and later a scrape mark, thought to be from the no. 3 engine nacelle, commencing some 285m (940 ft) from the threshold and 14m (40 ft) right of the centre line. These indications tally with FDR data and eye witness accounts to confirm that the aircraft was well aligned for landing although slightly right wing low, but touched down considerably short of the normal aiming point, the marking for which is 400 m (1,312 ft) from the threshold. The scrape mark curved gently off to the right and indicated that the aircraft left the runway some 820 m (2,700 ft) from the threshold. It was during this period when the aircraft was in the process of departing the runway that, at the preliminary interview, the co-pilot stated that he called '*go-around*' but the commander thought that *'on the ground we are heading towards the grass and if I do have full power something worse may happen'*. The CVR does not record the co-pilot's call of *'go-around'* or if the commander responded verbally, but power interruption to the CVR may already have occurred.

After the aircraft rolled, yawed and came to rest inverted, the commander stated that he saw fire and attempted to do some emergency procedures; however, he had difficulty in locating the fire handle but turned off the engine fuel switches before vacating the cockpit. He made no reference to altering his windshield wiper control, which was later found in the 'OFF' position with the control circuit breaker tripped. As the wiper arm was found in an unparked position after the accident, and all system components subsequently tested satisfactorily, no conclusions can be drawn that would substantiate the positions of the commander's windshield wiper control and circuit breaker as referred to above.

2.3. Aircraft serviceability

The aircraft was dispatched from Bangkok with only one deferred item in the Technical Log. This item related to peeling of paint from the right winglet, and was not significant in the context of the accident.

The wealth of recorded data, coupled with the absence of any reported handling problem during the approach prior to entering the flare, established beyond all reasonable doubt that the aircraft controls were responding as designed to demands made by the commander.

Therefore, the serviceability of the aircraft was not considered to be a contributory factor to this accident.

2.4. Weather

2.4.1. Relevance

The weather conditions associated with STS 'Sam', which have been comprehensively detailed in paragraph 1.7 and the associated annexes, made approaches to HKIA difficult during the afternoon and early evening of 22 August 1999. Strong crosswinds, lateral gusts, severe turbulence, possible windshear and heavy rain all added to operating flight crew workload. In consequence, of 26 approaches flown in the period of three and three-quarter hours up to the accident, 10 resulted in go-arounds as a result of the weather conditions. Analysis of the prevalent weather conditions is therefore appropriate to establish the possible contribution of these factors to the accident.

2.4.2. Cloud base

ATIS information 'X-ray', current at the time of the accident, gave the cloud base as FEW at 1,000 ft and SCT ('scattered') at 1,600 ft. By comparison, the ceilometer located near the centre of the airport recorded the cloud base as fluctuating between 781 and 2,281 ft in the two minutes before the accident. The co-pilot advised *'approach light ahead'* to the commander just after the CAWS call at 1,000 ft and later advised ATC *'runway in sight around 700 ft'*. Hence, the cloud base was not a contributory factor in this accident.

2.4.3. Rain and visibility

ATIS information ‘X-ray’ gave a visibility of 800 m in heavy rain and a touchdown zone RVR of 650 m for RW 25L; however, a later touchdown zone RVR of 1,600 m was passed by ATC to the crew at 1041 hr with their landing clearance, some two minutes before the accident. Braking action was reported as good. The rain gauge situated near the centre of HKIA recorded 0.1 mm of rainfall in the five minutes before the accident, which the HKO has categorised as ‘*light to moderate*’. Sunset was due at 1050 hr.

The commander, in answer to a written query, gave his assessment of visibility through his windshield on final approach as ‘*moderate*’. Despite that assessment, it is possible that the impending sunset, overcast conditions, and rainwater on the windshields outside the sweep of the windshield wipers and on the unswept sidewindows, may have affected his peripheral vision; this may have resulted in him not appreciating the aircraft’s high rate of descent as it passed the normal flare height.

Therefore, visibility from the flight deck may have been a contributory factor to the accident.

2.4.4. Wind conditions

All the forecast and actual weather reports available to the commander, including those available on the ATIS broadcast, and the surface wind read by ATC from the RW 25L touchdown anemometer some 40 seconds before the accident, should have left the commander in no doubt as to the general conditions to expect on final approach - a strong gusting northwesterly crosswind on the company limit for a wet runway, severe turbulence and the possibility of windshear. Indeed, the commander of the B777 aircraft which landed successfully four minutes before the accident aircraft stated, in a later written report, that he was *'well aware of the shear effect that the aircraft would encounter in the final critical stage of landing'*.

Comparison of surface wind records from the four TDZ anenometers taken over the period encompassing the time of the accident, demonstrates a differing variation in wind speed and direction between the anemometer located at 25L TDZ and the other three TDZ anemometers (A5-3).

Unfortunately, the lack of QAR data meant that the actual winds experienced by CI642 on its final approach were not readily available to the investigators as described in paragraph 1.18.4. However in accordance with the Boeing study (paragraph 1.18.7), the net effect on CI642 was that the aircraft apparently suffered a loss of 20 kt airspeed but only 6 kt groundspeed in the last 50 ft of its approach. Whereas part of this loss may be attributable to early retardation of the thrust levers (see paragraph 2.2.2), part of the loss in the airspeed case could also be attributed to a loss of headwind component in the varying wind conditions.

Therefore, the variations in wind conditions experienced by CI642 on its final approach were a probable contributory factor to the accident.

With reference to Northwesterly through Northeasterly winds (see paragraph 1.7.10) it was considered that more information should be provided in the AIP regarding the presence of windshear and turbulence affecting the approaches and the TDZ areas for RW 25L and RW 25R during periods of STS.

It is therefore recommended that the HKO should provide CAD with more advisory meteorological information for inclusion in the AIP Section VHHH AD 2.23 paragraph 1.3.2.

2.5. Hong Kong International Airport

There were two aspects of the existing infrastructure at HKIA that are considered to be worthy of comment. These arise from examination of the surface wind velocities recorded by the RW 25R and 25L touchdown anemometers, as discussed in paragraph 2.4.4, and involve the location of the PTB in relation to the touchdown areas of the two runways referred to, and the unique location of the RW 25L touchdown anemometer.

2.5.1. Location of Passenger Terminal Building

HKIA is a comparatively new airport, having been opened in July 1998, and was designed to comply with all aspects of ICAO standards or guidelines. In particular, the proximity of buildings to active runways does meet the standards required by ICAO Annex 14.

It is also common knowledge that high terrain or man-made structures at certain major airports do cause local variations in certain wind conditions, and that these can affect aircraft on final approach or immediately after take off, but are within the control capabilities of modern public transport aircraft.

Despite the variations noted in paragraph 2.4.4 between readings from the RW 25R and 25L touchdown anemometers, and also in those extracted from the previous landing aircraft's QAR and that derived from CI642's FDR, the last windshear warning from the airport's WTWS for a RW 25L arrival occurred at 1016 hr, some 27 minutes before the accident. While this may have resulted from the equipment assessing any subsequent windshears as not exceeding its 15 kt design trigger point, both the previous landing aircraft and CI642 did experience some windshear as they entered the flare.

2.5.2. Location of Runway 25L touchdown anemometer

The location of the RW 25L touchdown anemometer, while unique compared with the other five anemometers located on the airport (see paragraph 1.7.7), does meet the guidelines contained in ICAO Document 8896.

2.6. Flight crew procedures

The remainder of the analysis examines flight crew procedures in respect of approach briefing, calculation of final approach speed and control of power on the approach.

2.6.1. The approach briefing

'Crew Briefing' is the fifth item in the 'Preparation for Descent Procedure' detailed at page NORM-10-33 of China Airlines MD11 FCOM Volume II. However, the briefing was not initiated until just after descent was commenced, and therefore due to increasing workload, arising from a combination of factors including observance of descent constraints, radio communications and weather avoidance, the briefing became disjointed, inaccurate and incomplete.

Of the items listed in the 'Flight Crew Before L/D Briefing' at page 94 of the MD11 SOP (a plasticised version of which was carried on the aircraft's flight deck), those referring to alternate airport, transition level, MSA (i.e. minimum safe altitude), field elevation, and aircraft go-around procedure (as opposed to the ATC missed approach procedure) were not included in the briefing, although some or all could have been of significance on the subsequent approach.

In the event, the inadequate approach briefing did not make a direct contribution to the accident, but did reflect negatively on the commander's attitude towards cockpit resource management.

Extracts from the quoted manuals showing the 'Preparation for Descent Procedure' and 'Flight Crew Before L/D Briefing' are at

Appendix 22.

2.6.2. Calculation of the final approach speed

The landing reference speed (Vref), provided by the aircraft's flight management system computer, is determined from the aircraft's weight on landing as predicted by the computer and the crew-entered landing flap setting. This function should be completed as part of the 'Preparation for Descent Procedure' detailed in the MD11 SOP, and provides a basic reference speed to which additives must be made. In this instance, the commander determined that the final approach speed should be 170 kt.

2.6.3. Control of power on the approach

The commander of CI642 elected to retain the use of the ATS throughout the approach. In consequence, as a response to the increase in speed to 175 kt at about 120 ft, the ATS had begun to retard the thrust, the throttles reaching the idle position by about 70 ft, so that the aircraft entered the flare with the power already at, or near, flight idle.

Therefore, the commander of CI642's failure to override the autothrottle system and apply power was a contributory factor to the aircraft's high rate of descent at touchdown, and therefore to the accident.

2.7. Cockpit resource management

2.7.1. Training requirement

China Airlines has a formal training requirement in Cockpit Resource Management (CRM) for all its flight deck crew. Both pilots had completed annual CRM training in the month preceding the accident.

2.7.2. CRM aspects of the approach

There were three aspects of crew performance prior to or during the approach which, although not bearing directly on the accident, do require comment. These were the delay in completing the approach briefing, the co-pilot's provision of incorrect information to the commander during the approach, and the control of power on the approach.

2.7.2.1. Delayed approach briefing

While some procedural aspects of the delayed approach briefing have already been discussed in paragraph 2.6.1, there are other more philosophical aspects which impinge on good CRM practice.

Thorough planning and briefing is the key to a safe, unhurried, professional approach, as is well emphasised in the China Airlines Flight Crew Training Manual for another of their aircraft types (B747-400). It is normal airline practice to complete the approach briefing late in the cruise phase of flight but at a suitable time prior to the descent, when crew activity is at a comparatively low level. Delaying the briefing into what might become a very busy descent, as did the commander of CI642, negates the aims as stated in the B747-400 manual, and puts undue pressure on the crew members prior to commencing what might well be a very demanding approach, as proved to be the case for CI642. It is therefore recommended that China Airlines reminds its MD11 pilots of the need for an early, complete approach briefing, and emphasises the rationale for this in both its CRM training and in the MD11 SOP.

2.7.2.2. Monitoring by the co-pilot

Perhaps as a result of his recent completion of company CRM training, when the need for good monitoring by the pilot-not-flying (PNF) would have been emphasised, there were two occasions during the approach when incorrect prompting by the co-pilot led the commander into actions which needlessly added pressure to the latter in his role both as handling pilot and aircraft commander.

The first occasion occurred when the co-pilot, who had just copied ATIS information 'X-ray' which included the runway in use as RW 25L, advised the commander, who had commenced briefing for an approach to RW 25L, that the runway in use was RW 25R. This led the commander to unnecessarily change the briefing for an approach to RW 25R. This mistaken impression was maintained for some 15 minutes of the descent and intermediate approach, and was only corrected when ATC radar vectored the aircraft for an ILS approach to RW 25L, and led to another hasty re-brief.

The second occasion was at about 2,000 ft on the approach when the commander queried if the co-pilot was ready for a go-around and correctly quoted the initial go-around altitude as '*2000*'. To this the co-pilot interjected '*actually 4500*', but the commander insisted, correctly, '*2000 until 3 mile*', with which the co-pilot then concurred. Such an unnecessary distraction at a late stage of the approach, while comparatively minor itself, detracts from the aim of a well coordinated crew performance. These interjections by the co-pilot, coming so soon after he had completed CRM training, may have arisen from a misplaced interpretation of the role of the monitoring pilot.

It is therefore recommended that China Airlines reviews the content of its CRM training course to ensure that contributions made by the monitoring pilot, in operational situations, are both accurate and appropriate.

In addition, it may be construed from the CVR that, after the copilot's call with regard to the decreasing indicated air speed (IAS) (at approximately 250 ft above the ground), his attention became fixed outside the cockpit. Certainly, the high rate of descent which was developing near the ground, coupled with the rapidly-decaying air speed, were not perceived by either pilot, either by sensory perception or by instrument indication.

It is further recommended therefore that China Airlines re-emphasise to flight crews the need, on instrument approaches, to continue to monitor the flight instruments as prescribed in the China Airlines Flight Operations Manual (FOM).

2.7.2.3. Use of the autothrottle system

The potentially confusing references in China Airline's operating manuals to use of the autothrottle system have been discussed in paragraph 2.6.3. In view of the significance of engine power in this accident, there would appear to be a need to address not only these confusing references, but also what may have become over-reliance by pilots on an automated system.

The autothrottle system in the MD11 is a ‘full-time’ system capable of automatically controlling a variety of parameters of the flight’s progress from the initiation of the take-off roll until 50 ft RA on final approach, after which it remains armed but normally inactive unless the ‘go-around’ switch is pressed to discontinue an approach. The pilot may disconnect the system by simply pressing a button on the outside of no. 1 or no. 3 thrust lever, or by selecting reverse thrust after landing. He may also intervene and adjust the thrust temporarily in flight by manually moving the thrust levers.

Whilst the operations manuals are not explicit regarding use of the autothrottle system, full time use of the system is known to have been encouraged by the manufacturer in operation of MD11 aircraft, and also in that of its predecessor, the DC 10. As in other areas of automation on the flight deck, this may encourage over-reliance on the automated system, to the point where the pilot may no longer be aware of the need to intervene when the system is either not coping with the operating conditions affecting the aircraft, or the operational situation is outside the system’s design parameters. One of the pilots did intervene by advancing the thrust levers when the speed fell to 157 kt just below 250 ft; however, more critically, the commander did not react to override the early retardation of the thrust levers and apply thrust to counteract the increasing rate of descent in the flare, as the commander of the previously landing aircraft did.

It is therefore recommended that China Airlines should review its MD11 training syllabuses to ensure that the crew monitor the automated systems on the flight deck, so as to be ready to intervene, or override manually, whenever necessary.

3. CONCLUSIONS

3.1. Findings

3.1.1. Both pilots met the required regulatory licensing and checking requirements to operate the flight.

3.1.2. The aircraft was properly maintained and serviceable to operate the flight.

3.1.3. The weather conditions encountered by CI642 were similar to the forecasts and observations available to the crew.

3.1.4. ATIS information X-ray at time one zero zero six referred to the runway in use as being runway two five left and that runway two five right was available on request. It further advised that the pilot could expect significant windshear and severe turbulence on approach and departure.

3.1.5. The reported visibility/RVR during the approach and landing met China Airlines' approach minima.

3.1.6. For more than an hour before the accident, the WTWS had been issuing turbulence alerts almost continuously for RW25L arrival. Between 1005 to 1016 hrs, the turbulence alerts were overridden intermittently by windshear alerts. After 1017 hrs, the WTWS issued turbulence alerts which remained effective up to the time of the accident and beyond. No windshear alerts were issued by WTWS during this period.

3.1.7. The descent clearance was given to CI642 at 1014. Shortly after commencing descent at 1017, the commander commenced the approach briefing for the wrong runway. No mention was made of the warnings of severe turbulence or significant windshear, or that the ATIS reported that RW 25R was available. This briefing given by the commander did not meet the China Airlines Operations Manual requirements in respect of either timing or content.

3.1.8. The co-pilot twice provided incorrect information to the commander during the descent and approach.

3.1.9. The approach was de-stabilised at about 250 ft by an excessive application of power, which increased the indicated airspeed to 175 kt, 15 kt above the correct final approach speed.

3.1.10. The commander used the crosswind landing approach technique recommended in the MD11 SOP, and had the aircraft correctly aligned in azimuth as it approached the flare.

3.1.11. The thrust levers began to retard towards the idle stop at 135 ft RA, reaching that position by 70 ft. Consequently, the thrust progressively reduced to flight idle by 35 ft where it remained to touchdown.

3.1.12. During the last thirteen seconds of flight, from approximately 150 ft RA, to touchdown, the aircraft's rate of descent varied between 1,200 ft/min and 240 ft/min. At 30 ft it was approximately 770 ft/min and progressively increased to 1,080 ft/min at touchdown.

3.1.13. Visibility from the flight deck may have contributed to the commander's failure to appreciate the increasing rate of descent prior to touchdown.

3.1.14. Neither pilot perceived the increasing rate of descent and decreasing indicated airspeed as the aircraft approached the landing flare.

3.1.15. The commander's attempt to flare the aircraft by initiating a small increase in pitch attitude, as prescribed in the MD11 Standard Operation Procedure (SOP) Manual was in the circumstances ineffective.

3.1.16. The maximum allowable landing weight for MD11, Registration B-150, was 430,000 lbs (195,454 kg). The estimated landing weight for CI642 at the time of the accident was 429,557 lbs

(195,253 kg), therefore the aircraft approached the flare only 443 lb (201 kg) below maximum landing weight, with the thrust levers already fully retarded which, in combination with a probable loss of headwind component, led to a loss of airspeed of 20 kt and an increasing rate of descent which reached approximately 18 feet per second at touchdown.

3.1.17. QAR information relating to the final 500 feet of the approach was lost due to the interruption of the power supply at impact, which caused loss of data in the volatile buffer storage.

3.1.18. At the time of the accident, the anemometer at the touchdown zone of RW25R had recorded wind speeds and direction over a period of time, which remained relatively constant. However, over the same period of time, the wind speeds and direction recorded at RW25L showed periodic variations which on occasions were significant.

3.1.19. The aircraft touched down slightly right wing low (3.5-4°) on its right main landing gear at a rate of descent calculated as approximately 18 feet per second, well beyond the design structural limit of 12 feet per second.

3.1.20. The energy transmitted into the right main landing gear at touchdown exceeded the MD11's maximum certificated landing energy and was sufficient to fully compress (bottom) the right main landing gear strut exceeding the entire design margin, and to cause structural failure of the forward trunnion bolt and rear spar shear web.

3.1.21. The structural failure of the right wing rear spar resulted in the rupture of the right wing fuel tanks and subsequent fire.

3.1.22. The aircraft suffered extensive structural damage during its rolling and yawing movement following detachment of the right wing.

3.1.23. Subsequent tests and analysis indicated that the failures in the aircraft's structure were due to ductile overload and not to causes other than the accident.

3.1.24. Rescue services were on the scene within about one minute and immediately commenced fire-fighting and then rescue operations.

3.1.25. Passengers were evacuated through doors L3 and R1 and through a hole in the aircraft skin aft of door L2, and later through doors R2 and R4.

3.1.26. Some 200 passengers were rescued and led to safety within 8 minutes of the arrival at the scene of the rescue services. The remaining passengers left the aircraft in the early stages of the evacuation either unassisted or assisted by other passengers or crew members.

3.1.27. Two passengers died in the accident and one later in hospital, while 50 passengers and crewmembers received serious injuries and 153 received minor injuries.

3.1.28. Some passengers reported that there were not enough temporary shelters available, and that they had to stand in the open in heavy rain for 20 to 30 minutes.

3.2. Causal factors

3.2.1. The cause of the accident was the commander's inability to arrest the high rate of descent existing at 50 ft RA.

3.2.2. Probable contributory causes to the high rate of descent were:

(i) The commander's failure to appreciate the combination of a reducing airspeed, increasing rate of descent, and with the thrust decreasing to flight idle.

(ii) The commander's failure to apply power to counteract the high rate of descent prior to touchdown.

(iii) Probable variations in wind direction and speed below 50 ft RA may have resulted in a momentary loss of headwind component and, in combination with the early retardation of the thrust levers, and at a weight only just below the maximum landing weight, led to a 20 kt loss in indicated airspeed just prior to touchdown.

3.2.3. A possible contributory cause may have been a reduction in peripheral vision as the aircraft entered the area of the landing flare, resulting in the commander not appreciating the high rate of descent prior to touchdown.

4. RECOMMENDATIONS

As a result of the investigations, the following recommendations are made:

4.1. China Airlines should remind its MD11 pilots of the need for an early and complete approach briefing (paragraph 2.7.2.1).

4.2. China Airlines should review the content of its CRM training course to ensure that contributions made by the monitoring pilot, in operational situations, are both accurate and appropriate (paragraph 2.7.2.2).

4.3. China Airlines should review its MD11 training syllabuses to ensure the crew monitor the automated systems on the flight deck, so as to be ready to intervene, or override manually, whenever necessary (paragraph 2.7.2.3).

4.4. China Airlines should consider the introduction of a 'Flight Instructor Guide' of a type used by other MD11 operators and which includes advice to training staff on techniques to be followed during crosswind landings (paragraph 1.18.1).

4.5. China Airlines should, in association with the Boeing Company, amend the recommended landing procedures in the MD11 SOP to include procedures for approaches and landings in more demanding weather conditions (paragraph 2.2.2).

4.6. China Airlines should ensure that crosswind landing limitations noted in its publications are consistent throughout (paragraph 1.18.1).

4.7. China Airlines should re-emphasise to flight crews the need on instrument approaches, to continue to monitor the flight instruments in the final stages of the approach as prescribed in the China Airlines Flight Operations Manual (FOM) (paragraph 2.7.2.2).

4.8. The Boeing Company and the equipment vendor should conduct a study to examine methods for preventing the loss of QAR data in the event the equipment is switched off in a non standard way such as by an interruption to the power supply (paragraphs 1.11.4/1.18.4).

4.9. CAD should give consideration to the installation of equipment, such as video recorders, to monitor the touch down zones of Runways 25 R/L and 07 R/L (paragraph 1.18.5).

4.10. With reference to local wind effects, HKO should provide information regarding the character of airflow in the vicinity of the TDZ of RW 25L and RW 25R in conditions of severe tropical storms and, in particular, when the wind directions are between northwest, through north, to south with the purpose of providing the CAD with further advisory meteorological information to be included in the Hong Kong AIP (paragraph 2.4.4 and 2.5.1).

These recommendations are addressed to the regulatory authority or concerned party, having responsibility for the matters with which the particular recommendation is concerned. It is for that authority or party, to decide whether and what action is taken.

ACKNOWLEDGEMENT

The invaluable contributions of the Aviation Safety Council, Air Accident Investigation Branch (UK), the National Transportation Safety Board (USA) and The Boeing Commercial Airplane Group, Long Beach are gratefully acknowledged.

Y.K. LEUNG

Inspector of Accidents

Accident Investigation Division

Civil Aviation Department

Hong Kong Special Administrative Region

China

ATIS

\# to be included when appropriate
* Tick or delete as appropriate.

ATMD – 7 (Revised 6/99)

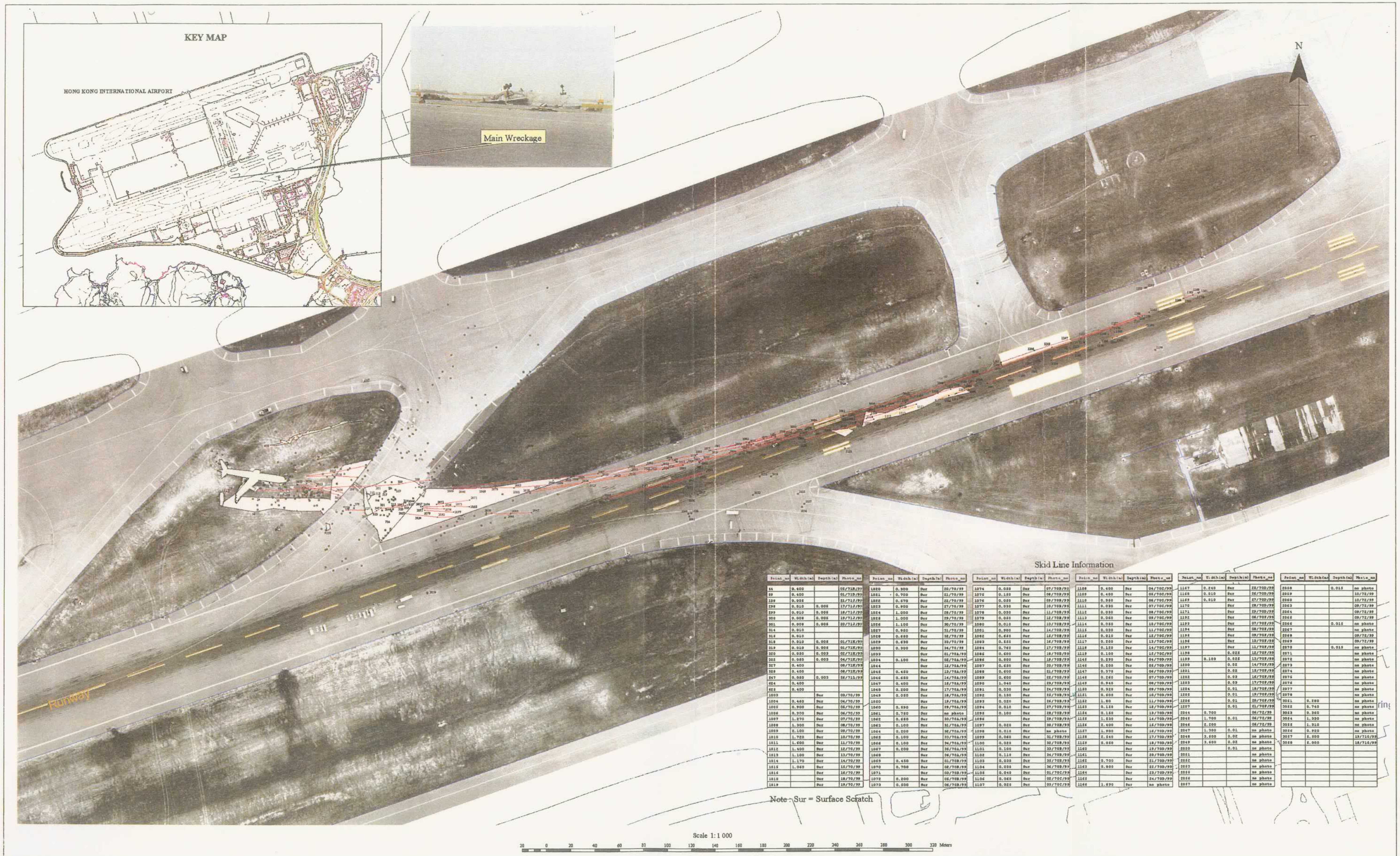
1. Hong Kong International Airport Information W at time 0940
2. Runway in use : ☑ 25L RWY 25R AVBL ON REQ
   ☐ ______ for Arrival, ______ for Departure
3. Expect : (type of Approach/Departure)*
   ☑ ILS-DME Approach
   ☐ LLZ-DME Approach
   ☐ Others ______ (specify)
   ☐ Arriving cargo flights expect RWY 07R/25L* ILS-DME/LLZ-DME Approach*
4. Significant runway surface conditions, NAVAIDS status and other essential information*#
   ☑ Runway surface wet / ~~damp~~
   ☐ Others BRAKING ACTION REPORTED AS GOOD ______ (specify)
5. Surface Wind Degrees 320 Knots 30 MAX 45 kts
   Maximum/Gusts Degrees ______ Knots ______
6. Visibility 1400 ~~Km~~/m* IN RVR 07L / 25R* ______ m#
   07R / 25L* ______ m#
7. Present weather#*
   ☐ Thunderstorm/Heavy Rain/Rain/Light Rain/Drizzle/Passing Showers/Fog/Haze/
   Others ______ (specify)
8. Cloud below 5000ft AMSL FEW 1000 SCT 1600
9. Surface wind/visibility/cloud base changing rapidly due ______
10. Temperature 25 Dew point 24 QNH 986 hPa
11. Significant Met. phenomena in approach, take-off & climb-out areas*#
    ☑ Expect significant wind shear/~~moderate~~/severe turbulence/~~in vicinity of CB~~ on APP/DEP
    ☐ Others ______ (specify)
12. Trend-type landing forecast TEMPO VIS 1000 M
13. Acknowledge information W on freq. 119.1/119.35* for Arrival & 129.9/124.65/122.55* for Departure

ATIS

\# to be included when appropriate
* Tick or delete as appropriate

ATMD – 7 (Revised 6/99)

1. Hong Kong International Airport Information X at time 1006
2. Runway in use : ☑ 25L RWY 25R AVBL ON RQ
   ☐ ______ for Arrival, ______ for Departure
3. Expect : (type of Approach/Departure)*
   - ☑ ILS-DME Approach
   - ☐ LLZ-DME Approach
   - ☐ Others ______ (specify)
   - ☐ Arriving cargo flights expect RWY 07R/25L* ILS-DME/LLZ-DME Approach*
4. Significant runway surface conditions, NAVAIDS status and other essential information*#
   - ☑ Runway surface (wet)/ ~~damp~~*
   - ☐ Others BRAKING ACTION REPORTED AS GOOD ______ (specify)
5. Surface Wind Degrees 300 Knots 35
   Maximum/Gusts Degrees ______ Knots ______
6. Visibility 800 ~~Km~~/m* IN (RVR) ~~07L/25R~~* ______ m#
   ~~07R~~/(25L)* 650 m#
7. Present weather*#
   - ☐ Thunderstorm/(Heavy Rain)/Rain/Light Rain/Drizzle/Passing Showers/Fog/Haze/
     Others ______ (specify)
8. Cloud below 5000ft AMSL FEW 1000 SCT 1600
9. Surface wind/visibility/cloud base changing rapidly due ______
10. Temperature 25 Dew point 24 QNH 986 hPa
11. Significant Met. phenomena in approach, take-off & climb-out areas*#
    - ☑ Expect significant wind shear/~~moderate~~/severe turbulence/~~in vicinity of CB~~ on APP/DEP
    - ☐ Others ______ (specify)
12. Trend-type landing forecast ______
13. Acknowledge information X on freq. 119.1/(119.35)* for Arrival & (129.9)/124.65/122.55* for Departure



Skid Line Information

Point_no	Width(m)	Depth(m)	Photo_no
44	0.400		05/71B/99
89	0.400		01/71D/99
108	0.005		21/71J/99
298	0.010	0.005	17/71J/99
299	0.010	0.005	18/71J/99
300	0.008	0.005	19/71J/99
301	0.008	0.005	20/71J/99
314	0.010		
315	0.010		
318	0.010	0.005	01/71K/99
319	0.010	0.005	01/71K/99
320	0.050	0.003	02/71K/99
322	0.080	0.003	04/71K/99
327	0.400		08/71K/99
328	0.400		08/71K/99
547	0.050	0.003	26/71L/99
624	0.400		
625	0.400		
1003		Sur	03/70/99
1004	0.460	Sur	04/70/99
1005	0.900	Sur	05/70/99
1006	0.900	Sur	06/70/99
1007	1.270	Sur	07/70/99
1008	1.300	Sur	08/70/99
1009	2.100	Sur	09/70/99
1010	1.720	Sur	10/70/99
1011	1.600	Sur	11/70/99
1012	1.400	Sur	12/70/99
1013	1.100	Sur	13/70/99
1014	1.170	Sur	14/70/99
1015	1.060	Sur	15/70/99
1016		Sur	16/70/99
1018		Sur	18/70/99
1019		Sur	19/70/99

Point_no	Width(m)	Depth(m)	Photo_no
1020	0.300	Sur	20/70/99
1021	0.700	Sur	21/70/99
1022	0.570	Sur	22/70/99
1023	0.900	Sur	27/70/99
1024	1.000	Sur	28/70/99
1025	1.000	Sur	29/70/99
1026	1.100	Sur	30/70/99
1027	0.950	Sur	31/70/99
1028	0.650	Sur	32/70/99
1029	0.630	Sur	33/70/99
1030	0.300	Sur	34/70/99
1033		Sur	01/70A/99
1034	0.100	Sur	02/70A/99
1044		Sur	12/70A/99
1045	0.450	Sur	13/70A/99
1046	0.650	Sur	14/70A/99
1047	0.400	Sur	15/70A/99
1048	0.200	Sur	17/70A/99
1049	0.050	Sur	18/70A/99
1050		Sur	19/70A/99
1060	0.590	Sur	29/70A/99
1061	0.750	Sur	no photo
1062	0.650	Sur	30/70A/99
1063	0.100	Sur	31/70A/99
1064	0.200	Sur	32/70A/99
1065	0.100	Sur	33/70A/99
1066	0.100	Sur	34/70A/99
1067	0.200	Sur	35/70A/99
1068		Sur	36/70A/99
1069	0.450	Sur	01/70B/99
1070	0.700	Sur	02/70B/99
1071		Sur	03/70B/99
1072	0.200	Sur	05/70B/99
1073	0.500	Sur	06/70B/99

Point_no	Width(m)	Depth(m)	Photo_no
1074	0.050	Sur	07/70B/99
1075	0.150	Sur	08/70B/99
1076	0.050	Sur	09/70B/99
1077	0.030	Sur	10/70B/99
1078	0.030	Sur	11/70B/99
1079	0.050	Sur	12/70B/99
1080	0.010	Sur	13/70B/99
1081	0.900	Sur	14/70B/99
1082	0.680	Sur	15/70B/99
1083	0.550	Sur	16/70B/99
1084	0.760	Sur	17/70B/99
1085	0.600	Sur	18/70B/99
1086	0.800	Sur	19/70B/99
1087	0.650	Sur	20/70B/99
1088	0.600	Sur	21/70B/99
1089	0.600	Sur	22/70B/99
1090	1.040	Sur	23/70B/99
1091	0.030	Sur	24/70B/99
1092	0.130	Sur	25/70B/99
1093	0.020	Sur	26/70B/99
1094	0.010	Sur	27/70B/99
1095	0.100	Sur	28/70B/99
1096		Sur	29/70B/99
1097	0.020	Sur	30/70B/99
1098	0.010	Sur	no photo
1099	0.060	Sur	31/70B/99
1100	0.020	Sur	32/70B/99
1101	0.100	Sur	33/70B/99
1102	0.110	Sur	34/70B/99
1103	0.030	Sur	35/70B/99
1104	0.030	Sur	36/70B/99
1105	0.040	Sur	01/70C/99
1106	0.060	Sur	02/70C/99
1107	0.020	Sur	03/70C/99

Point_no	Width(m)	Depth(m)	Photo_no
1108	0.400	Sur	04/70C/99
1109	0.400	Sur	05/70C/99
1110	0.350	Sur	06/70C/99
1111	0.030	Sur	07/70C/99
1112	0.030	Sur	08/70C/99
1113	0.060	Sur	09/70C/99
1114	0.050	Sur	10/70C/99
1115	0.030	Sur	11/70C/99
1116	0.010	Sur	12/70C/99
1117	0.200	Sur	13/70C/99
1118	0.120	Sur	14/70C/99
1119	0.100	Sur	15/70C/99
1145	0.230	Sur	04/70D/99
1146	0.200	Sur	05/70D/99
1147	0.370	Sur	06/70D/99
1148	0.260	Sur	07/70D/99
1149	0.940	Sur	08/70D/99
1150	0.320	Sur	09/70D/99
1151	0.600	Sur	10/70D/99
1152	1.80	Sur	11/70D/99
1153	0.150	Sur	12/70D/99
1154	0.150	Sur	13/70D/99
1155	1.530	Sur	14/70D/99
1156	2.400	Sur	15/70D/99
1157	1.900	Sur	16/70D/99
1158	2.540	Sur	17/70D/99
1159	0.050	Sur	18/70D/99
1160		Sur	19/70D/99
1161		Sur	20/70D/99
1162	0.700	Sur	21/70D/99
1163	0.800	Sur	22/70D/99
1164		Sur	23/70D/99
1165		Sur	24/70D/99
1166	1.690	Sur	no photo

Point_no	Width(m)	Depth(m)	Photo_no
1167	0.240	Sur	25/70D/99
1168	0.010	Sur	26/70D/99
1169	0.010	Sur	27/70D/99
1170		Sur	28/70D/99
1171		Sur	29/70D/99
1192		Sur	06/70F/99
1193		Sur	07/70F/99
1194		Sur	08/70F/99
1195		Sur	09/70F/99
1196		Sur	10/70F/99
1197		Sur	11/70F/99
1198		0.025	12/70F/99
1199	0.100	0.025	13/70F/99
1200		0.02	14/70F/99
1201		0.02	15/70F/99
1202		0.03	16/70F/99
1203		0.03	17/70F/99
1204		0.01	18/70F/99
1205		0.01	19/70F/99
1206		0.01	20/70F/99
1207		0.01	21/70F/99
2044	0.700		06/72/99
2045	1.700	0.01	06/72/99
2046	2.200		06/72/99
2047	1.300	0.01	no photo
2048	3.800	0.02	no photo
2049	3.600	0.02	no photo
2050		0.01	no photo
2051			no photo
2052			no photo
2053			no photo
2055			no photo
2056			no photo
2057			no photo

Point_no	Width(m)	Depth(m)	Photo_no
2058		0.015	no photo
2059			10/72/99
2060			10/72/99
2063			09/72/99
2064			09/72/99
2065			09/72/99
2066		0.015	no photo
2067			no photo
2068			09/72/99
2069			09/72/99
2070		0.015	no photo
2071			no photo
2072			no photo
2073			no photo
2074			no photo
2075			no photo
2076			no photo
2077			no photo
2078			no photo
3051	0.280		no photo
3052	0.740		no photo
3053	0.360		no photo
3054	1.330		no photo
3055	1.310		no photo
3056	0.920		no photo
3057	5.500		19/710/99
3058	8.000		18/710/99

Note : Sur = Surface Scratch

Legend

Large Wreckage

Scattered Wreckage

Small Wreckage

Burn Mark

Skid Line

Point Number

Note:

Use the point number to locate the photograph taken on the ground of the features. The photographs are kept in the Annex to this plan.

Survey of the Aircraft Accident to McDonnell Douglas MD-11 at Hong Kong International Airport at Chek Lap Kok on 22 August 1999

Plan No.: M590-1

Geodetic Survey Section
Survey and Mapping Office
Lands Department

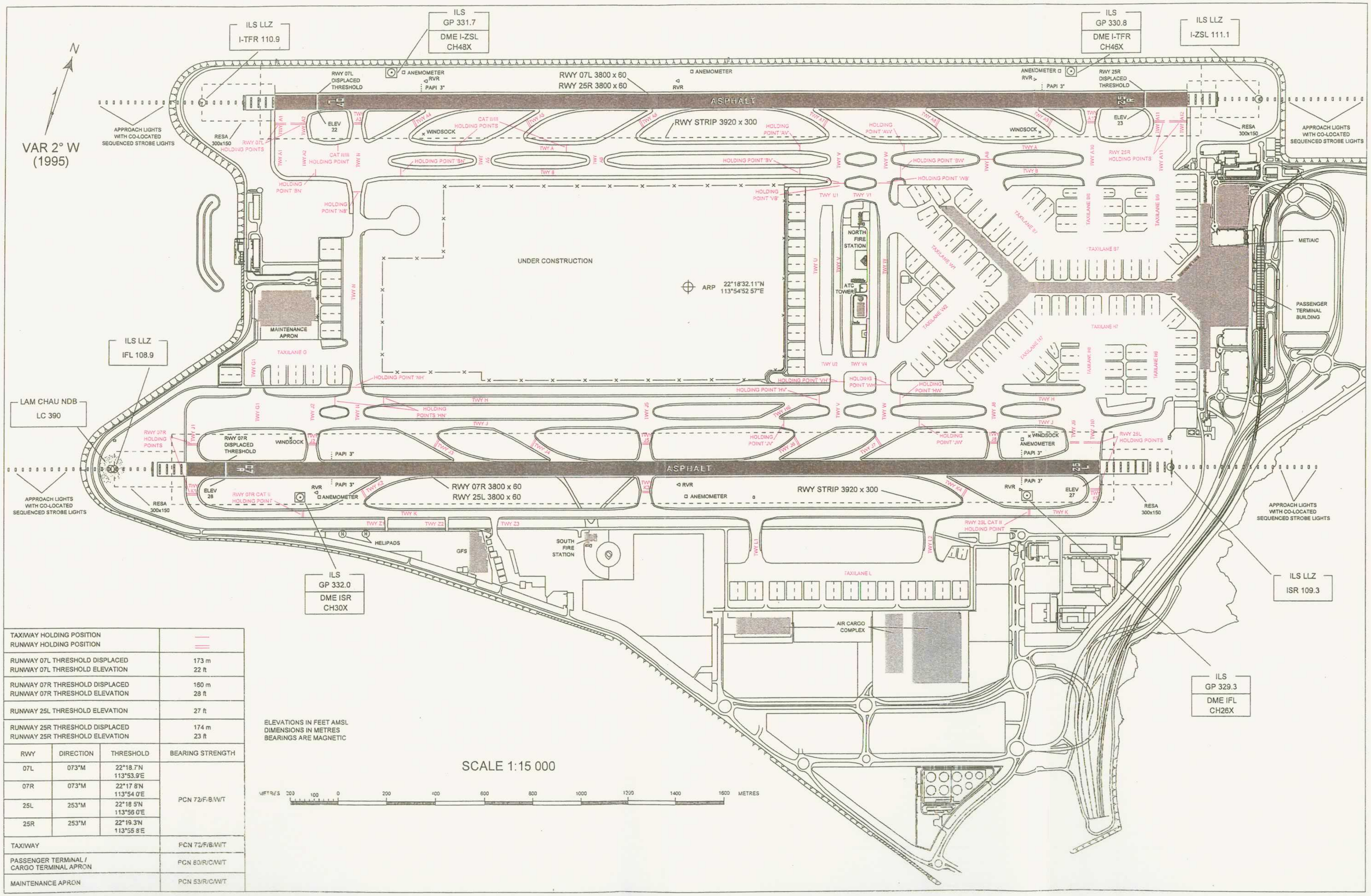
AERODROME CHART (AERODROME LAYOUT)

22° 18'32.11"N
113° 54'52.57"E

ELEVATION 19 FT AMSL

TWR	118.4 / 118.2
GMC	121.6 / 122.55

HONG KONG INTERNATIONAL AIRPORT



TAXIWAY HOLDING POSITION RUNWAY HOLDING POSITION	
RUNWAY 07L THRESHOLD DISPLACED RUNWAY 07L THRESHOLD ELEVATION	173 m 22 ft
RUNWAY 07R THRESHOLD DISPLACED RUNWAY 07R THRESHOLD ELEVATION	160 m 28 ft
RUNWAY 25L THRESHOLD ELEVATION	27 ft
RUNWAY 25R THRESHOLD DISPLACED RUNWAY 25R THRESHOLD ELEVATION	174 m 23 ft

RWY	DIRECTION	THRESHOLD	BEARING STRENGTH
07L	073°M	22°18.7'N 113°53.9'E	PCN 72/F/B/W/T
07R	073°M	22°17 8'N 113°54 0'E	
25L	253°M	22°18 5'N 113°56 0'E	
25R	253°M	22°19.3'N 113°55 8'E	
TAXIWAY			PCN 72/F/B/W/T
PASSENGER TERMINAL / CARGO TERMINAL APRON			PCN 80/R/C/W/T
MAINTENANCE APRON			PCN 53/R/C/W/T

CIVIL AVIATION DEPARTMENT, HONG KONG
Cartography by Survey and Mapping Office, Lands Department

One-minute mean RVR data – RW 25L/25R

Ending-time (hh:mm:sec)	RW 25L Touchdown (m)	RW 25L Mid-point (m)	RW 25L Roll-out (m)	RW 25R Touchdown (m)	RW 25R Mid-point (m)	RW 25R Roll-out (m)
10:25:00	1000	900	900	600	800	1000
10:25:10	1000	900	900	650	800	1000
10:25:20	1000	900	900	650	800	1000
10:25:30	1100	900	1000	650	800	1000
10:25:40	1100	900	1000	650	800	1100
10:25:50	1100	1000	1000	650	800	1100
10:26:00	1100	1000	1000	600	900	1100
10:26:10	1100	1000	1000	600	900	1100
10:26:20	1100	1000	1000	600	800	1100
10:26:30	1100	1000	1000	600	900	1000
10:26:40	1100	1000	1100	600	800	1000
10:26:50	1000	1000	1100	600	800	1000
10:27:00	1000	1100	1100	650	800	1000
10:27:10	1000	1100	1100	650	800	1000
10:27:20	1000	1200	1100	650	800	1000
10:27:30	1000	1300	1100	650	800	1100
10:27:40	1000	1300	1100	650	900	1100
10:27:50	1100	1200	1100	650	900	1100
10:28:00	1100	1200	1100	650	900	1100
10:28:10	1200	1200	1100	650	900	1100
10:28:20	1200	1200	1100	650	800	1100
10:28:30	1200	1200	1100	650	800	1100
10:28:40	1200	1200	1100	600	800	1100
10:28:50	1200	1300	1100	600	800	1100
10:29:00	1200	1300	1100	600	800	1200
10:29:10	1200	1300	1100	600	800	1200
10:29:20	1300	1400	1100	600	900	1200
10:29:30	1300	1400	1100	600	900	1200
10:29:40	1300	1400	1100	650	900	1200
10:29:50	1300	1400	1100	650	900	1200
10:30:00	1300	1500	1100	700	900	1200
10:30:10	1300	1500	1100	700	900	1100
10:30:20	1300	1500	1100	700	900	1100
10:30:30	1300	1500	1200	700	900	1100
10:30:40	1200	1500	1200	700	900	1100
10:30:50	1300	1400	1200	700	900	1000
10:31:00	1300	1300	1200	750	900	1000
10:31:10	1300	1300	1300	750	900	1000
10:31:20	1400	1300	1300	750	900	1000
10:31:30	1400	1300	1300	750	900	1000
10:31:40	1400	1400	1300	750	900	1000
10:31:50	1500	1500	1200	750	900	1000
10:32:00	1500	1600	1200	750	900	1100
10:32:10	1500	1600	1200	750	900	1100

One-minute mean RVR data – RW 25L/25R

Ending-time (hh:mm:sec)	RW 25L Touchdown (m)	RW 25L Mid-point (m)	RW 25L Roll-out (m)	RW 25R Touchdown (m)	RW 25R Mid-point (m)	RW 25R Roll-out (m)
10:32:20	1500	1500	1200	750	900	1100
10:32:30	1500	1500	1200	750	900	1100
10:32:40	1500	1400	1200	750	900	1100
10:32:50	1500	1400	1200	750	900	1100
10:33:00	1600	1400	1200	750	900	1100
10:33:10	1600	1500	1200	700	1000	1200
10:33:20	1600	1500	1200	700	1000	1200
10:33:30	1600	1600	1200	700	1000	1200
10:33:40	1600	1700	1300	700	1000	1200
10:33:50	1700	1700	1300	650	1000	1200
10:34:00	1700	1600	1300	650	1000	1200
10:34:10	1700	1600	1300	650	1000	1200
10:34:20	1700	1600	1300	650	1000	1200
10:34:30	1700	1600	1300	700	1000	1200
10:34:40	1700	1600	1300	700	1000	1200
10:34:50	1700	1600	1400	700	1000	1100
10:35:00	1600	1600	1400	750	1000	1100
10:35:10	1600	1600	1400	750	1000	1100
10:35:20	1600	1600	1400	750	1000	1100
10:35:30	1700	1600	1500	750	1000	1100
10:35:40	1700	1600	1500	750	1100	1100
10:35:50	1700	1600	1600	750	1100	1200
10:36:00	1700	1600	1600	750	1100	1200
10:36:10	1700	1700	1600	800	1100	1300
10:36:20	1700	1700	1600	800	1100	1300
10:36:30	1600	1700	1600	800	1100	1400
10:36:40	1600	1700	1600	800	1100	1500
10:36:50	1600	1700	1600	800	1100	1500
10:37:00	1800	1600	1600	800	1100	1500
10:37:10	1800	1700	1600	900	1100	1500
10:37:20	1800	1600	1600	900	1100	1500
10:37:30	1800	1600	1700	900	1100	1500
10:37:40	1600	1500	1700	900	1100	1500
10:37:50	1500	1500	1700	900	1100	1500
10:38:00	1500	1500	1700	900	1100	1500
10:38:10	1500	1500	1700	900	1100	1500
10:38:20	1600	1600	1700	900	1200	1500
10:38:30	1700	1600	1700	900	1200	1500
10:38:40	1800	1800	1700	900	1200	1500
10:38:50	1800	1800	1700	900	1200	1500
10:39:00	1900	1900	1700	900	1300	1500
10:39:10	1900	1900	1700	900	1300	1500
10:39:20	1900	2000	1700	900	1300	1400
10:39:30	1800	2000	1700	900	1300	1400

One-minute mean RVR data – RW 25L/25R

Ending-time (hh:mm:sec)	RW 25L Touchdown (m)	RW 25L Mid-point (m)	RW 25L Roll-out (m)	RW 25R Touchdown (m)	RW 25R Mid-point (m)	RW 25R Roll-out (m)
10:39:40	1800	2000	1700	900	1300	1400
10:39:50	1800	2100	1700	800	1300	1400
10:40:00	1800	2100	1700	800	1300	1400
10:40:10	1800	2100	1700	800	1300	1400
10:40:20	1800	2100	1800	800	1200	1400
10:40:30	1700	2200	1800	800	1200	1400
10:40:40	1600	2200	1800	800	1200	1400
10:40:50	1600	2000	1800	800	1200	1400
10:41:00	1600	1900	1700	900	1200	1500
10:41:10	1600	1900	1700	900	1200	1500
10:41:20	1600	1900	1700	900	1300	1500
10:41:30	1600	1900	1600	900	1300	1500
10:41:40	1700	1900	1600	900	1300	1500
10:41:50	1800	2200	1600	900	1300	1500
10:42:00	1800	2300	1700	900	1300	1400
10:42:10	1800	2300	1700	900	1300	1400
10:42:20	1800	2200	1700	900	1300	1400
10:42:30	1800	2200	1800	900	1300	1400
10:42:40	1900	2200	1800	900	1300	1400
10:42:50	1900	2200	1800	900	1300	1500
10:43:00	1900	2200	1800	900	1400	1500
10:43:10	1900	2200	1800	900	1400	1500
10:43:20	1900	2200	1800	900	1400	1600
10:43:30	1900	2200	1800	1000	1500	1600
10:43:40	2000	2300	1800	1000	1500	1700
10:43:50	2000	2300	1800	1000	1500	1700
10:44:00	1800	2400	1900	1000	1500	1700
10:44:10	1700	2300	1900	1000	1500	1700
10:44:20	1600	2300	1900	1000	1500	1600
10:44:30	1600	2300	1900	1000	1500	1600
10:44:40	1600	2300	1900	1000	1400	1600
10:44:50	1600	2300	1800	1000	1400	1600
10:45:00	1700	2300	1800	1000	1400	1600

Two-minute mean wind data – RW 07L/07R touchdown zones

Ending-time (hh:mm:sec)	Direction (degrees)	RW 07L Speed (knots)	Gust (knots)	Direction (degrees)	RW 07R Speed (knots)	Gust (knots)
10:25:00	317	34	50	306	30	36
10:25:10	317	34	50	306	31	36
10:25:20	317	34	50	308	31	36
10:25:30	316	35	50	308	31	36
10:25:40	317	36	50	309	31	40
10:25:50	316	36	50	310	32	40
10:26:00	315	36	50	311	33	40
10:26:10	314	36	49	311	33	40
10:26:20	315	36	49	312	32	40
10:26:30	315	37	49	314	32	40
10:26:40	314	37	49	315	31	40
10:26:50	315	38	49	315	29	40
10:27:00	315	38	49	315	29	40
10:27:10	315	39	49	314	29	40
10:27:20	316	40	49	314	29	40
10:27:30	317	40	50	313	29	39
10:27:40	316	40	50	313	29	39
10:27:50	317	40	50	313	29	38
10:28:00	317	40	50	313	29	38
10:28:10	317	39	50	313	28	38
10:28:20	316	39	50	310	29	38
10:28:30	315	39	50	310	29	38
10:28:40	315	39	50	308	30	38
10:28:50	315	38	50	308	31	40
10:29:00	315	38	50	308	32	40
10:29:10	315	39	50	308	32	40
10:29:20	315	38	50	307	31	40
10:29:30	315	38	44	307	31	40
10:29:40	316	38	44	307	31	40
10:29:50	316	38	44	306	31	40
10:30:00	316	38	44	306	31	40
10:30:10	317	39	46	306	30	40
10:30:20	317	39	46	305	30	40
10:30:30	317	39	46	307	31	40
10:30:40	317	39	46	307	31	40
10:30:50	317	40	46	307	30	38
10:31:00	318	41	46	307	30	35
10:31:10	318	41	46	307	30	35
10:31:20	318	41	47	307	30	35
10:31:30	317	41	47	308	30	35
10:31:40	317	41	47	308	30	35
10:31:50	317	41	47	308	30	36

Two-minute mean wind data – RW 07L/07R touchdown zones

		RW 07L			RW 07R	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:32:00	317	42	47	308	31	36
10:32:10	317	41	47	309	32	40
10:32:20	317	40	47	309	32	40
10:32:30	317	40	47	309	32	40
10:32:40	317	39	47	309	32	40
10:32:50	317	39	47	309	32	40
10:33:00	317	39	47	309	32	40
10:33:10	317	38	47	309	32	40
10:33:20	317	37	45	310	32	40
10:33:30	317	37	45	310	31	40
10:33:40	316	37	45	310	31	40
10:33:50	316	37	45	310	30	40
10:34:00	317	36	45	310	30	40
10:34:10	316	37	45	309	28	35
10:34:20	316	37	45	309	28	35
10:34:30	317	37	45	309	28	35
10:34:40	317	38	47	309	27	35
10:34:50	317	38	47	310	27	33
10:35:00	316	38	47	310	27	33
10:35:10	316	38	47	311	26	31
10:35:20	317	38	47	312	26	31
10:35:30	316	37	47	314	25	31
10:35:40	316	37	47	315	25	31
10:35:50	315	36	47	315	25	31
10:36:00	315	36	47	315	25	31
10:36:10	316	36	47	316	25	31
10:36:20	316	36	47	317	25	31
10:36:30	316	36	47	317	25	31
10:36:40	316	35	45	317	25	31
10:36:50	316	35	45	318	25	31
10:37:00	316	34	40	318	25	31
10:37:10	317	35	46	316	26	31
10:37:20	317	36	46	316	26	31
10:37:30	317	36	46	315	26	31
10:37:40	317	37	46	314	27	31
10:37:50	318	37	46	313	27	31
10:38:00	317	37	46	313	27	31
10:38:10	317	37	46	313	27	35
10:38:20	316	37	46	312	28	35
10:38:30	316	37	46	311	28	35
10:38:40	315	37	46	311	28	35
10:38:50	315	37	46	311	28	35

Two-minute mean wind data – RW 07L/07R touchdown zones

		RW 07L			RW 07R	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:39:00	314	38	46	311	29	35
10:39:10	314	37	42	310	29	35
10:39:20	313	37	44	310	29	35
10:39:30	313	37	44	310	29	35
10:39:40	313	38	44	311	29	35
10:39:50	313	38	46	311	29	36
10:40:00	313	38	46	311	29	36
10:40:10	313	39	46	312	30	39
10:40:20	314	39	46	312	30	39
10:40:30	314	38	46	312	30	39
10:40:40	314	38	46	311	30	39
10:40:50	313	38	46	310	31	39
10:41:00	313	37	46	310	31	39
10:41:10	313	37	46	309	31	39
10:41:20	313	37	46	309	31	39
10:41:30	312	36	46	309	32	39
10:41:40	312	36	46	308	32	39
10:41:50	312	36	45	308	32	39
10:42:00	312	35	44	308	32	39
10:42:10	312	35	43	308	31	37
10:42:20	312	35	44	308	31	37
10:42:30	312	36	44	308	31	37
10:42:40	312	36	44	308	30	36
10:42:50	312	36	44	309	30	36
10:43:00	313	36	44	310	29	35
10:43:10	313	36	44	311	28	33
10:43:20	314	35	44	311	28	33
10:43:30	315	35	44	310	28	33
10:43:40	315	34	44	310	28	33
10:43:50	315	34	44	311	27	33
10:44:00	315	33	44	311	27	33
10:44:10	314	32	44	311	27	34
10:44:20	315	32	42	312	27	34
10:44:30	315	32	42	311	27	35
10:44:40	316	32	41	310	28	36
10:44:50	316	32	39	310	28	36
10:45:00	317	32	39	310	29	36

Two-minute mean wind data – RW 07L/25R and RW 07R/25L mid-points

	RW 07L/25R			RW 07R/25L		
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:25:00	324	38	47	305	33	40
10:25:10	324	37	44	305	34	40
10:25:20	324	38	47	306	33	40
10:25:30	325	39	47	308	33	40
10:25:40	325	39	47	308	34	43
10:25:50	325	39	47	309	34	43
10:26:00	324	40	47	309	35	43
10:26:10	324	40	47	310	35	43
10:26:20	324	40	47	309	36	43
10:26:30	323	40	47	309	36	43
10:26:40	323	40	47	309	36	43
10:26:50	323	40	47	309	36	43
10:27:00	323	40	47	309	36	43
10:27:10	324	41	47	311	35	43
10:27:20	324	40	47	310	35	43
10:27:30	324	40	48	310	35	43
10:27:40	324	39	48	310	35	42
10:27:50	324	39	48	310	35	42
10:28:00	323	40	48	310	35	42
10:28:10	323	40	48	310	35	42
10:28:20	324	40	48	311	35	42
10:28:30	324	40	48	311	35	42
10:28:40	324	40	48	310	35	42
10:28:50	324	40	48	309	35	42
10:29:00	323	40	48	309	35	42
10:29:10	324	40	48	309	36	42
10:29:20	324	40	48	310	36	42
10:29:30	324	40	45	310	36	42
10:29:40	324	39	45	310	36	42
10:29:50	324	40	47	309	36	42
10:30:00	324	40	47	308	36	42
10:30:10	323	39	47	307	35	42
10:30:20	323	40	51	307	35	42
10:30:30	324	40	51	307	35	42
10:30:40	324	40	51	307	35	42
10:30:50	323	41	51	307	36	44
10:31:00	323	41	51	307	36	44
10:31:10	323	42	51	307	36	44
10:31:20	322	42	51	307	37	44
10:31:30	322	42	51	307	37	44
10:31:40	322	42	51	308	36	44
10:31:50	322	42	51	307	36	44

Two-minute mean wind data – RW 07L/25R and RW 07R/25L mid-points

	RW 07L/25R			RW 07R/25L		
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:32:00	322	42	51	308	35	44
10:32:10	322	42	51	309	35	44
10:32:20	322	42	51	309	34	44
10:32:30	321	42	51	310	34	44
10:32:40	321	41	51	310	34	44
10:32:50	321	40	48	310	34	44
10:33:00	321	40	48	310	33	42
10:33:10	321	40	48	309	33	42
10:33:20	321	40	48	309	33	42
10:33:30	321	41	48	309	32	42
10:33:40	321	41	48	307	33	42
10:33:50	321	40	48	307	33	42
10:34:00	321	40	46	306	34	42
10:34:10	321	40	46	306	35	42
10:34:20	322	40	46	306	35	42
10:34:30	322	40	46	306	35	42
10:34:40	322	40	46	306	35	41
10:34:50	323	40	46	306	35	42
10:35:00	324	39	46	306	36	46
10:35:10	324	39	46	307	37	46
10:35:20	324	39	46	307	37	46
10:35:30	324	39	46	307	37	46
10:35:40	324	39	46	307	37	46
10:35:50	324	38	46	308	37	46
10:36:00	324	38	46	309	37	46
10:36:10	324	38	44	309	36	46
10:36:20	324	38	44	309	36	46
10:36:30	324	38	44	309	36	46
10:36:40	324	38	44	309	35	46
10:36:50	323	37	44	309	34	46
10:37:00	322	37	44	309	33	44
10:37:10	321	37	44	308	32	41
10:37:20	321	37	44	308	32	40
10:37:30	321	38	44	308	32	40
10:37:40	321	38	44	308	32	40
10:37:50	321	38	45	308	32	40
10:38:00	322	38	45	308	32	40
10:38:10	322	38	45	308	32	40
10:38:20	321	37	45	308	32	40
10:38:30	321	37	45	308	32	40
10:38:40	321	37	45	308	32	40
10:38:50	321	37	45	309	33	40

Two-minute mean wind data – RW 07L/25R and RW 07R/25L mid-points

	RW 07L/25R			RW 07R/25L		
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:39:00	321	37	45	309	33	40
10:39:10	322	37	45	309	33	40
10:39:20	322	37	45	309	33	40
10:39:30	323	36	45	310	33	39
10:39:40	323	36	45	310	33	39
10:39:50	323	36	44	309	33	39
10:40:00	323	37	44	310	33	39
10:40:10	322	38	47	310	33	39
10:40:20	322	38	47	309	33	39
10:40:30	323	38	47	309	33	39
10:40:40	322	38	47	310	34	39
10:40:50	322	38	47	310	33	39
10:41:00	322	38	47	310	33	39
10:41:10	322	38	47	310	32	39
10:41:20	321	38	47	309	31	39
10:41:30	321	39	47	308	31	39
10:41:40	320	39	47	309	32	40
10:41:50	320	39	47	309	32	40
10:42:00	319	39	47	309	32	40
10:42:10	319	39	47	309	32	41
10:42:20	318	38	45	309	32	41
10:42:30	318	38	45	308	32	41
10:42:40	318	38	45	307	32	41
10:42:50	317	38	45	306	32	41
10:43:00	317	38	45	306	33	41
10:43:10	317	39	45	306	33	41
10:43:20	318	39	45	306	33	41
10:43:30	318	38	45	306	33	41
10:43:40	319	38	45	305	33	41
10:43:50	319	38	42	306	32	41
10:44:00	320	37	42	306	32	41
10:44:10	320	37	42	307	32	37
10:44:20	320	37	42	308	31	37
10:44:30	321	37	42	308	31	37
10:44:40	322	37	42	309	31	37
10:44:50	322	37	42	309	31	37
10:45:00	322	37	42	309	31	37

Two-minute mean wind data – RW 25L/25R touchdown zones

		RW 25L			RW 25R	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:25:00	316	30	42	325	39	48
10:25:10	317	29	39	324	39	48
10:25:20	318	29	39	324	39	48
10:25:30	318	29	39	325	40	48
10:25:40	318	30	39	325	40	48
10:25:50	316	29	37	324	40	48
10:26:00	317	29	37	325	40	46
10:26:10	317	28	36	325	40	47
10:26:20	318	27	36	325	40	47
10:26:30	318	27	36	324	40	47
10:26:40	318	28	42	324	40	47
10:26:50	317	28	42	325	41	47
10:27:00	316	28	42	325	41	47
10:27:10	316	29	42	326	40	47
10:27:20	315	29	42	326	40	47
10:27:30	316	29	42	326	41	47
10:27:40	317	30	42	325	41	47
10:27:50	319	29	42	326	41	47
10:28:00	319	30	42	325	41	47
10:28:10	319	31	42	325	41	49
10:28:20	320	31	42	324	41	49
10:28:30	320	31	42	324	41	49
10:28:40	320	31	40	324	41	49
10:28:50	320	31	40	323	41	49
10:29:00	320	31	40	322	41	49
10:29:10	320	31	40	320	42	49
10:29:20	320	31	40	319	42	49
10:29:30	319	31	40	318	44	55
10:29:40	318	32	42	319	44	55
10:29:50	318	32	42	319	44	55
10:30:00	319	32	42	321	44	52
10:30:10	319	32	42	321	46	56
10:30:20	319	32	42	323	47	56
10:30:30	319	32	42	324	44	56
10:30:40	320	31	42	325	39	51
10:30:50	320	31	42	325	38	48
10:31:00	320	31	42	325	39	48
10:31:10	320	30	42	325	40	48
10:31:20	321	31	42	325	40	47
10:31:30	322	31	42	325	41	47
10:31:40	322	31	40	325	41	47
10:31:50	322	30	39	324	41	49

Two-minute mean wind data – RW 25L/25R touchdown zones

Ending-time (hh:mm:sec)	RW 25L Direction (degrees)	RW 25L Speed (knots)	RW 25L Gust (knots)	RW 25R Direction (degrees)	RW 25R Speed (knots)	RW 25R Gust (knots)
10:32:00	322	30	39	322	41	49
10:32:10	322	30	39	321	42	49
10:32:20	322	29	39	322	42	48
10:32:30	322	29	39	322	42	48
10:32:40	322	29	39	322	41	45
10:32:50	321	29	39	321	39	45
10:33:00	321	29	39	320	40	52
10:33:10	321	28	39	320	41	52
10:33:20	321	28	39	320	41	52
10:33:30	320	27	35	320	41	52
10:33:40	320	27	36	320	41	52
10:33:50	319	27	36	320	41	52
10:34:00	319	27	36	320	41	52
10:34:10	318	28	44	320	41	52
10:34:20	317	29	44	320	41	52
10:34:30	317	29	44	320	41	52
10:34:40	317	29	44	320	40	52
10:34:50	318	29	44	320	39	48
10:35:00	318	29	44	320	39	47
10:35:10	319	29	44	321	39	47
10:35:20	319	29	44	321	38	47
10:35:30	320	29	44	321	38	47
10:35:40	320	29	44	320	37	45
10:35:50	320	29	44	320	36	45
10:36:00	321	29	44	320	36	45
10:36:10	321	29	39	320	37	46
10:36:20	321	29	39	321	37	46
10:36:30	321	29	39	321	37	46
10:36:40	320	29	42	321	37	46
10:36:50	320	30	42	321	37	46
10:37:00	321	30	42	321	37	46
10:37:10	320	30	42	321	38	46
10:37:20	319	30	42	320	39	46
10:37:30	319	29	42	320	39	46
10:37:40	319	29	42	321	40	46
10:37:50	319	29	42	321	40	46
10:38:00	319	29	42	321	39	46
10:38:10	320	29	42	321	39	46
10:38:20	319	29	42	321	39	46
10:38:30	320	28	42	321	39	46
10:38:40	320	27	36	321	39	46
10:38:50	319	26	36	321	39	46

Two-minute mean wind data – RW 25L/25R touchdown zones

		RW 25L			RW 25R	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:39:00	318	26	36	321	39	46
10:39:10	318	26	36	322	38	46
10:39:20	318	26	36	322	37	44
10:39:30	318	26	36	322	37	45
10:39:40	318	26	36	322	37	45
10:39:50	318	26	35	322	37	45
10:40:00	319	25	34	322	38	45
10:40:10	318	24	32	322	38	45
10:40:20	318	23	32	322	38	45
10:40:30	318	23	32	322	38	45
10:40:40	318	24	32	322	39	45
10:40:50	318	24	32	322	39	45
10:41:00	318	25	33	321	39	45
10:41:10	319	25	33	322	39	45
10:41:20	319	25	33	322	39	45
10:41:30	319	25	33	321	39	45
10:41:40	319	25	33	321	38	45
10:41:50	319	25	33	321	38	45
10:42:00	317	26	36	321	38	45
10:42:10	318	26	36	320	38	45
10:42:20	318	27	36	320	37	45
10:42:30	318	27	36	320	36	44
10:42:40	317	28	36	320	36	42
10:42:50	317	28	36	319	35	41
10:43:00	317	27	36	318	36	41
10:43:10	316	26	36	318	36	42
10:43:20	317	26	36	318	36	43
10:43:30	316	25	36	318	37	43
10:43:40	317	24	36	318	37	43
10:43:50	317	25	36	318	37	43
10:44:00	318	24	35	318	37	43
10:44:10	318	24	35	318	37	43
10:44:20	318	25	39	318	37	43
10:44:30	319	25	39	318	38	43
10:44:40	319	25	39	318	38	43
10:44:50	319	26	39	319	38	43
10:45:00	320	26	39	319	38	43

Note : Gust figures evaluated from running 3 – second mean wind sequence

Ten-second mean wind data – RW 07L/07R touchdown zones

	RW 07L		RW 07R	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:25:00	310	28	312	34
10:25:10	312	32	315	32
10:25:20	308	31	313	28
10:25:30	313	42	313	28
10:25:40	317	42	312	37
10:25:50	313	36	313	38
10:26:00	311	38	315	33
10:26:10	318	46	315	33
10:26:20	322	41	322	26
10:26:30	318	40	322	24
10:26:40	317	39	319	22
10:26:50	318	39	308	27
10:27:00	312	35	308	27
10:27:10	313	38	305	32
10:27:20	320	44	315	31
10:27:30	320	48	304	33
10:27:40	315	39	304	33
10:27:50	316	40	315	31
10:28:00	316	34	313	31
10:28:10	314	31	308	31
10:28:20	311	38	304	29
10:28:30	314	42	304	29
10:28:40	311	37	300	28
10:28:50	315	36	305	36
10:29:00	314	35	307	30
10:29:10	314	39	307	30
10:29:20	317	39	309	27
10:29:30	323	41	302	28
10:29:40	323	42	308	30
10:29:50	320	41	305	33
10:30:00	318	35	305	29
10:30:10	318	42	306	28
10:30:20	316	42	301	31
10:30:30	313	37	315	29
10:30:40	316	44	315	29
10:30:50	313	43	310	31
10:31:00	321	43	308	31
10:31:10	316	39	309	30
10:31:20	316	45	308	28
10:31:30	316	40	307	30
10:31:40	322	42	311	32
10:31:50	324	44	312	35

Ten-second mean wind data – RW 07L/07R touchdown zones

	RW 07L		RW 07R	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:32:00	316	40	306	32
10:32:10	313	31	307	37
10:32:20	314	30	312	34
10:32:30	314	37	309	32
10:32:40	316	33	311	31
10:32:50	320	41	312	28
10:33:00	319	40	309	31
10:33:10	315	34	308	31
10:33:20	314	33	312	29
10:33:30	317	40	311	24
10:33:40	318	41	309	24
10:33:50	324	40	308	27
10:34:00	317	36	307	26
10:34:10	311	34	306	27
10:34:20	314	36	306	27
10:34:30	319	39	308	28
10:34:40	317	43	308	28
10:34:50	317	40	318	27
10:35:00	317	42	318	27
10:35:10	315	34	324	24
10:35:20	315	31	325	21
10:35:30	313	31	326	21
10:35:40	314	33	319	28
10:35:50	313	35	319	28
10:36:00	316	36	309	26
10:36:10	317	34	313	27
10:36:20	318	35	317	24
10:36:30	316	36	309	29
10:36:40	324	38	314	24
10:36:50	316	36	317	28
10:37:00	318	35	320	27
10:37:10	318	45	313	27
10:37:20	319	41	313	27
10:37:30	316	34	308	29
10:37:40	316	38	313	26
10:37:50	316	37	309	25
10:38:00	313	37	310	26
10:38:10	312	38	308	31
10:38:20	310	33	305	33
10:38:30	310	36	311	38
10:38:40	315	39	315	32
10:38:50	313	35	315	32

Ten-second mean wind data – RW 07L/07R touchdown zones

	RW 07L		RW 07R	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:39:00	315	38	315	30
10:39:10	312	39	309	30
10:39:20	309	39	314	27
10:39:30	312	42	314	27
10:39:40	315	39	315	25
10:39:50	314	39	309	31
10:40:00	318	40	310	33
10:40:10	318	43	310	36
10:40:20	315	34	310	36
10:40:30	310	33	308	34
10:40:40	310	32	305	31
10:40:50	310	33	303	34
10:41:00	311	35	303	34
10:41:10	309	36	308	33
10:41:20	308	34	316	29
10:41:30	309	35	316	28
10:41:40	312	35	304	29
10:41:50	315	37	304	29
10:42:00	316	40	307	30
10:42:10	316	38	307	29
10:42:20	313	39	308	26
10:42:30	311	34	308	26
10:42:40	315	35	313	28
10:42:50	313	36	316	27
10:43:00	315	35	311	27
10:43:10	315	30	316	28
10:43:20	316	30	316	28
10:43:30	316	30	308	26
10:43:40	312	28	309	28
10:43:50	319	29	317	24
10:44:00	315	27	317	24
10:44:10	313	32	310	30
10:44:20	317	36	308	27
10:44:30	317	38	301	31
10:44:40	319	35	307	34
10:44:50	321	35	307	34
10:45:00	321	38	313	31

Ten-second mean wind data – RW 07L/25R and RW 07R/25L mid-points

	RW 07L/25R		RW 07R/25L	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:25:00	325	34	310	35
10:25:10	320	35	298	34
10:25:20	320	45	311	32
10:25:30	326	43	314	32
10:25:40	326	43	308	40
10:25:50	324	40	312	40
10:26:00	324	40	313	38
10:26:10	318	36	312	39
10:26:20	318	36	302	37
10:26:30	316	42	305	35
10:26:40	324	40	314	33
10:26:50	327	34	315	33
10:27:00	329	40	311	32
10:27:10	325	42	311	31
10:27:20	323	37	304	34
10:27:30	327	44	308	33
10:27:40	321	37	310	39
10:27:50	321	37	315	37
10:28:00	320	42	316	39
10:28:10	324	43	311	35
10:28:20	324	40	306	36
10:28:30	322	40	305	36
10:28:40	321	37	306	34
10:28:50	324	42	307	33
10:29:00	325	39	306	37
10:29:10	327	38	310	40
10:29:20	327	38	315	35
10:29:30	327	40	312	34
10:29:40	323	35	311	38
10:29:50	321	44	309	36
10:30:00	321	44	301	32
10:30:10	321	38	302	34
10:30:20	323	46	305	33
10:30:30	326	42	302	32
10:30:40	321	43	306	38
10:30:50	322	48	301	42
10:31:00	320	45	310	41
10:31:10	324	40	312	40
10:31:20	319	36	312	39
10:31:30	319	36	315	37
10:31:40	321	35	313	32
10:31:50	320	45	307	28

Ten-second mean wind data – RW 07L/25R and RW 07R/25L mid-points

	RW 07L/25R		RW 07R/25L	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:32:00	321	44	310	25
10:32:10	321	44	309	28
10:32:20	319	40	314	28
10:32:30	319	42	306	29
10:32:40	323	37	305	40
10:32:50	321	38	310	36
10:33:00	321	38	306	35
10:33:10	321	37	304	35
10:33:20	324	42	310	37
10:33:30	317	43	308	36
10:33:40	317	43	300	35
10:33:50	322	39	303	34
10:34:00	324	38	302	34
10:34:10	325	44	307	35
10:34:20	322	40	307	32
10:34:30	322	40	309	34
10:34:40	326	36	306	37
10:34:50	330	39	310	39
10:35:00	324	34	310	42
10:35:10	324	34	313	42
10:35:20	324	40	311	38
10:35:30	322	38	303	35
10:35:40	318	38	308	37
10:35:50	324	37	309	34
10:36:00	324	37	312	34
10:36:10	322	39	308	30
10:36:20	324	37	308	28
10:36:30	321	37	307	29
10:36:40	321	37	309	30
10:36:50	320	37	307	30
10:37:00	321	33	309	32
10:37:10	318	40	311	31
10:37:20	318	40	304	32
10:37:30	321	42	303	35
10:37:40	324	40	313	36
10:37:50	322	40	309	32
10:38:00	327	37	311	35
10:38:10	323	33	303	30
10:38:20	322	33	308	32
10:38:30	320	38	312	31
10:38:40	322	37	309	32
10:38:50	321	36	312	33

Ten-second mean wind data – RW 07L/25R and RW 07R/25L mid-points

Ending-time (hh:mm:sec)	RW 07L/25R Direction (degrees)	RW 07L/25R Speed (knots)	RW 07R/25L Direction (degrees)	RW 07R/25L Speed (knots)
10:39:00	320	36	309	33
10:39:10	325	36	312	37
10:39:20	323	35	313	35
10:39:30	324	39	313	35
10:39:40	324	39	306	29
10:39:50	320	42	305	34
10:40:00	327	42	313	31
10:40:10	325	45	306	30
10:40:20	325	45	302	33
10:40:30	320	37	312	36
10:40:40	319	34	313	35
10:40:50	323	34	314	28
10:41:00	318	36	310	27
10:41:10	318	36	309	29
10:41:20	315	39	305	30
10:41:30	323	42	308	33
10:41:40	319	43	312	38
10:41:50	319	43	311	35
10:42:00	315	39	305	31
10:42:10	315	40	303	33
10:42:20	314	37	303	33
10:42:30	319	35	302	35
10:42:40	319	35	299	32
10:42:50	315	33	305	32
10:43:00	320	39	309	32
10:43:10	321	39	307	34
10:43:20	324	40	303	31
10:43:30	325	38	311	31
10:43:40	322	37	307	30
10:43:50	321	38	319	29
10:44:00	320	36	309	31
10:44:10	320	36	312	29
10:44:20	318	33	309	29
10:44:30	323	35	308	32
10:44:40	320	38	306	35
10:44:50	320	38	306	35
10:45:00	321	37	312	32

Ten-second mean wind data – RW 25L/25R touchdown zones

	RW 25R		RW 25L	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:25:00	325	41	328	30
10:25:10	322	42	324	26
10:25:20	325	39	323	28
10:25:30	326	37	319	26
10:25:40	326	40	309	25
10:25:50	321	40	300	28
10:26:00	325	40	315	28
10:26:10	325	44	318	23
10:26:20	323	42	319	23
10:26:30	324	41	317	31
10:26:40	329	40	318	36
10:26:50	328	41	310	36
10:27:00	331	41	319	32
10:27:10	323	36	320	31
10:27:20	327	43	317	29
10:27:30	326	41	329	30
10:27:40	323	40	327	30
10:27:50	322	41	319	26
10:28:00	321	39	312	29
10:28:10	319	47	326	35
10:28:20	320	44	326	30
10:28:30	320	41	315	31
10:28:40	322	39	318	32
10:28:50	319	45	314	31
10:29:00	322	42	320	32
10:29:10	321	44	320	36
10:29:20	321	46	317	31
10:29:30	317	45	314	27
10:29:40	320	41	313	38
10:29:50	320	45	322	34
10:30:00	322	49	320	29
10:30:10	323	52	326	33
10:30:20	327	38	327	25
10:30:30	323	35	319	31
10:30:40	324	37	326	28
10:30:50	324	42	320	31
10:31:00	325	41	320	27
10:31:10	326	40	321	31
10:31:20	323	42	322	33
10:31:30	331	41	323	36
10:31:40	323	40	323	32
10:31:50	320	44	320	31

Ten-second mean wind data – RW 25L/25R touchdown zones

	RW 25R		RW 25L	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:32:00	322	42	320	29
10:32:10	324	42	325	23
10:32:20	321	43	320	24
10:32:30	323	39	319	28
10:32:40	322	42	327	31
10:32:50	322	36	311	24
10:33:00	321	40	317	28
10:33:10	318	37	322	25
10:33:20	319	39	322	27
10:33:30	320	39	314	29
10:33:40	326	43	320	33
10:33:50	323	41	315	28
10:34:00	316	39	311	28
10:34:10	319	39	312	35
10:34:20	319	40	317	34
10:34:30	320	38	320	31
10:34:40	321	38	326	29
10:34:50	318	37	325	25
10:35:00	321	36	315	27
10:35:10	325	35	331	26
10:35:20	322	33	328	26
10:35:30	320	35	314	30
10:35:40	318	33	323	31
10:35:50	322	37	321	32
10:36:00	319	35	314	28
10:36:10	323	43	317	31
10:36:20	323	40	324	28
10:36:30	319	40	316	30
10:36:40	320	41	318	34
10:36:50	322	40	325	33
10:37:00	322	37	320	31
10:37:10	319	40	323	25
10:37:20	320	43	316	24
10:37:30	318	42	319	19
10:37:40	326	38	318	28
10:37:50	321	36	320	33
10:38:00	321	33	314	34
10:38:10	322	37	324	32
10:38:20	322	40	317	24
10:38:30	323	41	325	21
10:38:40	321	41	313	21
10:38:50	323	35	321	24

Ten-second mean wind data – RW 25L/25R touchdown zones

	RW 25R		RW 25L	
Ending-time (hh:mm:sec)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:39:00	321	37	311	24
10:39:10	322	31	319	29
10:39:20	322	33	313	22
10:39:30	324	43	322	26
10:39:40	326	39	315	27
10:39:50	322	38	323	26
10:40:00	320	37	328	20
10:40:10	321	38	316	21
10:40:20	319	44	314	19
10:40:30	321	45	317	22
10:40:40	319	42	322	24
10:40:50	322	40	318	26
10:41:00	319	35	314	31
10:41:10	323	33	324	29
10:41:20	324	38	317	27
10:41:30	321	36	321	29
10:41:40	317	30	320	29
10:41:50	320	38	316	24
10:42:00	320	38	307	29
10:42:10	319	38	325	28
10:42:20	316	37	315	25
10:42:30	317	31	319	26
10:42:40	318	37	310	31
10:42:50	314	36	319	27
10:43:00	312	37	311	19
10:43:10	317	40	317	21
10:43:20	319	41	321	22
10:43:30	322	39	319	21
10:43:40	320	35	322	22
10:43:50	318	37	321	27
10:44:00	321	36	317	21
10:44:10	319	38	323	28
10:44:20	318	39	320	35
10:44:30	320	39	325	29
10:44:40	317	36	312	32
10:44:50	321	38	323	33
10:45:00	317	41	319	24

1-second wind direction and speed recorded at 25L/25R TDZ anemometers

Date	Time (UTC)	RW 25L Direction (degrees)	RW 25L Speed (knots)	RW 25R Direction (degrees)	RW 25R Speed (knots)
22-Aug-99	10:42:00	310	28	319	34
22-Aug-99	10:42:01	334	31	321	36
22-Aug-99	10:42:02	328	28	320	37
22-Aug-99	10:42:03	324	28	319	37
22-Aug-99	10:42:04	339	25	319	37
22-Aug-99	10:42:05	329	27	321	40
22-Aug-99	10:42:06	324	31	319	39
22-Aug-99	10:42:07	326	31	319	38
22-Aug-99	10:42:08	323	29	315	37
22-Aug-99	10:42:09	310	26	318	36
22-Aug-99	10:42:10	311	23	319	39
22-Aug-99	10:42:11	311	23	318	39
22-Aug-99	10:42:12	311	26	318	40
22-Aug-99	10:42:13	311	24	315	39
22-Aug-99	10:42:14	320	23	315	38
22-Aug-99	10:42:15	319	25	316	36
22-Aug-99	10:42:16	326	24	319	37
22-Aug-99	10:42:17	330	24	319	36
22-Aug-99	10:42:18	314	26	315	36
22-Aug-99	10:42:19	299	26	315	34
22-Aug-99	10:42:20	310	25	314	31
22-Aug-99	10:42:21	314	27	315	28
22-Aug-99	10:42:22	313	26	315	29
22-Aug-99	10:42:23	313	28	314	29
22-Aug-99	10:42:24	299	28	319	30
22-Aug-99	10:42:25	314	31	316	30
22-Aug-99	10:42:26	314	27	314	33
22-Aug-99	10:42:27	340	22	319	31
22-Aug-99	10:42:28	321	21	318	33
22-Aug-99	10:42:29	326	21	320	33
22-Aug-99	10:42:30	334	27	321	35
22-Aug-99	10:42:31	323	34	320	33
22-Aug-99	10:42:32	320	36	313	32
22-Aug-99	10:42:33	320	35	321	34
22-Aug-99	10:42:34	311	30	318	38
22-Aug-99	10:42:35	300	29	318	38
22-Aug-99	10:42:36	293	29	319	37
22-Aug-99	10:42:37	308	26	318	40
22-Aug-99	10:42:38	303	31	318	41
22-Aug-99	10:42:39	323	31	320	40
22-Aug-99	10:42:40	303	28	321	41
22-Aug-99	10:42:41	318	25	318	42
22-Aug-99	10:42:42	318	26	315	42
22-Aug-99	10:42:43	331	26	318	39

1-second wind direction and speed recorded at 25L/25R TDZ anemometers

Date	Time (UTC)	RW 25L Direction (degrees)	RW 25L Speed (knots)	RW 25R Direction (degrees)	RW 25R Speed (knots)
22-Aug-99	10:42:44	326	29	318	36
22-Aug-99	10:42:45	318	29	315	39
22-Aug-99	10:42:46	313	29	314	37
22-Aug-99	10:42:47	311	28	313	30
22-Aug-99	10:42:48	314	27	309	29
22-Aug-99	10:42:49	324	24	314	30
22-Aug-99	10:42:50	316	23	309	33
22-Aug-99	10:42:51	314	23	304	31
22-Aug-99	10:42:52	319	21	299	30
22-Aug-99	10:42:53	318	20	318	35
22-Aug-99	10:42:54	309	19	310	40
22-Aug-99	10:42:55	311	18	313	38
22-Aug-99	10:42:56	310	19	314	37
22-Aug-99	10:42:57	309	18	318	38
22-Aug-99	10:42:58	299	18	314	37
22-Aug-99	10:42:59	301	18	313	40
22-Aug-99	10:43:00	323	20	316	39
22-Aug-99	10:43:01	320	21	314	40
22-Aug-99	10:43:02	320	23	320	41
22-Aug-99	10:43:03	321	23	314	38
22-Aug-99	10:43:04	319	20	321	39
22-Aug-99	10:43:05	324	20	318	35
22-Aug-99	10:43:06	308	19	314	37
22-Aug-99	10:43:07	283	19	318	41
22-Aug-99	10:43:08	320	18	321	43
22-Aug-99	10:43:09	345	22	316	43
22-Aug-99	10:43:10	306	20	319	41
22-Aug-99	10:43:11	335	20	314	41
22-Aug-99	10:43:12	339	17	318	39
22-Aug-99	10:43:13	294	14	320	42
22-Aug-99	10:43:14	303	15	321	43
22-Aug-99	10:43:15	311	21	319	42
22-Aug-99	10:43:16	320	24	318	41
22-Aug-99	10:43:17	331	28	321	40
22-Aug-99	10:43:18	324	28	320	39
22-Aug-99	10:43:19	325	26	316	39
22-Aug-99	10:43:20	325	24	319	41
22-Aug-99	10:43:21	319	25	320	39
22-Aug-99	10:43:22	323	24	326	40
22-Aug-99	10:43:23	309	22	324	39
22-Aug-99	10:43:24	328	22	320	39
22-Aug-99	10:43:25	325	21	325	39
22-Aug-99	10:43:26	314	22	320	40
22-Aug-99	10:43:27	321	21	320	41

1-second wind direction and speed recorded at 25L/25R TDZ anemometers

Date	Time (UTC)	RW 25L		RW 25R	
		Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
22-Aug-99	10:43:28	318	20	320	37
22-Aug-99	10:43:29	315	19	320	35
22-Aug-99	10:43:30	321	18	320	38
22-Aug-99	10:43:31	323	17	320	37
22-Aug-99	10:43:32	316	19	321	34
22-Aug-99	10:43:33	315	20	319	34
22-Aug-99	10:43:34	318	21	320	31
22-Aug-99	10:43:35	330	19	325	34
22-Aug-99	10:43:36	333	19	321	38
22-Aug-99	10:43:37	320	25	318	37
22-Aug-99	10:43:38	318	29	316	38
22-Aug-99	10:43:39	330	26	320	36
22-Aug-99	10:43:40	315	24	321	35
22-Aug-99	10:43:41	309	27	318	31
22-Aug-99	10:43:42	316	30	318	32
22-Aug-99	10:43:43	319	29	320	36
22-Aug-99	10:43:44	320	26	318	37
22-Aug-99	10:43:45	319	26	318	35
22-Aug-99	10:43:46	330	26	316	38
22-Aug-99	10:43:47	329	26	318	39
22-Aug-99	10:43:48	329	26	319	40
22-Aug-99	10:43:49	325	25	321	40
22-Aug-99	10:43:50	316	24	318	39
22-Aug-99	10:43:51	311	23	324	37
22-Aug-99	10:43:52	328	23	321	36
22-Aug-99	10:43:53	334	21	321	36
22-Aug-99	10:43:54	329	22	326	37
22-Aug-99	10:43:55	334	24	324	38
22-Aug-99	10:43:56	314	23	320	35
22-Aug-99	10:43:57	301	19	316	35
22-Aug-99	10:43:58	305	17	318	37
22-Aug-99	10:43:59	305	17	320	34
22-Aug-99	10:44:00	305	19	319	30

1-second wind direction and speed recorded at 07L/07R TDZ anemometers

Date	Time	RW 07L		RW 07R	
	(UTC)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
22-Aug-99	10:42:00	315	43	304	31
22-Aug-99	10:42:01	316	43	310	31
22-Aug-99	10:42:02	324	42	310	30
22-Aug-99	10:42:03	316	43	303	31
22-Aug-99	10:42:04	316	38	308	31
22-Aug-99	10:42:05	311	37	313	31
22-Aug-99	10:42:06	319	37	309	29
22-Aug-99	10:42:07	316	35	303	27
22-Aug-99	10:42:08	309	32	301	28
22-Aug-99	10:42:09	320	33	308	27
22-Aug-99	10:42:10	314	36	303	27
22-Aug-99	10:42:11	314	36		
22-Aug-99	10:42:12	316	37		
22-Aug-99	10:42:13	313	36		
22-Aug-99	10:42:14	314	36		
22-Aug-99	10:42:15	318	41		
22-Aug-99	10:42:16	314	43		
22-Aug-99	10:42:17	315	45		
22-Aug-99	10:42:18	310	45		
22-Aug-99	10:42:19	310	38		
22-Aug-99	10:42:20	309	35		
22-Aug-99	10:42:21	315	35	305	28
22-Aug-99	10:42:22	311	38	308	26
22-Aug-99	10:42:23	313	34	303	24
22-Aug-99	10:42:24	313	34	300	26
22-Aug-99	10:42:25	313	36	310	25
22-Aug-99	10:42:26	306	33	314	25
22-Aug-99	10:42:27	304	33	309	27
22-Aug-99	10:42:28	310	32	309	27
22-Aug-99	10:42:29	313	31	308	29
22-Aug-99	10:42:30	316	31	313	27
22-Aug-99	10:42:31	323	32	305	26
22-Aug-99	10:42:32	313	29	311	27
22-Aug-99	10:42:33	313	30	309	27
22-Aug-99	10:42:34	310	28	311	28
22-Aug-99	10:42:35	309	33	313	29
22-Aug-99	10:42:36	315	37	310	29
22-Aug-99	10:42:37	320	37	315	27
22-Aug-99	10:42:38	316	40	318	30
22-Aug-99	10:42:39	320	42	316	31
22-Aug-99	10:42:40	315	44	319	28
22-Aug-99	10:42:41	319	43	329	29
22-Aug-99	10:42:42	313	40	309	29
22-Aug-99	10:42:43	316	39	304	27

1-second wind direction and speed recorded at 07L/07R TDZ anemometers

Date	Time (UTC)	RW 07L Direction (degrees)	RW 07L Speed (knots)	RW 07R Direction (degrees)	RW 07R Speed (knots)
22-Aug-99	10:42:44	316	39	310	27
22-Aug-99	10:42:45	314	38	310	28
22-Aug-99	10:42:46	308	30	311	28
22-Aug-99	10:42:47	314	31	326	27
22-Aug-99	10:42:48	311	31	326	25
22-Aug-99	10:42:49	309	34	319	25
22-Aug-99	10:42:50	313	32	316	24
22-Aug-99	10:42:51	310	34	311	24
22-Aug-99	10:42:52	315	35	310	23
22-Aug-99	10:42:53	319	35	306	25
22-Aug-99	10:42:54	315	36	306	26
22-Aug-99	10:42:55	314	36	315	30
22-Aug-99	10:42:56	313	35	304	28
22-Aug-99	10:42:57	315	33	314	27
22-Aug-99	10:42:58	315	35	318	27
22-Aug-99	10:42:59	319	34	311	28
22-Aug-99	10:43:00	315	33	311	28
22-Aug-99	10:43:01	313	32		
22-Aug-99	10:43:02	311	33		
22-Aug-99	10:43:03	310	29		
22-Aug-99	10:43:04	316	31		
22-Aug-99	10:43:05	315	31		
22-Aug-99	10:43:06	321	30		
22-Aug-99	10:43:07	315	29		
22-Aug-99	10:43:08	316	27		
22-Aug-99	10:43:09	315	29		
22-Aug-99	10:43:10	319	33		
22-Aug-99	10:43:11	321	31	313	28
22-Aug-99	10:43:12	314	32	316	29
22-Aug-99	10:43:13	315	33	320	30
22-Aug-99	10:43:14	309	32	319	28
22-Aug-99	10:43:15	314	30	306	27
22-Aug-99	10:43:16	314	28	316	29
22-Aug-99	10:43:17	319	28	315	28
22-Aug-99	10:43:18	321	27	314	28
22-Aug-99	10:43:19	318	28	315	28
22-Aug-99	10:43:20	316	29	321	29
22-Aug-99	10:43:21	319	29	306	27
22-Aug-99	10:43:22	318	32	310	24
22-Aug-99	10:43:23	320	33	308	26
22-Aug-99	10:43:24	318	33	308	26
22-Aug-99	10:43:25	319	32	313	26
22-Aug-99	10:43:26	315	30	304	25
22-Aug-99	10:43:27	318	31	306	23

1-second wind direction and speed recorded at 07L/07R TDZ anemometers

Date	Time (UTC)	RW 07L Direction (degrees)	RW 07L Speed (knots)	RW 07R Direction (degrees)	RW 07R Speed (knots)
22-Aug-99	10:43:28	309	30	301	25
22-Aug-99	10:43:29	310	27	306	29
22-Aug-99	10:43:30	311	26	314	29
22-Aug-99	10:43:31	313	28	303	29
22-Aug-99	10:43:32	314	28	305	29
22-Aug-99	10:43:33	311	26	305	31
22-Aug-99	10:43:34	311	26	316	30
22-Aug-99	10:43:35	314	27	304	28
22-Aug-99	10:43:36	310	28	308	30
22-Aug-99	10:43:37	314	28	309	27
22-Aug-99	10:43:38	311	31	313	26
22-Aug-99	10:43:39	311	31	313	26
22-Aug-99	10:43:40	311	29	315	25
22-Aug-99	10:43:41	314	31	305	28
22-Aug-99	10:43:42	320	31	315	27
22-Aug-99	10:43:43	319	30	311	25
22-Aug-99	10:43:44	324	30	324	26
22-Aug-99	10:43:45	320	29	318	25
22-Aug-99	10:43:46	318	29	324	24
22-Aug-99	10:43:47	320	28	320	23
22-Aug-99	10:43:48	315	28	319	21
22-Aug-99	10:43:49	318	27	311	22
22-Aug-99	10:43:50	319	28	320	24
22-Aug-99	10:43:51	320	26		
22-Aug-99	10:43:52	320	26		
22-Aug-99	10:43:53	316	24		
22-Aug-99	10:43:54	316	24		
22-Aug-99	10:43:55	310	24		
22-Aug-99	10:43:56	311	25		
22-Aug-99	10:43:57	315	28		
22-Aug-99	10:43:58	318	29		
22-Aug-99	10:43:59	315	29		
22-Aug-99	10:44:00	313	30		

One-minute mean cloud base heights

Ending-time (hh:mm:ss)	Cloud base (feet)
10:41:00	1300
10:41:10	1300
10:41:20	900
10:41:30	900
10:41:40	1200
10:41:50	800
10:42:00	900
10:42:10	900
10:42:20	1100
10:42:30	2300
10:42:40	2300
10:42:50	2300
10:43:00	1400
10:43:10	1400
10:43:20	1300
10:43:30	1200
10:43:40	1200
10:43:50	1400
10:44:00	1400

Notes :

i) Cloud base height (feet above mean sea level) measured by ceilometer at meteorological enclosure

ii) Touchdown elevation of RW25L ≡ 27 feet

iii) Aerodrome elevation is 19 feet above mean sea level.

Five-minute cumulative rainfall data

Ending-time (hh:mm:ss)	Rainfall (mm)
10:41:00	0.2
10:41:10	0.2
10:41:20	0.2
10:41:30	0.2
10:41:40	0.2
10:41:50	0.2
10:42:00	0.2
10:42:10	0.2
10:42:20	0.1
10:42:30	0.1
10:42:40	0.1
10:42:50	0.1
10:43:00	0.1
10:43:10	0.1
10:43:20	0.1
10:43:30	0.1
10:43:40	0.1
10:43:50	0.1
10:44:00	0.1

Notes : i) Rainfall recorded by rain gauge at meteorological enclosure

WTWS Alerts

ISSUE TIME: 22/08/1999 10:05

07RA	MOD	TURB	ARR
07RD	WSA	15K+	1MD
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	WSA	15K+	3MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:06

07RA	MOD	TURB	ARR
07RD	WSA	20K+	1MD
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	WSA	20K+	3MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:07

07RA	MOD	TURB	ARR
07RD	WSA	20K+	1MD
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	WSA	20K+	3MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:08

07RA	MOD	TURB	ARR
07RD	WSA	20K+	1MD
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	WSA	20K+	3MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:09

07RA	MOD	TURB	ARR
07RD	WSA	20K+	1MD
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	WSA	20K+	2MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:10

07RA	MOD	TURB	ARR
07RD	WSA	20K+	1MD
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	WSA	20K+	2MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:11

07RA	MOD	TURB	ARR
07RD	WSA	15K+	1MD
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	WSA	15K+	2MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:12

07RA	MOD	TURB	ARR
07RD	WSA	20K+	1MD
07LA	MOD	TURB	ARR
07LD	WSA	15K +	RWY
25RA	WSA	15K +	3MF
25RD	MOD	TURB	DEP
25LA	WSA	20K+	3MF
25LD	MOD	TURB	DEP

WTWS Alerts

ISSUE TIME: 22/08/1999 10:13

07RA	MOD	TURB	ARR
07RD	WSA	15K+	1MD
07LA	MOD	TURB	ARR
07LD	WSA	15K+	RWY
25RA	WSA	15K+	2MF
25RD	MOD	TURB	DEP
25LA	WSA	15K+	2MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:14

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	WSA	15K+	RWY
25RA	WSA	15K+	2MF
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:15

07RA	MOD	TURB	ARR
07RD	WSA	20K+	1MD
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	WSA	20K+	2MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:16

07RA	MOD	TURB	ARR
07RD	WSA	15K+	1MD
07LA	MOD	TURB	ARR
07LD	WSA	15K+	1MD
25RA	WSA	15K+	1MF
25RD	MOD	TURB	DEP
25LA	WSA	15K+	2MF
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:17

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	WSA	15K+	RWY
25RA	WSA	15K+	2MF
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:18

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:19

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:20

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	MOD	TURB	DEP
25RA	MOD	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:21

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:22

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:23

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	MOD	TURB	DEP
25RA	MOD	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:24

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	MOD	TURB	DEP
25RA	MOD	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:25

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	MOD	TURB	DEP
25RA	MOD	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:26

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	MOD	TURB	DEP
25RA	MOD	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:27

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	MOD	TURB	DEP
25RA	MOD	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:28

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA	MOD	TURB	ARR
07LD	SVR	TURB	DEP
25RA	SVR	TURB	ARR
25RD	MOD	TURB	DEP
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

ISSUE TIME: 22/08/1999 10:29

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:30

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:31

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:32

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:33

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:34

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:35

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:36

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:37
07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:38
07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:39
07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:40
07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:41
07RA
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD

ISSUE TIME: 22/08/1999 10:42
07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:43
07RA
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD

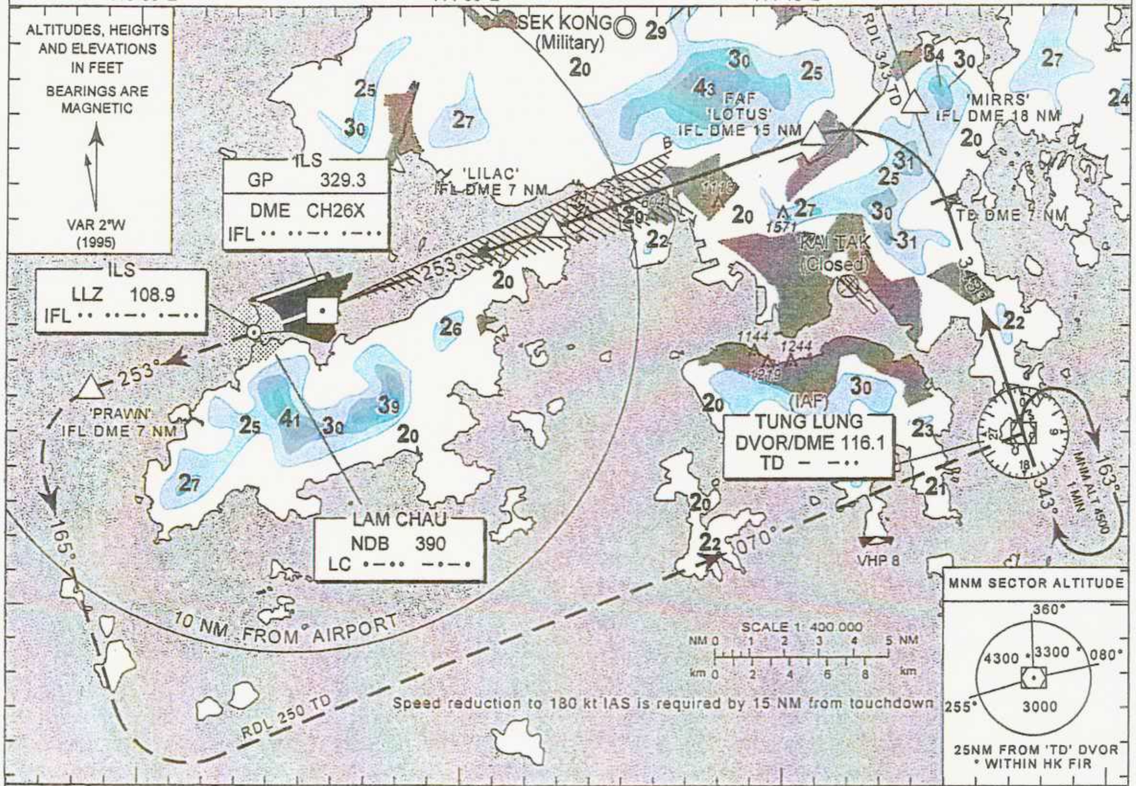
ISSUE TIME: 22/08/1999 10:44
07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

WTWS Alerts

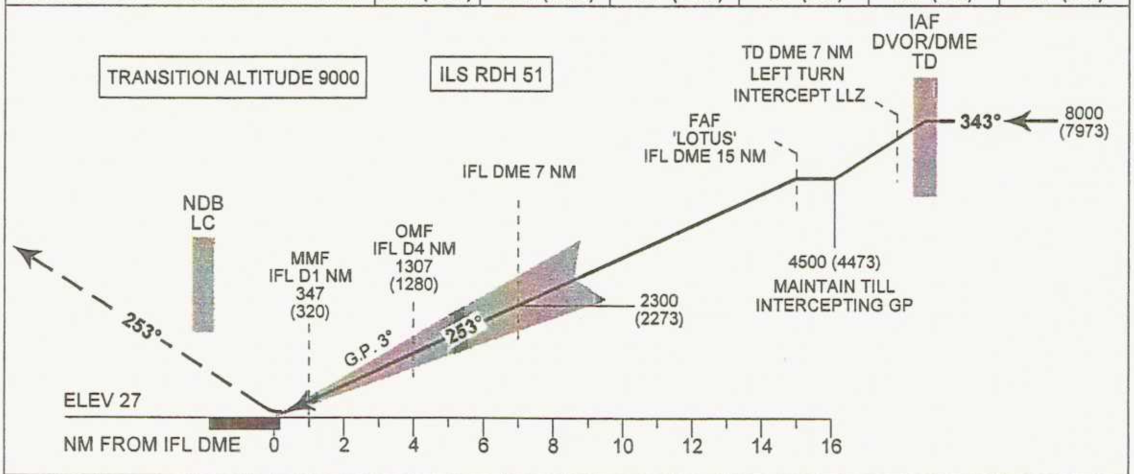
ISSUE TIME: 22/08/1999 10:45

07RA	MOD	TURB	ARR
07RD	MOD	TURB	DEP
07LA			
07LD	MOD	TURB	DEP
25RA	MOD	TURB	ARR
25RD			
25LA	MOD	TURB	ARR
25LD	MOD	TURB	DEP

INSTRUMENT APPROACH CHART	AERODROME ELEV 19 FT HEIGHTS RELATED TO THR RWY 25L - ELEV 27 FT	TWR 118.4 APP 119.1	HONG KONG INTERNATIONAL ILS / DME RWY 25L (TD FEED-IN)



Recommended Profile	DME IFL	5	4	3	2	1
Nominal 3° GP Descent Rate 320 FT/NM	ALT (HGT)	1627 (1600)	1307 (1280)	987 (960)	667 (640)	347 (320)



	Climb gradient	
	2.5% (152 ft/NM)	3.2% (195 ft/NM)*
CAT I OCA (OCH)	437 ft (410 ft)	227 ft (200 ft)
CAT II OCA (OCH) (approved operators)	367 ft (340 ft)	127 ft (100 ft)

* **This climb gradient must be achieved until passing 1,800 ft AMSL**

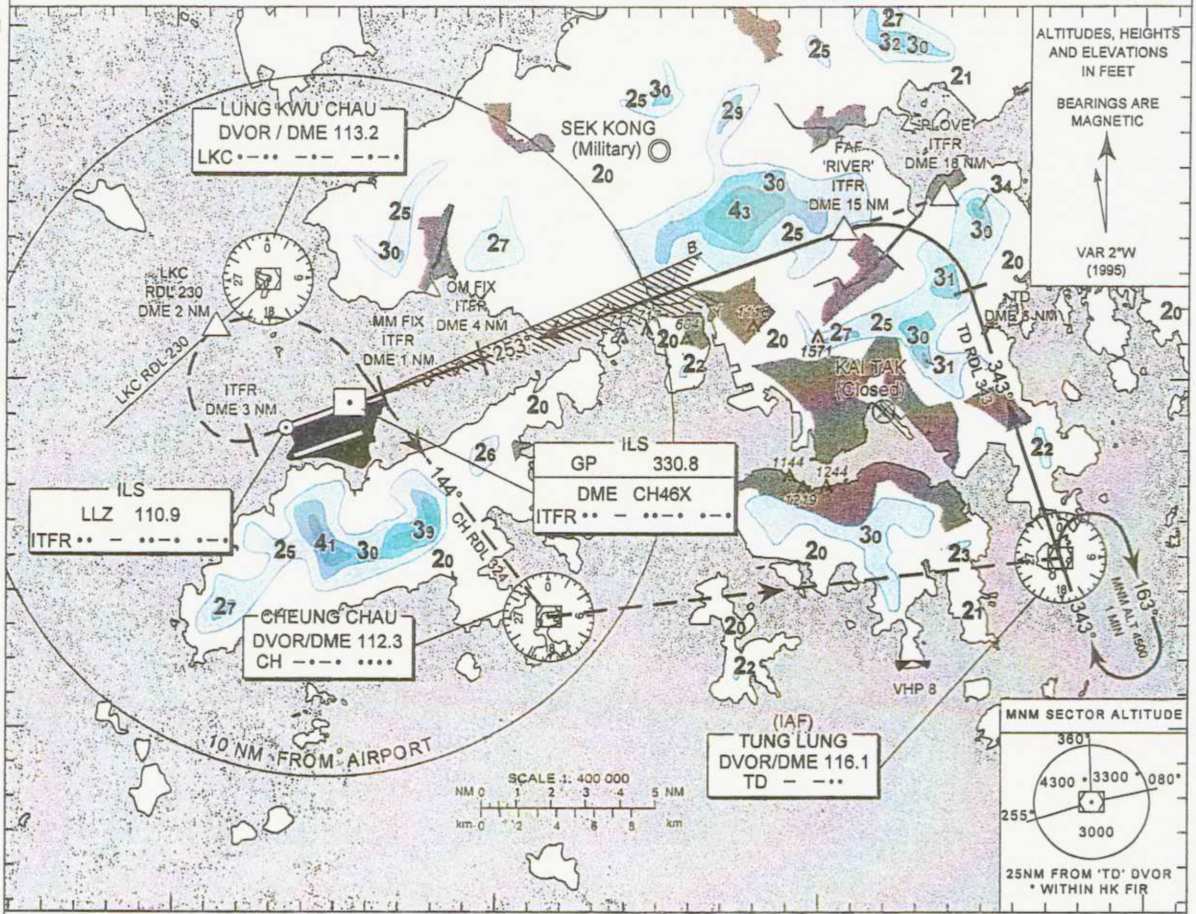
MISSED APPROACH

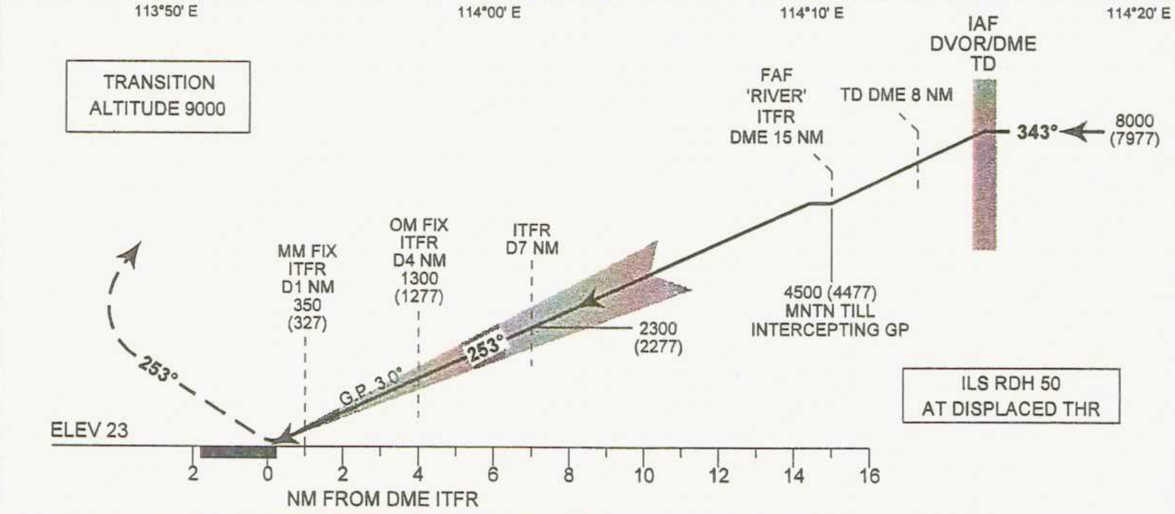
Climb to 2,000 ft. Remain on the extended runway centreline tracking 253°M (or bearing 253°M to/from LC NDB). At IFL DME 3 NM (west of airport) climb to 4,500 ft. At PRAWN (IFL DME 7 NM) turn left to track 165°M to intercept RDL 250 TD DVOR and join the TD holding pattern or as directed by ATC.

NOTE 1 A speed restriction of 185 kt IAS or less is required until established on track 165°M.

NOTE 2 Aircraft discontinuing an approach at or above 2,000 ft must continue on the glidepath to 2,000 ft and maintain until IFL DME 3 NM west of the airport.

INSTRUMENT APPROACH CHART	AERODROME ELEV 19 FT HEIGHTS RELATED TO THR RWY 25R - ELEV 23 FT	TWR 118.2 APP 119.1	HONG KONG INTERNATIONAL ILS / DME RWY 25R (TD FEED-IN)





	Climb gradient			
	2.5% (152 ft/NM)	**3% (183 ft/NM)***	**4% (243 ft/NM)***	**4.3% (262 ft/NM)***
CAT I OCA (OCH)	934 ft (911 ft)	694 ft (671 ft)	292 ft (269 ft)	223 ft (200 ft)
CAT II OCA (OCH) (approved operators)	858 ft (835 ft)	618 ft (595 ft)	216 ft (193 ft)	123 ft (100 ft)

*** These climb gradients must be achieved until passing 3,000 ft AMSL**

MISSED APPROACH

Climb to 2,000 ft. Remain on the extended runway centreline tracking 253°M. At ITFR DME 3 NM (west of airport), climb to 3,000 ft and turn right to establish LKC DVOR RDL 230 inbound. At LKC DME 2 NM, climb to maintain 4,500 ft and turn right to establish inbound on CH DVOR RDL 324. At CH turn left direct to TD DVOR and hold or proceed as directed by ATC.

NOTE 1 For ILS CAT III approach, aircraft must achieve a missed approach climb gradient of 4.3% (262 ft/NM) or greater until passing 3,000 ft AMSL.

NOTE 2 A speed restriction of 185 kt or less is required until established on CH RDL 324.

NOTE 3 Aircraft discontinuing the approach at or above 2,000 ft must continue on the glidepath to 2,000 ft. Maintain 2,000 ft on the extended runway centreline until ITFR DME 3 NM (west of airport).

RELEVANT CVR TRANSCRIPTS
DESCENT AND FINAL APPROACH

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:13:08	10:14:03	Radar	CI642	*DYNASTY 642, when ready descend to FL260.*			
10:13:13	10:14:08	CI642	Radar	*When ready descend FL260, DYNASTY 642.*			
10:13:28	10:14:23	Radar	CI642	*DYNASTY 642, contact Radar 126.3.*			
10:13:32	10:14:27	CI642	Radar	*Say again.*			
10:13:33	10:14:28	Radar	CI642	*DYNASTY 642, contact Radar 126.3.*			
10:13:38	10:14:33	CI642	Radar	*126.3, good day.*			
10:13:45	10:14:40	CI642	Radar	*Radar, DYNASTY 642 FL370.*			
10:13:50	10:14:45	Radar	CI642	*DYNASTY 642, Roger, when ready recleared FL130, reach by MANGO.*			
10:13:56	10:14:51	CI642	Radar	*Recleared FL130, reach by MANGO, 642.*			
10:14:06	10:15:01				P1	*We go to BAKER and hold, what is the last weather?*	
10:14:14	10:15:09				P2	*Latest wind?*	
10:14:15	10:15:10	ATIS	-	*Acknowledge information X-ray on frequency 119.35 for arrival, 129.9 for departure. This is Hong Kong International Airport information X-ray at time 1008. Runway in use 25L, runway 25R available on request, expect ILS, DME approach, runway ……*			Remainder of ATIS broadcast overlayed by other RTF broadcasts but still audible at times.

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:14:55	10:15:50				P2	*Are you avoiding weather? Shall we request?*	
10:15:03	10:15:58	CI642	Radar	*DYNASTY 642, request heading 360 due to weather.*			
10:15:08	10:16:03	Radar	CI642	*360 DYNASTY 642 approved.*			
10:15:11	10:16:06	CI642	Radar	*Thank you.*			
10:15:29	10:16:24				P1	*We can make it, wind 300, 35 at 255 is 45, 25 knots, 25 knots crosswind.*	
10:15:51	10:16:46				P2	*Are we going down now?*	
10:15:52	10:16:47				P1	*Yes, you told the heading?*	
10:15:55	10:16:50				P2	*Yes*	
10:15:57	10:16:52				P1	*Let's go down, X-ray, we are only clear ……*	
10:16:01	10:16:56	CI642	Radar	*DYNASTY 642, leaving 370 for 130 now.*			
10:16:06	10:17:01				P1	*OK, we try it.*	
10:16:10	10:17:05	Radar	CI642	*Roger, DYNASTY 642, when clear weather, track direct to MANGO.*			
10:16:14	10:17:09	CI642	Radar	*When clear weather, direct to MANGO.*			
10:16:19	10:17:14				P2	*When clear weather, direct to MANGO.*	
10:16:21	10:17:16				P1	*Ah?*	
10:16:22	10:17:17				P2	*When clear weather, direct to MANGO.*	
10:16:24	10:17:19				P1	*We are leaving for 130.*	

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
							Non-pertinent cockpit conversation
10:17:08	10:18:03				P1	*OK. Which runway 25? Left, ILS25L, 8000, TD, to 4500, minimum 227, 227, go-around down 2000, or up 2000 until 3 miles, then PRAWN, maintain 165 to 4500 TD.*	Approach briefing for RW25L.
10:18:16	10:19:11				P1	*If we are at 300, 35 that's OK.*	
10:18:19	10:19:14				P2	*We are, we are using runway 25, 25 Right? Minima is 223, minima 223.*	
10:18:30	10:19:25				P1	*223, 25L.*	
10:18:36	10:19:31				P2	*25 Right.*	
10:18:39	10:19:34				P1	*Who said 25R, the control?*	
10:18:42	10:19:37				P2	*Yes.*	
10:18:51	10:19:46				P1	*223.*	
10:19:00	10:19:55				P2	*Are we clear of weather?*	
10:19:02	10:19:57				P1	*MANGO.*	
10:19:04	10:19:59	CI642	Radar	*DYNASTY 642 clear of weather, now direct to MANGO.*			
10:19:09	10:20:04	Radar	CI642	*DYNASTY 642, thank you.*			

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:19:28	10:20:23				P1	*OK. 227, from TD to 4500 then go down 2000 on glide, cross 7 miles, 2300, 4 miles 1300, minimum 223, go-around 2000, 3 miles then turning right, and leaving 3000 to 4500, intercept 270, turn to the right, 185, otherwise its too complicated, speed 185 eh, right?*	Approach briefing for RW25R.
10:20:27	10:21:22				P1	*If you land, haven't, please be sure, people going out, very important.*	
10:21:16	10:22:11				P1	*Is that correct 25L, recognise?*	
10:23:16	10:24:11				P2	*We need visibility 800 metres or RVR 550.*	
10:23:38	10:24:33				P1	*How much is now?*	
10:23:39	10:24:34				P2	*Now is 800.*	
10:23:44	10:24:39				P1	*Cat II, we have Cat II?*	
10:23:46	10:24:41				P2	*No.*	
10:23:47	10:24:42				P1	*We can make for the wind, we can make Cat II for the wind, we must take Cat I we need.*	
10:24:05	10:25:00				P2	*Yes, Cat I, Cat I we need 800 metres.*	
10:24:12	10:25:07	Radar	CI642	*DYNASTY 642, contact Approach 119.35.*			
10:24:17	10;25:12	CI642	Radar	*119.35, DYNASTY 642, good day.*			
10:24:34	10:25:29	CI642	Appr	*Hong Kong, DYNASTY 642 passing 150 for 130 and we have information X-ray.*			
10:24:43	10:25:38	Appr	CI642	*DYNASTY 642, good evening and Roger, descend 8000 feet, QNH 986.*			

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:24:49	10:25:44	CI642	Appr	*8000 feet and 896.*			
10:24:52	10:25:47				P1	*986.*	
10:24:54	10:25:49	CI642	Appr	*986, DYNASTY 642.*			
10:24:58	10:25:53	Appr	CI642	*That's correct, QNH 986 is current.*			
10:25:01	10:25:56	CI642	Appr	*Roger.*			
10:25:20	10:26:15				P1	*Anti-ice for the water.*	
10:25:46	10:26:41				P1	*What speed be addable for landing? 157, we need 20 more that means 17, 170 correct?*	
10:26:14	10:27:09				P1	*And the medium for the braking action, eh?*	
10:26:21	10:27:16				P1	*Now is clean, we need now is the spray for the water but the China Airline has no spray, very effective with the heavy rain.*	
10:26:35	10:27:30				P2	*If we cannot see, we just go-around.*	
10:26:38	10:27:33				P1	*Yes, yes.*	
10:26:41	10:27:36	Appr	-	*This is Approach transmitting, just landed traffic reported the lightning strike at 400 feet approach height.*			
10:26:49	10:27:44				P1	*See the light at 400 feet.*	
10:27:45	10:28:40				P1	*Why are they requesting 25L? Should be a reason.*	Preceding traffic requested approach to 25L.
10:27:54	10:28:49				P2	*For us?*	
10:27:55	10:28:50				P1	*No, I mean Cathay requesting 25L.*	
10:28:00	10:28:55				P2	*Parking gate?*	
10:28:01	10:28:56				P1	*Ah, no.*	
10:28:02	10:28:57	CI642	CI Ops	*Operations, DYNASTY 642.*			

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:28:06	10:29:01	CI Ops	CI642	*642 go-ahead.*			
10:28:08	10:29:03	CI642	CI Ops	*Parking gate?*			
10:28:10	10:29:05	CI Ops	CI642	*Gate is S29.*			
10:28:18	10:29:13	CI642	CI Ops	*Our parking gate is 29.*			
10:29:01	10:29:56				Area	*'Altitude'.*	1000 feet before assigned altitude.
10:29:55	10:30:50				P1	*Wind is pushing ……*	
10:30:15	10:31:10	Appr	CI642	*DYNASTY 642, turn right by the heading of 010, descend 6000 feet.*			
10:30:21	10:31:16	CI642	Appr	*Heading 010, descend 6000 feet, DYNASTY 642.*			
10:30:42	10:31:37	Appr	CI642	*DYNASTY 642, reduce speed 220 knots.*			
10:30:47	10:31:42				P1	*220 knots.*	
10:30:48	10:31:43	CI642	Appr	*Speed 220 knots, DYNASTY 642.*			
10:31:35	10:32:30				Area	*'Altitude'.*	1000 feet before assigned altitude.
10:32:47	10:33:42	Appr	CI642	*DYNASTY 642, turn left heading 340, descend 4500 feet, DYNASTY 642.*			
10:32:53	10:33:48	CI642	Appr	*Heading 340, descend 4500 feet, DYNASTY 642.*			
							} Non-pertinent cockpit conversation
10:34:20	10:35:15				P1	*Slat extend.*	
10:34:22	10:35:17				P2	*Slat extend.*	

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:34:31	10:35:26	Appr	CI642	*DYNASTY 642, confirm your speed?*			
10:34:34	10:35:29				P1	*220 reducing.*	
10:34:34	10:35:29	CI642	Appr	*220.*			
10:34:35	10:35:30	Appr	CI642	*Roger reduce to 180 knots, I will take your slightly through the localiser for spacing.*			
10:34:41	10:35:36	CI642	Appr	*Roger reducing to 180 knots.*			
10:34:44	10:35:39				P1	*Flap 15.*	
10:34:55	10:35:50				P1	*We are down to Foxtrot Romeo ILS.*	
10:35:00	10:35:55	Appr	CI642	*DYNASTY 642, turn left on heading 230 to intercept the localiser from the right side, clear ILS approach runway 25L.*			
10:35:09	10:36:04	CI642	Appr	*Heading 230, confirm clear for ILS 25L?*			
10:35:13	10:36:08	Appr	CI642	*DYNASTY 642, heading 230 to intercept the localiser from the right side, clear ILS 25L.*			
10:35:21	10:36:16	CI642	Appr	*Roger, heading 230, clear for ILS25L, what RVR now?*			
10:35:26	10:36:21	Appr	CI642	*RVR is showing on runway 25L at the touchdown point 1300, at the midpoint 1600, at the stop end 1700 metre.*			
10:35:42	10:36:37	CI642	Appr	*Thank you sir.*			
10:35:44	10:36:39				P2	*25L, yes.*	

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:35:55	10:36:50				P1	*IFL, 25L, APPROACH/LAND so then go-around in sequence.*	Push of 'Approach/Land' control button to intercept ILS.
10:36:01	10:36:56				P2	*25L minimum is 22, 227 right? 25L minimum is 227.*	
10:36:17	10:37:12				P1	*2000, then go to PRAWN, climb 4500, turn left 165.*	
10:36:26	10:37:21				P1	*Speed is 185?*	
10:36:29	10:37:24				P2	*180.*	
10:36:31	10:37:26				P1	*180.*	
10:36:35	10:37:30				P2	*Sorry 180 …… max 185 when establish on 165.*	
10:36:46	10:37:41				P1	*LOC is alive, do we have the new …… yes 25R, we still have the 25R……*	Remainder blotted out by incoming transmission at 10:37:07.
10:37:07	10:38:02	Appr	CI642	*DYNASTY 642, you coming up the localiser now, maintain your speed 180 knots until 7 DME.*			
10:37:15	10:38:10	CI642	Appr	*Speed 180 knots until 7 DME, DYNASTY 642.*			
10:37:19	10:38:14				P1	*For the go-around please ……*	
10:37:21	10:38:16				P2	*Yes, standby.*	
10:38:23	10:39:18				P1	*14 miles leaving 4500, correct.*	
10:38:28	10:39:23	Appr	CI642	*DYNASTY 642, reduce speed now to 160 knots, contact Hong Kong Tower 118.4.*			
10:38:35	10:39:30	CI642	Appr	*160 knots, 118.4, DYNASTY 642.*			

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:38:48	10:39:43	CI642	Tower	*Tower, DYNASTY 642 with you on ILS 25L, 13 DME.*			
10:38:56	10:39:51	Tower	CI642	*DYNASTY 642, Hong Kong Tower, good evening, continue the approach 25L, number two, touchdown wind 230 degrees 26 knots gusting 36.*			
10:39:04	10:39:59	CI642	Tower	*Continue approach 25L, DYNASTY 642.*			
10:39:36	10:40:31	Tower	CI642	*Wind check acknowledge, 330 degrees 26 knots gusting 36 now.*			
10:39:59	10:40:54				P1	*We can't do it, another wind check below 1000 feet.*	
10:40:04	10:40:59				P2	*OK.*	
10:40:07	10:41:02				P1	*Gear down.*	
10:40:08	10:41:03				P2	*Gear down.*	
10:40:22	10:41:17				P1	*Go-around ready?*	
10:40:23	10:41:18				P2	*Yes.*	
10:40:24	10:41:19				P1	*2000.*	Discussion re missed approach procedure initial altitude.
10:40:34	10:41:29				P2	*Actually 4500.*	
10:40:36	10:41:31				P1	*2000 until 3 mile.*	
10:40:38	10:41:33				P2	*2000 until 3 mile.*	
10:40:50	10:41:45				P1	*Now is 330, OK flap 35.*	
10:40:54	10:41:49				P2	*Flap 35, medium.*	
10:41:10	10:42:05				P1	*Final checklist.*	
10:41:12	10:42:07				P2	*Final checklist, gear?*	
10:41:13	10:42:08	Tower	CI642	*DYNASTY 642, copy?*			
10:41:14	10:42:09				P1	*Negative.*	
10:41:15	10:42:10	CI642	Tower	*Negative.*			

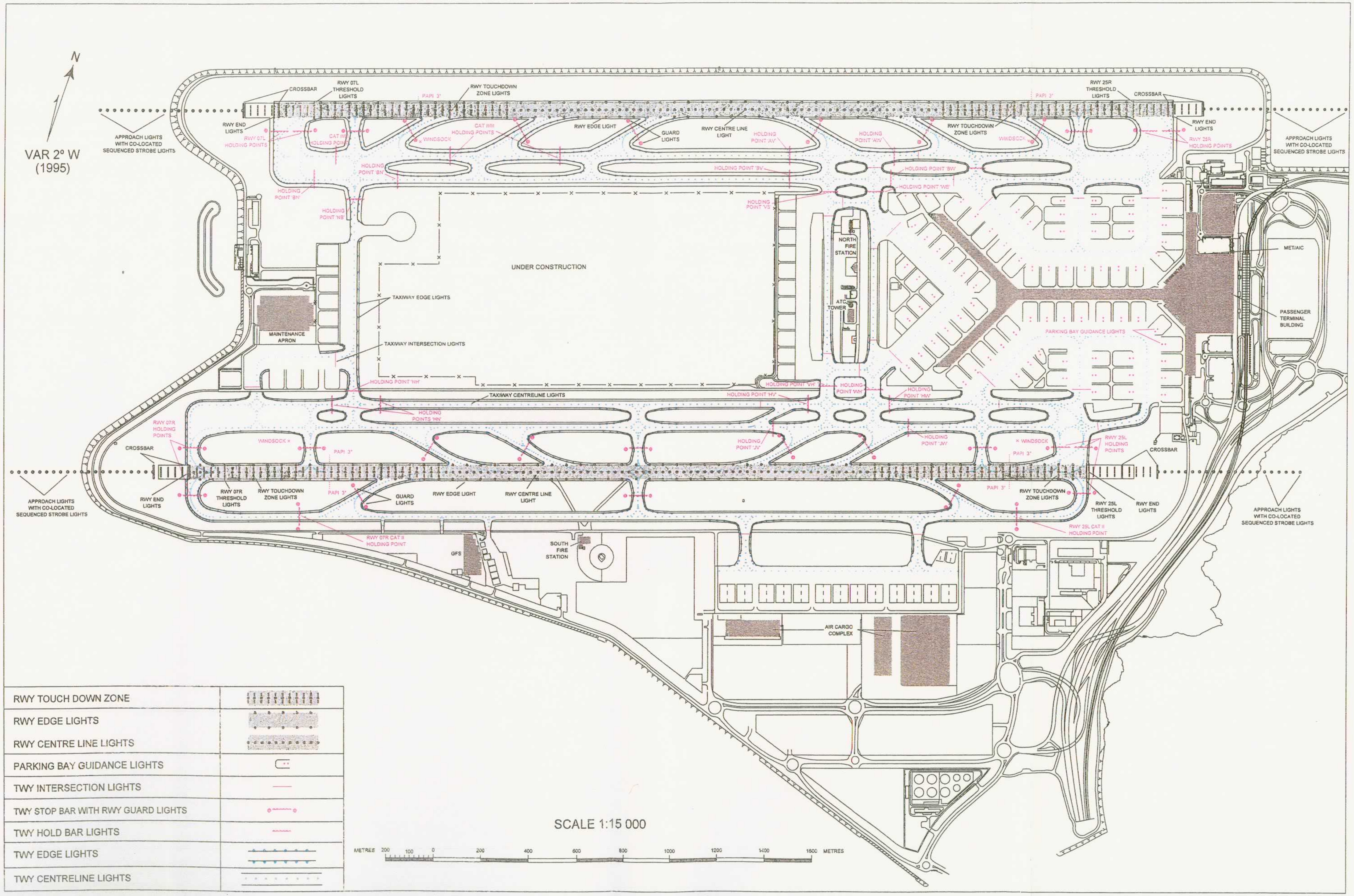
TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:41:17	10:42:12	Tower	CI642	*DYNASTY 642, braking action is good.*			
10:41:20	10:42:15	CI642	Tower	*Thank you.*			
10:41:22	10:42:17				P2	*Gear, 4 green, autobrake medium, spoiler arm, flap 35, ENA standby, final checklist standby ……*	Final word(s) blotted out by incoming RTF at 10:41:31.
10:41:31	10:42:26	Tower	CI642	*DYNASTY 642, the visibility at touchdown 1600 metre, touchdown wind 320 degrees at 25 knots, gust 33 knots, run way 25L clear to land.*			
10:41:44	10:42:39	CI642	Tower	*Clear to land runway 25L, thank you.*			
10:41:53	10:42:48				P2	*Dual land.*	
10:41:56	10:42:51				P1	*Check list?*	
10:41:57	10:42:52				P2	*Completed.*	
10:42:10	10:43:05				P2	*Speed.*	
10:42:15	10:43:10				Area	*'1,000'.*	
10:42:18	10:43:13			*Approach light, approach light ahead, do you need the wind again?*			
10:42:31	10:43:26				P1	*No, yes, wind check, wind check.*	
10:42:37	10:43:32				P2	*OK, now in sight 6 ……*	
10:42:40	10:43:35	CI 642	Tower	*DYNASTY 642, wind check again?*			
10:42:44	10:43:39	Tower	CI642	*DYNASTY 642, just about to give you that, 320 degrees 28 knots gusting 36 knots.*			
10:42:48	10:43:43	CI642	Tower	*Thank you and we have the runway in sight around 700 feet.*			
10:42:51	10:43:46				Area	*'500'.*	

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:42:52	10:43:47	Tower	CI642	*DYNASTY 642.*			
10:42:53	10:43:48				Area		Warning sound for autopilot disengage.
10:42:57	10:43:52				P2	*Go-around speed 185.*	
10:43:08	10:44:03				P2	*Left of course.*	
10:43:15	10:44:10				P2	*Speed.*	
10:43:19	10:44:14				Area	*'100'.*	
10:43:23	10:44:18				Area	*'50, 40, 30, 20, 10'.*	
10:43:26	10:44:21				Area		Sound of touchdown.
10:43:30	10:44:25						End of recording.

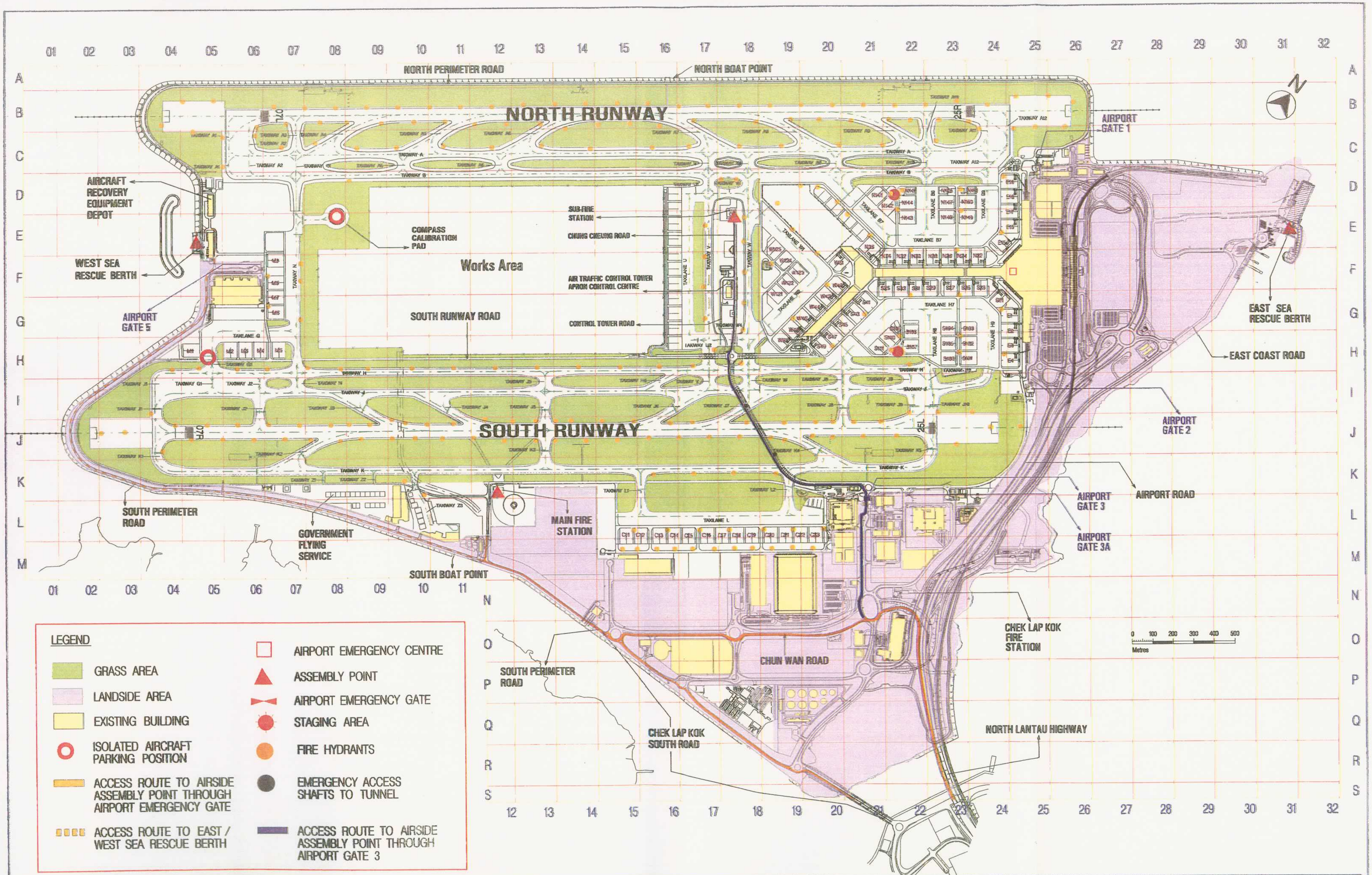
AERODROME CHART
(LIGHTING PLAN)

TWR 118.4 / 118.2
GMC 121.6 / 122.55

HONG KONG
INTERNATIONAL AIRPORT



CIVIL AVIATION DEPARTMENT, HONG KONG
Cartography by Survey and Mapping Office, Lands Department



A12-1

PLAN 10 - AIRPORT GRID MAP

Plot Date: 03/08/99
Filename: 151CA700.AOM

Tabulated FDR Data - 500 feet RA to Touchdown

subframe count	ALT (FEET)	RALT (FEET)	CAS (KTS)	TAT (DEG)	AOA (DEG)	ROLL (DEG)	PITCH (DEG)	HDG (DEG)	LONG G (G)	LATG (G)	NORMG (G)	AIL LO (DEG)	AIL LI (DEG)	AIL RI (DEG)	AIL RO (DEG)	ELEV (DEG)
											1.02547					0.175781
91616.125		507	167		4.74609	0.70312	3.16406		-1.08364	0.020414	1.06438			1.66992		
91616.25							3.16406	268.945			1.07812					1.93359
91616.375									-1.08364	0.014303	1.11474				1.31836	-1.75781
91616.5					6.67969	1.05468	3.16406				1.13763					
91616.625	1230								-1.08361	0.002081	1.12161	-1.8457				0.263672
91616.75							3.16406				1.05294					
91616.875									-1.08364	-0.016252	0.952224		-1.05469			-3.86719
91617					5.09766	1.05468	3.16406				0.945357					
91617.125		490	168.5						-1.08364	-0.026437	0.927045			-1.66992		-2.02148
91617.25							2.8125	268.945			0.952224					
91617.375									-1.08364	-0.042733	0.981981				-2.19727	-1.58203
91617.5					5.27344	0.70312	2.8125				1.00487					
91617.625	1212			26.25					-1.08364	-0.018289	0.956802	2.02148				0.527344
91617.75							2.8125				0.945357					
91617.875									-1.08364	-0.014215	0.988848		0.791015			-2.10937
91618					5.09766	0.70312	2.8125				0.954513					
91618.125		481	168						-1.08364	-0.020326	0.977403			-0.615234		-0.351562
91618.25							2.8125	268.945			0.986559					
91618.375									-1.06734	-0.016252	0.981981				-0.703125	0.966797
91618.5					4.92188	0.35156	2.8125				0.970536					
91618.625	1201								-1.07345	0.002081	0.998004	-1.49414				1.05469
91618.75							2.8125				0.991137					
91618.875									-1.08364	0.004118	1.01403		1.93359			-0.703125
91619					4.92188	0	2.8125				1.04607					

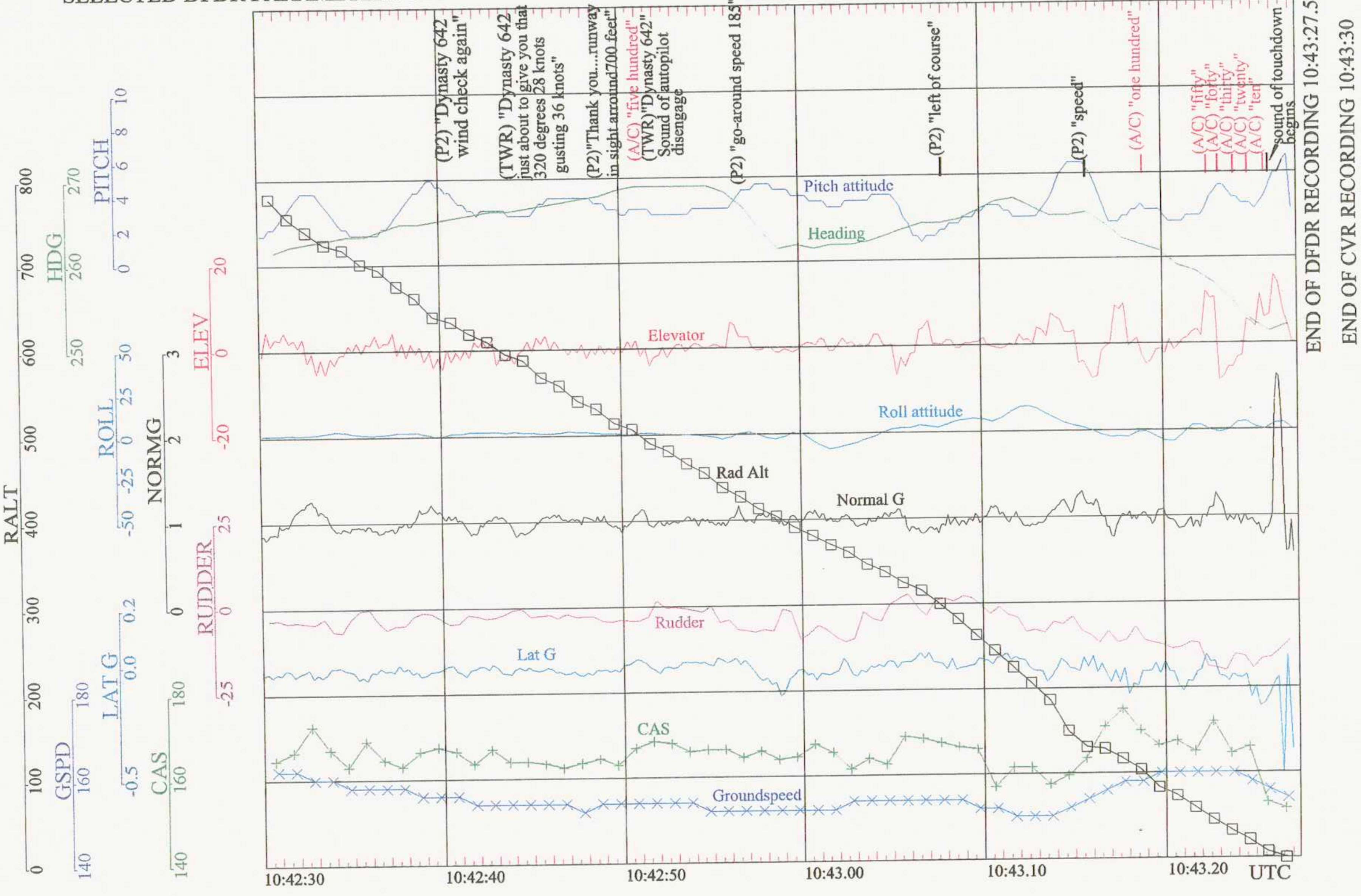
Tabulated FDR Data - 500 feet RA to Touchdown

subframe count	ALT (FEET)	RALT (FEET)	CAS (KTS)	TAT (DEG)	AOA (DEG)	ROLL (DEG)	PITCH (DEG)	HDG (DEG)	LONG G (G)	LATG (G)	NORMG (G)	AIL LO (DEG)	AIL LI (DEG)	AIL RI (DEG)	AIL RO (DEG)
91635.625	990				5.27344	7.0312	2.8125				1.01174				
91635.75				26.75					-1.08364	-0.001993	1.01174	5.44922			
91635.875							3.16406				1.05981				
91636									-1.08364	-0.018289	1.13077		11.1621		
91636.125		245	157		6.32812	5.62496	3.16406				1.10788				
91636.25									-1.08364	0.010229	1.13305			-7.55859	
91636.375							3.16406	266.836			1.10101				
91636.5									-1.0816	0.01634	1.03009				0.966797
91636.625	978				7.91016	7.73432	3.16406				1.05523				
91636.75									-1.08364	0.030599	1.01403	-11.0742			

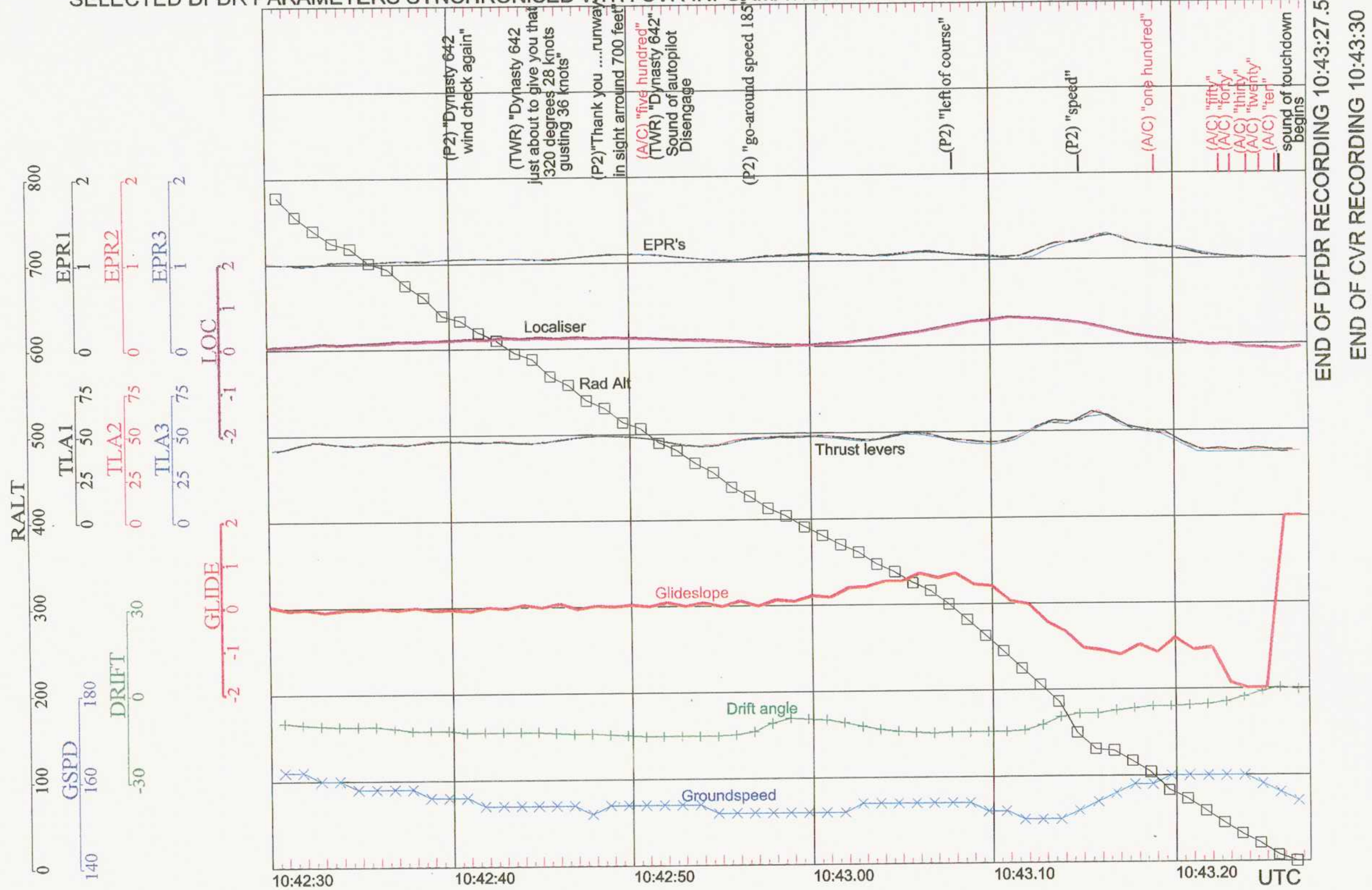
subframe count	ELEV (DEG)	RUD UP (DEG)	RUD LO (DEG)	STAB (DEG)	FLAP DEG	SPL 5L DEG	SPL 3L DEG	SPL 3R DEG	SPL 5R DEG	LAT (DEGS)	LON (DEGS)	GSPD (KTS)	DRIFT DEG	MINS	DME 1 NM	DME 2 NM	LOC (DOT)	GLIDE (DOT)	G WT	C of G	T FUEL
91635.625	1.75781									22.325592											
91635.75									1.8457		113.9296										
91635.875	-0.087891		-3.07617		33.75																
91636																					
91636.125	-0.351562																				
91636.25						6.24023						152	-14.4141								
91636.375	-0.615234	-1.05469		-8.96484																	
91636.5																	0.635081	0.0534194			
91636.625	-0.703125									22.325592											
91636.75								3.60352			113.9296										

subframe count	EPR 1	EPR 2	EPR 3	N1 1	N1 2	N1 3	N2 1	N2 2	N2 3	EGT E1 DEG C	EGT E2 DEG C	EGT E3 DEG C	FF E1 LB H	FF E2 LB H	FF E3 LB H	TLA 1 (DEG)	TLA 2 (DEG)	TLA 3 (DEG)	FCOUNT	SYNC
91635.625																				3
91635.75									80.75									42.5391		3
91635.875			1.02344									798								3
91636																43.9453			1910	4
91636.125	1.03125																			4
91636.25																				4
91636.375																	43.9453			4
91636.5		1.01953																		4
91636.625																				4
91636.75																				4

SELECTED DFDR PARAMETERS SYNCHRONISED WITH CVR INFORMATION - FINAL APPROACH AND LANDING



SELECTED DFDR PARAMETERS SYNCHRONISED WITH CVR INFORMATION - FINAL APPROACH AND LANDING



The Boeing Company
P.O. Box 3707
Seattle, WA 98124-2207

13 October 2000
B-H200-17074-ASI

FILE B-150
19 OCT 2000

Mr. Y. K Leung
Civil Aviation Department
10/F Commercial Building
Airport Freight Forwarding Centre
2 Chun Wan Road
Chek Lap Kok
Hong Kong

BOEING

Subject: Sink Rate Calculations - China Airlines MD11 B-150 Accident Hong Kong – 23 September 1999

Reference: E-mail Jim Adams to Rick Howes, item ii, 25 September 2000

Dear Mr. Leung:

Per the reference request, the following provides the methodology used to calculate the sink rate of the subject airplane. The sink rate calculation uses an Adams-Bashforth 2-integration scheme, starting 35 seconds before the airplane contact with the runway. The initial sink rate is determined by using the change in radio altitude over one second. When the initial sink rate has been established, the vertical acceleration is integrated using the following equations from the Adams-Bashforth 2-integration scheme:

$$Vz(1) = radalt(2) - radalt(1)$$
$$Vz(i) = vz(i-1) + (1.5 * nz(i) * g - 0.5 * nz(i) * g) * dt$$

Where vz is the sink rate, nz is the vertical acceleration – 1, g is the gravitational acceleration of 32.2 ft/s^2, and dt is the time difference between samples.

A script was created to loop through these calculations to develop a time history of the sink rate for the final 35 seconds of the flight. Since the impact (right main landing gear contact with runway surface) sink rate is dependent on the value used for the starting sink rate, the starting point is moved forward by one second and the sink rate is recalculated using the new starting point.

To verify the calculated sink rate is accurate, it is integrated to calculate the radio altitude. This calculated radio altitude is then compared with the radio altitude recorded on the DFDR. Any difference in these values is corrected by adding a bias to the vertical acceleration and recalculating the sink rate and radio altitude.

A calculated sink rate of approximately 18 feet per second was determined using the above methods for this accident. The attached plots show the sink rate calculations for each of the starting points, which is approximately 18 feet per second. The second plot shows the radio altitude calculations with the recorded radio altitude (raw and adjusted for terrain height).

If you have any further questions, please do not hesitate to contact me.

BOEING

Very truly yours,

R. J. Howes

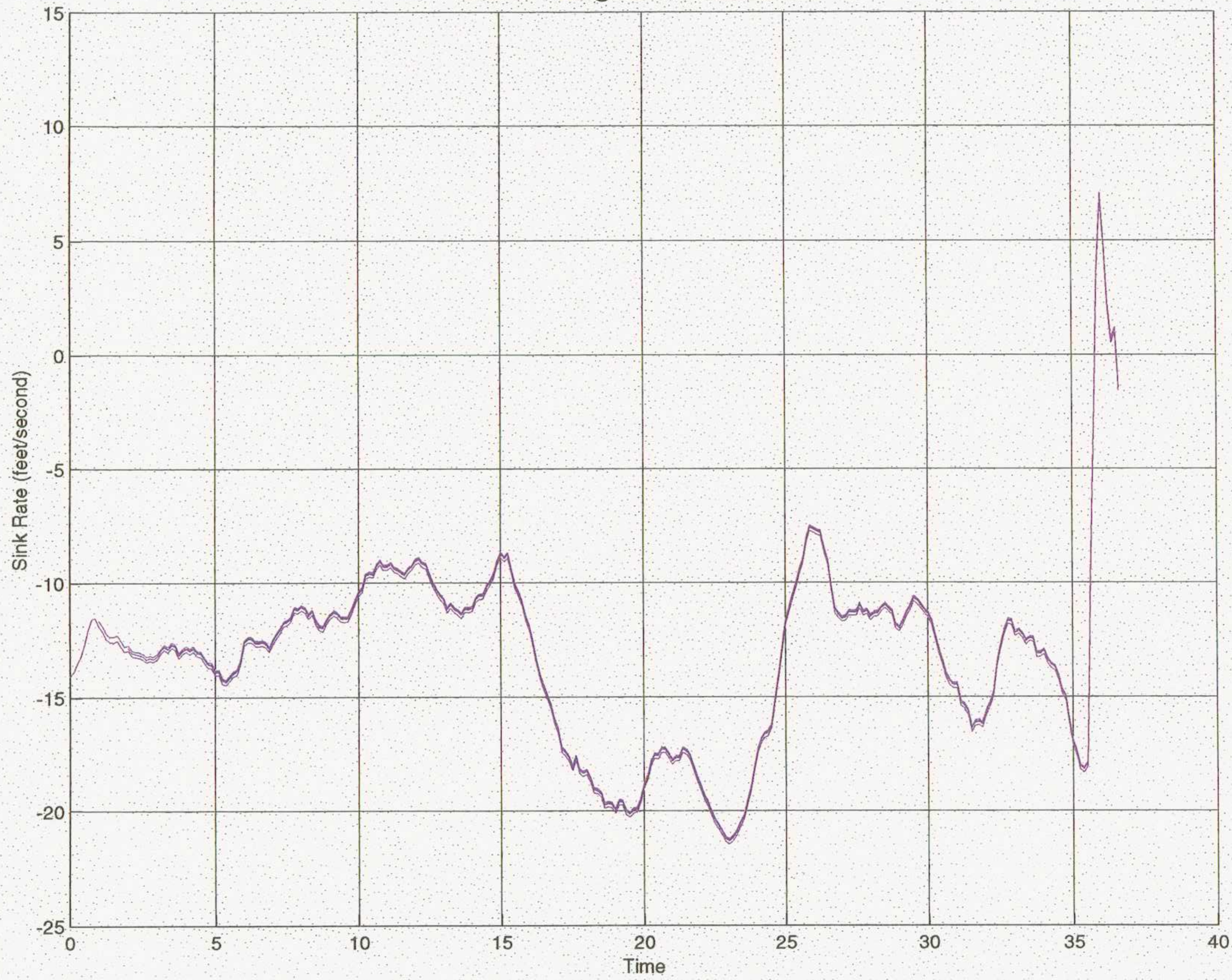
for: Ronald J. Hinderberger
Director, Airplane Safety
Org. B-H200, MC 67-PR
Telex 32-9430, STA DIR AS
Phone (425) 237-8525
Fax (425) 237-8188

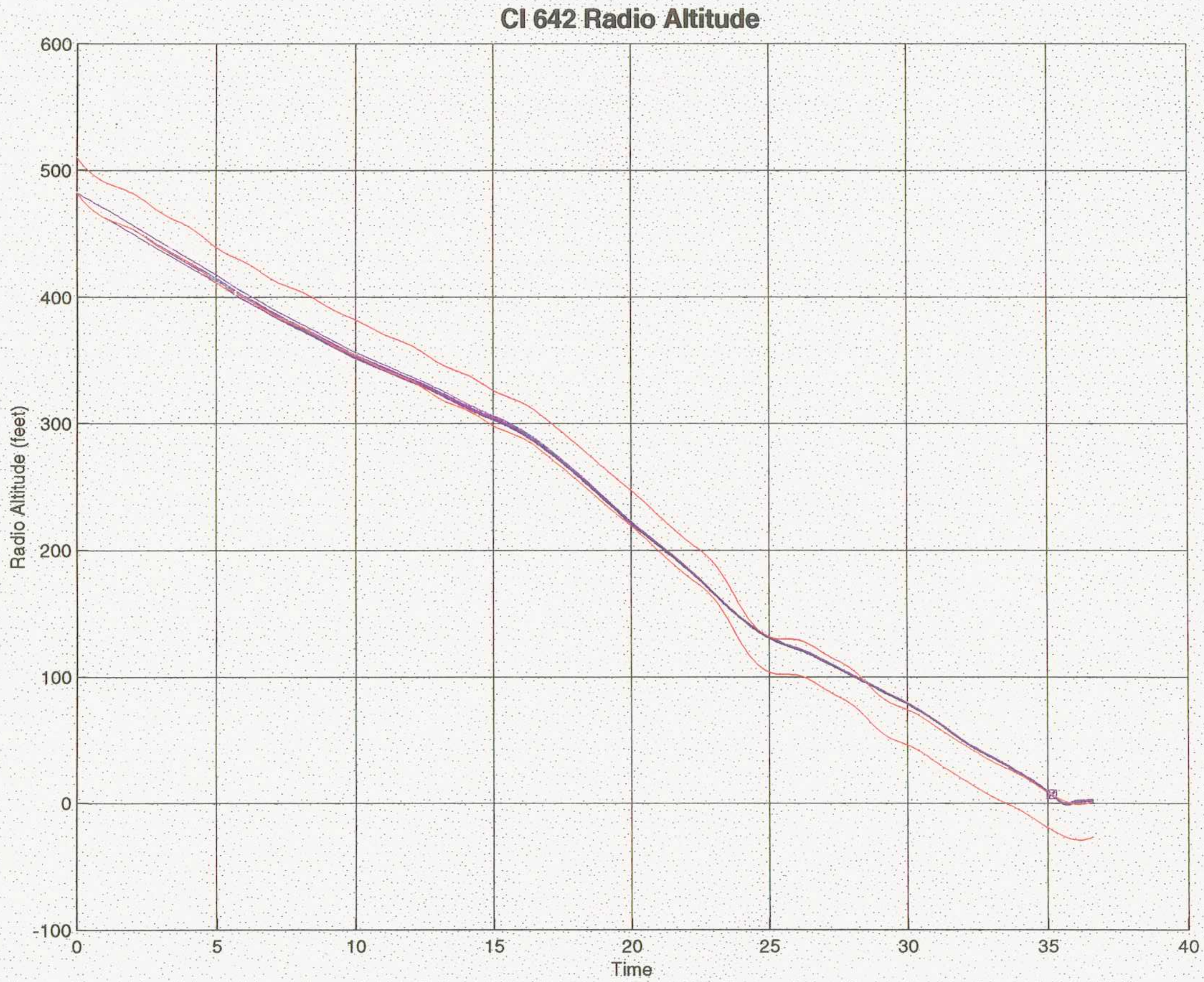
Encl:

- Boeing Figure 1, *CHI 642 Integrated Sink Rates*, and Figure 2, *CHI 642 Radio Altitude*

cc: Mr. Bob Benzon, NTSB, AS-10 (for Mr. John O'Callaghan)
Dr. Kay Yong, Taiwan ASC,
Captain Samson Yeh, China Airlines

CI 642 Integrated Sink Rates




CI 642 Radio Altitude
Radio Altitude (feet)
600
500
400
300
200
100
0
-100
0
5
10
15
20
25
30
35
40
Time

WRECKAGE INFORMATION

1. Fuselage

The fuselage was found inverted at the main wreckage with severe impact damage and fire damage (Figure 1). The crown of the fuselage was crushed downward for the entire length (nose to tail). The pilot and co-pilot's windows were cracked and the side windows were pulled out and were lying outside the cockpit. There was no evidence of any bird strike or foreign object damage on the cockpit windows. The right side of the fuselage suffered slight impact damage just aft of the R1 entry door. The skin at this location was torn in the vertical direction (Figure 2).

The remaining fuselage on the right side was intact and suffered no impact damage. There was evidence of heavy external soot and fire damage on the skin and right wing fairing just forward of the right wing front spar. The lower wing fairing aft of the right main landing gear wheel well exhibited severe scrape/grind marks. These scrape marks were at 30 degrees angle (nose left orientation).

About a 10-feet section of the right wing upper and lower skins with front and rear spars remained attached to the fuselage (Figure 3). The trapezoid fitting which connects the fixed and folding retractable side brace of the right main landing gear remained attached to the fuselage. This fitting suffered no fire damage and was fractured in tension at the brace connection. The fractured surface exhibited overload features. This fracture surface area was cut from the fitting for detailed metallurgical examination. The right main landing gear had separated from the wing and fuselage point and was found near the aft right side of the fuselage under the right horizontal stabilizer (Figure 4).

The left fuselage suffered crushing damage just aft and forward of the L1 entry door. A large section of the fuselage common to L2 door from Station 735 to Station 1059 was pushed out (Figure 5). The remaining portion of the fuselage remained intact with minor impact damage. The aft section of fuselage suffered external fire damage and soot damage on left and right sides.

2. Wings

2.1. Left wing

The left wing remained attached to the fuselage and was found at the main wreckage (Figure 6). The inboard section of the wing exhibited evidence of sooting. There was evidence of scrape marks on the upper wing skin in a span-wise direction outboard of no.1 engine location. The leading edge at the inboard section was slightly damaged and suffered fire damage. The leading edge at the no.1 engine location was crushed aft and slightly upwards. The inboard slats remained attached to the wing and were found in extended position (approximately 30 degrees position). The leading edge outboard of the no.1 engine suffered severe impact and fire damage at various locations. The slats outboard of the no. 1 engine remained attached to the wing and were in the extended position. The outboard end of the slat suffered fire damage. The wing structure outboard from Station 855 suffered severe fire damage with the structure exhibiting melting. The front and the rear spars of the outboard section suffered severe fire damage and had sagged. The wing tip suffered severe fire damage. The outboard aileron and the wing-lets were consumed by fire. The spoilers remained intact with no apparent damage.

The inboard flap and the inboard aileron remained attached to the wing structure. There was evidence of slight scrape marks on the upper surface of the flap. The outboard flap remained attached with minimum damage. The left main landing gear remained attached to the attachment fitting on the wing. There was no damage to the attachment fitting.

2.2. Right Wing

The right wing fractured between the no. 3 engine nacelle and the right side fuselage at Station 163 on the leading edge and Station 197 at the rear spar (Figure 3). About a 15-feet section of the front spar and a six-feet section of the rear spar remained attached to the fuselage. The upper and the lower skins between the front and the rear spar of the inboard section remained attached to the fuselage and exhibited upwards bending. About a six-feet section of the outboard front spar separated from the upper skin near the fractured end and the spar cap was cracked. The remaining nine-feet section remained attached to the upper skin and exhibited no bending. The stringers between the front and rear spar exhibited upward bending. The fractured surface exhibited overload features. There was evidence of slight fire damage and soot damage on the front spar and associated structure. Some of the fractured surfaces were sooted. The soot/fire damage was not very significant as compared to the outboard section of the wing.

The wing outboard from the fracture was in one section and was found about 300 feet from the nose of the airplane in the main wreckage (Figure 7). The upper skin exhibited sooting from the fracture to Station 772 and was consumed by fire from Station 772 to the tip. There was a crack of about 30 inches long at the middle of the upper skin in a span-wise direction. The fractured surface on this crack was sooted. The upper skin was bulged upward 12 inches forward of the rear spar on the upper skin and the side rib. The upper skin bulge was 38x46 inches in area and bulged up for about two inches. The leading edge suffered severe impact damage and fire damage. The inboard slat was detached and recovered at the site. The middle and outboard slats suffered severe fire damage and remained attached to the leading edge. The leading edge from the fracture to Station 538 suffered fire damage. The inboard end of the leading edge suffered severe impact damage and was dented at various locations. The leading edge outboard of Station 538 was consumed by fire. There was no evidence of heavy scrape marks on the upper skin. Only light scrape marks were observed at the inboard end on the upper skin in a fore and aft direction. The wing tip suffered severe fire damage on the upper skin. The strobe lens reflector and the case with the bulb remained intact and suffered fire damage. There was no evidence of any scrape marks on the wing tip structure on the lower skin. The right wing lower skin was intact from the inboard fracture location to the tip and suffered severe fire damage. There was no evidence of any heavy scrape marks on the lower skin.

The inboard fractured end of the lower skin exhibited severe scrape marks and grinding on the edge of the skin at a 45-degree angle.

The inboard flap was missing and was found on the left side of the runway in the vicinity of the main wreckage. The inboard aileron and the outboard flap suffered severe fire damage and were separated from the wing. These control surfaces were found at close proximity to the right wing. The outboard aileron was consumed by fire along with the outboard section of the wing.

The engine pylon forward attachment fitting (tombstone fitting) that attached to the engine pylon remained attached to the front spar and was fractured across the middle. The fractured end exhibited evidence of bending aft. The forward wing pylon mount fitting was pulled downward at the forward end and was slightly bent inboard. The aft pylon mount fitting remained attached to the lower skin with no bending. The aft pylon mount remained attached to the lower skin and was slightly bent aft. All the fasteners on the aft mount bulkhead sheared.

The forward and aft main landing gear attach fitting suffered severe damage. The aft lug of the forward mount fractured between 4 o'clock to 10 o'clock position (view looking forward - see Figure 8). The fractured surface exhibited soot accumulation and slight discoloration. The forward mount was cracked and exhibited impact damage in an upward direction. The forward mount shear pin was sheared off and a portion of the shear pin remained with the forward lug (Figure 9). The remaining piece was attached to the landing gear. The fractured surface on the shear pin was heavily sooted. The aft mount was fractured, and both the lugs along with a large piece of fitting remained attached to the landing gear including the shear pin (Figure 10). The entire area of the main landing gear fitting and fractured surfaces exhibited evidence of sooting. The piece of the head-end of the main landing gear actuator remained attached to the fitting.

3. Landing Gears

3.1. Right Main Landing Gear

The right main landing gear was separated from its mount. The forward shear pin was sheared off from the forward mount and half of the shear pin remained in the forward lug of the forward mount. This section of the shear pin was pushed out and exhibited severe soot damage on the fracture surface. The remaining portion of the shear pin remained on the forward lug of the landing gear and exhibited some bending. The fractured surface on this portion exhibited surface rust and the fractured surfaces could not be examined. The aft lug of the forward mount fractured between the 4 o'clock and 10 o'clock positions. This section of the lug fractured into two pieces and was found on the runway between the touchdown point and the main wreckage. The mating fractured surface on the wing forward mount aft lug exhibited some discoloration but the mating fractured surface of the lug that was found on the runway did not exhibit any discoloration. All surfaces on the aft lug exhibited evidence of overload features. There was no evidence of fire or soot on the pieces of lug found on the runway. The forward fitting that remained attached to the landing gear fitting suffered soot damage. The forward mount fractured in the middle and exhibited impact damage in an upward direction (Figure 8).

The landing gear fitting between the forward and aft mount fractured and a portion of the fitting was missing. This section was attached to the landing gear with the aft pin still in place. This piece also exhibited impact damage between the forward and aft mount. The landing gear fitting between the forward and aft mounts suffered severe soot damage and the soot was evident on the fracture surfaces.

The right main landing gear strut remained intact and was fully extended at the main wreckage site. The strut was deflated later for safe handling. The folding side brace remained attached to the gear. The upper rib of the folding side brace was fractured and twisted near the end that attached to the fuselage. A small section of the fixed brace remained attached to the trapezoidal fitting along with the folding side brace (Figure 11). The trapezoidal fitting fractured from the trapezoidal panel that attached to the fuselage (Figure 12). The trapezoidal panel pillow block remained attached to the fixed and folding brace. The fractured surface exhibited evidence of overload features. There was no evidence of fire damage or soot damage to the right main landing gear.

The truck beam suffered impact damage and was cracked at the aft stop location on the upper surface. The forward stop exhibited severe impact damage on the upper surface. All four tyres remained attached to the truck beam. The outboard tyres remained inflated and the pressures in the tyres were 200 psi each. The inboard tyres were deflated. The inboard side-wall of the inboard tyres exhibited severe scuff marks generally in radial direction. There was no evidence of any fire damage to the landing gear tyres.

3.2. Centre Landing Gear

The centre landing gear fractured at the bottom of the cylinder (oleo) near the axle (Figure 13). The fractured surface exhibited overload features with a 45-degree shear lip and was severely rusted. The wheel truck with tyres was found on the runway near the main wreckage. There was evidence of heavy impact damage on the right hydraulic brake reservoir that attached on the wheel. The heavy impact mark was a 3/8-inch wide indentation and ranged up to 1/2 inch deep. There was no evidence of any fire damage or soot damage to the centre gear truck assembly. Only one tyre was inflated and did not exhibit any scuff mark on the inner or outer side. The other tyre was deflated and suffered severe sharp cuts on its side.

The strut remained attached to the fuselage with the inner cylinder (oleo) compressed all the way in. The lower end of the strut exhibited grinding consistent with runway contact. These grind marks was approximately at 45 degrees with respect to airplane centreline and about 30 degrees nose left. These grind marks covered about 50% of the circumferential surface. The body gear remained attached to the fuselage. There was no evidence of any damage to the gear-to-fuselage attachment point. There was no evidence of any fire damage on the centre landing gear.

A small section of the base of the oleo (lower cylinder) of about five inches long with torque link was separated from the centre gear. The fractured surfaces on both sides exhibited overload and were rusted.

3.3. Left Main Landing Gear

The left main landing gear remained attached to the wing and fuselage with its attachment point. There was no evidence of any impact damage or fire damage to the left main landing gear. The gear cylinder was extended and the gear was in the lock position with the folding and fixed side braces intact. The tyres remained attached to the truck beam assembly and suffered no damage.

3.4. Nose Landing Gear

The nose landing gear remained attached to the nose fuselage with minimum structural damage. The strut was in an extended position. The right tyre separated from the hub and was found near the main wreckage. The tyre exhibited heavy cut damage in the bead area of the tyre. The hub fractured circumferentially. The left tyre remained attached to the axle and was scuffed on the inboard side-wall. There was no evidence of fire damage to the nose landing gear.

4. Engine Pylons

4.1. No. 1 Engine Pylon

The no. 1 engine remained attached to the left wing at its forward attachment point. The forward attachment point is the tombstone fitting and remained fully attached to the upper and lower spar of the pylon. This tombstone fitting was bent forward about 60 degrees. The pylon separated at the rear mount fitting. The fitting fractured in the middle of the lug. The fractured surface exhibited evidence of overload failure. There was no evidence of any fire damage to the pylon-wing attachment structure.

4.2. No. 2 Engine Pylon

The no.2 engine pylon was separated from the empennage and was found intact. The front portion of the inlet duct was separated from the engine and the vertical stabilizer broke off at the manufacturing joint on the top of the pylon.

4.3. Engine No. 3 Pylon

The no. 3 engine separated from the wing at its pylon attachment points and was found in the grassy area near the right wing (Figure 14). The front (tombstone fitting) pylon mount fractured about 24 inches from the upper wing skin. This fitting suffered severe fire damage and the web and the cap was bent aft at the fractured end. The tombstone fitting was attached to the wing front spar and pulled out of the pylon about five inches below the pylon upper spar. The upper spar that the front links were attached, was broken out of the pylon and attached to the wing mount. A large section of the tombstone fitting remained with the engine pylon. The web and the cap were bent forward with slight twisting. The rear engine mount and bulkhead separated from the pylon in one piece and remained attached to the wing. The rear engine mount separated from the left and right pylon skin and all the fasteners were pulled out of the skin. The upper spar cap at the outboard side of the pylon was bent in a "U" shape and the web/ skin separated from the cap indicating that the pylon was experiencing loads in the inboard direction. The upper spar cap at the inboard side remained attached to the web with no noticeable bending. The inboard pylon skin was bent inboard.

5. Empennage

The right horizontal stabilizer remained attached to the empennage with severe impact damage (Figure 4). The section outboard of Station 292 was bent down. The inboard section remained attached to the empennage. The right stabilizer suffered soot damage on the leading edge, upper and lower skins. The leading edge and lower skin exhibited severe scrape marks and these scrape marks were on top of the sooted leading edge and skin. The scrape marks were in three distinct directions. One set of scrape marks near the leading edge ran in span-wise direction. The second set was about 30 degrees anti-clockwise from the span-wise direction (view looking down), while the third one was about 70 degrees anti-clockwise from the span-wise direction (view looking down). There were other scrape marks in various directions. These scrape marks are indication of runway contact. The leading edge of the stabilizer was dented and crushed at various locations. The outboard end of the leading edge was crushed aft. The inboard and outboard elevators remained attached to the horizontal stabilizer and suffered severe fire damage.

The left horizontal stabilizer fractured at Station 290 (Figure 15). The inboard section remained attached to the empennage with upper skin. This section exhibited upward bending. The lower skin was fractured at the root in a jagged fracture pattern. The front spar and the associated structure at the fractured location were bent aft. The upper and lower skin suffered soot damage. The inboard elevator remained attached with no impact damage but exhibited severe soot damage. The outboard elevator fractured at Station 290. There was no scrape marks observed on the inboard section of the horizontal stabilizer.

The vertical stabilizer right skin fractured approximately at Station 525 and at Station 426 on the left side (Figure 16). The left skin and the associated structure were bent to the left. The front spar fractured at Station 525 and the lower section of the front spar web was missing. The front spar at the fracture was bent slightly to the left. The rear spar fractured at Station 525 and was bent aft. The second fracture on the rear spar was at Station 444. At this location the spar was bent aft. The left skin from Station 525 was still attached to the upper vertical stabilizer but the right skin was missing. The upper forward and aft rudders remained attached to the vertical. The lower forward and aft rudders fractured at approximately Station 426. The rudder section below this station suffered severe fire damage. A portion of the lower vertical stabilizer (lower from Station 426) remained with the lower rudder and suffered fire damage. The vertical stabilizer fractured at the base just above the no.2 engine. The rear spar and aft centre spar fractured about 10 inches above the base and was bent aft The forward centre and front spar attachment point fractured six inches above the base and exhibited no bending. All the fractured surfaces exhibited evidence of overload.

6. Powerplants

The accident aircraft was powered by three Pratt & Whitney model PW4460 engines. All three engines were found at the crash site. None of the engines displayed signs of engine fire or non-contained events. All of the engine cowling and nacelle hardware was found forward of the aircraft touchdown area. The Full Authority Digital Engine Control (FADEC) was removed from each engine for analysis of engine fault information by the FADEC manufacturer. No further engine disassembly was required for investigation.

6.1. No. 1 engine; s/n: 723907 (Figure 17)

After the accident, no. 1 engine remained attached to the pylon structure. The engine and pylon had separated from the left wing at the front and rear pylon mounts. The engine was inverted, along with the wing, with the 12 o'clock position of the fan case resting on the ground. The inlet structure was separated from the engine forward of A-flange. The fan rotor and fan blades were intact. Fifteen of the fan blades were slightly bent opposite the direction of rotation. The other 21 fan blades were not significantly bent while two fan blades were slightly bent in the direction of rotation. The fan case showed signs of fan blade tip contact with the fan case attrition material. The Low Pressure Compressor (LPC) inlet vanes were intact and did not show signs of distress. No significant damage was found to the LPC blades and vanes that could be seen from the LPC inlet. The fan exit guide vanes were intact. The fan cowl doors were separated from the nacelle. The thrust reverser doors were found in the stowed position. The rear stages of the low-pressure turbine were intact and showed no indication of distress. No indication of engine failure or debris was found in the turbine exhaust case. The exhaust nozzle and tail cone remained intact and were not significantly distressed. There were no indications of any scrape marks on the engine nacelle.

6.2. No. 2 engine; s/n: 723968 (Figure 18)

After the accident, no. 2 engine remained attached to the inlet and engine mounting structure. The engine, inlet, and mounting structure separated from the aircraft along the diverter structure of the vertical stabilizer. The inlet duct was breached radially inward and forward of the fan face. Debris was found in the inlet duct in front of the fan face. The fan rotor and fan blades were intact. Foreign object impact damage was observed on the fan blades in the form of nicks and local deformations of the fan blade leading edges. The inlet, fan section, LPC, and bypass air surfaces were thinly covered in soot, consistent with the external, post-accident fire. No damage beyond slight foreign object damage was observed on the LPC inlet vanes or blades. The fan exit guide vanes remained intact. The fan cowl doors were separated from the fan case, one of which was found on the side of the runway. The bypass and core cowl doors remained on the engine and showed impact damage from external directions. The thrust reverser doors were found in the stowed position. No indication of engine distress was found on the 6th stage LPC blades or in the turbine exhaust case. The exhaust tail cone and nozzle remained attached to the engine.

6.3. No. 3 engine; s/n: 723952 (Figure 19)

After the accident, no. 3 engine remained attached to the pylon structure. The engine and pylon structure was separated from the right wing at both the front and rear pylon mounts. The engine mounts did not exhibit any signs of distress. The inlet duct separated from the engine immediately forward of A-flange. The inlet exhibited abrasion marks at the 6 o'clock position. The fan case separated from the engine at C-flange, just behind the fan exit guide vane outer platform mounts. The separated fan case structure showed no signs of non-containment. Engine externals mounted near the 6 o'clock position of the fan case exhibited abrasion marks. The fan containment belt, yellow in color, displayed heavy fraying in the 6 o'clock region. Fragments of the belt material were found on the runway. The fan hub was intact and contained all 38 fan blade attachments. Three fan blades were fractured at roughly 50% span while 25 fan blades were fractured at the part-span shroud location. The remaining 10 fan blades were of full length and bent opposite the direction of fan rotation. The LPC shroud was intact, with the 1st stage LPC stators showing signs of foreign object damage. Ground debris was found throughout the bypass ducts and the LPC.

The upper intermediate case struts were deformed rearward, while the lower struts were crushed into the engine core cowl. The outer structure of the bypass duct, including the thrust reverser, was collapsed radially inward on both the left and right sides of the nacelle. Scuff marks consisting of gray paint were found at the 10 & 11 o'clock positions. Two pieces were removed for further examination. The right thrust reverser door was in the stowed position. The left thrust reverser door was separated from the engine, along with the thrust reverser cascades. The thrust reverser cascades were in place on the right side of the engine. The lowest external region of the thrust reverser doors exhibited two distinct patterns of abrasion or grinding. One of the patterns of abrasion was oriented roughly along the engine centreline in the fore to aft direction. The second pattern of abrasion was oriented approximately 35 degrees right of engine centreline, also in the fore to aft direction. The 6th stage low-pressure turbine blades showed no signs of distress. The lower third of the turbine exhaust case was crushed radially inward at T-flange; however, P-flange was only slightly deformed. No engine debris was found in the turbine exhaust case. The exhaust nozzle was separated from T-flange. The exhaust tail cone suffered radial impact at the 6 o'clock position, but remained attached to the turbine exhaust case.

GENERAL COMMENTS

All station numbers are approximate
Conventional sign orientation with the aeroplane on gear
No evidence of any inflight collision or fire

Main Wreckage (Figure 1)

Right-hand Forward Fuselage (Figure 2)

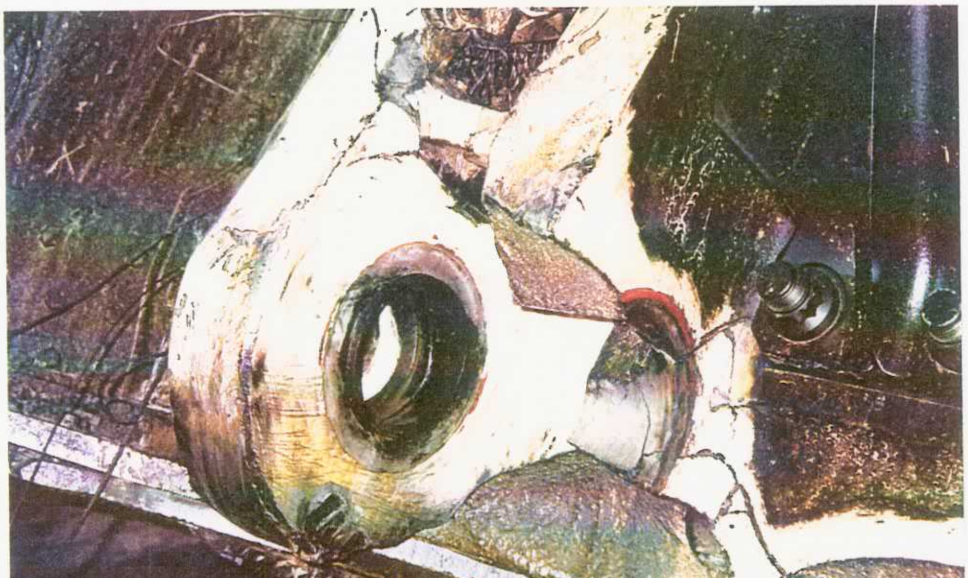
Right Wing Root Section (Figure 3)

Right Main Landing Gear and Right Horizontal Stabilizer (Figure 4)

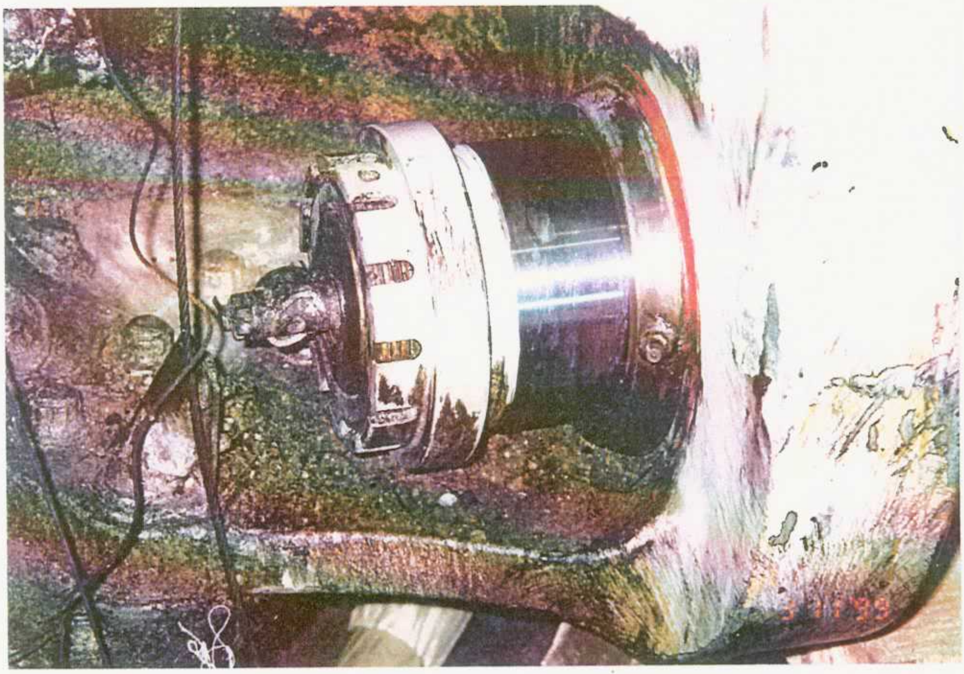
Left Forward Fuselage (Figure 5)

Left Wing (Figure 6)

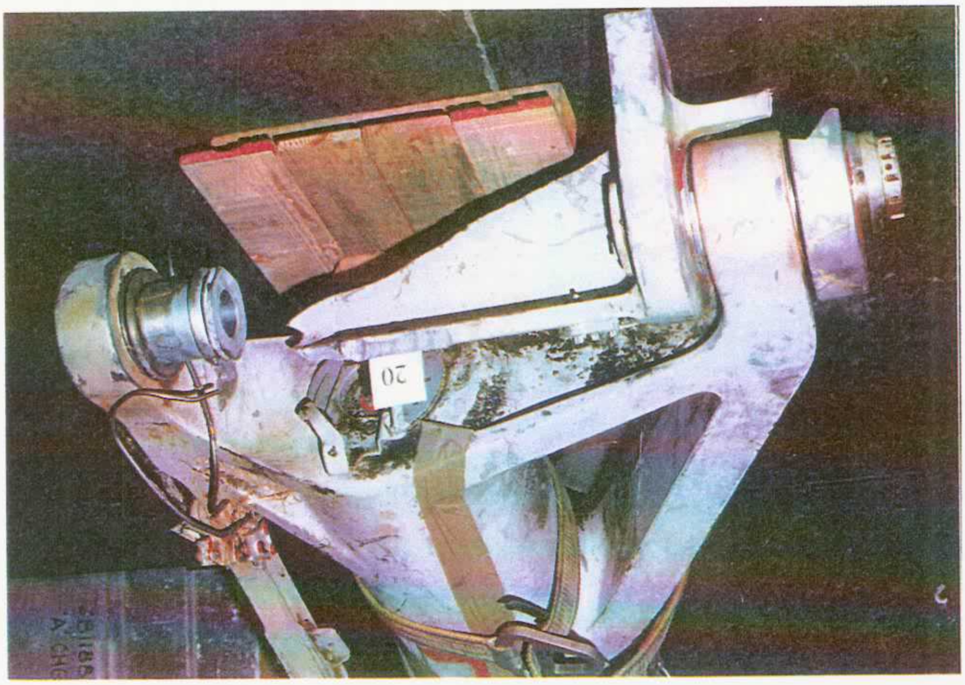
Right Wing Detached from Main Fuselage (Figure 7)



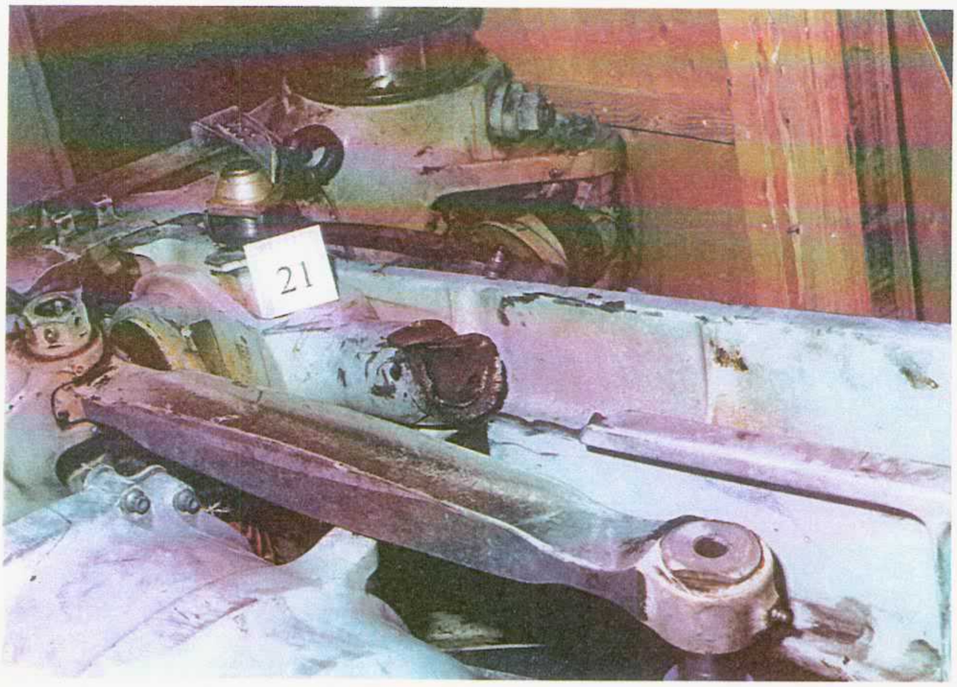
Right Main Landing Gear (RMLG) Forward Attachment Fitting (Figure 8)



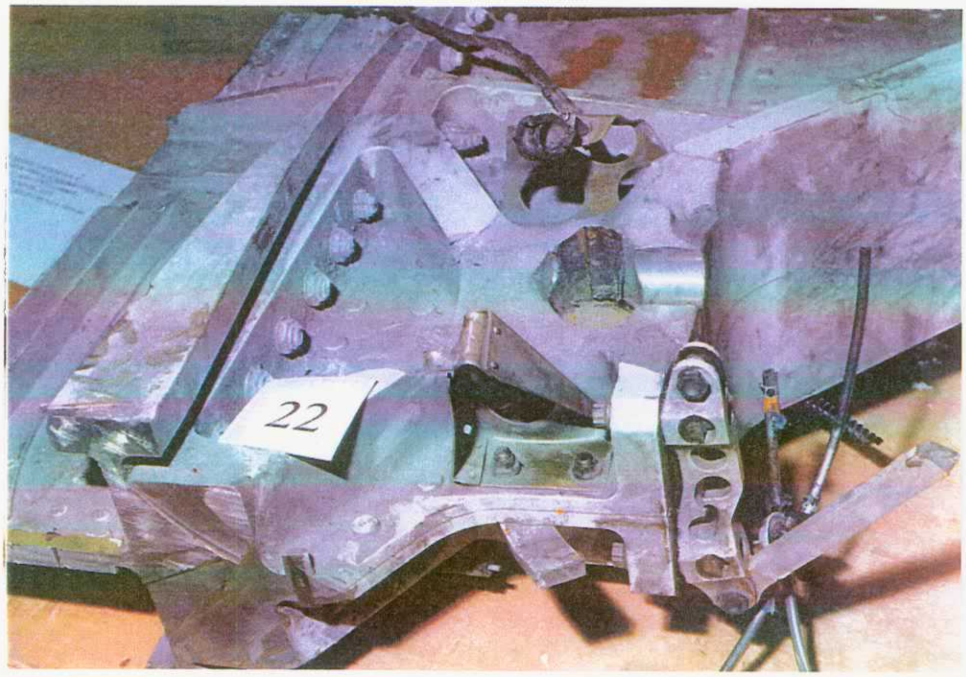
Forward Shear Pin (Trunnion Bolt) (Figure 9)



Fractured RMLG Aft Attachment Fitting with Aft Shear Pin (Trunnion Bolt)
(Figure 10)

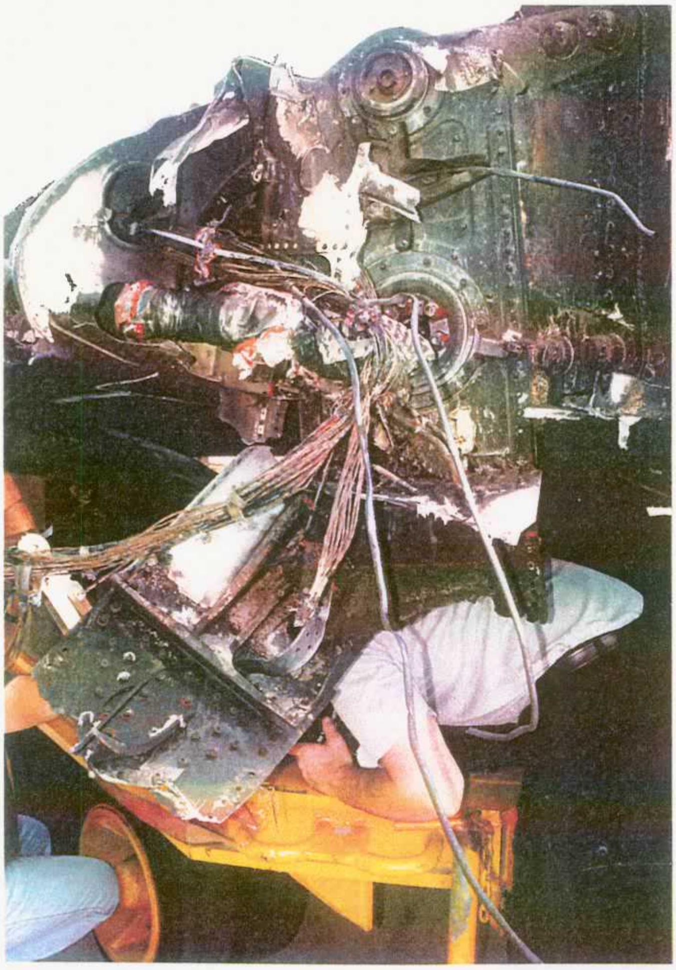


Fractured Fixed Side-Brace (Figure 11)



Fractured Trapezoidal Panel (Figure 12)

Fractured Center Landing Gear Oleo (Figure 13)



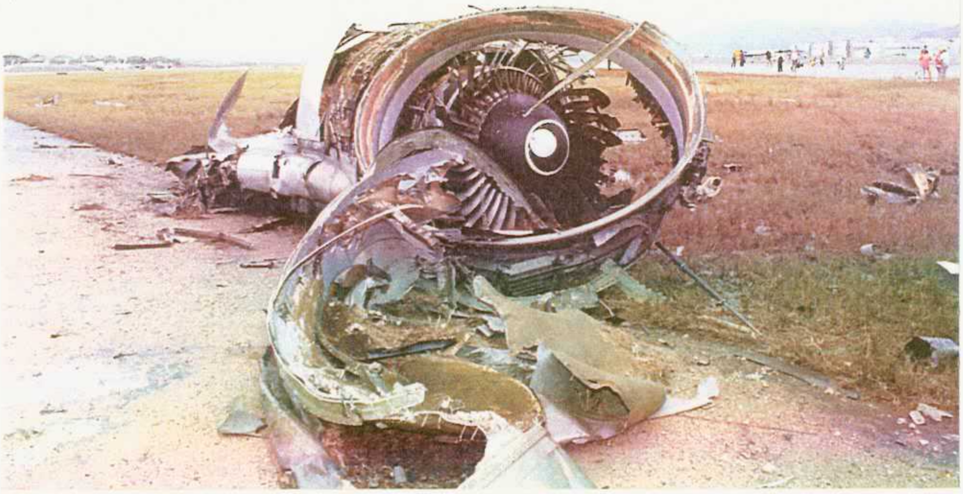
No. 3 Engine Pylon to Wing Forward Attachment Structure (Figure 14)

Left Horizontal Stabilizer (Figure 15)

Vertical Stabilizer (Figure 16)

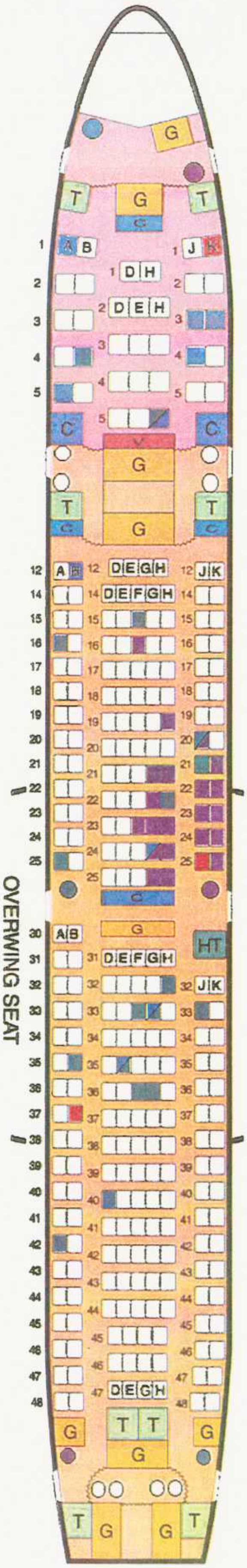
No.1 Engine (Figure 17)

No.2 Engine (Figure 18)



No.3 Engine (Figure 19)

SEAT LOCATIONS OF SERIOUSLY INJURED PERSONS



圖示說明 KEY TO AMENITIES

華夏商務客艙 Dynasty Business Class	經濟客艙 Economy Class
V 影音控制室 Video Control Center	HT 殘障設備盥洗室 Handicap Toilet
T 盥洗室 Toilet	G 機上廚房 Galley
C 衣帽間 Coat Closet	

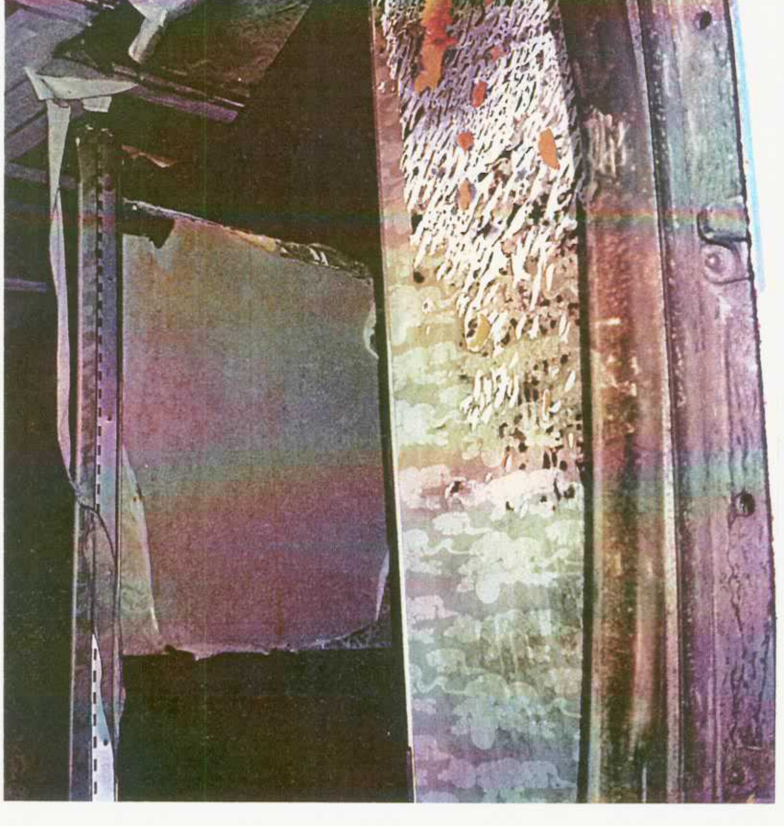
LEGEND

- Dead (3 pax)
- Burn or Scald (21 pax, 3 F/A)
- Head Injury (10 pax, 1 F/A)
- Other Injuries (18 pax, 2 F/A)

Photographs of Damaged Fuselage

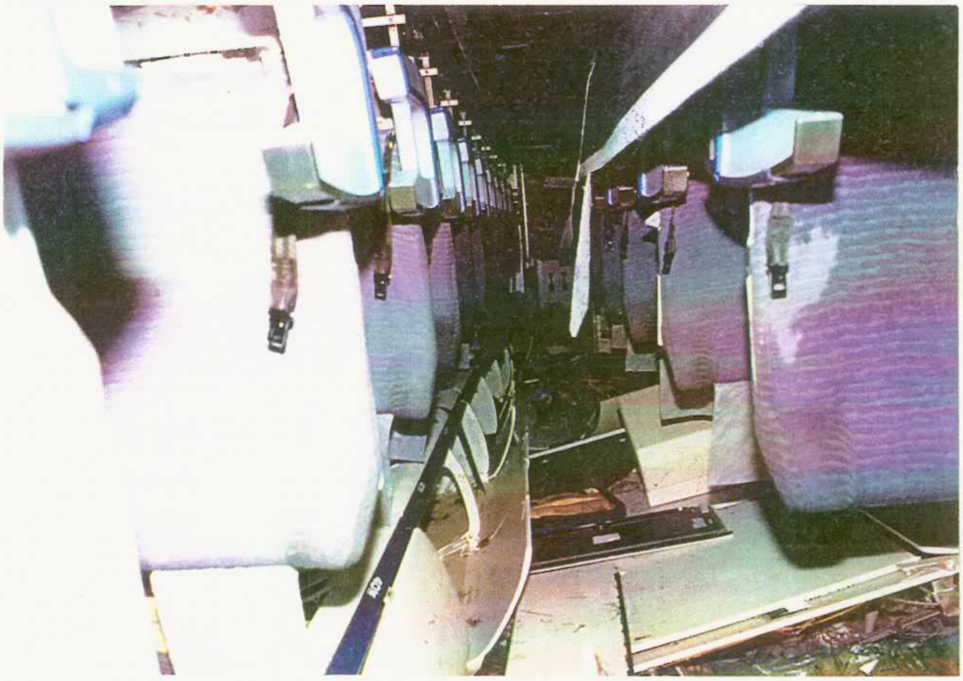
1. General view of main wreckage.

2. View of seats 1J and 1K.



3. View of the lavatory just inside Door 3R.

4. View of the Business Class section of the cabin.



5. View of the Economy Class section of the cabin.

6. View of right side of fuselage including Door 1R.

7. View of left side of fuselage including Door 3L.

8. View of crack in right fuselage (forward) including Door 2R.

9. View of crack in right fuselage (aft).

Enclosure to: B-H200-17041-ASI

MDC-00K1121

Sequence and Characteristics of the Structural Failure of the Mandarin Airlines (China Airlines) MD-11 Fuselage Number 518 – August 22,1999 Accident at Hong Kong International Airport

REVISION: NEW

ISSUE DATE: AUGUST 11, 2000

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REFERENCES

Reference 1 China Air Accident "Performance Group Report"

Reference 2 MDC-00K1008, "Materials and Process Engineering Report on Mandarin Airlines (China Airlines) MD-11 Fuselage Number 518 Accident at Hong Kong International Airport, Hong Kong, China"

1.0 DESCRIPTION OF STRUCTURAL ARRANGEMENT

A rendering of the MD-11 structural arrangement in the vicinity of the main landing gear is included as Figure 1. Note that the rendering is "artistic" in character and incorrectly shows some structure which should (from the view depicted) be hidden.

The MD-11 main landing gear is cantilevered off the rear spar of the wing. Two trunnion bolts attach the main landing gear strut (blue) to the wing fitting (green). The wing fitting attaches to the rear spar (yellow). Vertical, drag and side loads applied to the landing gear are reacted through the trunnion bolts into the wing fitting and from there into the main torque box of the wing.

The forward of the two main landing gear trunnion bolts is a designed "fuse". For very high drag loads (as might be encountered during an off-runway excursion, or if the landing gear struck an obstruction) the forward bolt is designed to shear as the forward main landing gear trunnion moves downward.

Loads about the main landing gear pivot axis (gear sideloads) are reacted via a trusslike structure made up of the folding side brace (magenta), the fixed brace (light blue), and the strut. This arrangement results in loads which are primarily up and down (vertical) at the joint where the truss attaches to the fuselage. The loads at this joint are primarily up when an inboard acting sideload is applied to the landing gear, and down when the sideload is outboard.

The fuselage attach point for the truss is on a machined beam referred to as the "trap panel" because of its trapezoidal shape. The trap panel is shown in red in Figure 1.

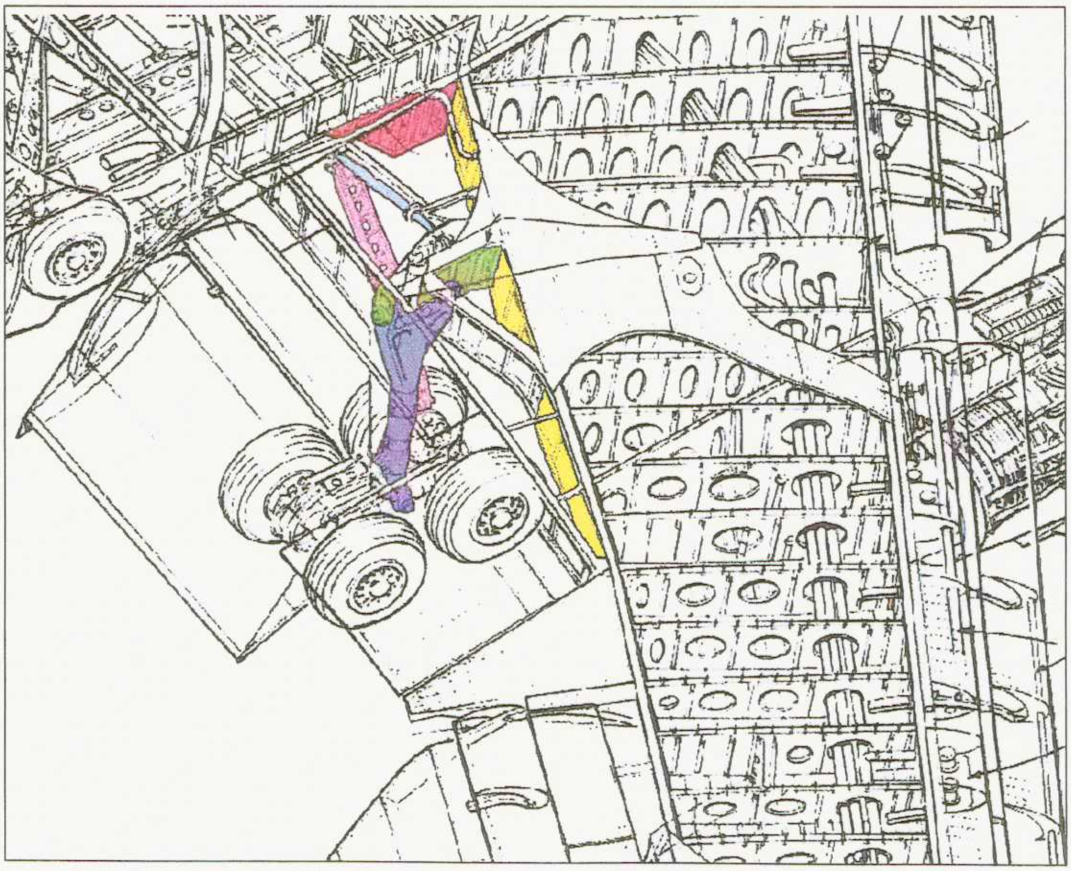


Figure 1. MD-11 Structural Arrangement in the vicinity of the MLG-to-Wing attachment

2.0 LANDING CONDITIONS

The attitude of the accident aircraft, along with the velocity and acceleration components were estimated from data obtained from the flight data recorder. More detail is available in the report published by the Performance Group of the accident investigation team (Reference 1). From a structural loads perspective the most significant of these parameters is the sink rate (velocity towards the ground) which has been estimated to be in the vicinity of 18-20 feet-per-second. The next most significant parameter is the roll attitude (approximately 3 degrees right-wing-down).

It should be noted that the design sink rate for a symmetric landing (zero degrees roll) is 10 feet-per-second. Recognizing that the kinetic energy which must be absorbed to decelerate an aircraft moving towards the ground is a function of the velocity *squared*, it is observed that the energy from a 20 foot-per-second sink rate is four times (not double) that from a 10 foot-per-second sink rate. And since the aircraft was rolled right at touchdown, most of the load was taken by the right-hand main landing gear.

3.0 LANDING SIMULATION

MD-11 crash landing simulation analyses were run using initial conditions consistent with the accident aircraft at touchdown. The aircraft was rolled right-wing-down 3 degrees, pitched nose-up 4.5 degrees, and was descending at nearly 20 feet-per-second. There was no perceptible roll rate and the lift on the airplane was roughly equal to its weight. The high sink rate combined with the rolled attitude caused

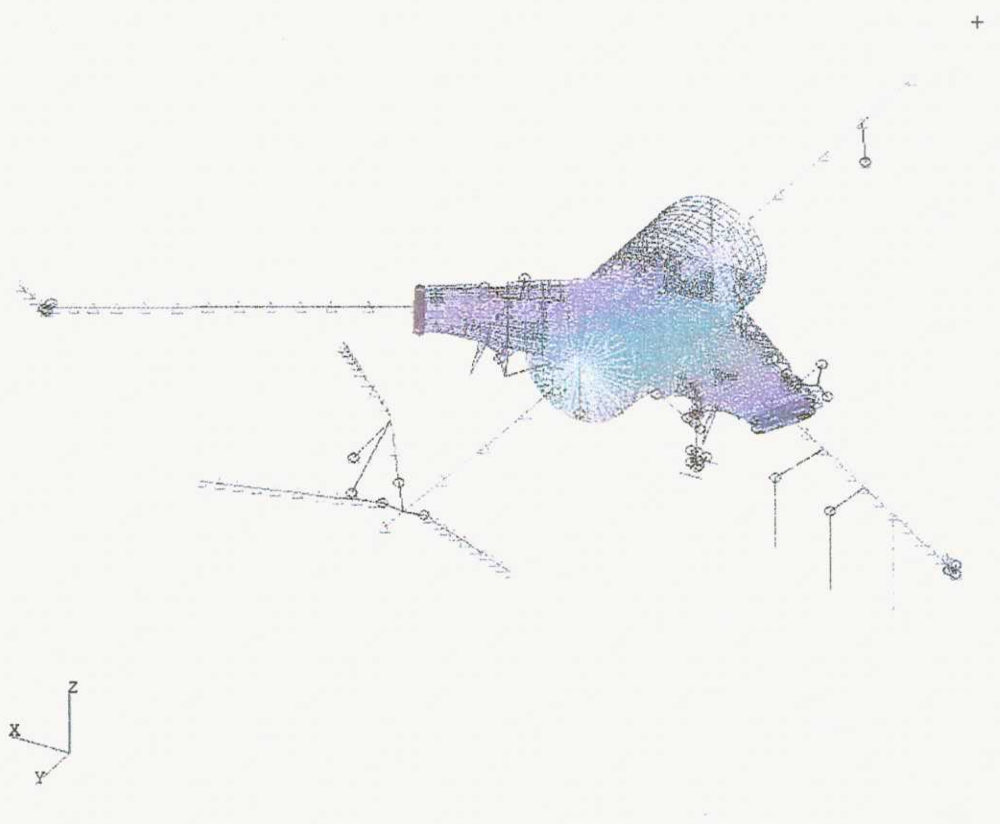


Figure 2. MD-11 Dynamic Landing FE Model

bottoming of the right main landing gear strut and generated a vertical load "spike" which failed structure in the area where the right main landing gear attaches to the right wing.

The structural failures (of the right wing rear spar in particular) which were observed in this accident bore notable similarities to those that were observed for a FedEx MD-11 that was involved in a crash landing at Newark, New Jersey on July 31st, 1997. A significant amount of analysis was conducted to simulate the FedEx accident and estimate structural loads on the right main landing gear, the right MLG-to-wing attach fitting, the right wing rear spar, and the right landing-gear-side-brace-fitting-to-trap-panel joint. These analyses were conducted using an in-house aircraft dynamic landing program (B7DC), a commercially available finite element program (MSC NASTRAN), and a commercially available nonlinear kinematics code (ADAMS).

Based on knowledge and experience gained in analyzing the FedEx accident a simplified analysis technique was developed for studying the effects of very high sink rate landings on aircraft structure. The crash landing analyses performed for this accident utilized MSC NASTRAN. A transient nonlinear solution was run using a detailed finite element model of the MD-11 inboard wing and center fuselage, combined with a coarser idealization of the remaining structure. (See Figure 2). The main landing gear was idealized using the BUSH1D element, which allowed the gear nonlinear spring and damping characteristics to be input in table form. The results from this model were compared and correlated with certification analyses (for cases within the design limits of the aircraft) and with the FedEx ADAMS analysis and were shown to be satisfactory.

The most significant differences in the structural loads applied to the aircraft during the FedEx and the China Airlines accidents lay in the drag loads applied to the right main landing gear. Landing gear drag loads were not significant for the FedEx accident. This is because the aircraft touched down, bounced, then landed a second time at a high sink rate and sink acceleration, and at a significantly rolled attitude. Since the high vertical loads occurred on the second touchdown, the wheels were already spinning and drag loads were minimal. The high vertical loads for the China Air accident occurred at the initial touchdown so "spin-up" and "spring-back" (plus and minus drag) loads were significant.

The existence of significant drag loads for the China Air accident required an adjustment to the simplified NASTRAN analysis technique. Spin-up and spring-back loads (essentially a time history of the main landing gear drag loads) were estimated using B7DC (the certification landing gear loads analysis program) and the time history was manually input into the NASTRAN solution. The peak load from the B7DC time history was phased to correspond with the peak right main landing gear vertical load.

Figure 3 displays the landing gear strut and tire loads for the China Airlines baseline case (Case 4.010). The structure responds linearly for this case and it is assumed that all of the lift on the right-hand wing is lost when the right main landing gear load reaches 600,000 lbs. (This assumption is consistent with analyses that were run for the FedEx crash simulations, which used ADAMS to dynamically calculate wing lift as a function of local angle of twist). For the China Airlines analysis, both the left main landing gear and the center landing gear pick up load well before the right main landing gear reaches its peak load.

The strut and total-tire load time histories should be equal for a given gear (note that the right main landing gear strut load oscillates near its peak and separates after the peak due to NASTRAN convergence problems). These convergence problems do not have a significant effect on the time history of the other gear loads or the peak value of the right main landing gear total-tire load.

Time histories of key loads from Case 4.010 are plotted in Figure 4. From the figure, the right main landing gear strut load peaks at 1.4 million pounds, the peak rear spar shear flow is 35,000 lbs/in, and the peak load on the right main landing gear forward trunnion bolt is 1.2 million pounds. The rear spar shear flow is well in excess of what is required to fail the rear spar shear web and the forward trunnion bolt load is roughly that which is required to fail it.

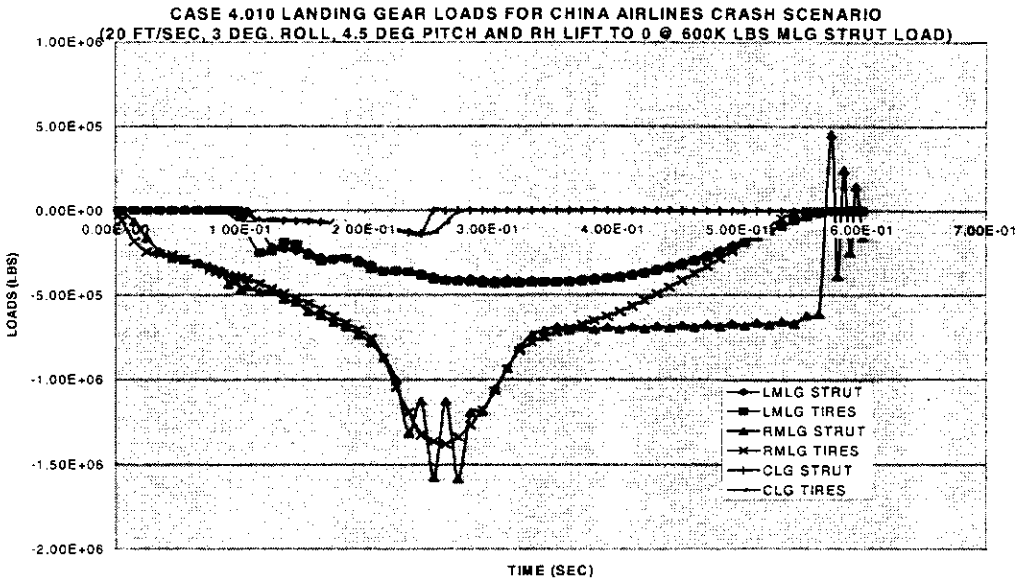


Figure 3. Case 4.010 Landing Gear Loads for China Airlines Crash Scenario

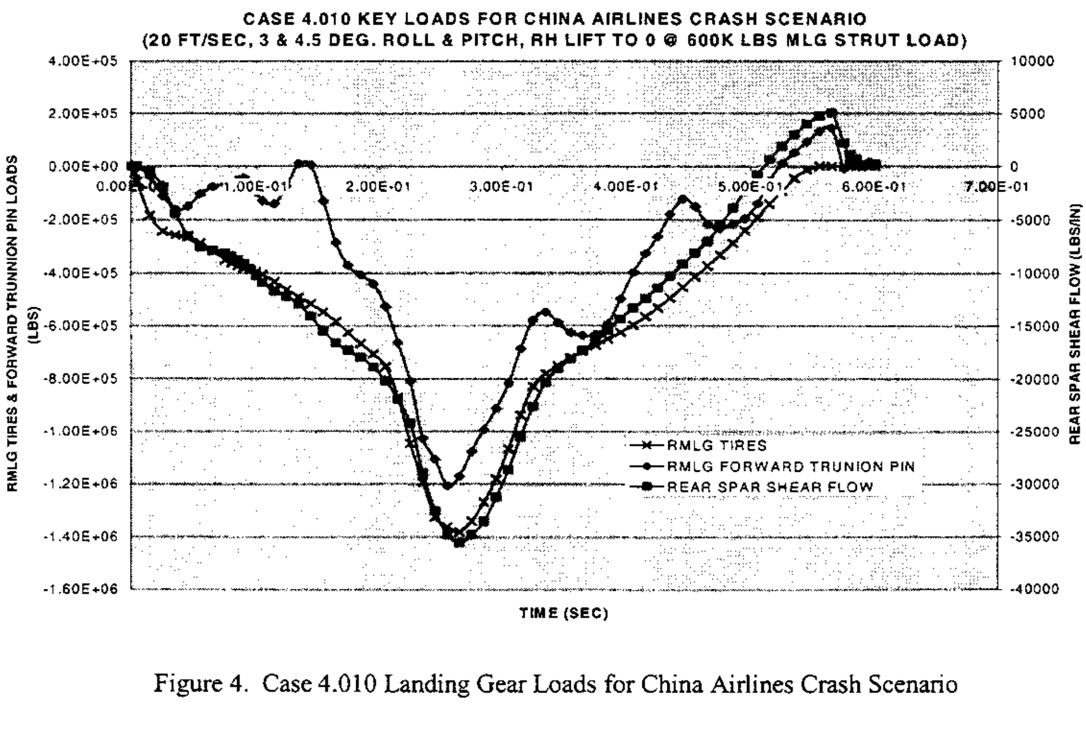


Figure 4. Case 4.010 Landing Gear Loads for China Airlines Crash Scenario

The results of this analysis, although not rigorous, confirm that loads high enough to fail the forward trunnion bolt and the rear spar shear web are feasible, and that the failure sequence described in the following sections is reasonable.

4.0 STRUCTURAL FAILURE SEQUENCE

The most likely sequence of structural failures is summarized below. Details and supporting evidence are included in the Sections 5.0 through 11.0.

- Due to the combination of a high sink rate and a right-wing-low rolled attitude, the right main landing gear shock strut bottomed and the vertical load on the right main gear "spiked".
- The forward trunnion bolt on the right main landing gear sheared upwards as a result of a very high vertical gear load combined with a large "springback" moment.
- The forward trunnion of the right main landing gear was driven upwards and contacted the MLG-to-wing attach fitting, damaging the fitting.
- The rear spar web and caps of the right wing fractured, inboard of the MLG-to-wing attach fitting.
- The inboard upper wing panel of the right wing began to collapse from back to front.
- The outboard (right) wing twisted significantly nose down which caused the MLG-to-wing attach fitting to move up, and the main landing gear tires to move aft and outboard.
- The track attached to the inboard flap on the right wing was pried off the rollers that support it at the fuselage side-of-body.
- The inboard flap on the right wing twisted off its outboard hinge support fitting and separated from the aircraft.
- Excessive movement of the right main landing gear and its wing attach fitting imparted large "prying" loads on the side-brace-fitting-to-trapezoidal-panel (S-B-F-T-T-P) joint.
- The right main landing gear fixed brace failed near the S-B-F-T-T-P joint.
- With the side brace failed, large sideloads were introduced to the S-B-F-T-T-P joint by the folding side brace.
- The S-B-F-T-T-P joint failed; first the inboard attach bolt fractured, then an outboard section of the outboard trapezoidal panel "split off" releasing the outboard attach bolt and its barrel nut.
- The right main landing gear strut, now released from the fuselage (trap panel), pivoted outboard; the trunnion arms contacted the MLG-to-wing attach fitting. The resulting "short couple" (prying) loads finished separating the landing gear from the attach fitting.
- The right nacelle contacted the runway (at about the same time as the inboard flap was separating the S-B-F-T-T-P joint was failing) and the right wing engine/pylon assembly was twisted off. (The pylon-wing separation appears to have been dominated by side loads applied to the nacelle rather than vertical loads).
- The aircraft began to roll clockwise having lost the integrity of the right wing, yet still carrying enough speed to generate meaningful lift on the left hand wing.
- Failures beyond this point were consequent, are not considered particularly relevant, and were not studied in detail.

5.0 FORWARD TRUNNION BOLT FAILURE

The first structural element thought to have failed in this accident is the forward trunnion bolt, also known as the "zero margin trunnion pin". This bolt is designed to reliably shear at a predetermined load (approximately 1.2 million lbs) and acts as a "fuse" when the main landing gear is subjected to excessive drag loads. Figure 5 shows the location of the zero margin trunnion pin.

When acting as a fuse against excessive drag load the zero margin trunnion pin fails by shearing downwards (i.e. the forward trunnion of the main landing gear moves downward relative to the wing attach fitting). In this accident this bolt failed in the *upwards* direction due to a combination of high landing gear vertical load, and a high "springback" moment. Both the high vertical load and the high "springback" moment were a result of the excessive (18-20 ft/sec) sink rate.

"Spin-up" and "springback" loads occur when an aircraft touches down and the tires are not yet spinning (a normal occurrence). First the runway exerts a drag force ("spin-up") on the tires which starts them spinning and bends the strut aft. As the tires spin up the drag force disappears and the strut "springs

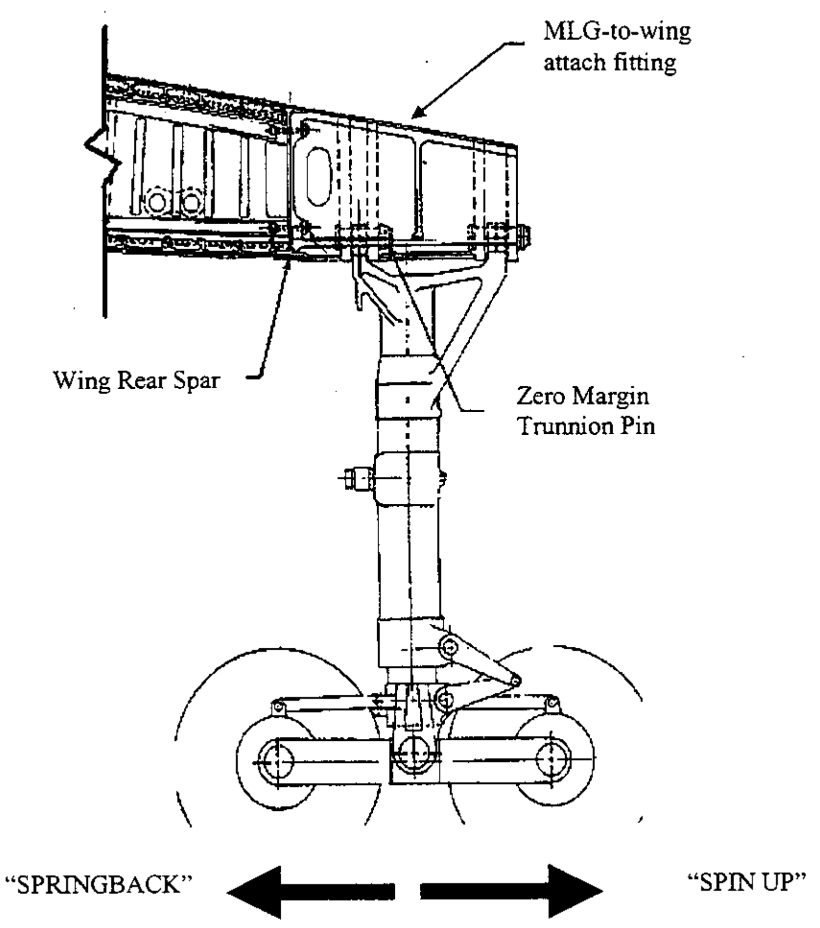


Figure 5. Main-Landing-Gear-to-Wing Attach Arrangement

back" (bending the strut forward). For conditions within the aircraft design range this phenomenon is well known and understood, and analytical tools are available to calculate the associated loads.

As described in Section 3 the spin-up and springback loads for this accident were estimated using B7DC (an in-house aircraft dynamic landing program). When the estimated springback loads were combined with the vertical loads predicted for a 20 ft/sec touchdown, it was shown that a 1.2 million lb load on the forward trunnion bolt was within the feasible range.

It should be noted that the structural loads presented in Section 3 are estimates and are based on analytical extrapolation in to a regime for which we have little or no data to establish correlation. In fact we believe the springback moment obtained from B7DC is probably underestimated.

The results of the metallurgical examination of the forward trunnion bolt are presented in the Boeing Materials and Process Engineering Report (Reference 2) in Section 4.5.2. The findings are consistent with the theory that the forward trunnion bolt failed as the forward trunnion of the main landing gear was moving upwards relative to the wing attach fitting. This relative motion is most evident in Figure 38 of Reference 2, which shows how the aft portion of the bolt is bent down.

Note that the bolt failed at the forward zero-margin groove. The bolt is loaded in double-shear; there are zero-margin grooves at both shear interfaces.

6.0 DAMAGE TO THE MAIN-LANDING-GEAR-TO-WING ATTACH FITTING

After shearing the forward trunnion bolt at the forward zero-margin groove, the forward trunnion of the right main landing gear was driven upwards and contacted the wing attach fitting, damaging the fitting. This is clearly evident in a photograph taken at the crash site (Figure 6) and in Figures 34 and 35 of the Materials and Process Engineering Report (Reference 2).

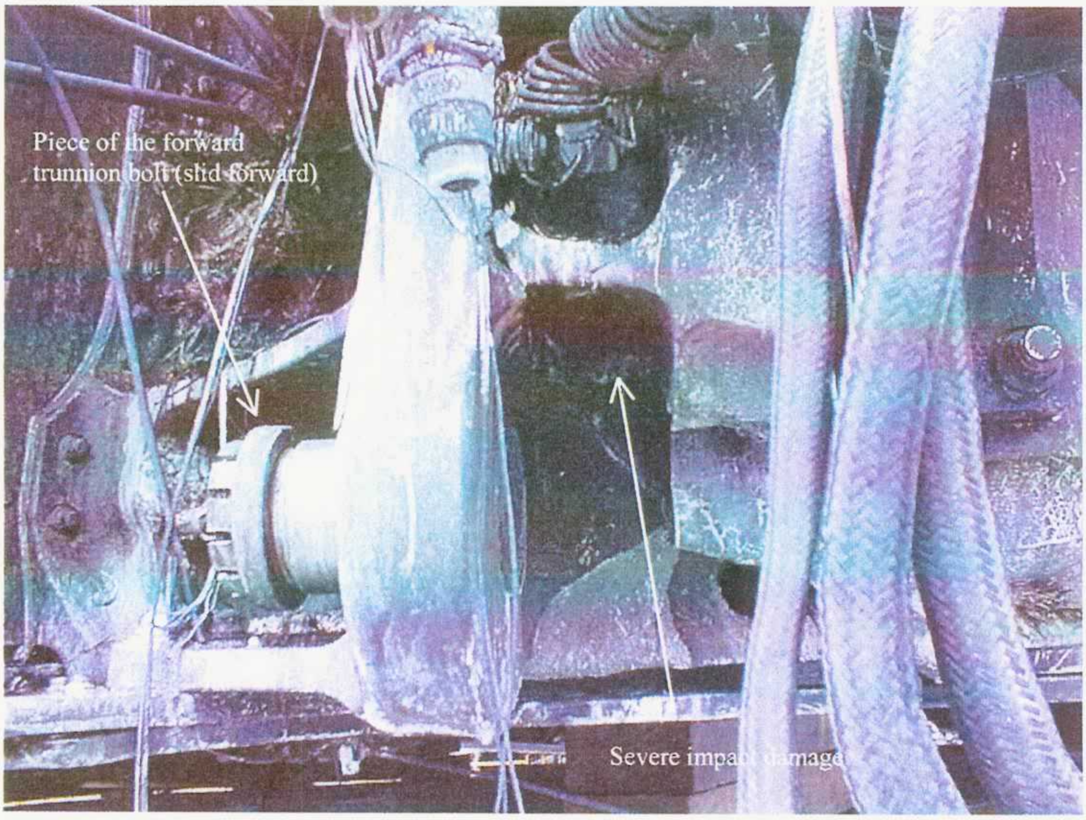


Figure 6. Damage to MLG-to-Wing Attach Fitting at the forward lugs

7.0 REAR SPAR FAILURE

With the forward trunnion bolt sheared, and the forward trunnion of the right main landing gear jammed upwards into the wing attach fitting, the vertical load on the gear was driven into the wing rear spar. Both rear spar webs fractured (in this area the web is doubled for failsafe reasons), along with the upper and lower rear spar caps. The rear spar web fractures were oriented roughly 45 degrees relative to the spar caps, as is typical of shear overload of a beam web.

The rear spar web was identified as the first structural element thought to have failed in the FedEx accident that occurred in Newark, New Jersey on August 31st, 1997. A significant amount of analysis was conducted to validate the FedEx failure sequence, so this failure mode was quickly recognized when the wreckage of the China Airlines aircraft was examined.

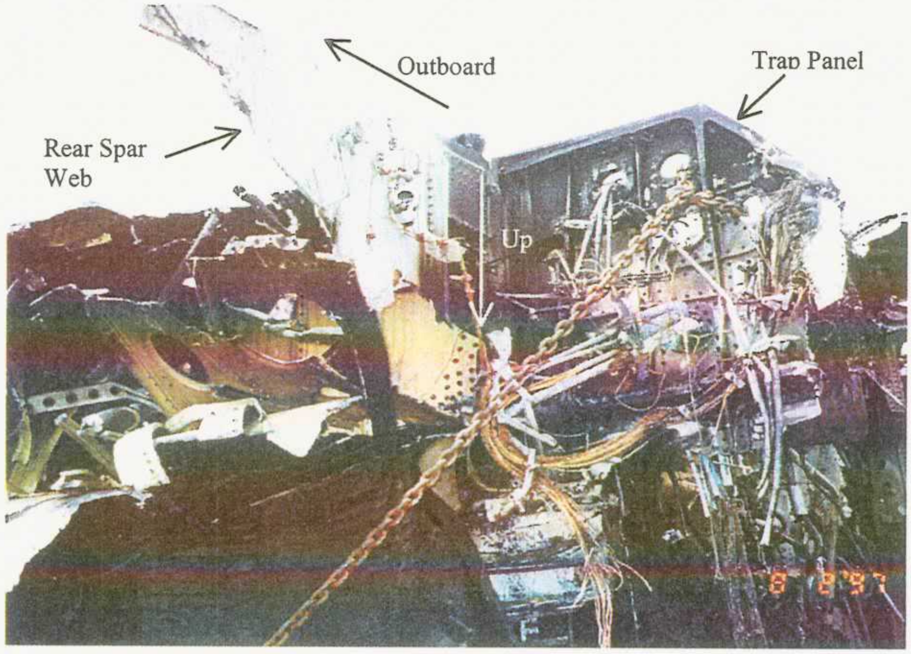


Figure 7. Right Wing Rear Spar Web Fracture from Ship 553 (FedEx - Newark)

A photograph of the FedEx aircraft showing the right wing rear spar web fracture is included as Figure 7. Note that the aircraft is inverted in this photograph.

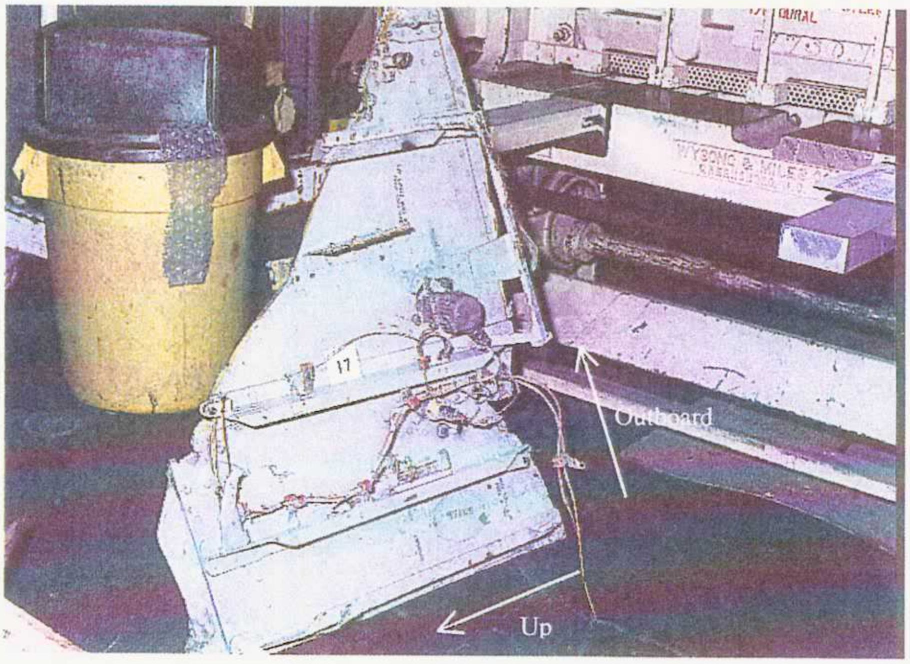


Figure 8. Right Wing Rear Spar Web Fracture from Ship 518 (China Airlines)

A lab photograph of the right wing rear spar web which was cut from the China Airlines aircraft is included as Figure 8. When examined closely it was observed that the rear spar web fractures from the two accidents occurred at almost identical locations.

8.0 INBOARD FLAP DEPARTURE

The inboard flap is located just aft of the main landing gear (Figure 9) and is supported at its inboard end by a track/roller arrangement (Figure 10) and at its outboard end by a simple hinge (Figure 11). The track is mounted on the flap and the rollers on the fuselage (Figures 12 and 13). The outboard hinge is supported off the wing rear spar.

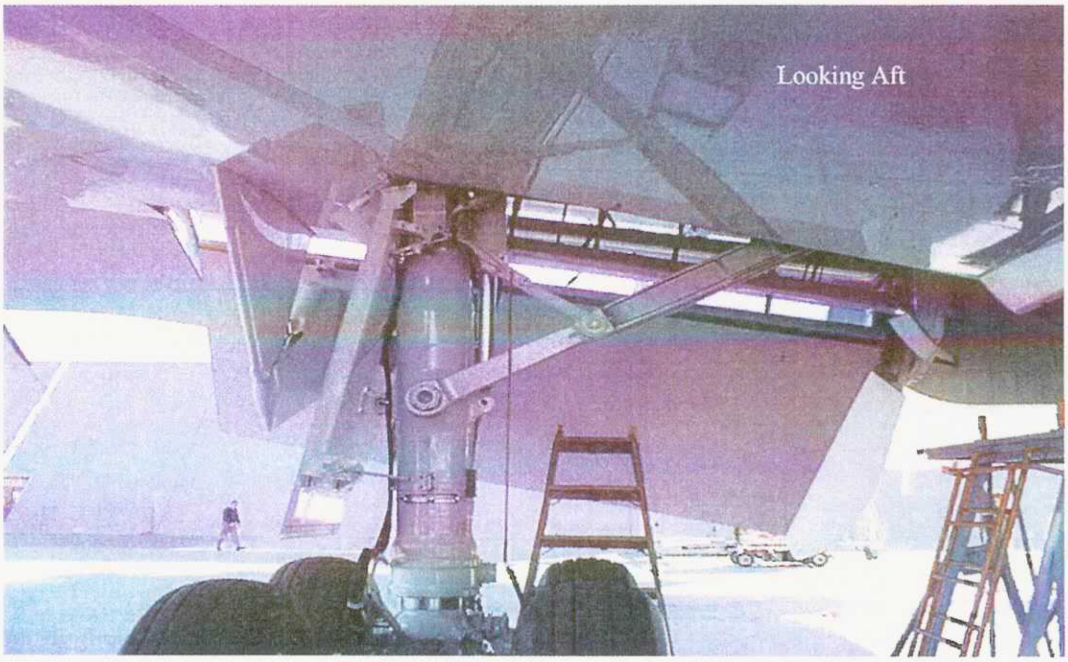


Figure 9. Inboard Flap (Location relative to MLG)

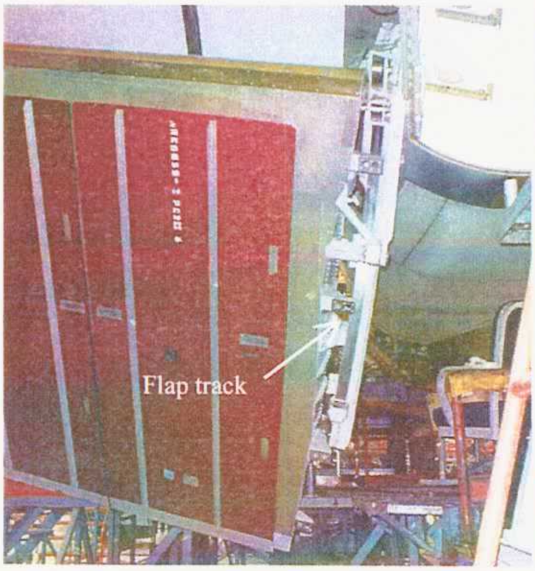


Figure 10. Inboard Flap inboard support

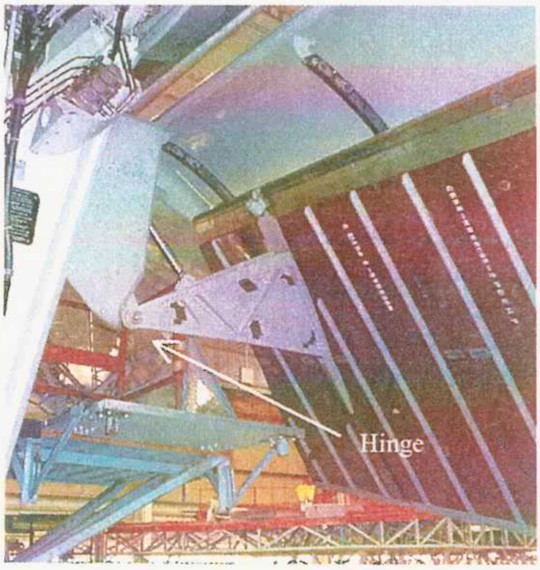


Figure 11. Inboard Flap outboard support

The flap track is an I-beam with return lips on the inboard legs of the two caps. The upper "lip" is captured by three side rollers which limit the outboard motion of the flap track (Figures 13 and 14).

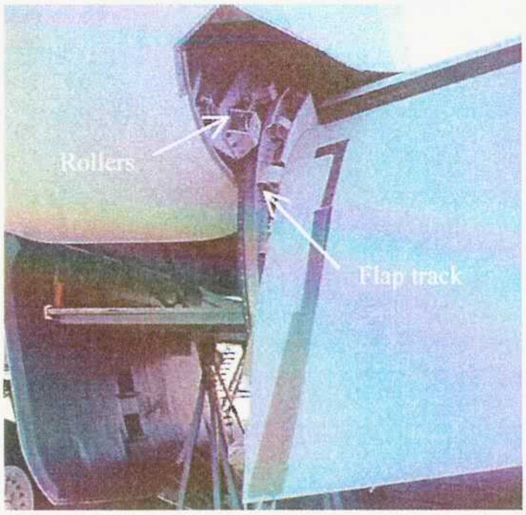


Figure 12. Inboard Flap track and rollers

Figure 13. Inboard Flap rollers (flap removed)

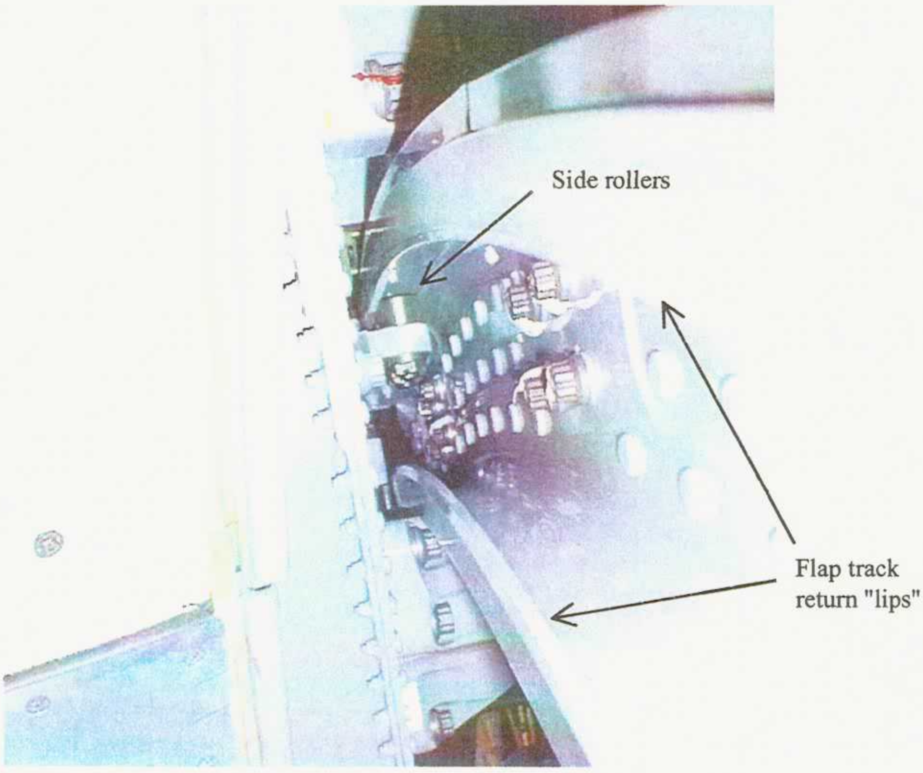


Figure 14. Inboard flap track and side rollers

With the aircraft structurally intact the nominal side loads (inboard-outboard) are small as is evident by the relative size of the side rollers.

Continuing the failure sequence of the China Airlines accident, fractures of the wing rear spar webs, and of the upper and lower spar caps destroyed the integrity of the right wing as a "box structure" resulting in very large relative displacements between the inboard flap's inboard support (mounted to the fuselage) and its outboard support (mounted to the wing, outboard of the landing gear). This relative movement effectively pried the flap track off its roller support system. Once the inboard end became unsupported, the flap easily twisted off its outboard hinge, separating at the tension bolts where the aft hinge attaches to the flap box.

As was the case for the wing rear spar failure mode, there are some observed similarities in the FedEx and China Airlines inboard flap failures. Both inboard flaps were found near the beginning of the debris field, were relatively intact (having almost no lower surface damage), and evidenced local shear-out failures of the flap track lips at the side roller locations.

The China Airlines inboard flap was found off to the left of the runway and is thought to have been carried there by the crosswind (which was blowing right-to-left) after it departed the aircraft. The flap, as it was found, is pictured in Figure 15. The FedEx inboard flap was found on a taxiway to the right of the runway (Figure 16); note there was little or no crosswind present when the FedEx accident occurred.

Figure 15. Right Inboard Flap from Ship 518 (China Airlines)

Figure 16. Right Inboard Flap from Ship 553 (FedEx - Newark)

It is viewed as significant that the lower surfaces of these flaps suffered no significant damage. The inboard flap would have been directly in the path of the main landing gear had the gear separated before the flap and would have been badly damaged. It is clear then, that the main landing gear did *not* "knock" the inboard flap off the aircraft.

The local shear-out failure of the flap track is evident in a photograph taken at the accident site (Figure 17). The location of this failure is consistent with the position of the side rollers for the reported flap setting of 35 degrees. The same type of failure is observed in the photograph of the inboard flap from the FedEx-Newark aircraft (Figure 18); in this case the failure location is consistent with the reported flap setting of 50 degrees.

Figure 17. Right Inboard Flap track from Ship 518 (China Airlines)

Figure 18. Right Inboard Flap track from Ship 553 (FedEx-Newark)

9.0 DAMAGE TO SIDE-BRACE-FITTING-TO-TRAP-PANEL JOINT AND TO THE FIXED AND FOLDING SIDE BRACES

The location of the side-brace-fitting-to-trap-panel (S-B-F-T-T-P) joint is highlighted in Figure 19. A photograph of a this area (taken from inside the landing gear wheel well) in included as Figure 20 along with a sketch of the joint (with the fixed and folding side braces removed).

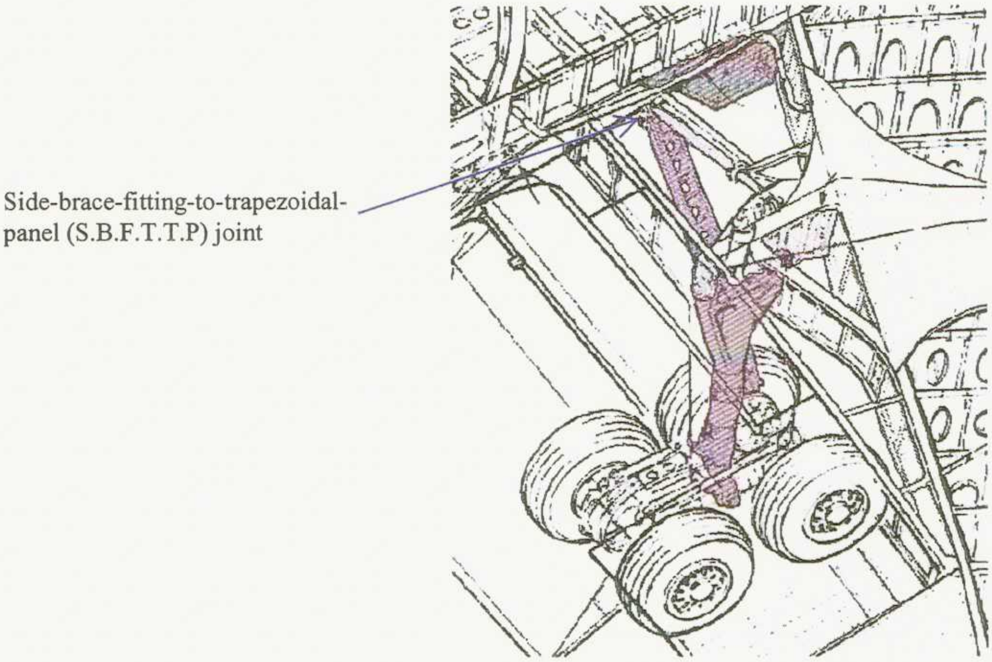


Figure 19. Location of the side-brace-fitting-to-trap-panel joint

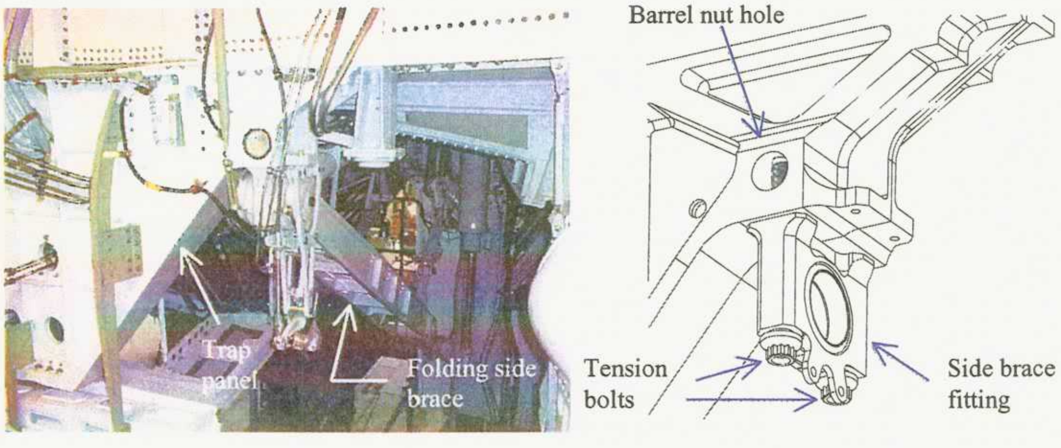


Figure 20. Side-brace-fitting-to-trap-panel joint (from inside the right wheel well)

The fixed brace and folding side brace are connected to one another and to the side brace fitting via a large pin. The side brace fitting is attached to the trap panel with two long tension bolts and mating barrel nuts. As discussed in Section 1.0 this joint is designed to take primarily vertical loads; the fore-and-aft and inboard/outboard loads are nominally small.

As was the case for the for inboard flap's departure, the damage to the S-B-F-T-T-P joint was the result of large relative displacements between attach points on the wing and on the fuselage. After the right wing rear spar failed, the MLG-to-wing attach fitting moved up (relative to the fuselage) and the outboard wing twisted severely nose-down. This motion effectively tilted the truss formed by the MLG strut, and the fixed and folding side braces, and applied a nose-down twist to the S-B-F-T-T-P joint. This applied twist rocked the side brace fitting (bottom-end-aft) and resulted in "impressions" on the lower surface of the trap panel (Figure 21). Similar impressions were observed on the underside of the trap panel from the FedEx-Newark accident aircraft.

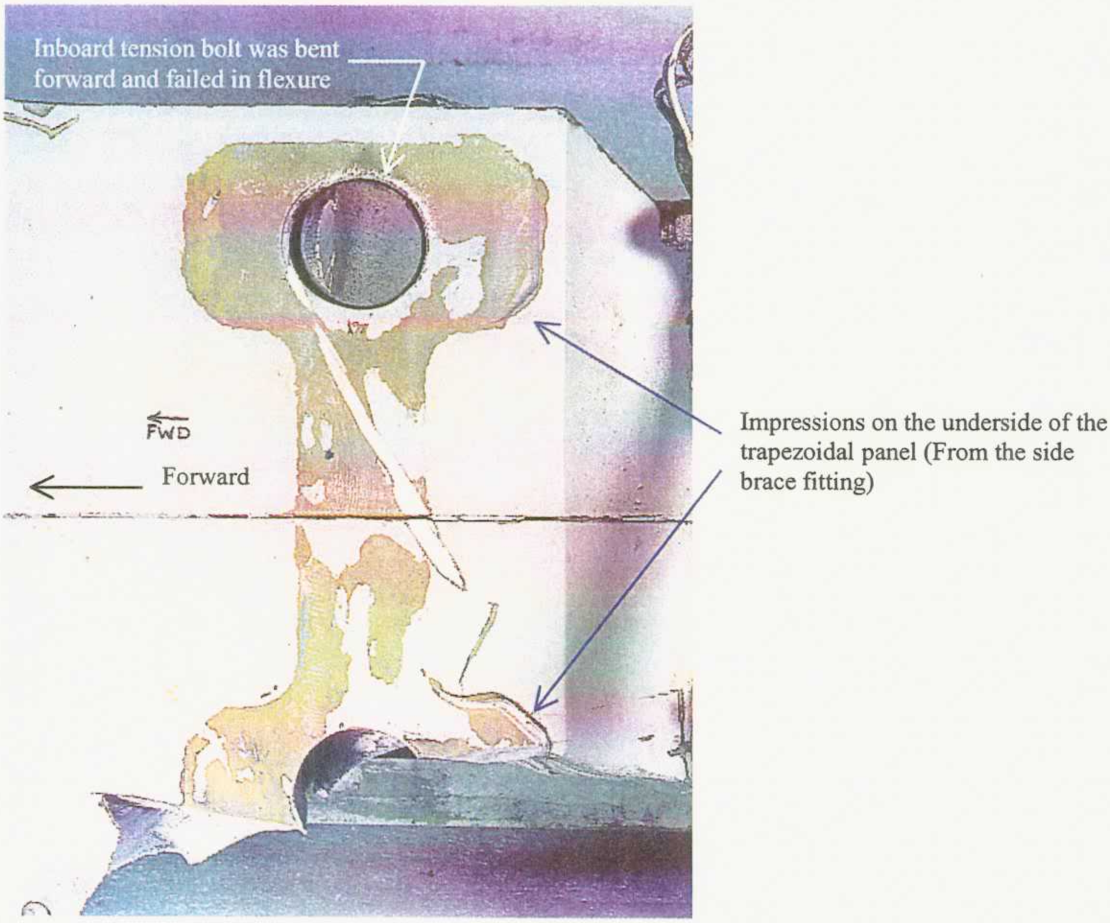


Figure 21. Underside of the right trapezoidal panel

Figure 22 is another photograph of the S-B-F-T-T-P joint area. The photograph is annotated to point out the limited clearance between the clevis end of the fixed brace and the side brace fitting. Excessive upward motion of the outboard end of the fixed brace (which is connected to the MLG-to-wing attach fitting) results in contact in the noted area, and creates a "short couple" prying load at the joint. Evidence of contact in this area for parts taken from the China Airlines accident aircraft is seen in Figure 23. Similar evidence was also noted for the FedEx-Newark accident aircraft.

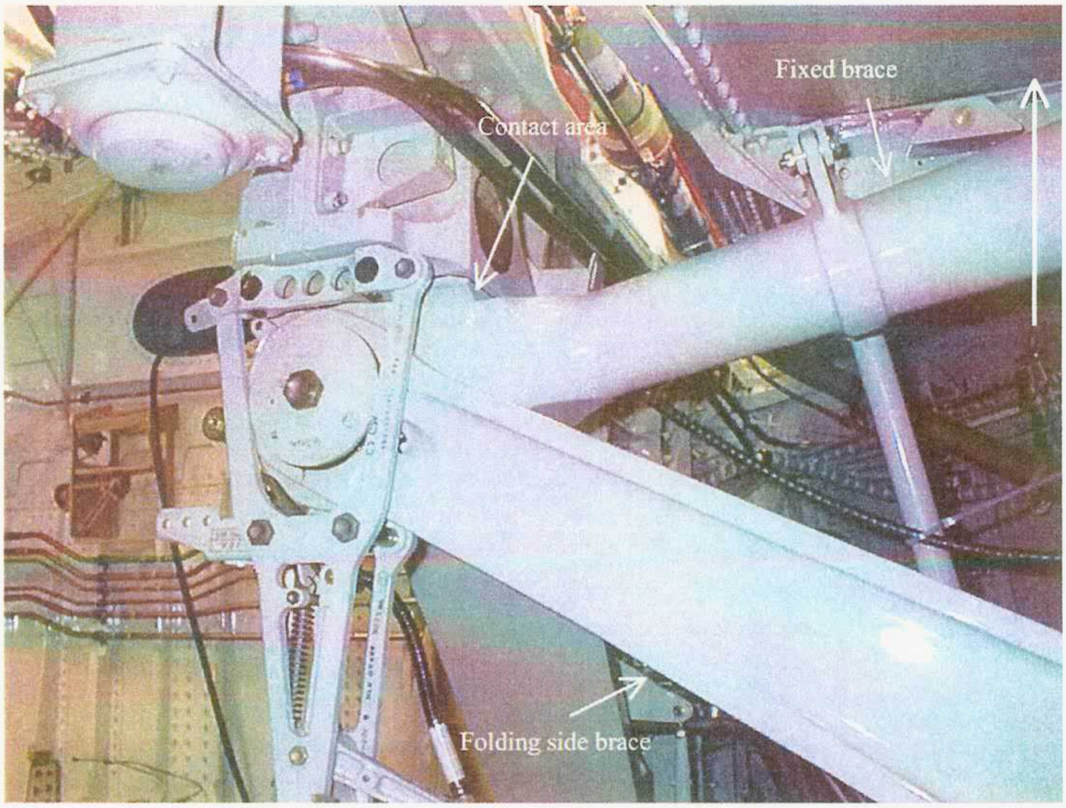


Figure 22. Side-brace-fitting-to-trap-panel joint (from aft and outside the right wheel well)

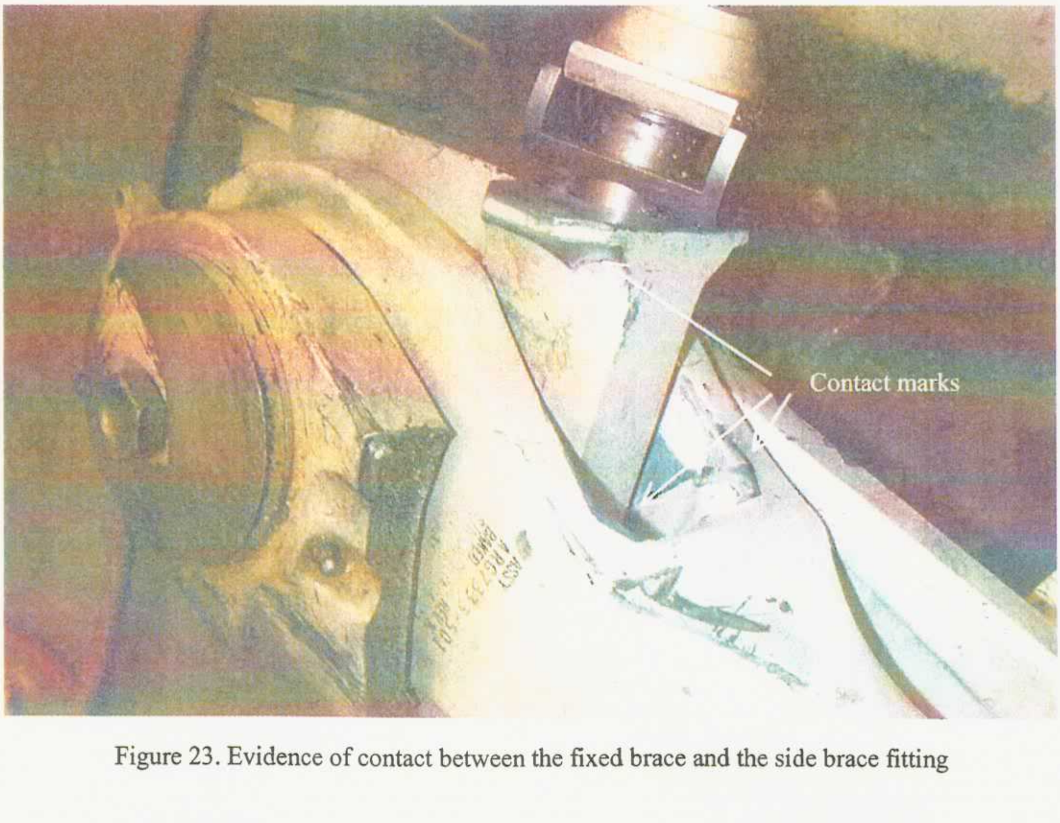


Figure 23. Evidence of contact between the fixed brace and the side brace fitting

The presence of a large prying load at the S-B-F-T-T-P joint results in severe distress to this joint. This manifests itself as localized high bending (flexure) at the outboard end of the fixed brace, and a large tension load on the inboard of the two tension bolts attaching the side brace fitting to the trap panel. Evidence of flexural distress of the fixed brace was observed in parts taken from both the China Airlines and FedEx-Newark accident aircraft. The fixed brace from the China Airlines aircraft failed completely (Figure 24). The fixed brace from the FedEx-Newark aircraft was bent and suffered a stress corrosion fracture (Figure 25). The stress corrosion fracture is attributed to residual stress resulting from a high flexural load. Note also in Figure 25 the evidence of local contact with the side brace fitting.

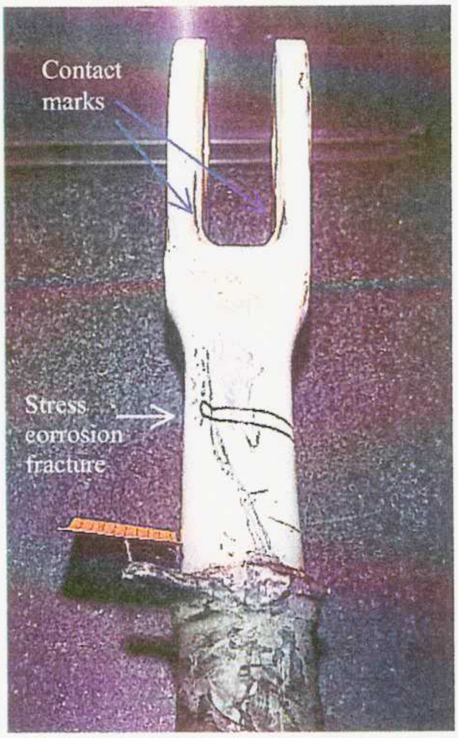


Figure 24. Outboard end of the fixed brace from Ship 518 (China Airlines) [left]
Figure 25. Outboard end of the fixed brace from Ship 553 (FedEx-Newark) [right]

Figure 24 also shows damage to the upper folding side brace. The upper folding side brace is an I-section "laid on its side" with lightening holes in the web (Figure 19). The fixed brace after it failed in flexure, appears to have dropped down into the upward facing "channel" of the I. Relative motion between the outboard wing and the fuselage then appears to have "punched" the inboard end of the fixed brace through the web and aft cap of the upper folding side brace.

The final two failures at the S-B-F-T-T-P joint involve the two tension bolts that attach the side brace fitting to the trap panel, and the trap panel itself. The inboard of the two tension bolts failed in flexure and was bent lower-end-forward (Figure 21 and also Figure 15 of Reference 2). This is thought to have been a consequence of the fixed brace having previously failed, coupled with the lower end of the main landing gear strut moving aft. The folding side brace, acting as a lever, would then apply a twist about the vertical axis of the S-B-F-T-T-P joint. Presuming the outboard tension bolt is acting as a pivot, this would tend to bend the inboard bolt forward.

The outboard tension bolt did not fail. Instead a portion of the outboard face of the trap panel appears to have "split off", releasing the outboard barrel nut and tension bolt (Figure 26). This is thought to have occurred *after* the inboard bolt had failed and appears to have been the result of a prying load applied by the outboard tension bolt, the prying load resulting from the folding side brace pulling outboard on the side brace fitting. (Note the photograph is upside-down relative to the normal position in the aircraft).

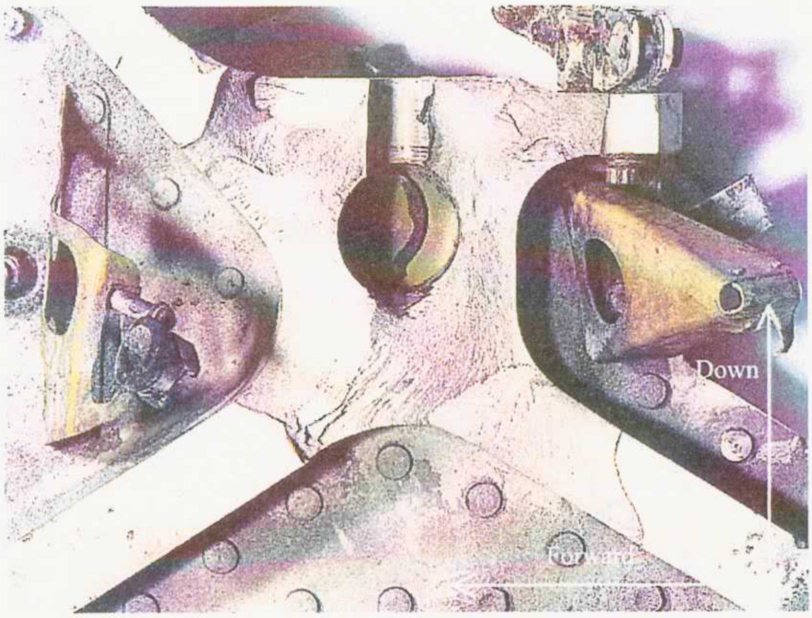


Figure 26. Outboard trap panel failure at the S-B-F-T-T-P joint

10.0 DAMAGE TO THE MAIN LANDING GEAR TRUNNION ARMS AND ADDITIONAL DAMAGE TO THE MLG-TO-WING ATTACH FITTING

There is clear evidence that the right main landing gear strut, once released at the S-B-F-T-T-P joint, rotated outboard and contacted its wing attach fitting. Similar observations were made for the parts from the FedEx-Newark accident aircraft (see Figures 27 and 28). This type of contact creates a "short couple" prying action that easily breaks the gear loose from the fitting.

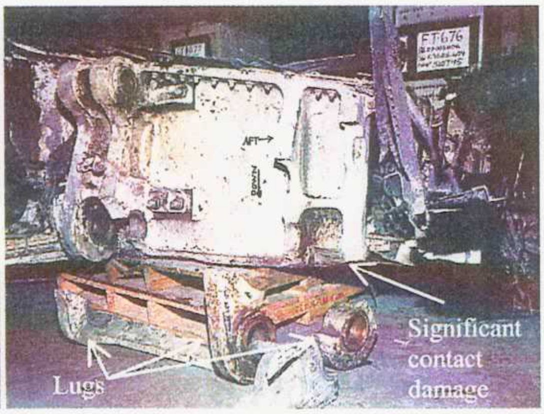


Figure 27. Right main landing gear strut from Ship 553 (FedEx-Newark) [left]
Figure 28. Right MLG-to-wing attach fitting from Ship 553 (FedEx-Newark) [right]

In the case of the China Airlines accident the markings indicating contact between the right main landing gear strut and the wing attach fitting are slightly different (and not quite as clear). This is primarily due to the fact that the forward trunnion connection was partially failed (See Section 5.0) before the strut rotated outboard. The contact area for the forward trunnion was therefore very localized, and quickly resulted in the fracture of the remaining connection (the aft lug). See Figures 29 and 30. The two lugs that support the *aft* trunnion, the fowardmost still connected to a large piece of the wing fitting, also

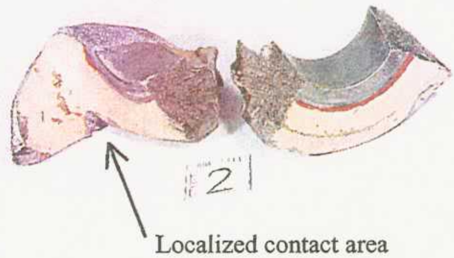


Figure 29. Wing fitting lugs that support the MLG forward trunnion [left]
Figure 30. Separated pieces of the aft wing fitting lugs that support the MLG forward trunnion [right]

cracked off as a result of the gear rotating outboard (Figure 31). This separated the right main landing gear from the aircraft. The contact area on the aft trunnion arm is shown in Figure 32. A photograph of the wing fitting, showing the mating area for the two aft trunnion support lugs, is included as Figure 33.

Figure 31. Right main landing gear assembly

Substantial sidewall abrasion was noted on the inboard sidewall of the aft inboard tire on the right main landing gear truck (Figure 34). This evidence further supports the theory that the gear rotated outboard putting the inboard sidewalls of the inboard tires in contact with the ground.

Figure 32. Aft trunnion arm of the right main landing gear strut [left]
Figure 33. Right MLG-to-wing attach fitting from Ship 518 (China Airlines) [right]

Figure 34. Inboard aft tire from the right main landing gear

11.0 RIGHT HAND WING PYLON FAILURE MODE

Figure 35 illustrates and describes the key elements of the attachment of the engine pylon to the wing. Figure 36 shows how the wing engine pylons are designed to "fuse" in the event of a wheels up landing to protect against rupture of the wing fuel tanks.

If the loads acting on the nacelle are primarily upwards, the engine pylon's aft attach bulkhead is designed to break at the top of the monoball housing, freeing the back end of the pylon and allowing the engine/nacelle to tilt up and act as a "ski". This failure mode has been verified by testing and validated in a number of in-service incidents. (As a point of reference, this *was* the observed failure mode for the right engine pylon from the FedEx-Newark accident).

Figure 37 shows that the right pylon failure mode was different for the China Airlines accident aircraft; the right engine pylon aft-attach bulkhead is still attached to the right wing. Figure 38 shows the right engine pylon. The observed failures suggest that the loads on the nacelle included a significant sideways component. This is thought to have occurred because the outboard wing, as the failure progressed, began to sweep further and further aft.

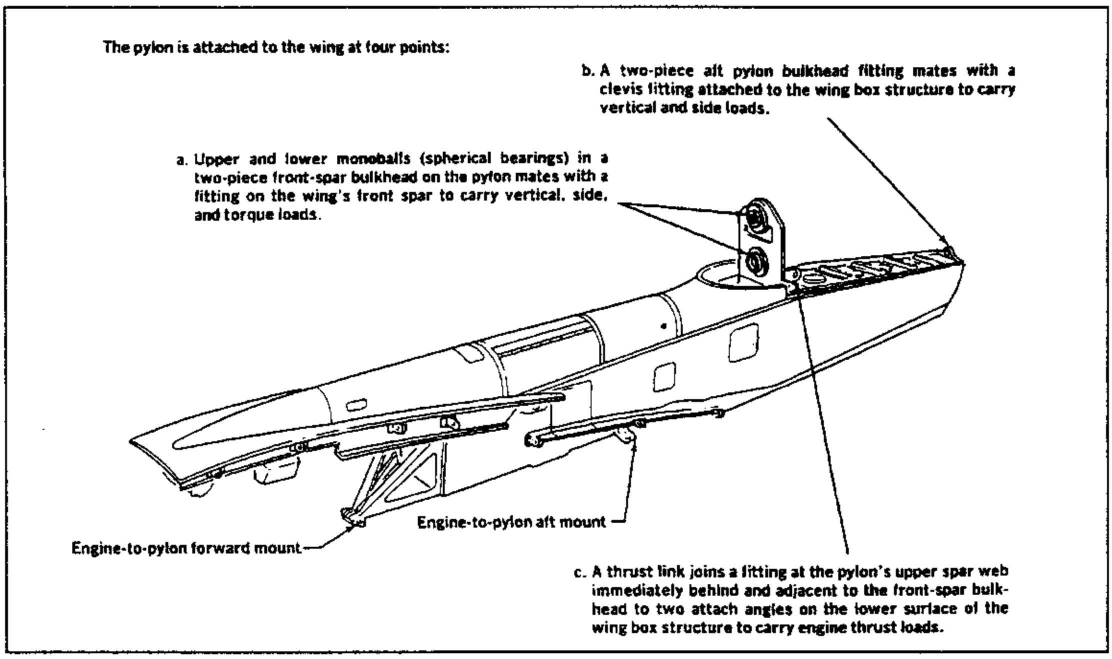


Figure 35. Pylon-to-wing attachment details

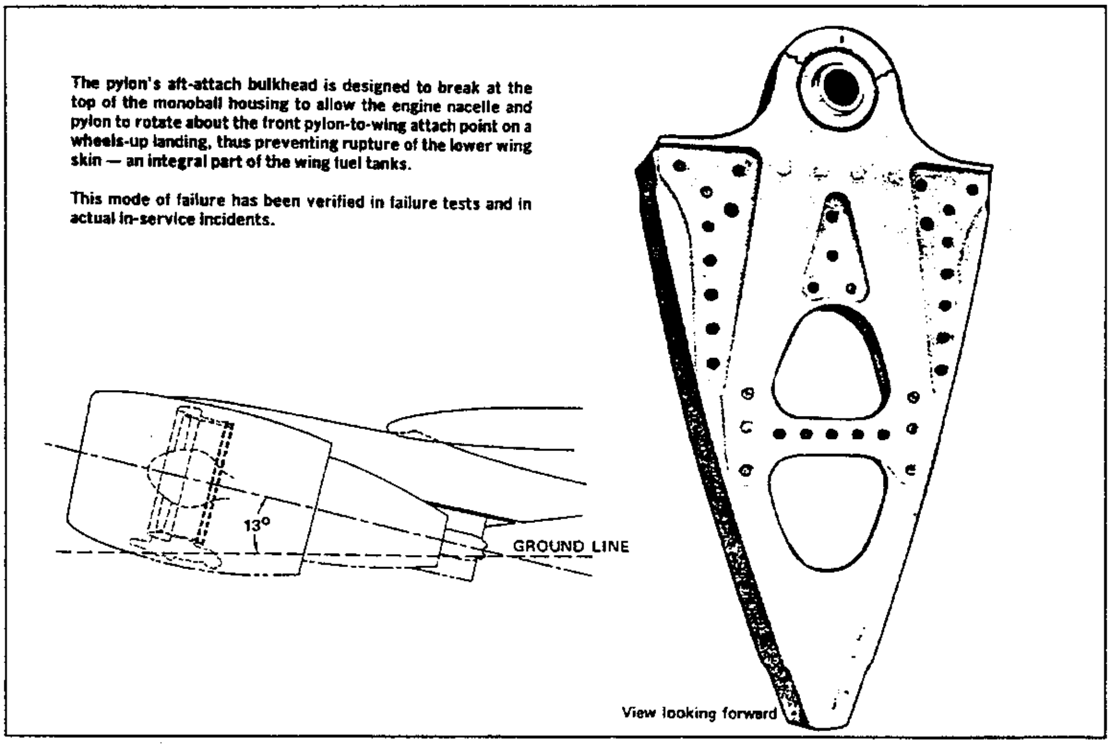


Figure 36. Wing pylon "fusing" mechanism

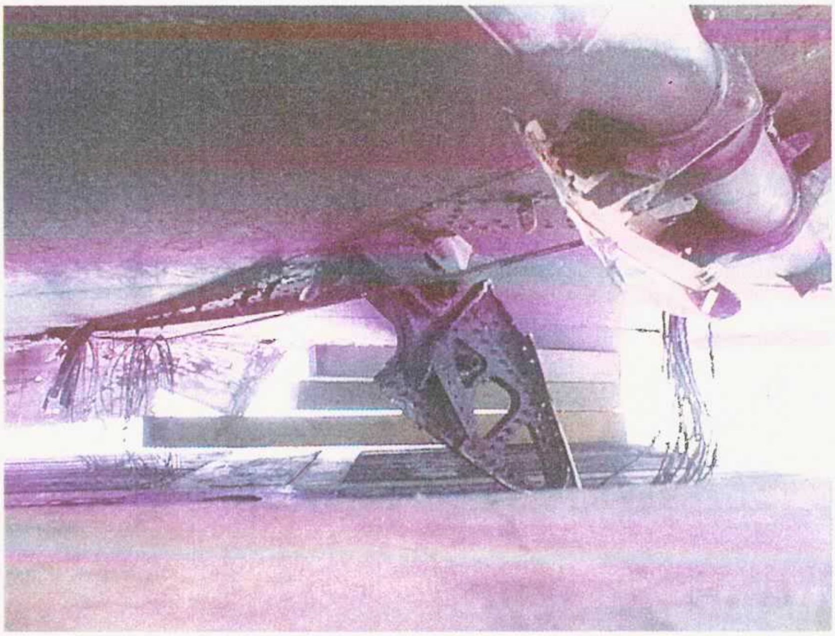


Figure 37. Right engine pylon aft-attach bulkhead still attached to the right wing

Figure 38. Right engine pylon

12.0 SUMMARY

Analysis was conducted to attempt to understand the structural failure sequence, failure modes, and failure characteristics of the accident aircraft. The analysis included primarily the review and examination of failed parts and photographs from the accident site, along with a limited amount of dynamic loads analysis using parameters taken from the Flight Data Recorder.

The analysis has produced a definition of a failure sequence that is reasonable and appears to have no significant inconsistencies with the accident observations.

The failure appears to have initiated with the forward trunnion bolt of the right hand landing gear (the trunnion shearing upwards) closely followed by failures of the inboard right wing rear spar webs and caps. These failures were the result of an extremely high vertical load and an associated "springback moment" applied to the right main landing gear. Both the high vertical load and the high "springback moment" were a result of the excessive (18-20 ft/sec) sink rate, and the slightly rolled (3 degrees right-wing-down) touchdown attitude.

民航處 *Civil Aviation Department*
飛行標準及適航部 Flight Standards and Airworthiness Division

香港赤鱲角駿運路 2 號機場空運中心商業大樓十樓
10/F Comm Bldg Airport Freight Forwarding Centre 2 Chun Wan Road Lantau Hong Kong

INVESTIGATION OF CAL 642 ACCIDENT ON 22 AUGUST 1999

TEST REPORT ON CAPTAIN'S WIPER MOTOR & ELECRICAL CIRCUIT COMPONENTS

Test Requirement:- Minutes of Accident Investigation Team Meeting dated 11 January 2000 Meeting Note item 6. a.

Location of Test:- Electrical Workshop 2110 at the HAECO Component Overhaul Facility at Tseung Kwan O (TKO)

Date of Test:- 17th February 2000

Test Witnesses:- C M Lee – Inspector of Accident, HKCAD
K W Lau – HAECO QA Head of Section, TKO

Items Tested:-

Wiper Motor and Drive Assembly (Captains Position)
Vendor - Rosemount Aerospace Inc, USA
P/N 2313M-537
S/N 00097

15 AMP Main Power Supply Circuit Breaker (Captains wiper)
Vendor – Jackson Inc, USA
P/N 700-030-15, (700-066-15) (76374-9137)
S/N None visible

5 AMP Wiper Control Power Supply Circuit Breaker (Captains wiper)
Vendor – Jackson Inc, USE
P/N 8500-005-5 (76374-9151)
S/N None visible

Captain's Wiper Control Switch
Vendor – Cole, USA
P/N 200-3061
S/N None visible

1. Testing Method and Considerations

All components were checked for any obvious damage prior to testing, none was evident. All components had been removed from the subject aircraft by HAECO. The wiper motor had been removed intact, together with attachment hardware. However, the circuit breakers (CBs) and control switch had been removed by the release of the attachment feature and the cutting of the associated circuit wiring. Therefore, the testing which was possible was applied to each separate unit/item, and not the physical circuit installed upon the subject aircraft. Although HAECO was nominated and willing to accomplish the testing, they do not hold specific maintenance approval for the MD-11 Wiper Motor, which being classified as a rotable component, would normally be tested and serviced in accordance with an approved Component Maintenance Manual (CMM). On the other hand, the CBs and Control Switch being of a consumable design, would not normally be the subject of overhaul and repair. Therefore, the scope of the testing was done on the basis that HAECO were not approved for these components, but possessed enough experience and knowledge to apply basic testing techniques. In addition to this, consideration must be given to the fact that unit specifications or CMM's were not to hand. On this basis, best practice was applied to the rudimentary scope of the testing that was possible. All test power was applied in accordance with MD-11 wiring diagrams, reference 30-43-01 supplied by China Airlines.

2 Unit Testing and Results

2.1 Wiper Motor Assembly

2.1.1 This unit was tested to establish the correct operation of the following features:

- i) Operation of the drive motor.
- ii) Operation of drive brake.
- iii) Functioning of parking switch circuit.

2.1.2 Witnessed operation of main drive motor:

- i) The unit ran smoothly without undue noise or vibration.
- ii) No load current draw at low speed was 5 amps.
- iii) No load current draw at high speed was 7.5 amps.
- iv) The output shaft to the wiper arm was witnessed to rotate back and forth in an arc of approximately 30 degrees.
- v) The unit brake released when power was applied, and had a circuit resistance of 60 ohms.
- vi) The wiper parking system interrupter switch was tested during motor operation and found to make and break as would be expected.

It was not possible to apply any representative working load to this unit while running due to the fact that no test bench is available at HAECO. Furthermore, the power and size of this unit is such that any additional testing could only be accomplished on a suitable test stand, or alternatively by the unit being temporarily installation upon another MD-11 aircraft. As no CMMs, or unit design specifications were available, we are unable to determine how this unit conforms to such data.

2.2 15 AMP Main Power Circuit Breaker

2.2.1 This unit was tested to establish the correct operation of the following features:

i) Ability to sustain a continuously applied current of 15 amps without tripping.
ii) Test the current overload protection of the unit.

2.2.2 Witnessed operation of the 15 amp CB:

i) This unit was able to carry a load of 15 amps for over 2 minutes without tripping.
ii) When tested in overload, a circuit trip occurred after 22 seconds with a load of 30 amps applied.

2.3 5 AMP Control System Power Circuit Breaker

2.3.1 This unit was tested to establish the correct operation of the following features:

i) Ability to sustain a continuously applied current of 5 amps without tripping.
ii) Test the current overload protection of the unit.

2.3.2 Witnessed operation of the 5 amp CB:

i) This unit was able to carry a load of 5 amps for over 2 minutes without tripping.
ii) When tested in overload, a circuit trip occurred after an average elapsed time of 6 to 8 seconds with a load of 10 amps applied.

2.4 Captains Wiper Control Switch

2.4.1 This unit was tested to establish the correct operation of the following features:

i) The switch rotated to all three detented positions.
ii) Basic circuit electrical resistance and continuity test across all six contact positions.
iii) Basic electrical insulation/leakage test of all terminal to switch the body (aircraft electrical grounding plane).

2.4.2 Witnessed results of the above switch tests:

i) The switch rotated with positive detents at three positions corresponding to OFF, LOW and HIGH.
ii) The resistance check applied to all switch contact positions produced the following results:

Across the "A" Contacts
C-1 = 1.2 ohms, C-2 = 2.2 ohms and C-3 = 1.5 ohms

Across the "B" Contacts
C-1 = 2.2 ohms, C-2 = 2.8 ohms and C-3 = 1.6 ohms

iii) The insulation tests applied to all of the "A" and "B" contacts to the unit body, resulted in an infinity ohmic resistance being achieved, indicating no circuit electrical breakdown.

3. Conclusion

In view of the limited amount of test and specification data to hand for these units, it is not possible to make comprehensive operation statements. However, from the witnessed rudimentary test results, and the condition of the subject components, there is nothing to suggest that they would not be able to operate and function, as designed.

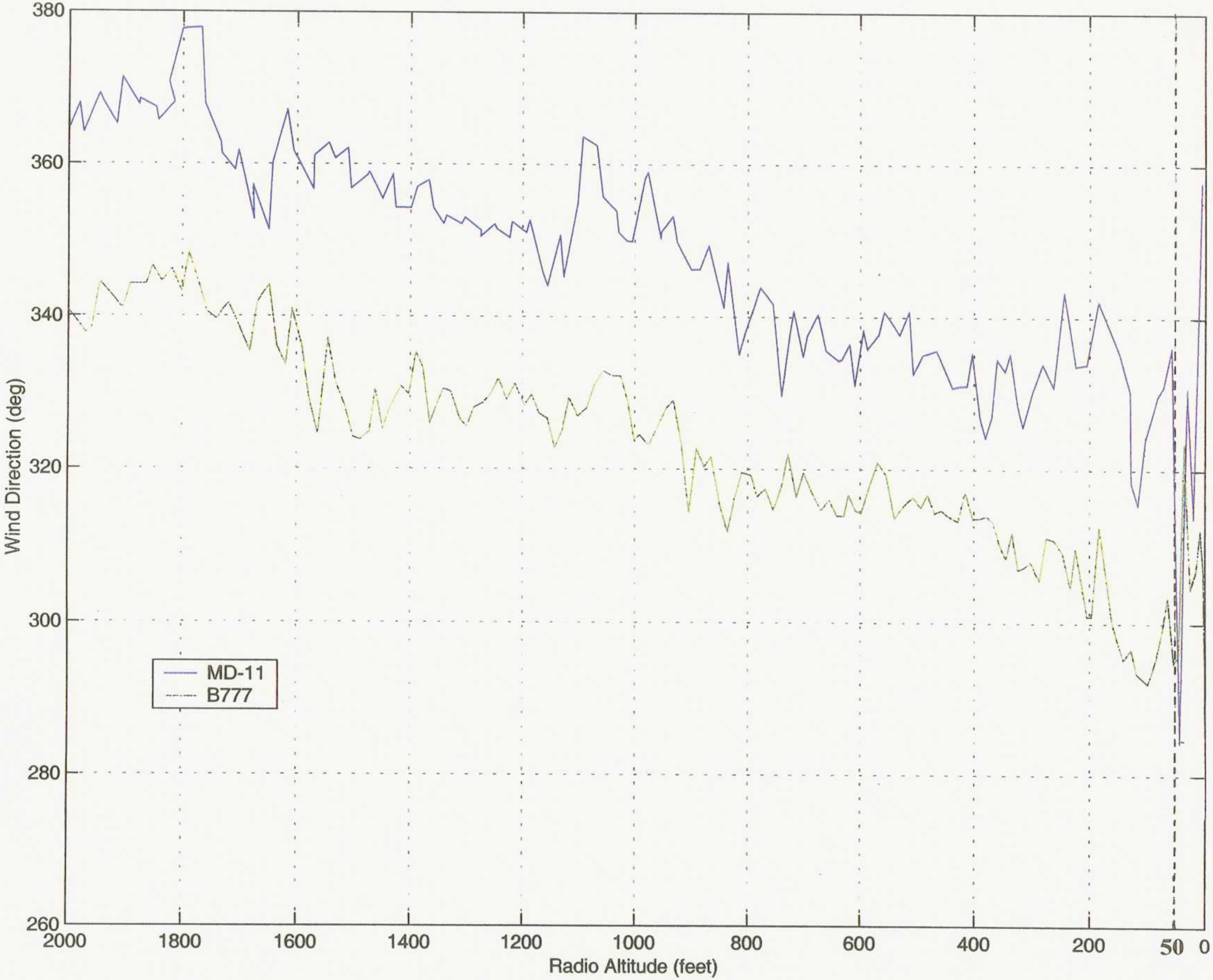
This witness test report was raised and presented by;

C M Lee - Inspector of Accident Signed:- [signature] Dated:- 18 February 2000

SUMMARY OF APPROACHES
HONG KONG INTERNATIONAL AIRPORT
0657 – 1044 Hours UTC, 22 August 1999

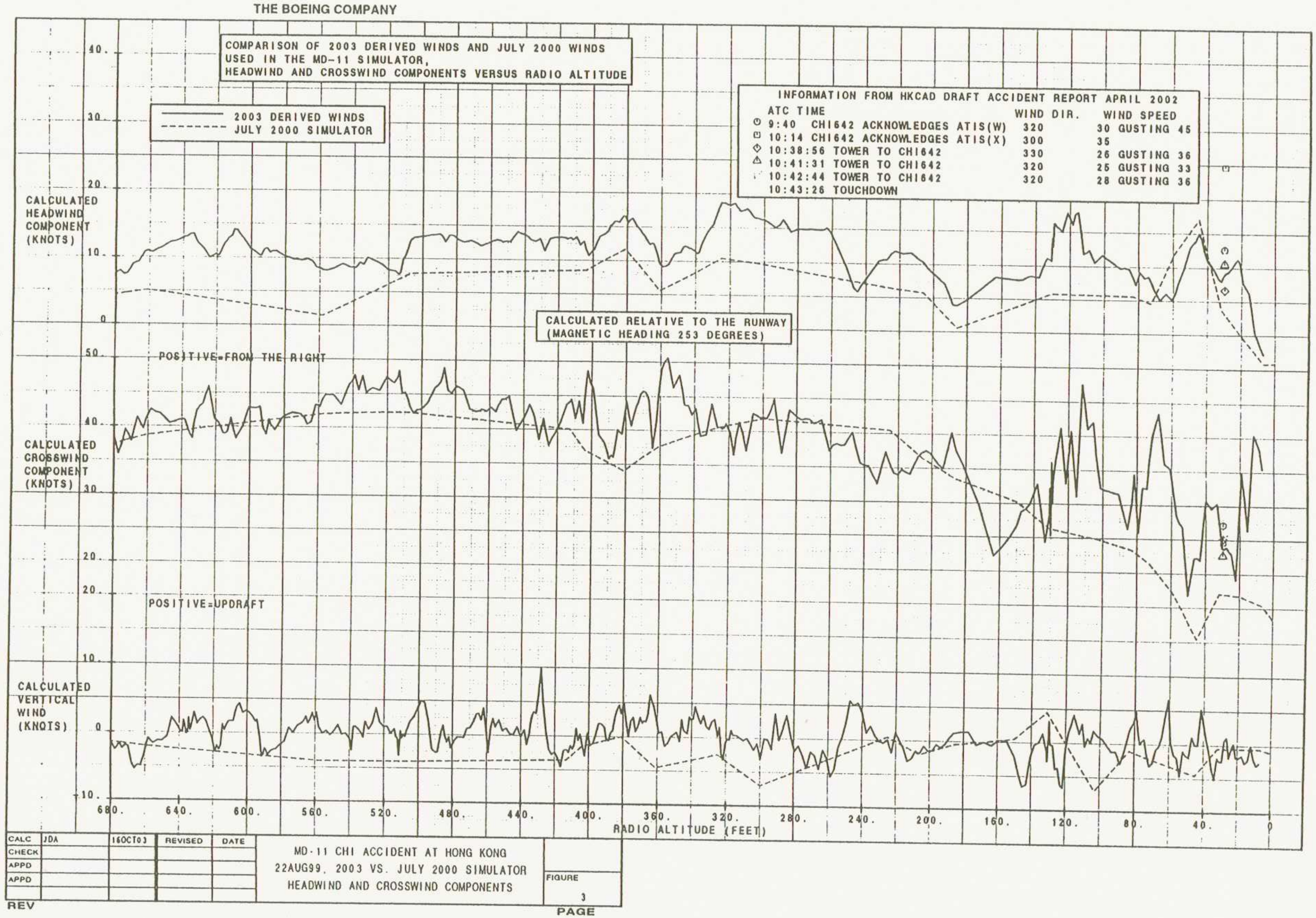
Aircraft type	Landed	Go-around	Comments
Runway in use 07R			
A330		0657	2nd go-around @ 0727
A330	0700		
MD82	0710		
MD11	0716		
A320	0721		
A330		0727	Diverted
A330		0735	Diverted
A330		0742	Diverted
Runway change to 25L			
A340		0818	Diverted
B742		0830	Diverted
B744	0849		
A340		0859	Diverted
B773	0915		
B744		0940	Diverted
A330		0945	2nd approach, landed 1019
B773	0947		
B772	0953		
A330	1002		
A330	1019		
B744	1024		
A340	1029		
B763	1031		
A330		1034	Diverted - airport closed due later accident
B744	1036		
B773	1040		
MD11	1043		Accident flight

COMPARATIVE WIND DATA – MD11 / B777 AIRCRAFT

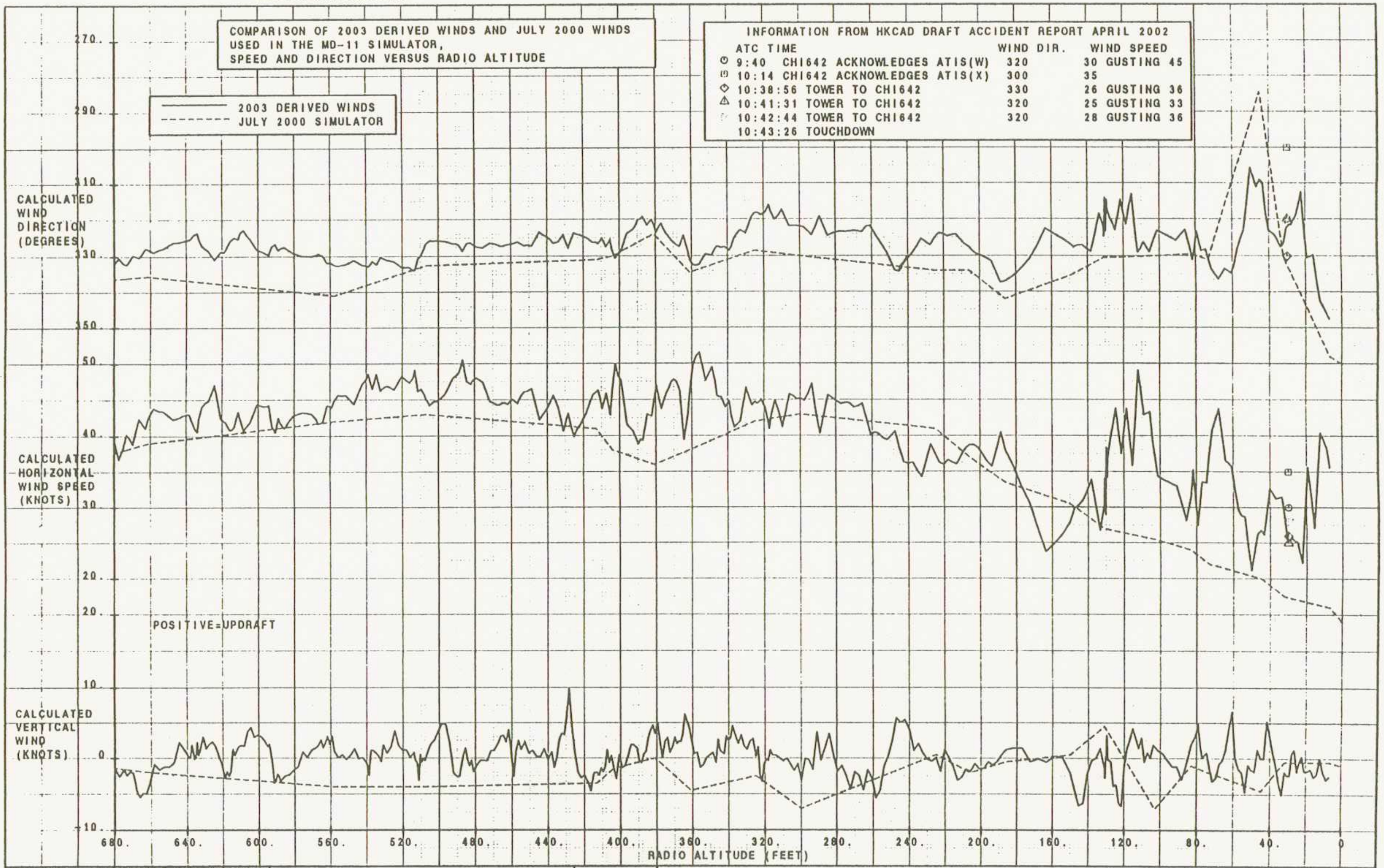


Note : See qualification at Paragraph 1.18.4 of the report regarding accuracy of MD11 wind data below 50 feet RA

Note : See qualification at Paragraph 1.18.4 of the report regarding accuracy of MD11 wind data below 50 feet RA


THE BOEING COMPANY
COMPARISON OF 2003 DERIVED WINDS AND JULY 2000 WINDS USED IN THE MD-11 SIMULATOR, HEADWIND AND CROSSWIND COMPONENTS VERSUS RADIO ALTITUDE
2003 DERIVED WINDS
JULY 2000 SIMULATOR
INFORMATION FROM HKCAD DRAFT ACCIDENT REPORT APRIL 2002
ATC TIME | WIND DIR. | WIND SPEED
9:40 CHI642 ACKNOWLEDGES ATIS(W) 320 30 GUSTING 45
10:14 CHI642 ACKNOWLEDGES ATIS(X) 300 35
10:38:56 TOWER TO CHI642 330 26 GUSTING 36
10:41:31 TOWER TO CHI642 320 25 GUSTING 33
10:42:44 TOWER TO CHI642 320 28 GUSTING 36
10:43:26 TOUCHDOWN
CALCULATED HEADWIND COMPONENT (KNOTS)
CALCULATED RELATIVE TO THE RUNWAY (MAGNETIC HEADING 253 DEGREES)
POSITIVE=FROM THE RIGHT
CALCULATED CROSSWIND COMPONENT (KNOTS)
POSITIVE=UPDRAFT
CALCULATED VERTICAL WIND (KNOTS)
40. 30. 20. 10. 0 50. 40. 30. 20. 20. 10. 0 -10.
680. 640. 600. 560. 520. 480. 440. 400. 360. 320. 280. 240. 200. 160. 120. 80. 40. 0
RADIO ALTITUDE (FEET)
CALC JDA 16OCT03
CHECK
APPD
APPD
REVISED DATE
REV
MD-11 CHI ACCIDENT AT HONG KONG 22AUG99, 2003 VS. JULY 2000 SIMULATOR HEADWIND AND CROSSWIND COMPONENTS
FIGURE 3
PAGE

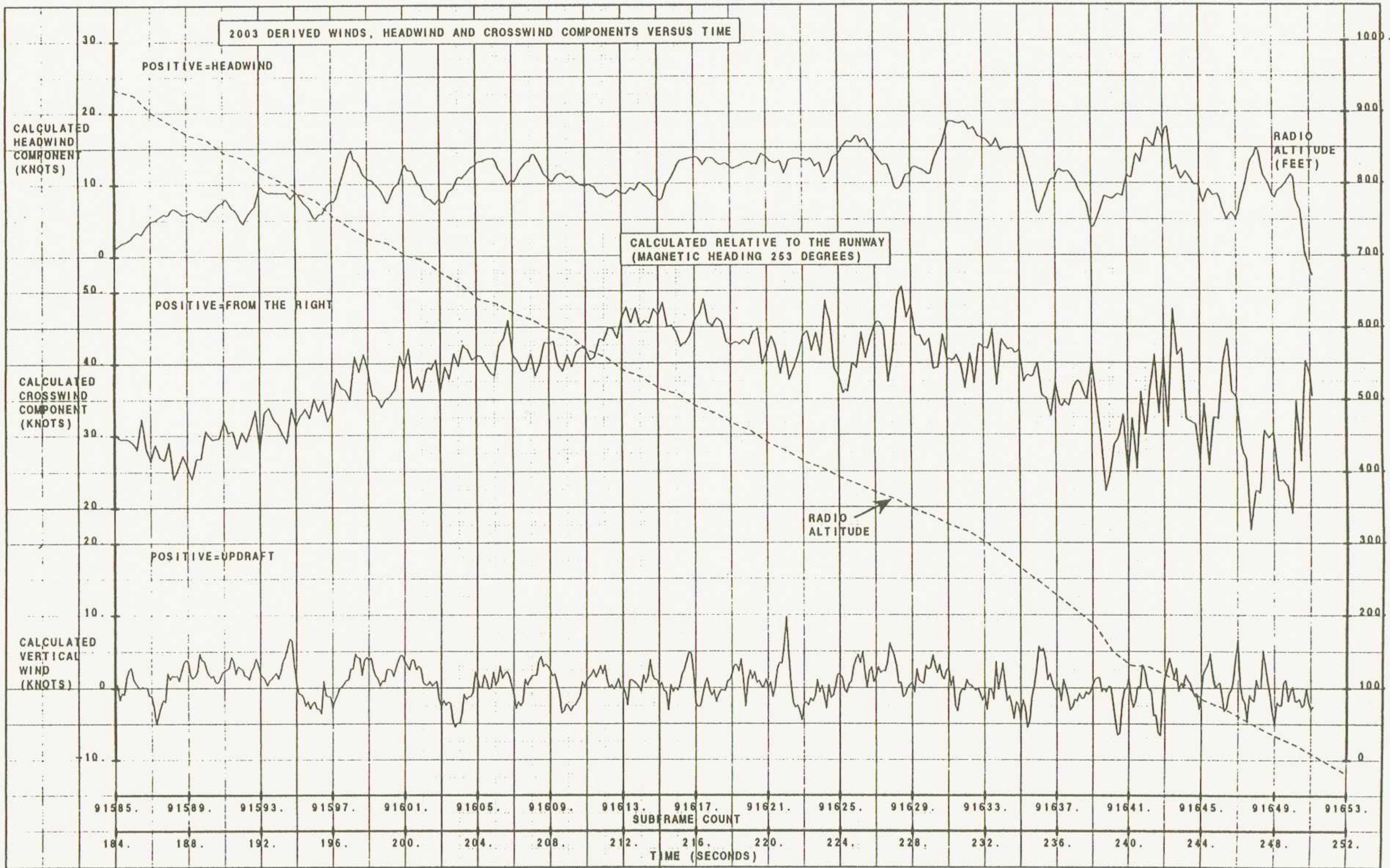
THE BOEING COMPANY



CALC	JDA	22OCT03	REVISED	DATE	MD-11 CHI ACCIDENT AT HONG KONG 22AUG99, 2003 VS. JULY 2000 SIMULATOR WIND SPEED AND DIRECTION	FIGURE 2
CHECK						
APPD						
APPD						

REV PAGE

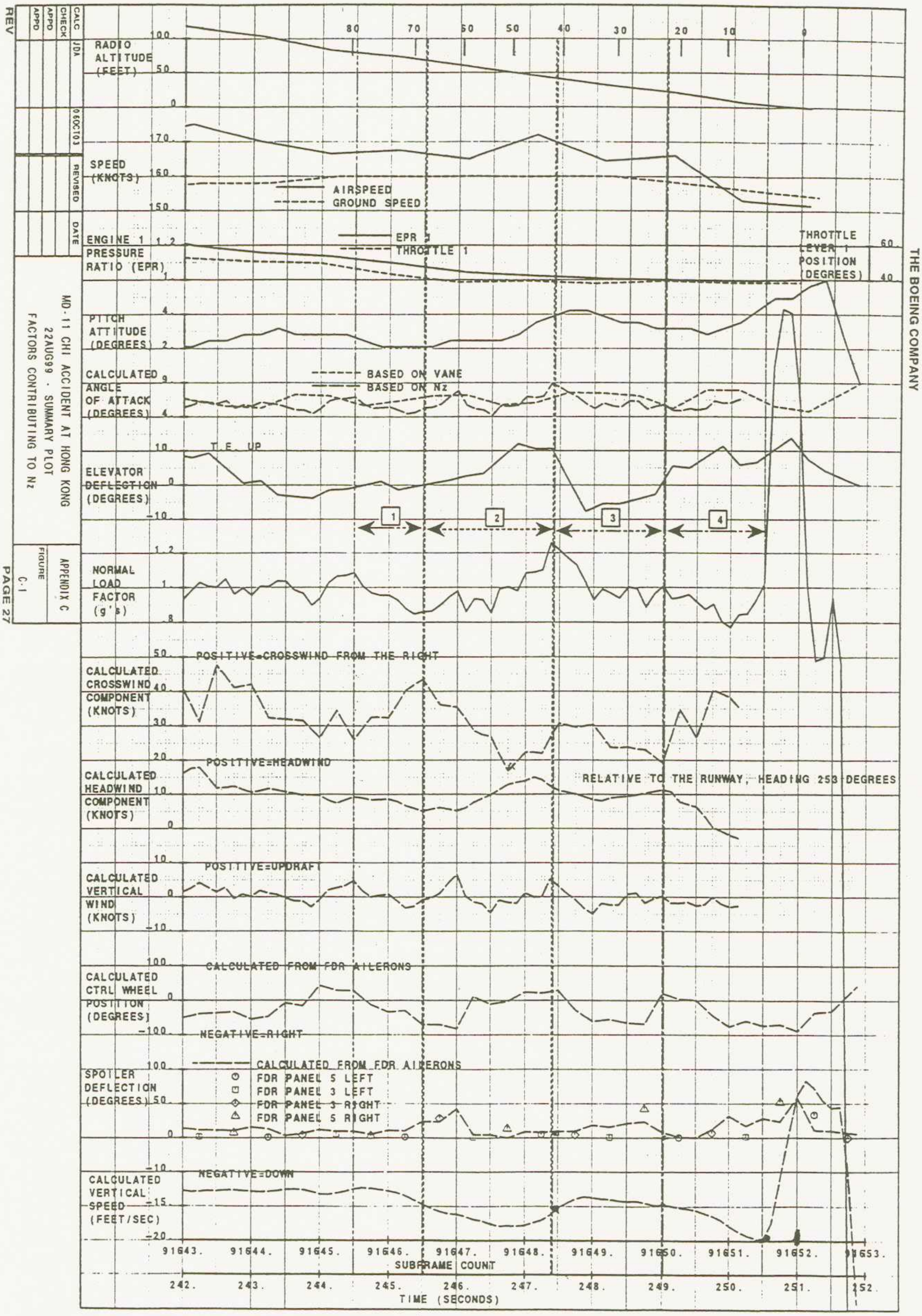
THE BOEING COMPANY

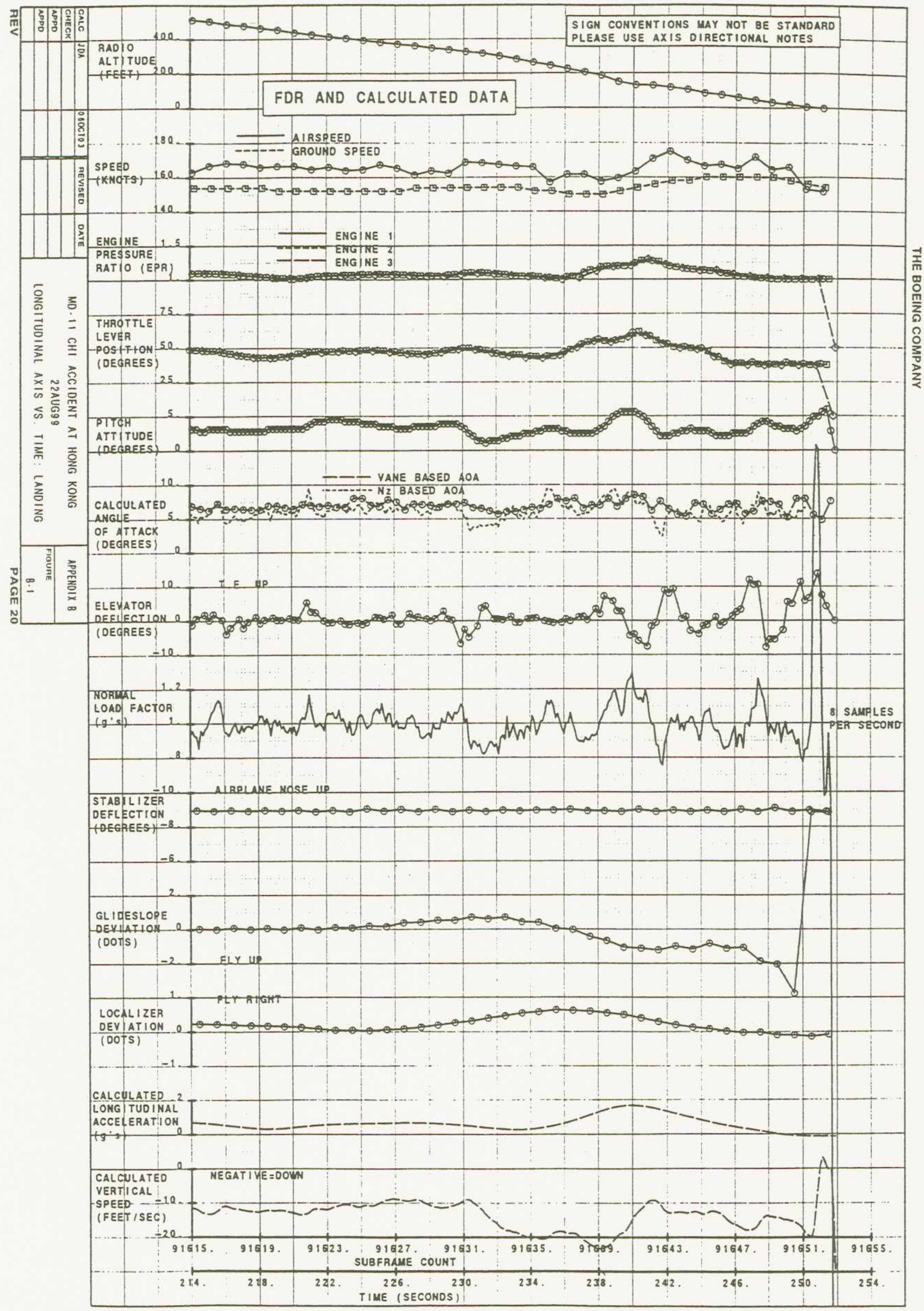


CALC	JDA	06OCT03	REVISED	DATE	MD-11 CHI ACCIDENT AT HONG KONG 22AUG99, 2003 DERIVED WINDS HEADWIND AND CROSSWIND VS. TIME	APPENDIX A
CHECK						FIGURE A-1
APPD						
APPD						

REV

PAGE 15


REV
CALC
CHECK
APPD
APPD
JDA
06OCT03
REVISED
DATE
MD-11 CHI ACCIDENT AT HONG KONG
22AUG99 - SUMMARY PLOT
FACTORS CONTRIBUTING TO Nz
APPENDIX C
FIGURE
C.1
PAGE 27
THE BOEING COMPANY
RADIO ALTITUDE (FEET)
SPEED (KNOTS)
AIRSPEED
GROUND SPEED
ENGINE 1 PRESSURE RATIO (EPR)
EPR
THROTTLE 1
THROTTLE LEVER 1 POSITION (DEGREES)
PITCH ATTITUDE (DEGREES)
CALCULATED ANGLE OF ATTACK (DEGREES)
BASED ON VANE
BASED ON Nz
ELEVATOR DEFLECTION (DEGREES)
T.E. UP
1
2
3
4
NORMAL LOAD FACTOR (g's)
CALCULATED CROSSWIND COMPONENT (KNOTS)
POSITIVE=CROSSWIND FROM THE RIGHT
CALCULATED HEADWIND COMPONENT (KNOTS)
POSITIVE=HEADWIND
RELATIVE TO THE RUNWAY, HEADING 253 DEGREES
CALCULATED VERTICAL WIND (KNOTS)
POSITIVE=UPDRAFT
CALCULATED CTRL WHEEL POSITION (DEGREES)
CALCULATED FROM FDR AILERONS
NEGATIVE=RIGHT
SPOILER DEFLECTION (DEGREES)
CALCULATED FROM FDR AILERONS
FDR PANEL 5 LEFT
FDR PANEL 3 LEFT
FDR PANEL 3 RIGHT
FDR PANEL 5 RIGHT
CALCULATED VERTICAL SPEED (FEET/SEC)
NEGATIVE=DOWN
91643. 91644. 91645. 91646. 91647. 91648. 91649. 91650. 91651. 91652. 91653.
SUBFRAME COUNT
242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252.
TIME (SECONDS)


FDR AND CALCULATED DATA
SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
RADIO ALTITUDE (FEET)
SPEED (KNOTS)
AIRSPEED
GROUND SPEED
ENGINE PRESSURE RATIO (EPR)
ENGINE 1
ENGINE 2
ENGINE 3
THROTTLE LEVER POSITION (DEGREES)
PITCH ATTITUDE (DEGREES)
CALCULATED ANGLE OF ATTACK (DEGREES)
VANE BASED AOA
Nz BASED AOA
ELEVATOR DEFLECTION (DEGREES)
T.E. UP
NORMAL LOAD FACTOR (g's)
8 SAMPLES PER SECOND
STABILIZER DEFLECTION (DEGREES)
AIRPLANE NOSE UP
GLIDESLOPE DEVIATION (DOTS)
FLY UP
LOCALIZER DEVIATION (DOTS)
FLY RIGHT
CALCULATED LONGITUDINAL ACCELERATION (g's)
CALCULATED VERTICAL SPEED (FEET/SEC)
NEGATIVE=DOWN
SUBFRAME COUNT
TIME (SECONDS)
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LONGITUDINAL AXIS VS. TIME: LANDING
APPENDIX B
FIGURE B-1
PAGE 20
REV
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APPD
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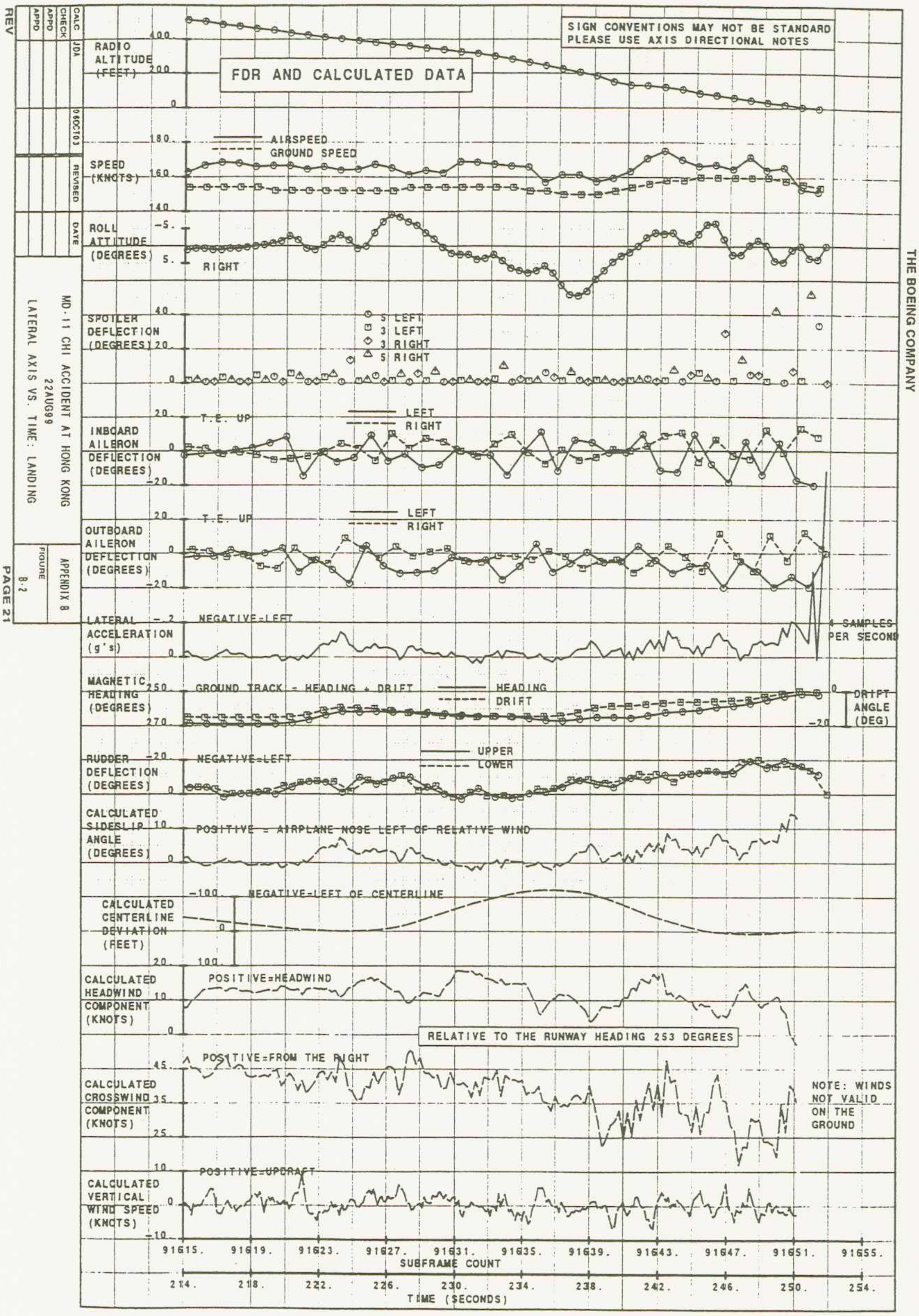
06OCT03
REVISED
DATE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SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
RADIO ALTITUDE (FEET)
SPEED (KNOTS)
AIRSPEED
GROUND SPEED
ROLL ATTITUDE (DEGREES)
RIGHT
SPOILER DEFLECTION (DEGREES)
5 LEFT
3 LEFT
3 RIGHT
5 RIGHT
INBOARD AILERON DEFLECTION (DEGREES)
T.E. UP
LEFT
RIGHT
OUTBOARD AILERON DEFLECTION (DEGREES)
LATERAL ACCELERATION (g's)
NEGATIVE=LEFT
4 SAMPLES PER SECOND
MAGNETIC HEADING (DEGREES)
GROUND TRACK = HEADING + DRIFT
HEADING
DRIFT
DRIFT ANGLE (DEG)
RUDDER DEFLECTION (DEGREES)
UPPER
LOWER
CALCULATED SIDESLIP ANGLE (DEGREES)
POSITIVE = AIRPLANE NOSE LEFT OF RELATIVE WIND
CALCULATED CENTERLINE DEVIATION (FEET)
NEGATIVE=LEFT OF CENTERLINE
CALCULATED HEADWIND COMPONENT (KNOTS)
POSITIVE=HEADWIND
RELATIVE TO THE RUNWAY HEADING 253 DEGREES
CALCULATED CROSSWIND COMPONENT (KNOTS)
POSITIVE=FROM THE RIGHT
NOTE: WINDS NOT VALID ON THE GROUND
CALCULATED VERTICAL WIND SPEED (KNOTS)
POSITIVE=UPDRAFT
91615. 91619. 91623. 91627. 91631. 91635. 91639. 91643. 91647. 91651. 91655.
SUBFRAME COUNT
214. 218. 222. 226. 230. 234. 238. 242. 246. 250. 254.
TIME (SECONDS)
THE BOEING COMPANY
REV
CALC JDA
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LATERAL AXIS VS. TIME: LANDING
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FIGURE B-2
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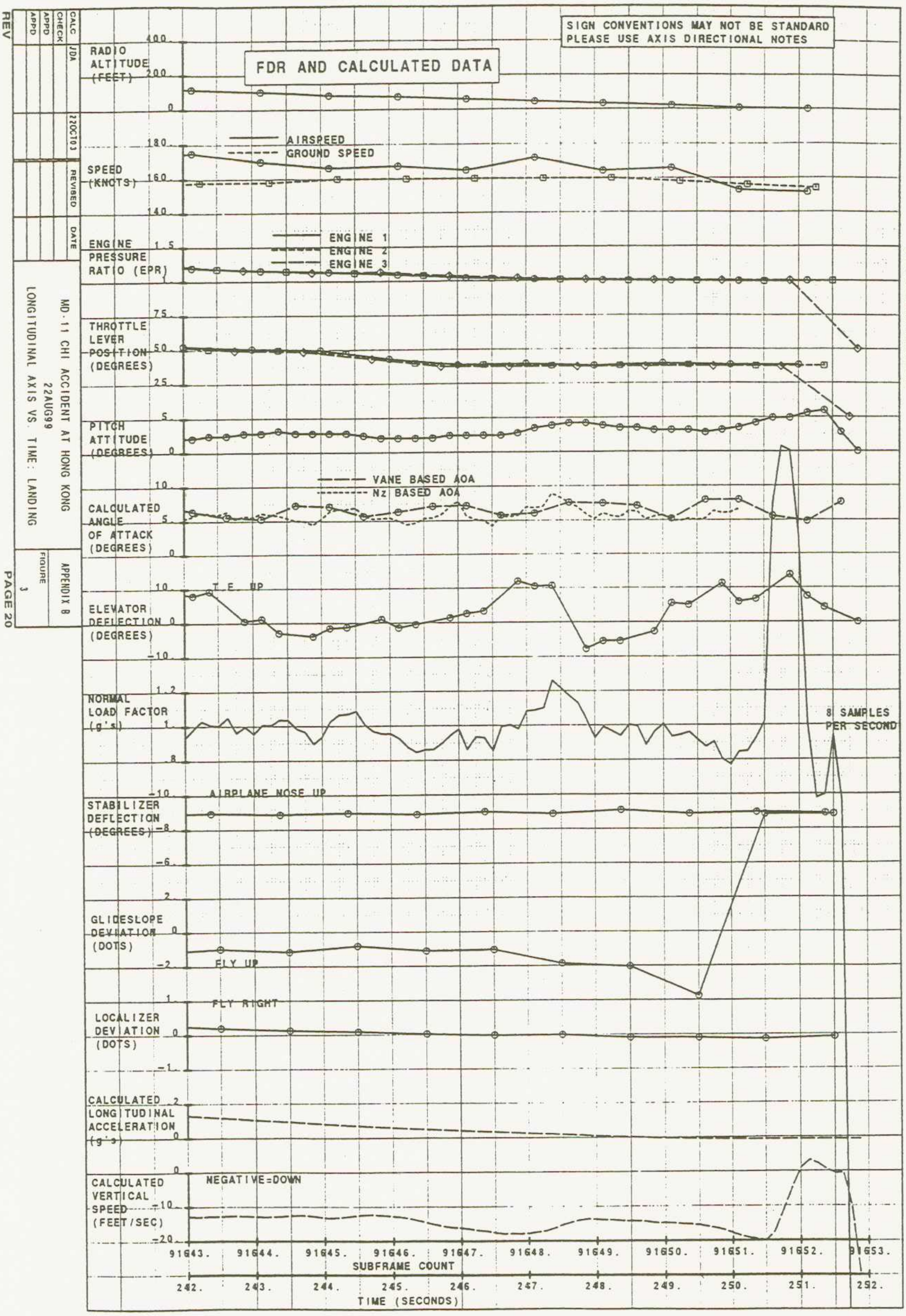
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Nz BASED AOA
ELEVATOR DEFLECTION (DEGREES)
T.E. UP
NORMAL LOAD FACTOR (g's)
8 SAMPLES PER SECOND
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GLIDESLOPE DEVIATION (DOTS)
FLY UP
LOCALIZER DEVIATION (DOTS)
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CALCULATED LONGITUDINAL ACCELERATION (g's)
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NEGATIVE=DOWN
SUBFRAME COUNT
TIME (SECONDS)
THE BOEING COMPANY
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LONGITUDINAL AXIS VS. TIME: LANDING
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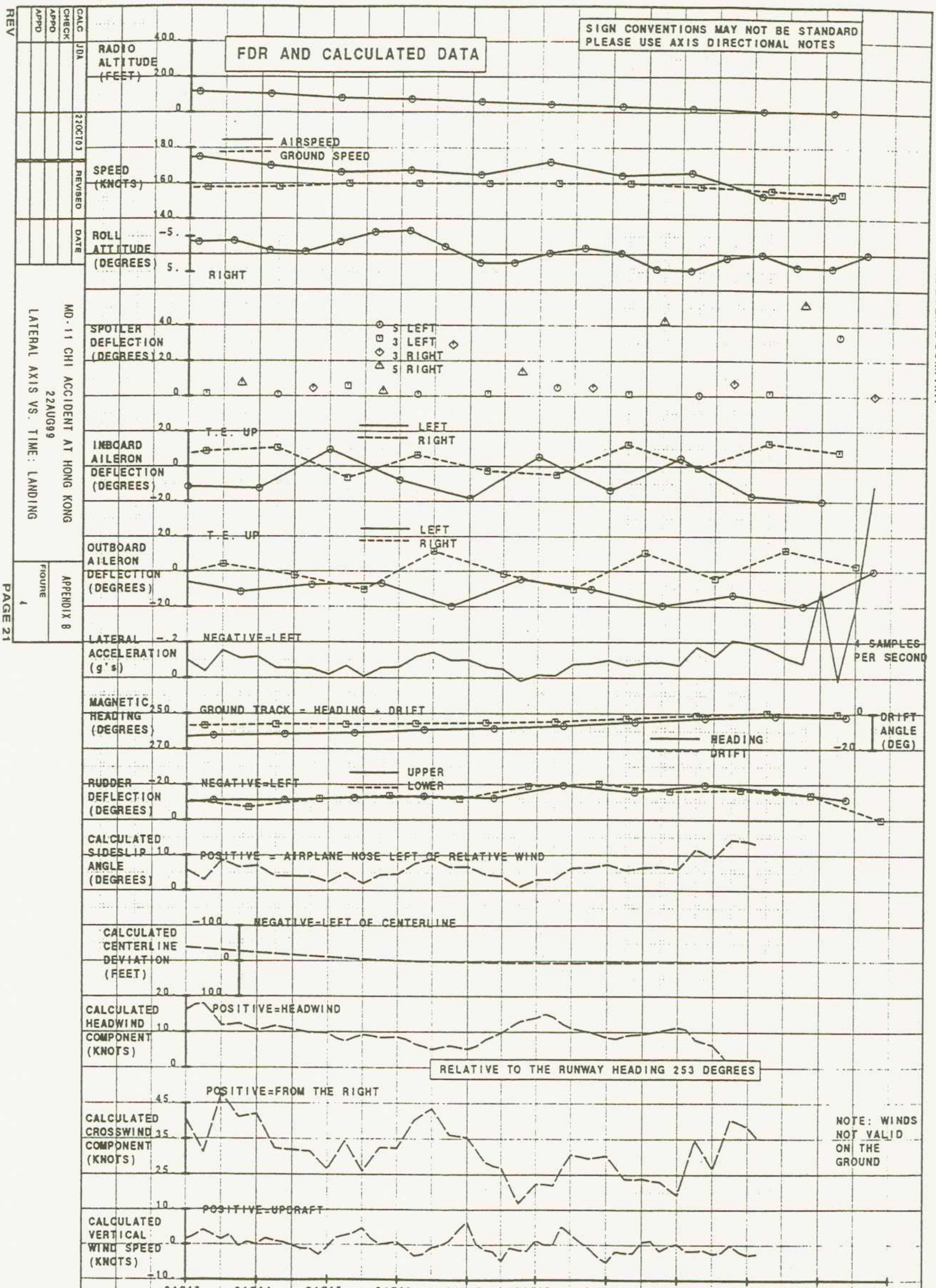
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3 RIGHT
5 RIGHT
INBOARD AILERON DEFLECTION (DEGREES)
T.E. UP
LEFT
RIGHT
OUTBOARD AILERON DEFLECTION (DEGREES)
LATERAL ACCELERATION (g's)
NEGATIVE=LEFT
4 SAMPLES PER SECOND
MAGNETIC HEADING (DEGREES)
GROUND TRACK = HEADING + DRIFT
HEADING
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POSITIVE=UPDRAFT
SUBFRAME COUNT
TIME (SECONDS)
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PREPARATION FOR DESCENT PROCEDURE

1. ATIS PNF

Acquire the destination weather information from destination ATIS or other appropriate source.

2. MCDU ACT F-PLN PAGE

(1) Select the ACT F-PLN page by pushing the F-PLN key. Page up with the ↑ key on the MCDU until the arrival airport is in view.

(2) Pushing the LS key adjacent to the waypoint prior to the destination selects the LAT REV page.

(3) To select the STAR page push LS key 1R.

(4) On the STAR page select the appropriate approach and landing runway on the right then select the appropriate STAR (if applicable) with the left LS keys. To return to the ACT F-PLN page push " * INSERT" (LS key 6L).

(5) If the approach selected has a transition option the MCDU will automatically display the options for pilot selection.

(6) After picking the appropriate transition push "*INSERT" line select key 6L or "ACT F-PLN" line select key 6R to return to the ACT F-PLN page.

3. MCDU APPROACH PAGE

Select the Approach Page, verify the landing field LENGTH and ELEV, select the desired flap setting for landing and crosscheck MCDUs for correct VREF speed.

NOTE

Landing field altitude is normally entered into the

MD－11 S.O.P.	NORMAL PROCEDURE	REV.	PAGE 94 01-01-95

pressurization controller by the FMS. In the event of an emergency return after climbing through 5000 feet above takeoff field altitude or diverting to an airport other than planned. Landing field altitude must be inserted by turning the MANUAL LDG ALT knob on the Cabin Pressurization Panel.

4. WINDSHIELD ANTI-ICE PNF

Use of windshield anti-ice when descending into high humidity conditions will prevent window fogging.

5. GLARESHIELD PF/PNF

On the EIS Control Panel rotate the RA/BARO Selector to RA or BARO as required and rotate the Minimums Control Knob to the correct Decision Height or Minimum Descent Altitude as appropriate for the approach being flown.

6. CREW BRIEFING PF

Please refer L/D briefing formats as followed:

FLIGHT CREW BEFORE L/D BRIEFING

(1) WX:
LANDING A/P____________________
ALTERNATE A/P____________________
(2) TIME OF DESCENT____________________
(3) TRANSITION LEVEL____________________
MSA____________________
(4) RUNWAY IN USE____________________
FIELD ELEVATION____________________
(5) STAR & MISS APPROACH PROCEDURE
(6) GO-AROUND PROCEDURE

PREPARATION FOR DESCENT PROCEDURE (CONT'D)

PUSH G/A BUTTON, ADVANCE THROTTLES
FLAPS 28, POSITIVE RATE, GEAR-UP.
ALT__________LEVEL CHANGE
ALT__________SPEED SELECT
THEN FLAP SKJ & CONTINUE CLIMB.

(7) FMS & NAV RADIO SET UP
(8) REMARK:

MD11 FLIGHT CREW CAT II APPROACH BRIEFING

1. WX :
   LANDING AIRPORT ATIS __________
   ALTERNATE AIRPORT __________
2. TIME OF DESCENT __________
3. TRANSITION LEVEL __________
   MSA __________
4. RUNWAY IN USE __________
   FIELD ELEVATION __________
   ILS FRQ & CRS __________
   LANDING CAT Ⅱ OR Ⅲ. DH OR AH __________
   AUTOLAND OR MANUAL LAND.
5. STAR & MISS APPROACH PROCEDURE __________
6. MINIMUM DIVERSION FUEL
7. GO-AROUND PROCEDURE.
   PUSH G/A BUTTON, ADVANCE THROTTLES.
   FLAPS 28, POSITIVE RATE, GEAR-UP.
   LEVEL CHANGE   PROFILE
   HEADING SELECT   OR   NAV
   SPEED SELECT   MAP
   MAP
   THEN FLAPS SKJ & CONTINUE CLIMB.
8. FMS & NAV RADIO SET-UP.
9. REMARK :

A22-2

PREPARATION FOR DESCENT PROCEDURE (CONT'D)

7. SEAT BELTS SWITCHES — PF
   Move SEAT BELTS switch to ON when beginning the descent from cruise altitude.
8. SHOULDER HARNESS — PF/PNF
   PF and PNF should fasten their shoulder harness before descend.
9. DESCENT/APPROACH CHECKLIST — PNF
   Begin the DESCENT/APPROACH checklist by accomplishing the check list through SEAT BELTS.

NOTE

Refer to supplemental procedures and procedures and techniques sections of the FCOM for operation of AUTO FLIGHT and MCDUs during descent phase of flight.

DESCENT TECHNIQUES

• STANDARD DESCENT PROCEDURE

1. The FMS will consider the optimum point to begin an unrestricted descent to a landing, however, in actual operations, when it is necessary to compute a TOD point, use the following rule-of-thumb:
   (1) Determine the altitude difference.
   (2) Drop the last three digits.
   (3) Multiply by three.
   (4) For an unrestricted descent to a landing, add 10 n.m.
   (5) For a descent to an intermediate altitude above 10000 feet, no additive required.
   (6) Adjust TOD point for wind (tailwind-earlier TOD headwind-later TOD):

China Airlines

MD-11 Accident, August 22,1999

At Hong Kong International Airport,

Hong Kong

Comments on the draft final report

By the

Aviation Safety Council

Taiwan

Submitted June 2002

TABLE OF CONTENTS

REFERENCES

Reference A - **CAD Aircraft Accident Report 1/2002** (Final Draft) dated April 2002.

Reference B - **ICAO ISRPs Annex 13** to the Convention on International Civil Aviation - **Aircraft Accident and Incident Investigation** Section 6.3.

Reference C - **ICAO ISRPs Annex 3** to the Convention on International Civil Aviation – **Meteorological Service for International Air Navigation**, Section 5.6.

Reference D -**CAD Aircraft Accident Report 1/2001** dated June 2001

Reference E -Fujita, T.T. **Manual of downburst identification for project NIMROD", University of Chicago, SMRP research Paper No.156,** 104pp.dated 1978

Reference F –Technical Note No.102, Hong Kong Observatory

Part 1

An Overview of the Comments from the ASC to the CAD on the Confidential Draft Final report Concerning the China Airlines Boeing MD-11 Accident at Hong Kong Airport, August 22nd 1999

ASC Comments

The ASC, Accredited Representative team on CI642 accident investigation has carefully studied and reviewed the CAD draft Final Report.

The sole purpose of the ASC's comments is to provide constructive feedback to Hong Kong on the draft Final Report. Our aim is to achieve a Final Report of the highest possible quality, and one that will make a significant contribution to the enhancement of international aviation safety.

The Guiding Principles of the ASC's review of the Hong Kong Draft Final Report

In accordance with the principles and spirit of Annex 13, our aim is to ensure that the Draft Final Report of the CI-642 investigation is accurate, objective and balanced, and does not apportion blame or liability.

We have considered the Hong Kong draft Final Report in the light of established and proven air safety investigation methodology. We have considered whether all of the relevant factual material gathered in the investigation has been included in the Hong Kong draft Final Report. We have also assessed the degree to which the analysis and conclusions are based upon sound investigation procedures and factual evidence.

Both CAD, Hong Kong and ASC, Taiwan share the common goal of pursuing excellence in aviation safety. Notwithstanding the difficulties that have been encountered, ASC hopes that the valuable lessons learned by both Hong Kong and Taiwan from the experience of the CI-642 investigation will enhance aviation safety.

The Hong Kong draft Final Report

The ASC considers that:

a) The Hong Kong draft Final Report minimizes the significance of the absence of high capability wind shear warning detection system at Chap-Lap-Kok Airport. The improvement of wind shear detecting system is a major challenge confronting the world aviation industry.

b) The Hong Kong draft Final Report also minimizes the finding of the three very valuable simulator lessons tested at Boeing facility, Long Beach, California.

c) The Hong Kong draft Final Report does not adequately address the RWY 25L and 25R wind difference analysis attributed from passenger terminal building. It should be considered in that context. See Figure 1 below.

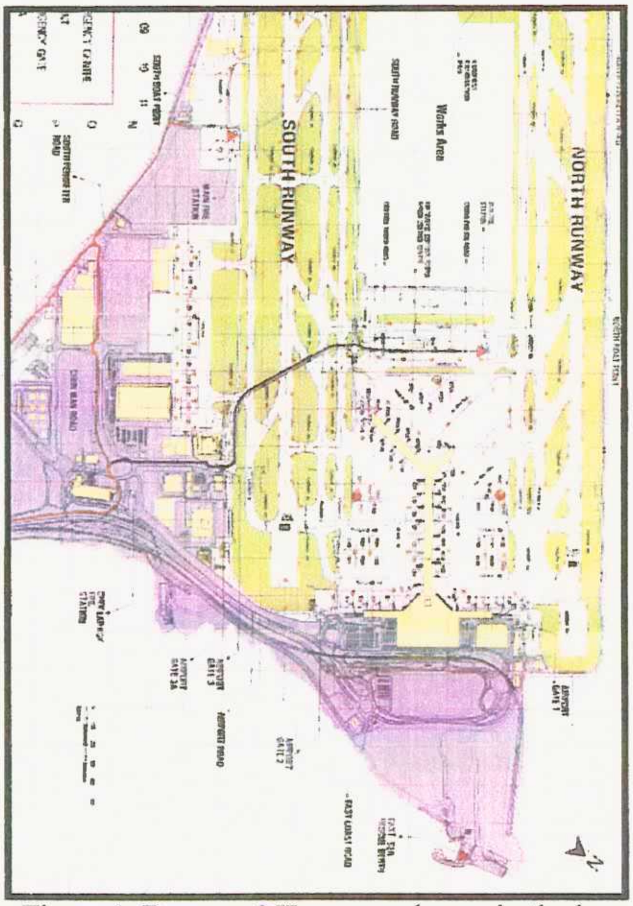


Figure 1. Runway 25L approach area in the lee of the Passenger Terminal Building

Part 2

Comments on Section 1, Factual Information

Reference A, Section 1.1. History of the flight Pg. 6 Para 3

ASC issues and Discussion

This paragraph contains: "…and exited through L1 door and began…" which does not reflect the actual fact, since the crew exited through a hole in the fuselage.

ASC proposed changes

Change Page 6, Para 3 of Ref. A Section 1.1 to read: "…and exited through a hole in the fuselage and began…"

Part 3

Comments on Section 2, Analysis

ASC proposes the following paragraphs and figures to support the findings as a result of analysis that based on recorded data and known aircraft characteristics.

(A) Wind derived from FDR data

According to FDR parameters, ASC interpolated the horizontal wind direction, wind speed, vertical wind speed and derived the following data as shown in Table 1.

UTC_Time (hh:mm:ss.s)	CAS (knots)	RALT (feet)	sink rate (DRA) (ft/s)	sinkrate VG (ft/s)	MHEading (deg)	ROLL (deg)	PITCH (deg)	GSPD (knots)	DRIFT (deg)	AOA#1 (deg)	AOA#2 (deg)	ELEV RIB (DEG)	ELEV ROB (DEG)	flight path angle (deg)	WSPD (Boeing) (Kts)	WINDIR (Boeing) (deg)	Vert.WSPD (Boeing) (Kts)
10:44:01.0	169.0	325	-13	-8.89	264	2.46	3.16	154	-14.42	6.86	5.45	-4.83	-1.76	-3.7	46.15	323.20	4.82
10:44:02.0	168.5	316	-9	-11.68	264	3.87	1.41	154	-14.77	5.27	4.57	4.31	5.89	-3.86	42.05	317.70	0.13
10:44:03.0	167.5	300	-16	-16.20	264	2.46	1.41	154	-14.42	3.69	4.39	0.26	1.32	-2.28	46.16	322.80	4.16
10:44:04.0	166.5	282	-18	-18.29	265	6.33	2.11	154	-14.42	4.39	4.92	-0.53	0.44	-2.28	47.86	326.10	1.80
10:44:05.0	166.0	263	-19	-19.91	266	7.74	2.46	152	-14.42	5.62	5.27	0.79	1.76	-3.16	43.27	320.60	0.28
10:44:06.0	157.0	245	-18	-19.21	267	5.63	3.16	152	-14.42	6.33	7.91	-0.62	-0.70	-3.17	39.66	322.10	-0.53
10:44:07.0	161.5	225	-20	-17.76	267	11.25	2.81	150	-14.06	7.21	8.09	-0.09	2.37	-4.4	37.33	321.00	2.11
10:44:08.0	161.5	206	-19	-18.82	266	14.42	2.46	150	-12.31	5.27	6.15	0.18	4.13	-2.81	26.70	317.00	3.01
10:44:09.0	157.5	186	-20	-21.33	265	9.49	3.16	150	-9.49	6.15	7.91	7.21	6.33	-2.99	35.74	325.00	0.96
10:44:10.0	159.5	150	-36	-17.89	265	4.57	5.27	152	-8.44	5.80	7.91	2.72	3.34	-0.53	27.67	315.40	-4.81
10:44:11.0	163.5	131	-19	-12.47	265	1.76	5.63	154	-8.44	8.96	8.44	-5.89	-7.82	-3.33	26.86	308.30	1.51
10:44:12.0	171.0	129	-2	-7.88	264	-2.46	3.52	156	-7.38	4.75	7.21	-0.53	0.18	-1.23	33.30	304.00	2.70
10:44:13.0	175.0	117	-12	-11.58	262	-3.52	2.11	158	-6.68	5.10	3.52	9.32	-0.44	-2.99	36.42	301.80	7.22
10:44:14.0	170.0	104	-13	-11.58	262	-1.05	2.81	158	-5.98	2.99	6.68	-2.90	-4.75	-0.18	31.58	307.60	0.92
10:44:15.0	166.5	88	-21	-12.06	261	-3.52	2.81	160	-5.98	6.33	3.69	-1.23	-2.37	-3.52	24.48	307.40	4.78
10:44:16.0	167.5	73	-10	-11.48	259	-6.68	2.11	160	-5.63	4.92	6.33	-0.44	0.88	-2.81	29.13	314.90	1.72
10:44:17.0	165.0	59	-14	-14.65	258	2.46	2.46	160	-5.27	6.50	3.87	3.34	1.58	-4.04	21.65	316.50	5.29
10:44:18.0	172.0	45	-14	-16.07	257	-0.35	3.52	160	-4.57	4.39	7.21	10.63	-8.53	-0.87	20.58	271.60	0.79
10:44:19.0	164.5	32	-13	-12.30	255	-0.35	3.87	160	-2.81	7.03	6.33	-5.45	3.43	-3.16	17.81	301.10	0.46
10:44:20.0	166.0	21	-11	-13.27	253	4.57	3.16	158	-1.05	2.81	7.91	5.01	3.69	0.35	18.49	298.00	-0.22
10:44:21.0	153.0	7	-14	-16.82	251	0.00	3.52	156	0.35	7.91	3.52	6.68	15.73	-4.39	20.87	341.60	4.14
T/ 10:44:22.0	151.5	-1	-8	4.43	252	3.87	5.63	154	-0.35	2.11	-4.57	4.22	-10.37	3.52	20.87	343.90	[illegible]

Table 1. FDR Parameters and Derived Wind Data

From table 1 ASC identified the following information:

(1) At altitude of 325 ft ~ 150 ft RA, the wind speed varied from 46.2 knots to 27.7 knots, and wind direction varied from 315 degree to 326 degree. This wind condition is consistent with the data of ground measurement.

(2) Sinking rate was integrated from vertical acceleration and found varied with parameters of the vertical acceleration and angle of attack.

(3) The vertical wind was found varied at different altitude till touch down.

(4) This high sinking rate was found affected by wind. At 117 ft RA and 32 ft the wind speed indicated 36 knots and 17.8 knots,

(B) Downdraft Analysis

Professor Fujita of University of Chicago stated the wind change in convective mode, with wind speed over 34 knots, is called downdraft. Fujita also pointed out that the over 12 ft/sec wind change rate could also be defined as a downdraft. (Reference E)

Wind shear refers to a change in the headwind or tailwind for more than a few seconds, resulting in changes in the lift to an aircraft. A decreased lift will cause the aircraft to go below the intended flight path. In the presence of significant windshear, a pilot has to take corrective action in a very short time. Turbulence is caused by rapid irregular motion of air. It brings about bumps or jolts. In severe cases, the aircraft might go momentarily out of control. (1.1 pp1 , Reference F)

Refer to Table 1; there are two major findings as below:

(1) The significant delta CAS or unsteady horizontal wind:

Between 300 ft ~ 186 ft, the CAS varied from 167.5 to 157.5kts (-10.0 kts).

Between 186 ft ~ 117 ft, the CAS varied from 157.5 to 175 (+17.5 kts).

Between 117 ft ~ 7 ft, the CAS varied from 175.0 to 153.7 (-21.3 kts).

(2) The significant vertical wind changed:

During passing 316 ft ~ 245 ft, the vertical wind speed varied from +8.13 to –0.53

During passing 206 ft ~ 150 ft, the vertical wind speed varied from +3.01 to –4.81.

During passing 59 ft ~ 21 ft, the vertical wind speed varied from +5.29 to –0.22.

Below 50 ft RA, according to Table 2, the sinking rate of CI642 varied from 16.1 ft/sec to 12.0 ft/sec. There were significant vertical accelerations data recorded in FDR. During this period, the ground speed indication was stable at 158 knots and the angle of attack (AOA) varied. ASC believes that below 50 ft RA, the aircraft encountered a downdraft that affected the descent rate.

UTC_Time (hh:mm:ss.s)	CAS (knots)	RALT (feet)	sink rate (DRA) (ft/s)	sinkrate VG (ft/s)	M Heading (deg)	ROLL (deg)	PITCH (deg)	GSPD (knots)	DRIFT (deg)	AOA (deg)	flight path angle (deg)	WSPD (Boeing) (Kts)	WINDIR (Boeing) (deg)	VERT ACC (g)	ELEV LIB (deg)	ELEV RIB (deg)	ELEV ROB (deg)	ELEV LOB (deg)
10:44:18.0	172	45	-14	-16.1	257.02	-0.35	3.52	160	-4.57	4.39	-0.87	20.38	271.60	1.083	10.55			
10:44:18.1				-15.7										1.087				
10:44:18.2				-15.3			3.87							1.101		10.63		
10:44:18.4				-14.2										1.261				
10:44:18.5				-13.4		-1.76	4.22			7.21	-2.99			1.215			-8.53	
10:44:18.6				-12.7										1.170				
10:44:18.7				-12.2			4.22							1.128				-7.73
10:44:18.9				-12.0										1.035				
10:44:19.0	164.5	32	-13	-12.3	254.91	-0.35	3.87	160	-2.81	7.03	-3.16	17.81	301.10	0.927	-5.45			
10:44:19.1				-12.3										0.991				
10:44:19.2				-12.5			3.52							0.966		-5.45		
10:44:19.4				-12.7										0.938				
10:44:19.5				-12.7		4.22	3.52			6.33	-2.81			1.003			-3.43	
10:44:19.6				-12.7										0.993				
10:44:19.7				-13.2			3.16							0.286				-2.72
10:44:19.9				-13.3										0.964				
10:44:20.0	166	21	-11	-13.3	252.8	4.57	3.16	158	-1.05	2.81	0.35	18.49	290.00	1.007	5.54			
10:44:20.1				-13.5										0.934				
10:44:20.2				-13.7			3.16							0.943		5.01		
10:44:20.4				-13.9										0.959				
10:44:20.5				-14.2		1.05	2.81			7.91	-5.1			0.916			3.69	
10:44:20.6				-14.7										0.874				
10:44:20.7				-15.1			3.16							0.904				11.34
10:44:20.9				-15.9										0.803				
10:44:21.0	153	7	-14	-16.8	251.39	0	3.52	156	0.35	7.91	-4.39	20.87	341.60	0.771	5.89			
10:44:21.1				-17.4										0.845				
10:44:21.2				-18.0			4.22							0.849		6.68		
10:44:21.4				-18.3										0.925				
10:44:21.5				-18.3		3.57	4.92			3.52	1.4			1.019			15.73	
10:44:21.6				-13.0										2.294				
10:44:21.7				-6.5			4.92							2.630				13.8
10:44:21.9				0.0										2.406				
10:44:22.0	151.5	-1	-8	4.4	252.1	3.87	5.63	154	-0.35	2.11	3.52	20.87	343.90	2.104	7.47			
10:44:22.1				4.5										1.005				
10:44:22.2				2.8			5.98							0.577		4.22		
10:44:22.4				1.1										0.497				
10:44:22.5										-4.57	4.57			0.938			-10.37	
10:44:22.6														0.403				
10:44:22.7														0.385				-9.49
10:44:22.9														0.316				

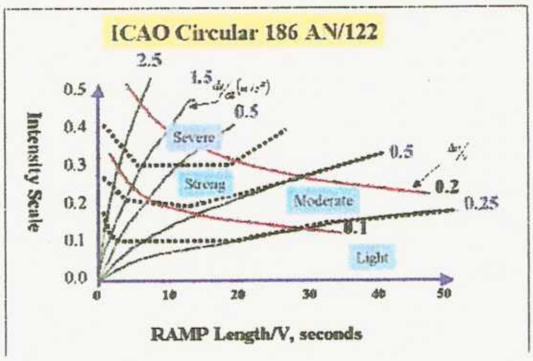
Downdraft

T/D

Table 2 Vertical Acceleration Variations Below 50 ft RA

(C) Wind Shear Identification from Flight Data Record

In 1987, ICAO proposed a method to measure the wind shear hazard (ICAO, 1987). This method categorizes the wind shear into four levels: light, moderate, strong and severe. The wind shear identification depends on two parameters, i.e. the air speed change and the proportion of air speed, as shown in Figure 3.



Wind Shear identification method - airspeed variation, published by ICAO. Source: Prof. Fujita, Univ. of Chicago, USA, 1985

Figure 3: Wind Shear Intensity classification

	UTC Time	CAS	delta CAS	dt	Ds/t	dv/dt	windshear level	delta YWSPD	delta WSPD	RA	AOA	Vert. Wind	WSPD (Boeing)	WINDIR (Boeing)	GSPD	TLA1	TLA2	TLA3	HEADING	PITCH1
	hh:mm:ss	kts	kts			(m/s^2)		(kts)	(kts)	ft	deg	(kts)	(Kts)	(deg)	KTS	(deg)	(deg)	(deg)	Deg	deg
	18:43:46	167.0								507.0	5.10				154.0	48.2	48.2	47.8	268.9	3.2
	18:43:47	168.5								490.0	5.10	4.1	50.4	337	154.0	46.8	46.1	45.0	268.9	3.2
	18:43:48	168.0								481.0	4.90	4.3	48.9	327	154.0	44.6	43.9	43.2	268.9	2.8
	18:43:49	166.0	-1.0	3.0	0.01	0.17	below light	-0.2	-4.7	466.0	4.90	3.9	45.8	326	154.0	43.2	43.2	42.9	268.9	2.8
	18:43:50	166.5								455.0	5.10	4.3	47.0	326	152.0	42.9	43.6	43.6	268.9	3.2
	18:43:51	166.5								438.0	5.10	3.3	44.4	324	152.0	44.3	46.1	46.1	268.2	3.2
	18:43:52	164.5								427.0	6.20	4.6	40.4	323	152.0	47.1	47.5	46.8	266.5	3.9
	18:43:53	166.0	-0.5	3.0	0.00	0.09	below light	-2.3	-3.6	413.0	6.20	2.0	43.4	323	152.0	47.5	47.5	47.5	263.7	4.6
	18:43:54	164.0								404.0	8.10	-0.4	46.0	326	152.0	48.2	47.8	47.5	261.6	4.2
	18:43:55	164.5								391.0	8.10	4.1	34.5	320	152.0	48.2	48.5	47.8	261.9	3.9
	18:43:56	167.5	1.5	3.0	0.01	0.26	below light	1.3	-4.0	381.0	7.00	3.3	39.4	316	152.0	48.5	48.2	47.1	261.6	3.5
	18:43:57	165.5								370.0	7.00	6.0	41.7	318	152.0	47.5	46.8	45.7	261.9	3.2
	18:43:58	161.5								361.0	6.20	6.0	39.0	325	154.0	46.1	45.7	45.0	261.9	3.5
	18:43:59	164.0								347.0	6.20	4.1	43.2	328	154.0	45.7	46.4	46.8	262.3	3.5
	18:44:00	162.5								338.0	6.90	2.4	42.4	329	154.0	48.2	48.5	48.9	263.0	3.9
	18:44:01	169.0	7.5	3.0	0.04	1.29	below light	-2.0	7.2	325.0	6.90	4.0	46.2	323	154.0	49.9	49.9	48.5	263.7	3.2
	18:44:02	168.5								316.0	3.70	8.1	42.1	318	154.0	48.9	48.2	46.4	264.4	1.4
	18:44:03	167.5								300.0	3.70	4.2	46.2	323	154.0	46.1	45.0	43.9	264.4	1.4
a	18:44:04	166.5								282.0	5.60	1.9	47.9	326	154.0	45.0	45.0	42.9	264.7	2.1
	18:44:05	166.0								263.0	5.60	0.4	43.3	321	152.0	43.9	43.6	42.5	265.8	2.5
	18:44:06	157.0	-11.5	4.0	0.07	1.38	moderate	-8.7	-2.4	245.0	7.20	-0.5	39.7	332	152.0	43.9	43.9	44.6	266.8	3.2
b	18:44:07	161.5								225.0	7.20	2.1	37.3	321	150.0	47.1	48.9	50.3	267.2	2.8
	18:44:08	161.5								206.0	6.20	3.0	36.8	31?	150.0	52.7	54.5	54.8	266.1	2.5
	18:44:09	157.5	-10.0	6.0	0.06	0.86	light	-3.2	-10.4	186.0	6.20	1.0	35.7	325	150.0	56.2	55.2	54.1	265.1	3.2
	18:44:10	159.5								150.0	9.00	-4.8	27.7	315	152.0	55.5	56.2	58.0	265.1	5.3
	18:44:11	163.5								131.0	9.00	1.5	26.6	308	154.0	61.2	61.9	59.1	265.4	5.6
c	18:44:12	171.0								129.0	5.10	2.7	33.3	30?	156.0	58.7	55.5	52.7	264.0	3.5
	18:44:13	175.0	17.5	4.0	0.10	2.25	strong	6.3	0.7	117.0	5.10	7.2	36.4	302	158.0	52.7	50.6	49.6	262.3	2.1
	18:44:14	170.0								104.0	6.30	1.0	31.6	308	158.0	50.6	49.6	48.5	261.6	2.8
	18:44:15	166.5								83.0	6.30	4.8	24.5	307	160.0	49.6	47.1	43.2	260.9	2.8
d	18:44:16	167.5								73.0	6.50	1.7	29.1	315	160.0	43.2	40.1	37.6	259.1	2.1
IDLE	18:44:17	165.0	-10.0	4.0	0.06	1.29	moderate	-1.9	-14.6	59.0	6.50	5.3	21.9	317	160.0	38.7	38.7	37.3	258.4	2.5
	18:44:18	172.0								45.0	7.00	0.8	20.4	272	160.0	39.4	38.0	37.3	257.0	3.5
	18:44:19	164.5								32	7.00	0.5	17.8	301	160.0	38.0	38.3	37.3	254.9	3.9
e	18:44:20	166								21	7.90	-0.2	18.5	298	158.0	39.4	38.3	37.3	252.8	3.2
	18:44:21	153								7	7.90	4.1	20.9	342	156.0	38.3	37.6	37.3	251.4	3.5
	18:44:22	151.5	-20.5	4.0	0.14	2.64	severe	5.3	0.5	-1	0.00	6.0	20.9	344	154.0	38.3	37.6	26.0	252.1	5.6

Table 3.Wind Shear Intensity in a,b,c,d,e zone at different altitude.

Based on table 3 data for calculating wind shear intensity, the result showed CI642 encountered a strong to severe wind shear below 200 feet. The intensity of wind shear varied with radio altitude is plotted in figure 3.

(1) a zone: 300 ft~ 245ft: Light to **moderate** wind shear [25 ~ 19sec. Prior to touch down]

(2) b zone: 245 ft~ 186ft: **Moderate** to Light wind shear [19 ~ 13sec. Prior to touch down]

(3) c zone: 186 ft~ 117 ft: Light to **Strong** wind shear [13 ~ 9sec. Prior to touch down]

(4) d zone :117 ft~ 59 ft: **Strong** to Moderate wind shear [9 ~ 6sec. Prior to touch down]

(5) e zone: 45 ft ~ -1 ft: Moderate to **Severe** wind shear [6 ~ 1sec. Prior to touch down]

(D) Summarized Comments of ASC's Analysis

1. During the final landing phase, the aircraft encountered unsteady airflow as downwash that was exacerbated to have a high descent rate at the 6 seconds and 2 seconds before touch down.
2. At the time of the six seconds and the two seconds before touchdown, the elevator position indicated increasing from+2 to +11degrees and +5.1 deg to +15.7 deg max respectively. ASC believes that the commander was working on the recovery to the high descent rate and provided large control column input. The pilots responded and recovered the first downdraft to have less descent rate. It took three seconds to recover the first downdraft.
3. The second downdraft happened at two seconds before touch down. The pilot did make his effort by pulling the column back and the elevators were moving up to a higher degree but no enough time for the pilot to recover.
4. The ASC believes that AOA is a significant parameter to the analysis in this accident. Angle of Attack in conjunction with normal acceleration and elevator deflection are of vital importance to differentiate between external forces acting on the aircraft and pilot-generated responses, was mentioned only in factual (paragraph 1.11.6.): "...fluctuated with increasing divergence between 3° and 8°..."and was not mentioned in the "Analysis" (Section 2. of Reference A).
5. Appendix A5-3-2 in Reference A shows a variation in TDZ wind direction of between 314° and 326° with speeds from 39kt to 43kt (Runway 25R) in comparison to a variation in TDZ wind direction of between 283° and 339° at 14kt to 28kt （Runway 25L） in the lee of the Passenger Terminal Building. This kind of wind change will affect the landing to a great extent.

Comments on Section 3, Conclusions

Cause Factors

Reference A, Section 3.2. Causal factor 3.2.1.

ASC issues and Discussion

According to the FDR data and ASC's analysis, the elevator was changed by the pilot's effort during final seconds of landing while the aircraft was encountering a downdraft and pouring rain on Runway 25L.It is in contrast with the statement that the pilot did not arrest the high sinking rate during landing.

ASC proposed changes

Change Causal Factor 3.2.1 to reflect the derivation from analysis of the data (Part 3, above), as follows:

3.2.1 **During the final two seconds before touchdown the aircraft encountered atmospheric conditions, which caused an increasing rate of descent, culminating in touchdown at a rate in excess of 18 fps.The existence of a downdraft condition at a point where landing aircraft normally flare for runway 25L was involved in this accident.**

Contributing factors to the downdraft condition were:

3.2.1.1 Rapidly changing strong wind and downdraft conditions resulting from an approaching tropical storm.

3.2.1.2 Large differences in wind velocity and direction between the approach path to runway 25L and that of runway 25R at Chep Lap Kok Airport, Hong Kong. (See Ref A appendix 5.3)

Reference A, Section 3.2. Causal factor 3.2.2.

ASC issues and Discussion

This Causal factor should be deleted in its entirety, for the following reasons:

(1) The FDR data show that the pilot flew the aircraft after passing the altitude of $21ft_{RA}$ fully configured for landing, on centerline, corrected for cross-wind and with a kinetic energy margin in excess of 15% for that gross weight and configuration. Additionally, the aircraft descent rate at that point (less than 2 seconds from touchdown) was less than that for a nominal 3° glide path (see Figure 4). Given the aircrafts excess energy at that time, the thrust was (and should have been) automatically retarding to idle, as designed by the manufacturer.

(2) The training manual contains no instructions or procedure for arresting rate of descent by adding thrust.

ASC proposed changes

Change Causal Factor 3.2.2 to reflect the derivation from analysis of the data (Part 3, above), as follows:

3.2.2.1 **Reduced visibility in heavy rain and dusk conditions which prevented visual detection of the increasing rate of descent until less than 1 second before touchdown, due to obscured peripheral vision and partially obscured forward vision in heavy rain.**

Reference A, Section 3.2. Causal factor 3.2.3.

<u>ASC issues and Discussion</u>

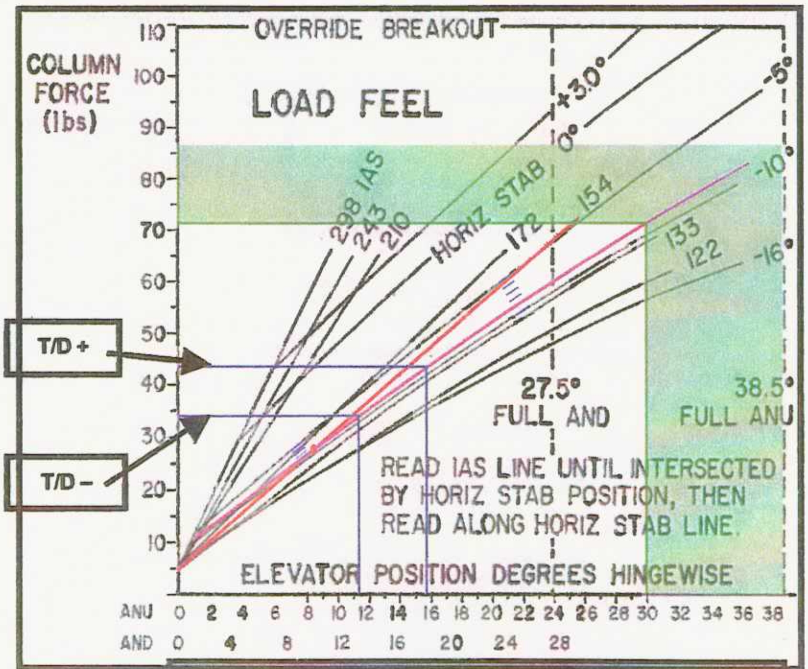
This conclusion is invalid and is included as cause factor 3.2.2.4, above; it may therefore be replaced.

<u>ASC proposed changes</u>

For completeness, in the interest of identifying all causes, which can pass the test of links of the accident chain, the following factors need to be included in the accident report.

3.2.3 The time critical location of the sudden onset of the severe downdraft, at a position and altitude less than two seconds prior to touchdown, which prevented pilot awareness of the phenomenon in sufficient time to effect corrective action prior to ground contact, was a contributing factor of the accident.

3.2.3.1 **Elevator control forces required achieving the large deflections necessary to arrest the descent rate in time, which were well in need of large input from the pilot (with one hand on the control wheel, See Figure.4 below).**



From CAL "MD-11 Lamm Schematics" McDonnell

Figure 4. MD-11 Elevator Load Feel force Gradient

3.2.4 Structural failure of the right main landing gear in such a fashion that fracture of the wing main spar rear web occurred, resulting in separation of the right wing followed by inversion of the fuselage was an important factor to this accident.

Contributing causes to the structural failure were:

3.2.4.1 Crosswind conditions that required asymmetric touch down.

3.2.4.2 Touch down sink rate in excess of design limit loads.

Design limit loads (12fps) such that a normal approach at maximum landing weight involves descent rates 40 to 50% in excess of limit loads. (13.9 to 15.2fps).

3.2.4.3 The absence of an energy absorbing landing gear structure which would dissipate excessive touch down loads without compromising the integrity of the wing main spar

Findings

General

Some of the Findings of Reference A exhibit in the absence of detailed analysis of the data of Flight Recorder.

Specific

Reference A, Section 3.1. Finding 3.1.16.

ASC issues and Discussion

It is normal for an aircraft to land at gross weights up to and including its published maximum landing weight, and since normal landing procedures require the choice of an approach speed (with additives as required for environmental conditions) predicated on landing weight, in no event can a loss of airspeed be attributed to the gross weight.

ASC proposed changes

Delete Finding 3.1.16.

Reference A, Section 3.1. Missing/Deleted Finding

ASC issues and Discussion

Finding 3.1.28, of the Reference D (Initial Draft Report dated June 2001):

> **3.1.28** During the final two seconds before touchdown the aircraft encountered atmospheric conditions, which caused an increasing rate of descent, culminating in touchdown at a rate in excess of 18fps.

was omitted from Reference A. **Since analysis of the data shows that this Finding accurately describes the primary causal factor of this accident, it should be included again.**

ASC proposed changes

Re-instate the Finding contained in paragraph 3.1.28 of Reference D (the Initial Draft report) into the final report.

Part 5

Comments on Section 4, Safety Recommendations

ASC considers Safety Recommendations **4.9** and **4.10** of **Reference A** to be of merit, and would like to add the following safety recommendations:

To Hong Kong International Airport

1. Enhance the capability of the WTWS system to enable detection of both vertical and horizontal components of wind shear on approach.

2. Enhance its emergency response planning in accordance with ICAO Document 9137 Part 7 Section 1.2 to provide a timely emergency shelter capability for survivors of an accident. (Reference A, Finding 3.1.28)