

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 (°) / 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 300° 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 230° 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 320° 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 4°), 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 October 1992

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 (V_{ref}) 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 V_{ref} ; 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. $V_{ref} + 5$ 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 $V_{ref} + 5$ kt and touches down at V_{ref} . 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 30°. 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 5°, and the stabiliser is then automatically adjusted to relieve sustained elevator deflection and maintain a full 5° of elevator authority. LSAS also limits pitch attitude to less than 10° of aircraft nose down (AND) or 30° 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 5°.

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 320°/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 310°/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 320°/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: 340°/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 310°/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 25° Celsius; dew point 24° Celsius; QNH 987 hPa; QFE 986 hPa; turbulence warning: moderate to severe turbulence in vicinity of cumulonimbus on approach and departure.

TEMPO: wind 330°/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 10° in wind direction (directions rounded to nearest 10°) 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 2.5° 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 °.

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 2° 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 62° at a rate of some 3° 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 9° and in pitch to 5° ANU. This stabilised the aircraft at one dot low on the glide slope and re-established the rate of descent associated with a normal 3° 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 38° 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 2° ANU and the angle of attack reduced to a mean of 4°.

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 3° and 8°, 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 12° up, then rapidly reversed to 8.5° down, and maintained at a negative angle of around 5° until approaching 21 ft RA; during this period, the pitch angle increased from around 3° ANU to just over 4° then returned to about 3.5° 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 15.7° up just before touchdown, the pitch angle simultaneously reached 4.9° 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 3° to 4° 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-qualified 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 Fuselage 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 (1st 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 3.5-4° right-wing-down and the pitch attitude was estimated to be 4.5° 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 ° 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 (15-20°) 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 10° 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 autolandings, 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 26° ANU to 18° 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 9.5° 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 12° at about 45 ft RA, immediately followed by a reversal to 8.5° down, which only succeeded in achieving a momentary increase in pitch attitude from about 3.5° ANU to 4.2°, then returning to 3.2°. As the aircraft passed 21 ft RA, up elevator was again applied, reaching almost 16° immediately before touchdown. While this did increase the pitch attitude to 4.5° 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 anemometers 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.

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