National Transportation Safety Committee

Aircraft Accident Report

SILKAIR FLIGHT MI 185

BOEING B737-300

9V-TRF

MUSI RIVER, PALEMBANG, INDONESIA

19 DECEMBER 1997

Jakarta, 14 December 2000

Department of Communications
Republic of Indonesia

Investigation of Aircraft Accident
SilkAir Flight MI 185
Boeing B737-300, 9V-TRF
Musi River, Palembang, Indonesia
19 December 1997

FINAL REPORT

Note:

- All times indicated in this report are based on FDR UTC time. Local time is UTC + 7 hours.

Abstract

This report is on the accident involving the SilkAir flight MI 185, a Boeing B737-300, which crashed into the Musi river near Palembang, South Sumatra, Indonesia, on 19 December 1997, at about 16:13 local time (09:13 UTC).

SilkAir flight MI 185 was operating as a scheduled passenger flight from Jakarta Soekarno-Hatta International Airport to Singapore Changi Airport.

The flight departed about 15:37 local time with 97 passengers, five cabin crew and two cockpit crew.

The airplane descended from its cruising altitude of 35,000 feet and impacted the Musi river, near the village of Sunsang, about 30 nautical miles north-north-east of Palembang in South Sumatra.

Visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules flight plan.

Prior to the sudden descent from 35,000 feet, the flight data recorders stopped recording at different times. There were no mayday calls transmitted from the airplane prior or during the descent.

All 104 persons on board did not survive the accident, and the airplane was completely destroyed by impact forces. Except parts of the empennage that found on land, most of the wreckage was found buried in the bottom of the Musi river.

About 73 percent by weight of wreckage was recovered, although due to the magnitude of destruction of the airplane, the small mangled pieces precluded finding clues, evidence or proof as to what have happened, how and why.

The safety issues in this report focused on the areas of flight operations, the flight data recorders, the human factors and control systems malfunctions.

The investigation yielded very limited data and information to make conclusions possible.

The report is pursuant to the technical investigation conducted by the National Transportation Safety Committee (NTSC) of Indonesia.

The investigation was conducted in accordance with the standards and recommended practices of Annex 13 to the Convention on International Civil Aviation. In accordance with Annex 13, the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

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Abbreviation

AAIB	Air Accidents Investigation Branch
AAIC	Aircraft Accident Investigation Commission
AC	Advisory Circular
AD	Airworthiness Directive
AFM	Airplane Flight Manual
AFS	Auto-Flight System
agl	above ground level
APU	Auxiliary Power Unit
ASB	Alert Service Bulletin
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATP	Airline Transport Pilot
ATPL	Airline Transport Pilot License
ATS	Air Traffic Services
BASI	Bureau of Aviation Safety Investigation
BEA	Bureau Enquétes Accidents
CAAS	Civil Aviation Authority of Singapore
CAM	Cockpit Area Microphone
CB	Circuit Breaker
CG	Center of Gravity
CPL	Commercial Pilot License
CRM	Crew Resource Management
CRT	Cathode Ray Tube
CVR	Cockpit Voice Recorder
DFDAU	Digital Flight Data Acquisition Unit
DME	Distance Measuring Equipment
E&E bay	Electrical and Electronic compartment
EDP	Engine Driven Hydraulic Pump
Elex	Electronics
EQA	Equipment Quality Analysis
F	Fahrenheit
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FD	Flight Director
FDR	Flight Data Recorder
FIR	Flight Information Region
FL	Flight Level
FTIR	Fourier Transfer Infrared
F/O	First Officer
GE	General Electric
GPS	Global Positioning System

GPWS	Ground Proximity Warning System
Hg	Mercury
HPa	Hecto Pascal
HQ	Head Quarters
Hz	Hertz
ICT	Industrial Computed Tomography
IFR	Instrument Flight Rules
ILS	Instrument Landing Systems
IP	Instructor Pilot
IRS	Inertial Reference System
JKT	Jakarta
KCAS	Knots Calibrated Airspeed
KEAS	Knots Equivalent Airspeed
Kg	Kilogram
KIAS	Knots Indicated Airspeed
kV	Kilo Volt
L	Left
LIP	Line Instructor Pilot
LOFT	Line Oriented Flight Training
MAC	Mean Aerodynamic Chord
MCIT	Ministry of Communication and Information Technology
M-CAB	Multipurpose Cab (simulator)
MEC	Main Engine Control
MHz	Mega Hertz
MM	Maintenance Manual
MSL	Mean sea level
N1	Engine Fan Speed
N2	Engine Compressor Speed
NG	Next generation
nm	Nautical mile
NNW	north-north-west
NTSB	National Transportation Safety Board
NTSC	National Transportation Safety Committee
PA	Public address
PATS	Play-back and Test System
PCU	Power Control Unit
PF	Pilot flying
PIC	Pilot in Command
PLB	Palembang
P/N	Part number
PNF	Pilot non flying
Psi	Pounds per square inch

PWC	PricewaterhouseCoopers
QAR	Quick access recorder
R	Right
RA	Radio altitude
RAPS	Replay and Presentation System
RSAF	Republic of Singapore Air Force
SB	Service bulletin
SEM	Scanning electron microscope
SIA	Singapore International Airlines
SIAEC	Singapore Airlines Engineering Company
SIN	Singapore
SL	Service letter
S/N	Serial number
SRM	Structure Repair Manual
SSCVR	Solid State Cockpit Voice Recorder
SSR	Secondary Surveillance Radar
TCAS	Traffic Collision Avoidance System
TOGA	Take-off / go-around
T/R	Thrust reverser
UFDR	Universal Flight Data Recorder
ULB	Underwater Locator Beacon
USA	United States of America
UTC	Universal Time Coordinated
Vd	Descent speed
VFR	Visual flight rules
VHF	Very High Frequency
VOR	Very high frequency Omni directional Range
VSV	Variable Stator Vane
XRD	X-ray diffraction

Glossary of Terms

Actuator	A device that transforms fluid pressure into mechanical fore
Aileron	An aerodynamic control surface that is attached to the rear, or trailing edges of each wing. When commanded, the ailerons rotate up or down in opposite directions
Auto-flight system	A system, consisting of the auto-pilot flight director system and the auto-throttle, that provides control commands to the airplane's ailerons, flight spoilers, pitch trim, and elevators to reduce pilot workload and provide for smoother flight. The auto- flight system does not provide control commands to the airplane's rudder system
Bank	The attitude of an airplane when its wings are not laterally level
Blowdown limit	The maximum amount of rudder travel available for an airplane at a given flight condition / configuration. Rudder blowdown occurs when the aerodynamic forces acting on the rudder become equal to the hydraulic force available to move the rudder
Catastrophic failure condition	A failure condition that will prevent continued safe flight and landing
Command mode	A position on the two autopilot flight control computers, that, when engaged, allows the autopilot to control the airplane according to the mode selected via the Mode Selector switches, which include Altitude hold, Vertical Speed, Level Change, Vertical Navigation, VOR Localizer, Lateral Navigation and Heading Select
Computer simulation	The NTSB computer workstation-based flight simulation software used flight controls, aerodynamic characteristics, and engine models (developed by Boeing) to derive force and moment time histories of the airplanes, which can be converted into airplane motion
Control wheel steering mode	A position on the two autopilot flight control computers that, when engaged, allows the autopilot to maneuver the airplane through the autofilight system in response to control pressure, similar that required for manual flight, applied by either pilot. The use of control wheel steering does not disengage the autopilot.
Cross-coupled	The ability of the aerodynamic motion about an airplane's control axes to constantly interact and affect each other in flight.
Crossover speed	The speed below which the maximum roll control (full roll authority provided by control wheel input) can no longer counter the yaw / roll effects of a rudder deflected to its blowdown limit.
Directional control	The function that is normally performed by the rudder by pilot input or yaw damper input (also known as yaw control)
E&E bay	An airplane compartment that contains electrical and electronic components.
Elevator	An aerodynamic control surface to the back of the horizontal stabilizer that moves the airplane's nose up and down to cause the airplane to climb or descend.
Empennage	The tail section of an airplane, including stabilizing and flight control surfaces
Flap	An extendable aerodynamic surface usually located at the trailing

	edge of an airplane wing.
G	A unit of measurement. One G is equivalent to the acceleration caused by the earth's gravity (32.174 feet/sec^2)
Galling	A condition in which microscopic projections or asperities bond at the sliding interface under very high local pressure. Subsequently, the sliding forces fracture the bonds, tearing metal from one surface and transferring it to the other.
Heading	The direction (expressed in degrees between 001 and 360) in which the longitudinal axis of an airplane is point, in relation to north
Hinge moment	The tendency of a force to produce movement about a hinge. Specifically the tendency of the aerodynamic forces acting on a control surface
Hydraulic fluid	Liquid used to transmit and distribute forces to various airplane components that are being actuated.
Hydraulic pressure limiter	A device incorporated in the design of the main rudder PCU on 737 next generation (NG) series airplanes to reduce the amount of rudder deflection when active. It is commanded to limit hydraulic system A pressure (using a bypass valve) as the airspeed is increased to greater than 137 knots, and it is reset as the airspeed is decreased to less than 139 knots.
Hydraulic pressure reducer	A modification on 737-100 through -500 series airplanes to reduce the amount of rudder authority available during those phases of flight when large rudder deflections are not required. The pressure reducer, added to hydraulic system A near the rudder PCU, will lower the hydraulic pressure from 3,000 to 1,000 pounds psi on 737-300, -400, and -500 series airplanes or to 1,400 psi on 737-100, and -200 series airplanes.
Hydraulic system A	For 737-300, -400, and -500 series airplanes: A system that includes an engine-drive hydraulic pump and an electrically powered pump that provides power for the ailerons, rudder, elevators, landing gear, normal nosewheel steering, alternate brakes, inboard flight spoilers, left engine thrust reverser, ground spoilers, the system A autopilot, and the autoslats through the power transfer unit
Hydraulic system B	For 737-300, -400, and -500 series airplanes: A system that includes an engine-drive hydraulic pump and an electrically powered pump that provides power for the ailerons, rudder, elevators, trailing edge flaps, leading edge flaps and slats, autoslats, normal brakes, outboard flight spoilers, right thrust reverse, yaw damper, the system B autopilot, autobrakes, landing gear transfer unit, and alternate nose-wheel steering (if installed).
Input shaft of the 737 main rudder PCU	When rudder motion is commanded, this device moves the primary and secondary dual-concentric servo valve slides by way of the primary and secondary internal summing levers to connect hydraulic pressure and return circuits from hydraulic systems A and B so that hydraulic pressure is ported to the appropriate slides of the dual tandem actuator piston to extend or retract the main rudder PCU piston rod
Interpolation	The determination, or approximation of unknown values based on known values

Kinematics	A process involving fitting curves through available FDR data (such as heading, pitch and roll), obtaining flight control time history rates from these curves, and obtaining accelerations from these accelerations using Newton's laws.
Knot	A velocity of one nautical mile per hour.
M-CAB	A Boeing multi-cabin flight simulator that can be modified to simulate a variety of aircraft models and scenarios. It is an engineering simulator that is capable of simulating events that are outside of normal flight regimes, but it is not used for flight training.
NG	Boeing's next generation 737 series, designated as the 737-600, -700, -800, and -900 models
Overtravel	The ability of a device to move beyond its normal operating position or range.
Pitch control	The function that is performed by the elevator by moving the control column forward or aft, which raises or lowers the nose of the airplane
Power control unit (PCU)	A hydraulically powered device that moves a control surface, such as a rudder, elevator, and aileron
Roll	Rotation of an airplane about its longitudinal axis
Roll control	The function that is performed by the ailerons and flight spoilers by moving the control wheel to the right or the left.
Rudder	An aerodynamic vertical control surface that is used to make the airplane yaw, or rotate, about its vertical axis
Reverse rudder response	A rudder surface movement that is opposite to the one commanded
Rudder hardover	The sustained deflection of a rudder at its full (blowdown) travel position
Rudder trim	A system that allows pilots to command a steady rudder input without maintaining foot pressure on the rudder pedals. It can be used to compensate for the large yawing moments generated by asymmetric thrust in an engine-out situation
Sideload	The effect of lateral acceleration, typical the result of sideslip or yaw acceleration
Sideslip	The lateral angle between the longitudinal axis of the airplane and the direction of motion (flight path or relative wind). It is normally produced by rudder forces, yawing motion resulting from asymmetrical thrust, or lateral gusts
Slat	An aerodynamic surface located on an airplane wing's leading edge that may be extended to provide additional lift
Spoiler	A device located on an airplane wing's upper surface that may be activated to provide increased drag and decreased lift
Yaw	Rotation of an airplane about its vertical axis
Yaw control	The function that is normally performed by the rudder by pilot input or yaw damper input, also known as directional control
Yaw damper (in the 737 main rudder PCU)	A system composed of the yaw damper control switch and a yaw damper coupler, that automatically corrects for yaw motion.

1 FACTUAL INFORMATION

1.1 History of Flight

Synopsis

On 19 December 1997, a SilkAir Boeing B737-300 aircraft, registration 9V-TRF, was on a scheduled commercial international passenger flight under Instrument Flight Rules (IFR), routing Singapore – Jakarta – Singapore.

The flight from Singapore to Jakarta operated normally. After completing a normal turn-around in Jakarta the aircraft departed Soekarno-Hatta International Airport for the return leg.

At 08:37:13 (15:37:13 local time) the flight (MI 185) took off from Runway 25R with the Captain as the handling pilot. The flight received clearance to climb to 35,000 feet (Flight Level 350) and to head directly to Palembang[1]. At 08:47:23 the aircraft passed FL245. Ten seconds later, the crew requested permission to proceed directly to PARDI[2]. The air traffic controller instructed MI 185 to standby, to continue flying directly to Palembang and to report when reaching FL350. At 08:53:17, MI 185 reported reaching FL350. Subsequently, the controller cleared MI 185 to proceed directly to PARDI and to report when abeam Palembang.

At 09:05:15.6, the cockpit voice recorder (CVR) ceased recording. According to the Jakarta ATC transcript, at 09:10:18 the controller informed MI 185 that it was abeam Palembang. The controller instructed the aircraft to maintain FL350 and to contact Singapore Control when at PARDI. The crew acknowledged this call at 09:10:26. There were no further voice transmissions from MI 185. The last readable data from the flight data recorder (FDR) was at 09:11:27.4. Jakarta ATC radar recording showed that MI 185 was still at FL350 at 09:12:09. The next radar return, eight seconds later, indicated that MI 185 was 400 feet below FL350 and a rapid descent followed. The last recorded radar data at 09:12:41 showed the aircraft at FL195. The empennage of the aircraft subsequently broke up in flight and the aircraft crashed into the Musi river delta, about 50 kilometres (30 nautical miles) north-north-east of Palembang at about 09:13. The accident occurred in daylight and in good weather conditions.

The route map and the crash site are depicted in Figure 1. The sequence of events is shown schematically in Figure 2.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	7	97	0
Serious	0	0	0
Minor/None	0	0	0
Total	7	97	0

[1] Coordinates (02.52.7S, 104.39.2E)
[2] Air Traffic Control reporting point (00.34.0S, 104.13.0E) north of Palembang in the Jakarta FIR near the boundary with the Singapore FIR. At PARDI, flights are transferred over to Singapore ATC

Very few human remains were recovered from the crash site and only six positive identifications were able to be made.

1.3 Damage to Aircraft

The aircraft was completely destroyed and severely fragmented on impact with the Musi river. The wreckage had penetrated deep into the river bottom. The destruction was such that mainly small mangled parts were recovered from the river. Parts of the rudder skin and the outboard sections of the horizontal stabilizer were recovered on land, the furthest was about four kilometres from the main impact site.

1.4 Other Damage

There was no damage to any other property.

1.5 Personnel Information

1.5.1 Pilot-In-Command (PIC)

Sex	Male
Age	41 years
Date of joining SilkAir	1 March 1992
Licence country of issue	Singapore
Licence type	ATPL (Airline Transport Pilot Licence)
Licence number	501923
Validity period of licence	1 November 1997 to 30 April 1998
Ratings	Boeing B737; Airbus A310 (not current)
Medical certificate	First class – issued 10 October 1997
Aeronautical experience	7173.3 hours
Experience on type	3614.7 hours
Last 24 hours	1.6 hours
Last 7 days	20.1 hours
Last 28 days	56.8 hours
Last 90 days	216.7 hours
Last line check	25 January 1997
Last proficiency check	7 August 1997
Instrument rating check	7 August 1997

1.5.2 First Officer (F/O)

Sex	Male
Age	23 years
Date of joining SilkAir	16 September 1996
Licence country of issue	Singapore
Licence type	CPL (Commercial Pilot Licence)
Licence number	503669
Validity period of licence	1 July 1997 to 30 June 1998

Ratings	Boeing B737
Medical certificate	First class – Issued 4 June 1997
Aeronautical experience	2501.7 hours
Experience on type	2311.8 hours
Last 24 hours	1.6 hours
Last 7 days	21.4 hours
Last 28 days	69.8 hours
Last 90 days	217.6 hours
Last line check	10 October 1997
Last proficiency check	15 September 1997
Instrument rating check	15 September 1997

1.6 Aircraft Information

1.6.1 Aircraft Data

Manufacturer:	Boeing Aircraft Company
Model:	B737-300 (see Figure 3)
Serial Number:	28556
Registration:	9V-TRF
Country of manufacture:	United States of America
Date of manufacture:	14 February 1997
Certificate of airworthiness:	AWC 433
Issued:	14 February 1997 (one year validity)
Certificate of registration:	S 153
Issued:	14 February 1997
Total airframe hours:	2238.6 hours
Engines:	2 x CFM 56-3B2 (CFM International)
Engine type:	Turbofan
Engine No1:	Serial Number: 858-480
Total engine hours:	2238
Total engine cycles:	1306
Engine No2:	Serial Number: 858-481
Total engine hours:	2238
Total engine cycles:	1306
Last Major Inspection:	Equalised Check #3 on 9-11 December 1997
Last Inspection:	9-11 December 1997
Hours since last inspection:	67 hours
Cycles since last inspection:	43 cycles
Total airframe cycles:	1306 cycles

1.6.2 Aircraft History

The aircraft was new when it was registered in the Republic of Singapore as 9V-TRF. Its Certificate of Registration was issued on 14 February 1997. At the time of the accident, the aircraft was operated by SilkAir Pte Ltd. It had completed all of its flight time with SilkAir.

1.6.3 Weight and Balance

	Maximum	Actual
Take-off weight:	61,234 kg	51,856 kg
Zero fuel weight:	47,627 kg	45,056 kg
Fuel at take-off:	--	6,800 kg
Dry Operating Weight:	--	34,192 kg
Take-off CG position:	8 – 27 %MAC	18.1 %MAC
Cargo on board:	5,710 kg	3,654 kg
Total number of persons:	--	104
Number of passengers:	--	97
Number of crew:	--	7

1.7 Meteorological Information

1.7.1 General Weather Condition over South Sumatra

Data gathered from the weather satellite imagery at 09:00 on 19 December 1997 and ground observation showed that South Sumatra was partly covered in some areas with cumulus, altocumulus and cirrus clouds, except over the northern part of South Sumatra (Singkep Island) which was covered with cumulonimbus clouds associated with thunderstorms.

1.7.2 Weather Report over Palembang and Its Surroundings

Weather observations received from weather stations around the area of the accident were as follows:

Station	Type of cloud	Weather	Temp/Dew point
Palembang	CuSc/Ac/Ci	Nil	30 / 25
Pangkal Pinang	CuSc/AcAs/Ci	Nil	29 / 25
Rengat	Cu/As/Ci	Nil	32 / 23
Dabo Singkep	Cb/Cu/As/Cs	Thunderstorm	26 / 25
Jambi	Cu/Ac/Ci	Nil	32 / 29

1.7.3 Information on Wind Directions and Strength

The reported wind directions and strength at 09:00 over South Sumatra were as follows:

Level	Direction	Speed
700 hPa (10,000 feet)	North-westerly	15 knots
500 hPa (19,000 feet)	North-easterly	10 knots
400 hPa (25,000 feet)	South-easterly	5 knots
300 hPa (31,000 feet)	South-easterly	10-15 knots
250 hPa (35,000 feet)	Easterly	15-20 knots

1.7.4 Weather En-route

Weather observed and reported from other aircraft:

- The PIC of Sempati 134 from Jakarta to Batam flying at FL310 (approximately two minutes ahead of MI 185) reported that due to weather conditions en-route he requested to fly direct PARDI.
- The PIC of Qantas 41 from Jakarta to Singapore flying at FL410, (approximately eight minutes behind MI 185) reported that the weather was good except for two or three isolated thunderstorms about ten miles to the east of track near Palembang. He also reported that no turbulence was encountered during his flight except for the last five thousand feet of the descent into Singapore.

1.8 Aids to Navigation

Navigational aids for en-route, approach and landing (VOR/DME, NDB and ILS) covering the route of flight from Jakarta to Singapore were operating normally at the time of the accident. The aircraft was tracking from a point near Jakarta directly to Palembang, then to PARDI. At PARDI, flights are transferred over to Singapore ATC

The data from the Palembang radar were transmitted to Jakarta for en route air traffic control by Jakarta ATC. These radar data were then recorded in the Jakarta ATC facility, [Reference 1].

1.9 Communications

Up to 09:10:26, the aircraft was communicating normally with Jakarta Control on frequency 132.70 MHz. There was no distress call received from the crew or distress signal received from the aircraft transponder. No emergency locator beacon transmissions were detected near the crash site. A transcript of the communications between the aircraft and ATC is given in Appendix C.

1.10 Aerodrome Information

The Soekarno-Hatta International Airport is located about 20 kilometres west of Jakarta (the crash site is approximately 420 kilometres north-north-west from the Jakarta airport). The airport has two concrete parallel runways, 07R/25L (3,360 metres) and 07L/25R (3,600 metres), with elevation between six and nine metres.

On the day of the accident both runways were checked and found in normal condition. The MI 185 flight took off from runway 25R using standard instrument departure Cengkareng 2 Golf.

Security checks of passengers, baggage and cargo were conducted in accordance with the standard procedures, [Reference 1].

1.11 Flight Recorders

1.11.1 FDR

The aircraft was equipped with a Sunstrand Data Corporation Universal Flight Data Recorder. The aircraft was fitted with a Teledyne common box Digital Flight Data Acquisition Unit (DFDAU). The DFDAU formats 296 parameters into a 64 words per second serial data stream, which is routed to the FDR.

The FDR module was recovered by divers on 24 December 1997. The FDR's underwater locator beacon (ULB) was found detached from the FDR at the accident site. Two of the enclosure's four retaining bolts were broken. The enclosure was partially opened (Figure 4.a). The partial opening exposed the tape between the two tape reels, near the write and erase heads, see Figure 4.b and c.

The FDR module was first cleaned and then packed in a container filled with clean water (to prevent the tape medium from drying out and becoming brittle). It was hand-carried to the United States National Transportation Safety Board (NTSB) HQ read-out facilities in Washington DC, USA[3]. The readout was accomplished by a play back hardware using a Replay and Presentation System software (RAPS) developed by the Canadian Transportation Safety Board, [Reference 2].

The data on the FDR tape was able to be read except from the short length of the exposed tape mentioned above. By examining the physical position of the tape as it was found when the casing was opened, it was determined that approximately 8 cm (3.15 inches) of the exposed tape contained data of the accident flight. The data (about 6.3 seconds) were not recovered because of damage to the exposed part of the tape.

The last recorded data that could be recovered was recorded at 09:11:27.4 (3,148.4 FDR Sub-frame Reference Time). At this time, the aircraft was in a flight configuration consistent with cruise flight at FL350. Based on the last recoverable data and the length of the damage tape, it is estimated that the FDR could have been stopped recording at 09:11:33.7.

1.11.2 FDR Data Recovery

The FDR tape was re-examined at the FDR manufacturer's facility in Redmond, Washington, USA on 22 January 1998. Examination at the manufacturer revealed that in several areas of the tape the magnetic oxide had separated from the Mylar backing.

Further attempts to retrieve information from the damaged portion were made by Quantegy, the tape manufacturer in Alabama, USA (March 1998), Digital Instruments (August 1998), the BEA - Bureau Enquétes-Accidents (December 1998) in Paris, France and again by Quantegy (March 1999). The method applied at BEA utilized a Garnet Microscope, while the test method used at the last attempt at Quantegy was destructive to the tape. These efforts did not disclose any additional information, [Reference 3].

The relevant extracts from the FDR are contained in Appendix B.

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[3] This paragraph has been modified according to the suggestion in Appendix M

1.11.3 CVR

An AlliedSignal Aerospace Solid State Cockpit Voice Recorder (SSCVR) with a duration of two hours was installed in the aircraft. Two channels were recorded, one channel dedicated to the cockpit area microphone (CAM) and the other channel recorded a combination of three other audio sources (Captain, First Officer and Observer). The last thirty minutes of recording contained four discrete channels of the four audio sources.

The memory module was recovered, in a relatively good condition, from the river by the dredge on 8 January 1998. The CVR's underwater locator beacon (ULB) was found detached from the CVR at the accident site.

The memory module was hand carried (immersed in water) to the NTSB in Washington DC for read out and analysis (see Figure 5.a). The memory board (Figure 5.b) was downloaded and decompressed using AlliedSignal's Playback and Test Station (PATS) hardware and software. The resulting download produced an excellent quality 30 minute 4 channel recording and an excellent quality two hour, one minute and 11 seconds 2 channel recording. There were no transients or identifiable signatures associated with the end of recording. The recording included the ground operations and takeoff from Jakarta until the CVR stopped at 09:05:15.6, [Reference 4]. It was verified that all the available memory had been correctly downloaded and there were no missing memory blocks, hidden or corrupted data.

A transcript of the last portion of the CVR is given in Appendix A.

1.12 Wreckage and Impact Information

Intensive searches were carried out by air in an area stretching up to nine kilometres (five nautical miles) to the east of the crash site. Land searches were performed in an area stretching up to five kilometres to the east of the crash site. Most of the aircraft wreckage was found at the crash site, concentrated in an area approximately 60 metres by 80 metres in the Musi river, which is approximately 700 metres wide and about eight metres deep at that location, see Figure 6.

Recovery of the wreckage was extremely difficult due to the poor visibility in the water and the fact that a lot of the wreckage had settled and got buried in the mud at the bottom of the river. Moreover, there was also a strong tidal current flow. Wreckage recovery during the early phases of the recovery operation was done manually by divers from the Indonesian and Singapore navies. The divers had to search for the wreckage by touch and use ropes to bring it to the surface. After a two-week period, dredging was employed for the recovery operation. A clam shell dredge systematically scoured the river bed at the crash site down to a depth of five metres below the clay surface.

The wreckage was very fragmented. The debris was deposited on a barge for the clay to be washed away before being transported to a hangar at Palembang Airport, for cleaning and disinfections before sorting and identification.

At the end of the recovery operation, including ten days of dredging, about 73 % by weight of the aircraft structure and system/actuator components had been recovered.

Parts of the empennage were found on land. They comprised the outboard sections of the right hand and left hand horizontal stabilizers, sections of the elevators, elevator tabs, rudder upper balance weight and honeycomb skin pieces. These pieces were found generally in an easterly direction from the impact site. The wreckage distribution, as determined by a hand-held GPS (Global Positioning System) unit, is shown in Figure 7. The right hand elevator tip was found about four kilometres to the east of the crash site. This was the furthest location where the wreckage pieces were found. The left hand elevator tip was found about 200 metres from the east river bank (or 700 metres from the location of the wreckage). This was the nearest location to the crash site among the wreckage pieces found on land. Lighter panels (composite materials) from skin of rudder and elevators were also found on land. These were picked up by local residents and handed over to the police and search and rescue helicopter pilots. The exact locations where the lighter panels were originally found could not be determined.

The aircraft parts found in the river were highly fragmented and mangled on impact, see Figure 8. As a result, all parts of the aircraft were mixed together on recovery, making sorting and identification of the many small pieces difficult. Particular attention was paid to finding parts of the control surfaces, actuators, electronic and avionics systems, engines, Section 48 (rear fuselage including aft pressure bulkhead) and the empennage (see Figure 10). The cockpit instrumental panel and circuit breakers panel were not recovered. The wing flaps, spoilers, ailerons, and leading edge slats and their supporting tracks, carriages and actuation systems were also accounted for. Cabin items such as seat structures, cushions, oxygen generators, etc. were also recovered and examined. Parts and components recovered were contaminated, stained and showing accelerated corrosion. River water and mud samples were taken to determine their effect on the condition of the recovered parts and components. Following cleaning, the parts were marked with the date and method of recovery (by diver or dredge). Where possible, parts were identified, part numbers noted and components were laid out in groups by sub-assembly, for example, wings, landing gears, etc. Empennage parts were laid out on the hangar floor in their approximate respective positions. Reconstruction was limited due to the degree of destruction of the aircraft.

The recovered structure and components were put in boxes and crates (to protect them from further damage), and labeled for shipping and storage. The small miscellaneous pieces which remained after the sorting were also placed in boxes and labeled for storage. The total amount of wreckage recovered was about 73 % of the aircraft empty weight (Appendix D).

After completion of the recovery operation, on 26 January 1998 the boxes of wreckage were transported overland from Palembang to a hangar in Curug, near Jakarta, for storage and partial empennage reconstruction.

1.12.1 Aircraft Structures

The aircraft structure debris was examined for evidence of an in-flight fire or explosion. No such evidence was observed, [Reference 5].

1.12.1.1 Wings

A large portion of the wing structure, including parts of the flight control surfaces, were recovered from the crash site and were severely fragmented. The largest piece was a wing panel approximately two metres long. Portions of logo light housings on both wing tips and the wing root fittings were identified. Examination showed no evidence of pre-existing corrosion or fatigue on the parts recovered.

All actuators, except one of the Krueger flap actuators, and support fittings of the leading edge slat were recovered. The examination of the actuators indicates that the leading edge slats and Krueger flaps were in the retracted position at impact.

The actuators, fittings, and support structure for all of the flight spoilers and all but one of the ground spoilers were accounted for. Positions of the spoiler actuators and rods indicate that the surfaces were retracted.

The two aileron power control units (PCUs), aileron tab rods and several pieces of aileron hinge fittings were identified.

All of the trailing edge flap transmissions and ball screws were also identified. The position of the ball screw trunnions indicates that the flaps were retracted.

Large fragments of the left hand and right hand landing gear beams, attachment fittings to the wing rear spar and the landing gear actuators were recovered. The positions of the landing gear actuators indicate that the landing gears were all in retracted position at impact.

1.12.1.2 Fuselage

All the fuselage structure that was recovered was retrieved from the crash site in the river. The structure of the fuselage was severely fragmented and was difficult to identify. The pieces that easily identified were those pieces containing the SilkAir logo and lettering, and those pieces from areas around the door frames. Various other fuselage parts that were identified included parts of the doors and door operating mechanisms, pieces of floor beams, seat tracks, floor and interior panels. It was very difficult to identify the positions of these parts within the aircraft because of the severe fragmentation of the structure.

Not all of the passenger oxygen generators were recovered. Examination of the recovered oxygen generators revealed no evidence of activation.

A maintenance document showed that a fuselage patch repair was carried out on the aircraft on 28 April 1997. The repair was carried out by SIA Engineering Company in accordance with the Boeing 737 Structural Repair Manual 53-00-01, [References 6 and 7].

The patch repair was just above the floor level and forward of the left hand aft passenger door between station 867 and station 907 and between stringer 14L and stringer 17L. The entire patch was found intact and was still attached to the surrounding skin, see Figure 9.

Most of the aft pressure bulkhead ring chord (about 80 per cent) was identified. Fifty of the 53 main stringer fitting locations were accounted for. About 15-20 per cent of the bulkhead web was identified. It should be noted that the web pieces are thin (about 0.8 mm) and they could have been swept away by the river current.

1.12.1.3 Empennage

The purpose of reconstructing and examining portions of the empennage was to attempt to understand the mode of failure and the structural integrity of the flight controls at the empennage area.

A wooden structure was constructed to mount parts of the horizontal stabilizer and elevators in their respective positions. The reconstruction facilitated documentation of the wreckage and the deformation of the pieces that had separated in-flight. The reconstruction work was done in a hangar in Curug near Jakarta, in March 1998. The reconstructed empennage is shown in Figure 11.

The reconstructed tail plane was examined for evidence of an in-flight fire or explosion. No such evidence was found or observed. However, fractures that were examined exhibited overload characteristics. It is not known how many of the reversed loading cycles were experienced by the structure prior to failure and separation of the outboard stabilizer sections. The damage and deformations of the major fracture surfaces were consistent with a rapid weakening structure from a number of excessive reverse loadings, [Reference 5].

Two major pieces of the right hand horizontal stabilizer were found on land. These two pieces were sections from the tip to approximately stabilizer station 249 and from station 249 to 166 (as measured along the chord-wise breaks). A portion of the leading edge section of the horizontal stabilizer was observed to have some fasteners missing. Two nut plates which had missing fasteners were removed and examined at the Bandung Institute of Technology, Bandung, Indonesia. The test results showed that the fasteners were attached at impact, [Reference 8].

The left hand horizontal stabilizer piece found on land was from the tip to stabilizer station 221 (as measured along the inter-spar break; the rear spar extended inboard to the next rib at station 212).

Several pieces of the elevators (right and left hand side) and control tabs were also found on land.

1.12.1.4 Horizontal Tailplane

<u>Left hand horizontal stabilizer</u> (Figure 10.b) - No impact marks were found or observed on the leading edge of this section. Both the front spar (upper and lower chords) and the rear spar upper chord were bent up near their fracture locations. The lower chord fracture was indicative of tensile failure but little deformation was observed. The rear spar web was crushed upward near the fracture location. The upper skin near the fracture was bent up. The upper skin of the leading edge and the interspar areas exhibited wrinkles. The rear spar web of the outboard left hand horizontal stabilizer section contained diagonal tension wrinkles, distortions and paint failures at several locations similar to the right hand horizontal stabilizer outboard sections. As on the right hand horizontal stabilizer, the

damage observed on the outboard left hand horizontal stabilizer section was consistent with high vertical and torsional loading. It is noted that the right hand horizontal stabilizer was severely deformed in the same approximate location as the left-hand horizontal stabilizer chord-wise break near station 221. The stabilizer front spar outboard of station 221 is a solid web, but inboard of this location, the front spar contains flanged lightening holes.

The upper and lower trailing edge beams had generally failed at the rib locations or along the attachment bolts to the ribs. Several pieces of trailing edge panels were found on land.

<u>Left Hand Elevator</u> (Figure 10.c) - The largest piece of the elevator was the portion from the tip to elevator station 195, including the tip balance weight. The stabilizer outboard trailing edge elevator hinge fitting (elevator station 213) remained attached to the outboard elevator section. Deformation of fasteners at this hinge location was indicative of the elevator and hinge moving aft and inboard relative to the left-hand horizontal stabilizer. All of the hinge fittings were identified except for the horizontal stabilizer rib hinge fitting located at elevator station 66. The elevator hinges and surrounding area at elevator stations 213 and 176 contained evidence of elevator over-travel in the up and down directions and twisting of the bearing hinge plates. The balance weights in the balance bay and support structure were recovered from the crash site. The elevator tab was recovered in three long pieces on land, except for the inboard hinge and tab mast fitting which were recovered from the crash site. The tab hinge and elevator hinge fitting at elevator station 66 were damaged resulting from twisting of the bearing and fittings. Both control rods for the left hand elevator displayed multiple helical breaks indicative of torsional loading. The torsional breaks were as if the trim tab had rotated clockwise (looking forward) relative to the stabilizer and elevator. All of the attachments for the tab control rods were accounted for. The tab lockout mechanisms and rods and the tab mast fittings were recovered from the crash site. The elevator PCUs for the right hand and left hand elevators were recovered. One of the units was found complete with the piston and rod, and the rod showed an elevator position near neutral. The piston and rod on the other unit were missing.

<u>Right hand horizontal stabilizer</u> (Figure 10.d) - The leading edge of the two right hand horizontal stabilizer sections showed no impact marks. Distortion and wrinkles were noted in the outboard areas of the horizontal stabilizer leading edge and interspar ribs and skin.

<u>Right hand elevator</u> (Figure 10.e) - All of the control tab pieces were identified except for the portion inboard of elevator station 66. The largest piece of the right hand elevator was the portion from the tip to elevator station 176, including the tip balance weight and elevator station 213 hinge fitting. All six elevator hinge fittings were identified. The hinges located at elevator station 121 and outboard were found on land. The elevator hinges and surrounding area at elevator stations 213 and 176 contained evidence of elevator over-travel in the up and down directions and twisting of the bearings or hinge plates. The bearing and the bearing plates of the elevator hinge at elevator station 195 were twisted as if the elevator outboard end moved upward relative to the horizontal stabilizer. Although the lower bolt was not found, evidence indicated that the bolt was present during the separation of the elevator. The balance weights in the balance bay and support structure were recovered from the crash site. The right hand elevator control tab rods were identified. Deformation of the rods at the right hand elevator showed that they

were bent in the downward direction. All of the attachments for the tab control rods and lockout mechanisms were accounted for. The tab lockout mechanisms and rods and the tab mast fittings were recovered from the crash site.

The horizontal stabilizer center section (the so-called "Texas Star") structure and the horizontal stabilizer jackscrew were recovered from the crash site in the river. The majority of the front and rear spars were found and identified. The horizontal stabilizer center section has two hinge supports at the rear end about which the horizontal stabilizer is pivoted. The front end of the Texas Star structure is connected to a ball-nut on the jackscrew which is used to move the horizontal stabilizer (Figure 10.f).

The majority of the front and rear spars were identified. All of the stabilizer terminal fitting installations were accounted for. Only the left hand stabilizer hinge fitting and Section 48-support beam were recovered.

1.12.1.5 Vertical Tailplane

The recovered parts of the vertical tailplane main box and hinge fittings were severely fragmented. All spar terminal fittings and the trailing edge rib rudder hinge fittings were accounted for.

An estimated 50 per cent (by area) of the rudder skin honeycomb pieces was found scattered on land. Small pieces of the rudder spar were retrieved from the river, as were parts of the mid-spar balance weight. The rudder PCU, the lower hinge and actuator fittings, as one unit, were recovered from the river and found to be severely damaged.

Vertical stabilizer (Figure 10.g) - All the vertical stabilizer spar terminal fittings and the fin trailing edge hinge fittings were accounted for at the crash site, indicating that the vertical stabilizer structure was intact at impact. Damage to the vertical stabilizer precluded a full accounting of the front spar and interspar structure. The rudder upper hinge showed evidence of over-travels in the left and right directions. Other hinges exhibited twisting damage consistent with excessive rudder movement in the clockwise direction (looking forward). However, it could not be determined when the twisting damage was incurred.

Rudder (Figure 10.h) - The rudder hinge fittings were complete except the ones at rudder station 194, which was found with the aft portion of the attachment missing. The rudder auxiliary actuator fitting was not recovered. Fifty percent (by area) of the rudder honeycomb skin panels were found on land.

1.12.2 Power plants

The aircraft was delivered on 14 February 1997 with two new CFM 56-3B-2 engines (Serial numbers 858-480 and 858-481) manufactured by CFM International. There were no reported problems with engine number one 90 days prior to the accident. According to the aircraft technical log serial number D 20608 there was only one maintenance action reported on the number two engine within a 90-day period preceding the accident. On 2 October 1997 it was reported that the ground idle fan and core speeds (N1 and N2) were higher than those of the number one engine. The number two engine ground idle speeds were adjusted to match those of the number one engine.

The engine hardware was recovered from the river. Both engines were severely damaged by the impact. It was estimated that about 85 percent by weight of both engines was recovered. All the major rotating components from both engines were accounted for. The recovered engine hardware include the fan disks and blades, compressor blades and vanes, turbine blades and vanes, variable stator vane (VSV) actuators, and main engine control (MEC) units.

1.12.2.1 Engine

The engines were severely fragmented. The inspections indicated that the operating conditions of the engines at the point of impact were as follows:

- The three recovered Variable Stator Vane (VSV) actuators have impact witness marks on the actuator rods indicating that both engines were running at high engine speed setting at impact.
- The high pressure compressor case fragments showed that VSV platforms were locked in an open (high speed) position - consistent with the impact witness marks on the actuator rods.
- All major rotating engine hardware, i.e. fan, compressor, high pressure and low-pressure turbine disks were recovered with no indication of disk failure.
- Disassembly and inspection of the two recovered MEC systems at the Woodward Governor Company, Rockton, Illinois, showed that the remaining servos and valves were in a high flow, high engine speed position.
- The recovered high-pressure compressor blades were bent in a direction opposite to the engine rotation, indicating that the engines were operating at the time of impact.
- The recovered engine casings were very fragmented and did not show any evidence of high energy uncontained rotating engine hardware.
- No evidence was found of pre or post impact engine fire. (There was no melted or soot-covered engine hardware recovered.)

1.12.2.2 Main Engine Control (MEC) / Governor

The disassembly and inspection at the Woodward Governor Company of the two recovered MEC systems indicated that:

- The recovered servos and valves were in a high flow, high engine speed position.
- The fuel valve rotor was found in an open position suggesting a high fuel flow.
- The governor servo piston appeared to be within approximately 0.25 mm of the maximum fuel flow stop screw.
- The tang from the coupler was found in a position of rotation suggesting that the power lever was at a high angle (i.e. near the full forward stop).
- The pump unloading and shutdown rotor was in a position of rotation indicating a run/open position.

1.12.2.3 Throttle Box

The throttle box was found with the engine thrust levers in forward thrust (i.e. high power) and the fuel shut-off levers were in the “run” position (see Section 1.12.3.3.j). It could not be determined to which of the two engines the throttle box belonged. These thrust lever positions are consistent with information derived from evidence found in engine parts such as the severe rotational damage to the rotating parts of the engine.

A portion of the throttle box that was also included in the MEC had a portion of the MEC throttle housing, power lever and shutdown lever still attached to it. The power lever was found in the open position. It was measured that the power lever was approximately one third of an inch (about 8 mm) away from the stop. This would be equivalent to approximately 12 degrees from the full forward stop. However, due to the severe deformation of this hardware, the accuracy can not be ascertained. It could not be conclusively determined to which of the two MECs this hardware belonged.

These above findings are consistent with engine operation under power at the time of impact. No evidence was found of pre-impact engine fire or uncontained engine failure, [Reference 9].

1.12.3 PCU and Actuator Tear Down and Examination

Most of the actuators and power control units (PCU) were damaged at impact. Forty-nine of the actuators recovered from the crash site were sent to Boeing Equipment Quality Analysis (EQA) Laboratories in Seattle for tear down and examination from 28 April 1998 to 8 May 1998. The tear down and examinations were performed under the control of representatives from AAIC (now NTSC), NTSB, FAA and Singapore MCIT.

1.12.3.1 Tear Down Activities

The activities of tear down and inspection of the actuators/servos are described in [Reference 10].

Tear down activities were carried out as follows:

- The shipment boxes containing the actuators were in good condition with intact seals on them.
- Positions of the hydraulic actuators/pistons and other parts were recorded using X-ray i.e. 200 kV real time X-ray, 300 kV and 425 kV digital radiography and Industrial Computed Tomography (ICT) modes.
- Measurements of the position of relevant mechanism, sleeves etc., were made directly on the parts or from X-ray films (using a scale factor for each film).
- Due to deformation, the tear down had to be done by some machining operation. The cutting operations were performed in such a way to minimize damage.
- The tear down activities were recorded in the form of written reports, video tapes and still pictures, [Reference 10].
- Samples of hydraulic fluids and deposits found in the actuators and PCUs were taken and analyzed in the Boeing Analytical Laboratory using Fourier Transform Infrared

(FTIR) spectroscopy, X-ray diffraction (XRD) and moisture content determination. Analysis and characterization were also performed on the water and mud samples from the river bottom taken on the 24 March 1998. The results of the analysis are attached in [Reference 11].

1.12.3.2 Spoiler/Flap/Slat/Thrust Reverser Actuators

Flight spoiler actuators – four units per aircraft: (*Items 7, 8, 9 & 10* in Appendix E) All four flight spoiler actuators were recovered and examined. The actuators were found to be in the fully retracted position (see Figure 18).

Outboard ground spoiler actuators – four units per aircraft: (*Items 15, 16 & 17* in Appendix E) Three out of the four actuators were recovered and examined. The actuators were found to be in the retracted and locked.

Inboard ground spoiler actuators - four units per aircraft: (*Items 18, 19, 20 & 21* in Appendix E) All four actuators were recovered and examined. The actuators were found to be in the fully extended and locked position.

Trailing edge flap ballscrews - eight units per aircraft: (*Items 24, 25 & 26* in Appendix E) Three out of the eight ballscrews were found and examined. The ballscrews were found fully retracted. It is confirmed by the fact that the actuators were interconnected by a single drive torque tube.

Leading edge flap actuators - four units per aircraft: (*Items 40, 41 & 42* in Appendix E) Three out of the four actuators were recovered and examined. Two actuators were found to be in the retracted position and one was slightly extended (1.84 inches) with score marks in the bottom of the bore near the retract position.

Leading edge slat actuators – six units per aircraft: (*Items 43, 44, 45, 46, 47 & 48* in Appendix E) All six actuators were recovered and examined. Five actuators were found to be fully retracted and one was found to be slightly extended (0.5 inch).

Locking thrust reverser actuators - two units per engine (four units per aircraft): (*Items 27, 28 & 29* in Appendix E) –Three out of the four actuators were recovered and examined. Two actuators were found to be in the stowed and locked position, while the third actuator was found in the stowed but unlocked position.

Non-locking thrust reverser actuators – four units per engine (eight units per aircraft): (*Items 32, 33, 34, 35, 36, 37 & 38* in Appendix E) (center and lower) Seven of the actuators were recovered and examined. The actuators were found to be in the stowed position.

Thrust reverser synchronization locks - two units per engine (four units per aircraft): (*Items 30 & 31* in Appendix E) - Two out of the four locks were recovered and examined. The locks were found in locked positions.

1.12.3.3 Actuators Found in Non-neutral Position

During the tear down examination, the following components were found to be not in the neutral position:

a) Main rudder power control unit (*Item 1* in Appendix E) - The main rudder actuator piston was found bent at the forward and aft ends. X-rays were taken to determine the internal state of the PCU. The rudder PCU was found in a position equivalent to 3 degree left rudder deflection. The measurement was made directly from the X-ray film.

In view of the condition of the actuator piston and the fact that the actuator is of the piston type, its position could have been changed on impact. Its position may not be indicative of the last position at impact.

b) The servo valve of the main rudder PCU (*Item 1.a.* in Appendix E) was X-rayed using computerized tomography prior to removal. The primary slide of the main rudder PCU servo valve was found to be in the half-rate position while the secondary slide was in the neutral position. The primary slide was able to move freely in the secondary slide. The secondary slide had to be removed with a force of 260 pounds. This could have been due to deformation of the servo valve housing during impact. No corrosion and scratch marks were observed on the primary and secondary slides. A mapping by means of a mini Boroscope was carried out on the internal surface of the secondary slide and the servo valve housing and this was recorded on video. No corrosion and scratch marks were observed on the internal surfaces of the secondary slide and the servo valve, [Reference 10].

c) Inspection showed that the yaw damper or modulating piston inside the main rudder PCU (*Item 1* in Appendix E) was in a position equivalent to a half degree of left rudder deflection.

d) The rudder trim actuator (*Item 14* in Appendix E) was found to be close to neutral.

e) The cam of the feel and centering unit (*Item 22* in Appendix E) had impact marks indicating a left rudder deflection, (Figure 12).

f) Standby rudder power control unit (*Item 2* in Appendix E)- The standby rudder PCU was found in a position equivalent to one degree right rudder deflection. The measurement was taken directly from the X-ray film. As the actuator is of the piston type, the position may not be indicative of the last position at impact.

g) Aileron power control units and autopilot servos (*Item 3 and 4* in Appendix E)– There are two ailerons PCUs, which are mechanically linked to a control quadrant. The piston of aileron PCU (3529) was found in a position equivalent to 3.5 degrees left aileron down, while the piston of aileron PCU (3509) was found in a position equivalent to 1.2 degrees left aileron up. There are two aileron autopilot servos (*Item 11.a. & 11.b.* in Appendix E). Both were found to be in the disengaged positions. Disengagement of detent pistons prevents modulating piston inputs to the PCUs.

h) Elevator power control units and autopilot servos (*Items 5 and 6* in Appendix E)- There are two elevators PCUs which are mechanically linked to one output torque tube connected to the left and right elevators. One PCU piston (3559) was found to be in an equivalent elevator position of 1.5 degree trailing edge up. The elevator PCU (3560) was found with the piston missing and its position could not be determined. There are two elevator autopilot servos (*Item 12.a. & 12.b.* in Appendix E). Both were found to be in the disengaged position. Disengagement of detent pistons prevents modulating pistons inputs to the PCUs.

i) Horizontal stabilizer jackscrew (*Item 23* in Appendix E) – The pictures of the broken jackscrew are shown in Figure 13. The jackscrew ball-nut was found in a horizontal stabilizer trim position of 2.5 units, equivalent to 0.5 degree horizontal stabilizer leading edge up[4]. During the tear down examination, the ball-nut could originally only rotate approximately 1/8 inch around the circumference. Only when an additional force is applied was it able to rotate an additional 3/8 inch. (Note: During cruise, as shown by the FDR data, [Reference 2], the horizontal stabilizer was at about 4.5 units, equivalent to 1.5 degree horizontal stabilizer leading edge down.)

j) Throttle box (*Item 39* in Appendix E) - The throttle box had a power lever and a fuel shutoff lever still attached. The position of these levers suggests that the engine was at high power forward thrust and that the fuel shutoff lever was in the "run" position.

The analysis of the hydraulic fluid samples taken from the contained cavities showed that the fluid was in a normal condition. There was no contamination and no moisture as shown from the FTIR spectra, [Reference 11].

1.12.4 Other Aircraft Components

Only 370 kilograms of electrical wires, connectors and circuit boards of the aircraft were recovered. The wires were found broken into short lengths. These were sorted according to the aircraft system wiring, i.e. CVR, FDR, autopilot etc. The examination of the recovered wires showed no evidence of corrosion, shorting, burning or arcing.

Other parts of the wreckage recovered from the river included the following:

- Portions of the auxiliary power unit (APU).
- Parts of the landing gear assemblies (oleo struts, landing gear door actuators, wheels, brakes, tire pieces, etc).
- Life rafts, seat frames, seat cushions (which were X-rayed for shrapnel), oxygen bottles, oxygen masks, medical kits, cabin fittings, partitions, galley equipment and fixtures, curtains, etc.
- Other actuators

1.13 Medical and Pathological Information

Medical records of the flight crew showed no significant medical history. Medical personnel, families and friends reported that both pilots were in good health. Due to the severity of the impact and resulting fragmentation of all persons on board no autopsies were able to be conducted. There were only six human remains identifiable.

1.14 Fire

There was no evidence found of pre-impact fire.

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[4] Relation between reading in units and deflection in degrees is given as follows: x units = x degrees + 3. According to the sign convention, deflection of horizontal stabilizer leading edge up means negative, and leading edge down means positive (see Figure 13).

1.15 Survival Aspects

This was not a survivable accident.

1.16 Tests and Research

1.16.1 CVR Circuit Breaker Actuation Test

Upon the completion of data readout by NTSB, the CVR was taken to AlliedSignal on 22 January 1998 for further testing. This testing was an attempt to verify if the termination of the CVR recording was due to loss of power by the pulling of the CVR circuit breaker or other means. The result was inconclusive. Therefore other tests had to be performed (see Appendix F).

There were three tests conducted in a B737-300 aircraft to investigate the CVR circuit breaker actuation sound signature.

<u>The first test</u>

The first test was carried out on-ground by NTSB and Boeing on 5 February 1998. The reason for this test was to have quiet ambient condition to provide the best opportunity for detection of circuit breaker actuation sound signature. The result showed that the CVR cockpit area microphone did record the CVR circuit breaker actuation. Actuation of a circuit breaker nearby gave a similar result.

<u>The second test</u>

The test (consisting of on-ground and in-flight tests) was conducted on 14 May 1998 and 15 May 1998 by NTSB.

The purpose of the ground test was to obtain an on-plane, on-ground CVR recording of the CVR circuit breaker actuation, and the purpose of the flight test was to obtain an on-plane, in-flight CVR recording of the CVR circuit breaker opening. In both tests the circuit breaker was actuated manually and through the introduction of faults to the aircraft’s wiring, i.e. short circuit and overload.

The results of these tests were compared with the accident CVR recording sound signatures. In the short circuit tests a distinctive 400 Hz tone is recorded on one or more of the CVR channels. No corresponding signatures could be identified on the accident recording. The same tests found that the area microphone is able to pick up a distinctive and identifiable snap sound that the circuit breaker makes when it is violently tripped by a short circuit. (Note: The CVR continues to run for 250 milliseconds before it runs out of power from the capacitor. As sounds travel about one foot per millisecond, it would take only six milliseconds to travel the approximately six feet distance from the circuit breaker to the area microphone. Hence the CVR was able to record the snap sound of the circuit breaker.)

The overload tests yielded similar results as the short circuit tests except that there was a slight time delay for the circuit breaker to trip and the snap sound was quieter but still identifiable. No corresponding sound signatures could be found in the accident recording.

The last set of tests was to examine the sound signatures when the CVR circuit breaker was manually pulled. The snap sound was identifiable on the ground without engines and air-conditioning operating. However in the flight tests, the addition of the background cockpit noise present during normal cruise obscures the sounds associated with the manual in-flight pulling of the cockpit circuit breaker. No corresponding sound signatures could be found in the accident recording.

The summaries of the results of the second tests are as follows:

- During an overload and a short circuit, the sound of the circuit breaker popping was loud enough to be identified on the CVR‘s area microphone channel, both on the ground and in-flight.
- During an overload and a short circuit, the CVR recorded unique and identifiable sound signature on one or more of the channels, both on the ground and in-flight.
- During the manual pull test on the ground, the sound of the circuit breaker was loud enough to be identified on the CVR recording.
- In cruise flight, normal cockpit background noise obscured the manual circuit breaker pull sounds. There were no unique electronic identifying sound signature recorded on the CVR.

<u>The third test</u>

The test was conducted in-flight using a B-737 SilkAir sister aircraft in Singapore on 16 October 1998 and supervised by the Indonesian AAIC (now NTSC), a FAA avionics inspector (representing NTSB) and Singapore MCIT representatives.

In the third test, several scenarios were performed where the CVR circuit breaker in the cockpit was manually pulled. The manual pulls were categorized as “soft”, “hard” and “string” pull. The soft pull was by pulling the circuit breaker with minimum noise. The hard pull was by pulling the circuit breaker normally. The string pull was by pulling on a string that was attached to the circuit breaker. This was to simulate a short circuit causing the circuit breaker to pop out.

All the tests were conducted with an identical AlliedSignal SSCVR 2-hours recorder as installed in the accident aircraft.

All four channels of the CVR recordings of the above three tests were analyzed using the same NTSB signal processing software that was used to analyze the accident CVR recording.

Several tests were done to document the sound that were recorded on the CVR during a soft, hard and string pull of the CVR circuit breaker. The test closely matched the data obtained from the second test (NTSB in-flight test above).

1.16.2 Captain Seat Belt Buckle Sound Test

To further understand several “metallic snap/clunk” sounds heard during the last few seconds of the accident recording, several seatbelt unbuckling actions were performed during the in-flight test on 16 October 1998. The test was done with the PIC seatbelt buckle only as the PIC had indicated his intention to leave the cockpit. The seatbelt sounds recorded during this test were then compared with the sounds from the accident recording.

The accident aircraft was equipped with headsets with "hot" boom microphones, in addition to the cockpit area microphone. In the MI 185 recording, the "metallic snap" sounds were picked up on the cockpit area microphone (Channel 4) of the CVR. The sounds were also picked up by the Captain's boom microphone (Channel 1) and the First Officer's boom microphone (Channel 2) of the CVR recording. The observer's station (Channel 3) contained no cockpit audio information probably because no microphone was attached.

The tests showed that the metallic snap sound associated with the Captain's right seatbelt buckle was of sufficient intensity to be recorded in all three channels (1, 2 and 4) of the CVR. The sound associated with the Captain's left seatbelt buckle was picked up by the cockpit area microphone (Channel 4) and the First Officer's boom microphone (Channel 2) but not by the Captain's boom microphone (Channel 1).

1.16.3 Voice Recognition of ATC Recording using Audio Spectral Analysis

According to FDR and radar data, MI 185 was still flying at FL350 for 6 minutes and 56 seconds after the CVR stopped recording. When the Jakarta ATC recording was compared to the CVR recording, it was noted that there was one routine radio transmission from MI 185 after the stoppage of the CVR. This was also confirmed from the VHF keying data of the FDR recording.

To confirm who made the last MI 185 transmission, i.e. "SilkAir one eight five roger …" at 09:10:26, a test was performed by comparing words from the last transmission in the ATC recording with the same words from the CVR recording from an earlier part of the flight. The First Officer made most of the air to ground radio transmissions. The flight's call sign of "SilkAir one eight five" was often used in these transmission.

The test results indicated that the voice print characteristics of the CVR radio transmission matched those derived from the ATC transmission. The most notable similarity is when the F/O said the call sign "SilkAir".

The comparison showed that the last transmission was carried out by the F/O.

1.16.4 Trajectory Studies

As some empennage parts were found away from the main impact point, trajectory studies were carried out by BASI [Reference 12] and by NTSB [Reference 13]. The studies were to determine the altitude at which the parts separated from the aircraft.

Both studies, see Figure 14, were based on the theory that the trajectory of a separated object was determined by its initial condition at the time of separation, such as mass, speed, heading, altitude and its aerodynamic characteristics as well as the wind direction.

The BASI study showed that the rudder balance weight (which had the highest ballistic coefficient – heavy with small frontal area) did not separate while the aircraft was cruising at FL350 but at a lower altitude.

The wreckage distribution and the relative positions of the individual parts to one another supported the finding from this study that the separation of the remaining components took place at a lower altitude near or below 12,000 feet.

1.16.5 Flutter Studies

The NTSB-Boeing Report [Reference 14] showed the following:

- During cruise at 35,000 feet at 0.74 Mach
  The applied static loads and aerodynamic flutter margins are well within the aircraft certified design requirements. The loads at this flight phase did not support the separation of the empennage structure.
- During descent from 35,000 feet to 20,000 feet
  The applied static loads and aerodynamic flutter margins developed above 20,000 feet are less than the aircraft design requirements and do not support the separation of the empennage structure.
- During descent from 20,000 feet to ground impact
  The applied static loads are less than the design ultimate load envelope and do not support separation of the empennage during the final descent below 20,000 feet. The estimated descent speed exceeded the 1.2 dive speed V_d analytical flutter clearance speed at approximately18,000 feet altitude. An onset of an empennage 22 Hz anti-symmetrical flutter mode was calculated to occur later in the descent at approximately 5,000 feet altitude (570 equivalent airspeed in knots-KEAS). A lower frequency 12 Hz anti-symmetrical flutter mode was calculated to occur at approximately 3,000 feet altitude (600 KEAS), see Figure 15.

1.16.6 Flight Simulation Tests

The simulation tests were performed to explore and understand the various combination of one or more malfunctions of flight controls, aircraft systems and power plants that could result in an extreme descent flight trajectory as suggested by the radar data points from the accident.

Two different simulators were used to conduct these simulation tests. The first is a Boeing "M-Cab" simulator, which is a full motion, multi-purpose, engineering flight simulator used to simulate various types of Boeing aircraft. In the case of B737-300, the nonlinear mathematical software has been validated up to Mach 0.87, and extrapolated using computational data up to Mach 0.99.

The second simulator was a Garuda Indonesia full motion airline training simulator that replicates the B737-300 aircraft and the software is validated up to the flight operations envelope.

The Boeing B737-300 aircraft has been designed to have a maximum operating cruise speed M_{mo} of 0.83 Mach, and maximum dive speed M_{md} of 0.89 Mach.

The results of these tests are tabulated in Appendix G.

1.17 Organizational and management information

- SilkAir (Singapore) Pte Ltd is a subsidiary of Singapore Airlines Ltd (SIA). It commenced operation in 1989 under the name Tradewinds. In April 1992 Tradewinds was renamed SilkAir, [Reference 15].

- At the time of the accident, SilkAir operated about 100 scheduled flights to about 20 business and holiday destinations in South-East Asia. SilkAir's routes were generally short haul regional routes, and aircraft and crew usually do not stay overnight outside Singapore. The company operated six Boeing B737 and two Fokker F70 aircraft. In mid-1997, SilkAir placed order for 5 new Airbus A320 and 3 new A319 aircraft to replace the B737s and F70s.

- SilkAir is controlled by a Board of Directors. The Board sanctions major decisions such as choice of aircraft, annual budgets and major expenditures. The General Manager oversees the functional operations of the four divisions within SilkAir. The four divisions are Flight Operations, Commercial, Finance, and Engineering. The majority of SilkAir's senior managers are seconded from SIA[5]. Decisions such as flight operations policies, personnel training and disciplinary matters are managed at divisional level. Each divisional manager is responsible for management within the division and coordination with other divisional managers. The divisional managers report to the General Manager, who reports to the SilkAir Board.

- The Fleet Manager B737 and the Fleet Manager F70 reported directly to the Flight Operations Manager. There were approximately 60 pilots and 150 cabin crew in the airline. Pilots were not represented by a labor union.

- SIA Flight Operations provides advice on issues such as policy, training and discipline. SilkAir management followed SIA procedures for the selection of pilots. Before 1997, SilkAir depended on SIA for recruitment, screening, and selection efforts. Ab initio pilots were interviewed and given assessments such as psychological (aptitude) test. RSAF and airline pilots who have flying experience were required to be interviewed only.

- Managers in Flight Operations administer promotion practices. Criteria for promotion to be a commander include performance, personal conduct, seniority, potential command ability and total time of 4,400 flying hours. Criteria for promotion to be a Line Instructor Pilot (LIP) include a minimum of 12 months in command, instructional skills and management potential. Criteria for promotion to be an Instructor Pilot (IP) include 12 months as a LIP and ability to function as a flight examiner. For expatriate pilots, IP is the highest management pilot position available.

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[5] This sentence has been modified according to the suggestion in Appendix M.

- Disciplinary processes were decentralized at SilkAir. There were two levels of disciplinary inquiries. The first was the Divisional Inquiry and it involved only management personnel from the work unit. The second was the Company Inquiry, which was conducted if the employee appealed against the outcome of the Divisional Inquiry. In a Company Inquiry, managers from the other divisions are included to form the inquiry panel. As SilkAir is a small organization, it is natural that disciplinary inquiries are rare[6]. SilkAir reported that pilots had only been involved in two previous inquiries: a Captain was demoted to First Officer for 2 years following an improper interaction with a stewardess; an IP was demoted following an incident involving a rejected takeoff.

1.18 Other Information

1.18.1 Air Traffic Control

The Jakarta Air Traffic Control was responsible for the control of the MI 185 flight from Jakarta to PARDI, a reporting point at the boundary of Jakarta FIR and Singapore FIR. The filed flight plan route was via ATS route G579. Actual route flown after departure was based on radar control. The Air Traffic Control Services provided by Soekarno-Hatta Clearance Delivery, Ground Control, Tower and Jakarta Approach were normal.

The ATC transcript reveals that at 08:47:23 MI 185 contacted Jakarta Control and reported climbing to FL350 and requesting direct PARDI. MI 185 was instructed to standby and to report reaching FL350, which was acknowledged by the aircraft. At 08:53:17 MI 185 reported maintaining FL350 and was cleared to fly direct to PARDI and to report abeam Palembang. At 09:10:18 Jakarta Control informed MI 185 of its position just passing abeam Palembang, and instructed MI 185 to contact Singapore on frequency 134.4 MHz at PARDI. MI 185 acknowledged the message. This was the last communication between Jakarta Control and MI 185. At 09:35:54 Jakarta Control requested GA 238 to relay a message to MI 185 to contact Singapore ATC on 134.4 MHz. The aircraft was never in contact with Singapore ATC (Appendix C).

1.18.2 Radar Surveillance

1.18.2.1 Radar Facilities.

There were two radar displaying systems in operation at the Jakarta ATC Center with data and information derived from six remote secondary surveillance radar (SSR) facilities located at Soekarno-Hatta (Jakarta), Halim Perdana Kusumah (Jakarta), Semarang, Palembang, Pontianak and Natuna island.

The two systems are:

1. The Thomson CSF AIRCAT 500 as primary system used by the ATC which had been in operation since 1985 with inputs from 5 (five) SSR (less Natuna Island). The AIRCAT 500 was capable of replaying displayed data but had no recording capability. Being in operation for 12 years the general condition and performance of the AIRCAT 500 was on a decline.

[6] This sentence has been modified as suggested by Appendix M.

2. The Hughes GUARDIAN System (later known as Raytheon GUARDIAN System) with inputs from all the above mentioned sites were in operation since 31 July 1997. It was in transition phase to replace the AIRCAT 500 to the GUARDIAN (Appendix H). The GUARDIAN System is capable of retrieving all recorded and displayed radar data and information.

1.18.2.2 Radar Data Output

The radar data and information recorded and displayed by the GUARDIAN system were sent to the United States in January 1998 for examination at Hughes Raytheon ATC laboratory at Fullerton, California. Data from Soekarno-Hatta (Jakarta) and Palembang SSR were selected for the examination as these two radars covered the flight path of MI 185 and provided information on date, time, altitude, x/y position, x/y velocity, ground speeds, range, azimuth and minimum visible altitude

1.18.2.3 Aircraft Flight Path Based on Radar

The radar data and information retrieved from the GUARDIAN system was further examined and corrected, by Boeing as well as NTSB, focusing particularly on the last twelve radar returns. Based on this final radar data, the aircraft flight path and its ground track projection was reconstructed, see [Reference 18] and Figure 16.

1.18.3 PIC’s Background and Training

1.18.3.1 Professional Background in RSAF

The PIC joined the Republic of Singapore Air Force (RSAF) as a pilot trainee on 14 July 1975. He obtained his ‘wings’ (fully operational) on 25 March 1977. During his RSAF career, the PIC flew many different types of fighter and training aircraft. He held senior flying and instructing positions. He reached the rank of Captain in 1980 and was promoted to Major in 1989. In 1990, the PIC was selected to joint the RSAF’s Black Knights aerobatic team. In 1991, the PIC applied to leave the RSAF under a voluntary early release scheme. The PIC met the eligibility requirements for the early release scheme as he was 35 years old and had at least six years in his immediate preceding rank. His application was accepted.

The PIC’s reason to leave RSAF and join SilkAir was to keep flying and to spend more time with his family.

The PIC obtained a US Federal Aviation Administration (FAA) Commercial Pilot Licence on 19 November 1991 and an Air Transport Pilot Licence on 26 November 1991 in Benton Kansas. He left full-time employment in the RSAF on 29 February 1992. He had approximately 4,100 hours flying experience at that time. The PIC served as a squadron pilot in the RSAF on a part-time basis from 1 March 1992 to 30 April 1993. He subsequently served in the military reserve, as a Major, in a non-flying capacity. In January 1997, the PIC was promoted to Deputy Divisional Air Liaison Officer in his reserve unit.

1.18.3.2 Professional Background with SilkAir.

The PIC formally joined SilkAir on 1 March 1992. He was initially employed as a Cadet pilot under a training program for pilots that did not have a Boeing B737 type rating and had no previous airline experience.

The PIC was assigned to the Airbus A310 fleet and commenced training on 30 May 1994. He was appointed First Officer on the aircraft on 15 August 1994. When SilkAir discontinued A310 operations, the PIC was re-qualified on the B737 in March 1995.

The PIC was selected for B737 command training on 22 October 1995. He was officially informed of his selection on 20 November 1995. He was appointed Captain on 27 January 1996, and confirmed in that position on 27 July 1996[7].

SilkAir wrote to the PIC on 8 April 1997[8] to advise him of his selection for LIP. He completed his training on 9 May 1997. He performed satisfactorily thereafter in this position. On 3 July 1997, SilkAir wrote to the PIC to advise him of his de-appointment as LIP. This was subsequently revised to 28 July 1997 following a company inquiry into an operational incident that occurred on 24 June 1997 (see Appendix I for details)[9].

The PIC had no problems with regard to his professional licence medical requirements. His last licence renewal medical examination was on 2 December 1997.

1.18.3.3 Financial Background Information

The financial background data of the PIC was gathered to determine whether financial factors could have affected the performance of the PIC.

At the time of the accident, the PIC operated a securities trading account in Singapore. This account was operated from June 1990 until the time of the accident. During 1990 – 1997 the PIC traded over 10 million shares, with the value and the volume of the trading fluctuating during this period. The PIC's accumulated total losses from share trading increased between 1993 and 1997, with moderate gains during 1997. There was no period of the PIC negative net worth. The PIC's trading activities was stopped on two occasions due to the non-settlement of his debt, i.e. from 9 April to 15 August 1997 and again from 9 December 1997 until the time of the accident. On the morning of 19 December 1997, the PIC promised the remisier to make a payment when he returned from his flight[10].

The PIC had several loans and debts at the time of the accident. The PIC's (and immediate family's) monthly income was calculated to be less (about 6%) than their monthly expenditure at the time of the accident.

The probate document indicates that the PIC had a number of insurance policies which provided benefits on the event of his death. Most of these policies were taken out many years prior to the accident. In December 1997 he was required by the financial institution

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[7] This paragraph has been amended according to suggestion in Appendix M.

[8] The LIP position was seen as a requirement for further promotion to instructor pilot or into management. The position also gave a pilot additional allowance of S$ 750 monthly.

[9] This paragraph has been amended according to suggestion in Appendix M.

[10] Content of this paragraph has been modified according to comments in Appendix M.

granting the property loan to take a mortgage insurance policy. The PIC underwent medical tests for the policy on 1 December 1997 and followed this with a formal application of 5 December 1997. The PIC did not specify the commencement date for the policy. On 12 December 1997 the insurance company informed the PIC that his application was accepted pending payment of the insurance premium. A cheque dated 16 December 1997 was sent to the insurance company by the PIC being payment for the premium. The commencement or the inception date of the policy was set by the insurance company to be 19 December 1997. This information was not conveyed to the PIC. The cheque was cleared on 22 December 1997.

An independent review of the NTSC's findings concerning the financial background of the PIC was undertaken by PricewaterhouseCoopers. Based on the review, PricewaterhouseCoopers made certain recommendations to the NTSC in order for the NTSC to refine its findings. (Note: PricewaterhouseCoopers was not a party to the investigation, but was engaged by the NTSC for this specific task).

1.18.3.4 Recent Behaviour

The PIC's family reported that events and activities were normal in the days before the accident. The PIC was reported to have slept and eaten normally. There were no reported changes in his recent behaviour. He was organizing his father's birthday party that was planned for 21 December 1997. No medical problems were reported or noted by airline's appointed medical clinics.

Work associates who observed the PIC on the day of the accident and on his most recent flights, reported nothing odd or unusual in his behaviour.

1.18.4 F/O's Background and Training

The F/O studied aviation at Massey University, New Zealand, between 1992 and 1993 and earned a Diploma of Aviation. As a part of this course, he acquired a Commercial Pilot Licence. He accumulated about 185 flying hours on light aircraft during this period. The F/O was selected for an internship programme with Garuda Indonesia airline. He then completed a B737 type rating in Melbourne, Australia. Based in Jakarta, he worked as an F/O for Garuda Indonesia between April 1994 and April 1996. He completed 1,309 flying hours on the B737 aircraft during this period. There were no reported operational events or problems in the F/O's career at Garuda Indonesia. The F/O left the airline at the end of his internship.

1.18.4.1 Professional Background with SilkAir

The F/O joined SilkAir on 19 September 1996. He attended B737 re-qualification training from 22 to 26 October 1996. During the base check on 26 October 1996, his performance was rated "above average" and he was cleared for line training, which he completed on 13 November 1996. No problems were noted during his training.

The F/O underwent two further base checks on 3 March and 15 September 1997. On both occasions his performance was rated as "above average". He completed a line check on 10 October 1997, and no problems were noted.

During his career in SilkAir, the F/O was not reported to be involved in any operational events. During the investigation, other SilkAir pilots described him as an above average pilot with very good handling skills. It was reported that command trainees sought after the F/O to be a support pilot during training because of his skills and good situation awareness. He was described as someone who was professional, followed procedures, and was willing to learn.

1.18.4.2 Financial Background Information

The F/O did not maintain any credit accounts in Singapore. At the time of the accident, the F/O maintained his savings in a savings account. His parents reported that he owed them an amount for initial flight training expenses which was less than the savings at that time. There were no specified repayment terms. He was reported to be saving money to further his flight training to qualify for an ATPL. There were no reports of any other loans or debts. The F/O had a life insurance policy bought in 1992 and a standard SilkAir policy[11].

1.18.4.3 Recent Behaviour

The F/O last flew on 16 December 1997. The F/O's associates and friends reported no changes or anything unusual in the F/O's behaviour in the weeks prior to the accident. He was reported to have eaten and slept normally in the days prior to the accident.

On the morning of 19 December 1997, two engineers who knew the F/O socially talked with him when the aircraft was being prepared for departure from Singapore. They made plans to meet that night. They reported that the F/O appeared to be normal and in good spirits.

The F/O planned to return to New Zealand in February 1998 to acquire additional pilot-in-command hours and obtain his ATPL.

1.18.5 Relationship Between the PIC and the F/O

From December 1996 through December 1997, the PIC and the F/O flew 18 sectors together across seven days (including the accident flight). The investigation found no evidence to indicate that there had ever been any difficulties in the relationship between the PIC and the F/O.

On the two hours of CVR information, there were no indications of any difficulties in the relationship between the two pilots. There were several cordial discussions not related to their work tasks at the time.

[11] Amended based on information in Appendix M.

2 ANALYSIS

2.1 Introduction

The investigation was conducted in accordance with the standards and recommended practices of Annex 13 to the Convention on International Civil Aviation. In accordance with Annex 13, the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

This was an extremely difficult and challenging investigation due to the degree of destruction of the wreckage, the difficulties presented by the accident site and the lack of information from the flight recorders during the final moments of the accident sequence.

The analysis is drawn from facts compiled in the engineering and systems, operations, and human factor aspects of the investigations.

Analysis on the engineering and systems aspect starts with the aircraft structural and systems integrity including trajectory and flutter analysis studies. The results of tear down and examination of the actuators are analyzed to determine the positions and conditions of the control surfaces, engines, and other related systems. Special attention is also given to the issues arising from previous B737 accidents, e.g. the Colorado Springs and Pittsburgh accidents, especially on the issue of the rudder power control unit (PCU). The stoppage of the flight recorders is analyzed based on the electrical wiring diagrams, as well as on-ground and in-flight tests performed in the USA and in Singapore. The maintenance aspect is analyzed in the last part of the engineering and systems section.

The investigation of the operations aspect covers general factors of the operation of the flight such as flight crew, air traffic control, weather, navigation, communication, flight trajectory and conditions based on CVR, FDR as well as radar data, and flight simulation exercises. The analysis focuses on the possible system failures and its effect to the aircraft descent trajectory as suggested from radar data points. The descent technique that arises from emergency situation and recovery from such extreme descent is also discussed.

The investigation of the human factor aspect of the accident took into consideration all available background data of the flight crew, and the results of the analysis in the other areas (e.g. engineering and systems, operations, etc). The analysis covers general human performance issues (such as medical, professional qualification, training, fatigue, impairment, improper in-flight management, etc), the human factor aspects of the CVR and ATC recordings, as well as specific human factor issues.

In accordance with Annex 13, a report was made to the relevant aviation security authorities in late 1999. While the technical investigation continued, aviation security authorities conducted a separate investigation, which is not covered in this report.

2.2 Aircraft Structural and Systems Integrity

Most of the wreckage was found and dredged from an area of about 60 m x 80 m in the river bed. The distribution of the wreckage found in the river was documented by a sonar picture and during dredging. The relatively small impact area indicated that the aircraft impacted at a relatively steep angle.

Although approximately 73% of the aircraft by weight was recovered, only a small amount of the wreckage were identifiable and in a condition useful for the investigation. The inspection of the recovered wreckage suggests that the aircraft was structurally intact until the outer sections of the horizontal stabilizers, elevators and sections of the rudder separated from the aircraft.

The examination of the fracture surfaces and wreckage fragments showed no evidence of pre-existing structural defects, fire or explosion in flight.

The examination of the recovered passenger oxygen generators revealed no evidence of activation from which it is concluded that the aircraft did not experience depressurization in flight.

One of the investigations is to determine the cause of the separation of parts of the empennage, as described in the following paragraphs.

2.2.1 Horizontal Stabilizers and Elevators

The recovered sections of the leading edge of the horizontal stabilizer found on land showed no surface impact marks. This suggests that the separation of the horizontal stabilizer sections was not initiated by a foreign object impact.

The damage on the horizontal stabilizer box structure showed characteristics of the occurrence of high vertical and torsional reverse loading. In addition, examination of the multiple small sections of front spar, leading edge, rear spar lower chord, trailing edge rib, and interspar ribs and skin (which were found on land) showed characteristics consistent with numerous cycles of reverse loading.

The parts of the horizontal stabilizer center section ("Texas Star") were recovered in the river and were found broken due to impact, see Figure 11. In the recovered parts no evidence was found which could be attributed to fatigue failure.

The elevator hinges and surrounding area at elevator stations 213 and 176 contained evidence of elevator over-travel in the up and down directions and twisting of the bearings or hinge plates. Deformation of the right hand elevator control tab rods showed that they were bent in the downward direction. Both control rods for the left-hand elevator displayed multiple helical breaks that indicate torsional loading.

2.2.2 Vertical Stabilizer and Rudder

All recovered parts of the vertical stabilizer box were found at the crash site. All of the vertical stabilizer spar terminal fittings and the fin trailing edge hinge fittings were also found at the crash site. This indicated that the vertical stabilizer structure was intact on impact.

All of the rudder hinge fittings were complete except for the hinge fitting of the rudder station 194, which was missing the aft portion of the attachment. The rudder upper hinge showed evidence of over travels in the left and right directions. Other hinges exhibited twisting damage consistent with excessive rudder movement in the clockwise direction (looking forward). However, because the hinge fittings were found at the crash site, it was difficult to determine whether the twisting damage was incurred during flight or during impact.

An estimated 50% by area of the rudder skin honeycomb pieces were found scattered on land. The top balance weight was found also on land. Small pieces of the rudder spar (still attached to the hinge fittings) were recovered from the crash site, as were parts of the mid-spar balance weight. This indicated that the rudder disintegrated partially in the air.

2.3 Break Up of the Empennage

Some parts of the empennage that separated in flight were found on land. Taking into consideration the relative positions of these empennage parts and their location with respect to the crash site, BASI and NTSB conducted trajectory studies (Section 1.16.4) to determine the trajectory of the aircraft and to estimate the altitude when the break-up could have occurred. Furthermore, to explain the reason for the empennage break-up, NTSB and Boeing conducted the flutter study as mentioned in Section 1.16.5.

2.3.1 Results of Trajectory Studies

The studies were based on the theory that the trajectory of a separated mass will be determined by its initial conditions at the moment of separation, taking into consideration speed, heading, and altitude, as well as its aerodynamic characteristics. Corrections to allow for wind speeds and directions were applied.

The results suggested that a separation had taken place at a low altitude near or below 12,000 ft., while the aircraft was flying at a high Mach number.

2.3.2 Results of Flutter Studies

Flutter studies undertaken suggested that the applied static loads and aerodynamic flutter margins developed during the cruise and descent above 20,000 feet are below the design and certification requirements or specifications and thus do not support the separation of the empennage structure above that altitude.

Below 18,000 ft altitude, the estimated descent speed exceeded the 1.2 V_d and an onset of an empennage 22 Hz anti-symmetrical flutter mode was calculated to have had occurred at approximately 5,000 ft altitude and 570 KEAS.

At approximately 3,000 ft and 600 KEAS a lower frequency 12 Hz anti-symmetrical flutter mode was calculated to have had occurred.

2.3.3 Explanation to the Break Up of the Empennage

Close examination of the wreckage (Section 1.12) supports the results of the flutter analysis (Section 2.3.2) and the trajectory analysis (Section 2.3.1).

The above results suggest that the separation of the empennage parts could have had occurred at an altitude near or below 12,000 ft, due to an unstable flutter as the aircraft exceeded 1.2 V_d.

2.4 Power Control Units and Actuators

2.4.1 Main Rudder PCU

As stated in Section 1.12.3.3.a, the position of the main rudder PCU actuator piston was measured to be in a position equivalent to a 3° left rudder deflection. The main rudder actuator piston was found bent at the forward and aft ends. It could not be determined whether its position reflected the last position before impact.

The yaw damper or modulating piston showed an equivalent of 0.5° left rudder deflection. However, as the modulating piston is a hydraulic piston, the position found may not necessarily indicate that the piston was at that position before impact.

Examination of the servo valve of the main rudder PCU showed no scratch marks on the surface of the slides, as well as in the internal bores of the valve. Corrosion deposits were found in the cavities of the PCU and other actuators examined. The presence of corrosion deposits could be due to immersion in the river water, or during the period of storage after recovery from the riverbed.

During the inspection, a force of 260 pounds (about 130 kg) was required to remove the secondary slide from the servo valve. This gripping force was due to a deformation of the valve housing - which was constructed from a stack of wafers. The deformation was caused by the impact forces on the PCU actuator rod and the servo valve body.

It is noted that some issues arose during investigation of the Colorado Spring (in 1991) and Pittsburgh (1994) accidents involving B737 aircraft. One of the issues was a possibility of the servo valve jamming due to thermal shock resulting in rudder reversal.

In the controlled laboratory test condition [Reference 16], it was found that problems due to thermal shock can arise. This can happen if the warm hydraulic fluid (at +77°C) rushes into a cold-soaked servo valve (at -40°C) causing the slides to expand against the valve housing. In such a temperature difference, a valve jamming could occur causing the rudder to move uncommanded or in a direction opposite to the rudder pedal command (rudder reversal). In real flight, the hydraulic temperature would not reach that high (+77°C) a level.

The rudder PCU fitted on the aircraft complies with the applicable Airworthiness Directives (AD) as described in Appendix J. The modifications to the PCU included one that enabled circulating of hydraulic fluid to warm up the valve to prevent the thermal shock problem.

Another possible uncommanded rudder movement is due to a corrosion caused by waste water to the yaw damper system components in the electrical and electronic (E&E) compartment. Such an incident occurred to a B737 in Bournemouth, UK (in 1995). An inspection of sister B737-300 aircraft of SilkAir was performed in March 1998. This aircraft was selected because it was fitted with similar internal configuration and forward galley modifications, as was the accident aircraft. The inspection showed that the E&E compartment of the sister aircraft was clean and free from any contamination. It could not be determined if the E&E compartment of accident aircraft was in similar condition. However, assuming that the accident aircraft was in similar condition, there would not have been corrosion caused by toilet water leaking into the E&E compartment.

2.4.2 Standby Rudder PCU

The standby rudder PCU was found at a position of 1° right rudder deflection, which was in conflict with the position of the main rudder PCU, which was at 3° left rudder. The standby rudder PCU is normally unpressurized. (The standby rudder PCU is activated by selecting a switch located on the forward overhead panel to the “Standby” position when there is failure of normal system).

As the standby PCU was a piston type and furthermore it was unpressurized, its position could change on impact. Its position may not be indicative of the rudder position at impact.

2.4.3 Aileron PCU

Examination of the Aileron PCU 3529 indicated a 3.5° left aileron down position, while the Aileron PCU 3509 indicated 1.2° left aileron up position. Both actuators were piston type and were mechanically linked, the evidence found was contradictory, and therefore the position of the ailerons at impact could not be determined.

2.4.4 Elevator PCU

The Elevator PCU 3559 was found to be in an elevator position of 1.5° trailing edge up, while the Elevator PCU 3560 was found with the piston missing and therefore the elevator position could not be determined. Both PCU actuators were mechanically linked to an output torque tube connected to the left and right elevators.

As the elevator PCU actuators were piston type, their position could change on impact. Therefore the position of the elevator at impact could not be determined.

2.4.5 Horizontal Stabilizer Jackscrew

During the tear-down examination, the horizontal stabilizer jackscrew was found in a position equivalent to a horizontal stabilizer trim position of 2.5 units. It was also observed that the ball nut could not be moved freely due to impact deformation. The upper end counter-bore (aft portion) was ovalized by the screw-shaft being forcibly extracted from the ball nut. The ball nut could be rotated 1/8 inch around the circumference, and only when an additional force is applied was it able to rotate an additional 3/8 inch, [Reference 10].

FDR data showed that the horizontal stabilizer position was at an average of 4.5 units while the aircraft was cruising at 35,000 ft. At this trim setting, the horizontal stabilizer leading edge is in a down position and corresponds with an aircraft nose-up attitude, [Reference 17].

The last data on the FDR showed the horizontal stabilizer trim was at 4.58 units, while the horizontal stabilizer jackscrew was found in a position equivalent to a horizontal stabilizer trim position of 2.5 units. The difference in the trim positions indicated a change of about 2.0 units (degrees) of the horizontal stabilizer position.

The horizontal stabilizer trim normally can be operated by three ways:

- by the autopilot trim (e.g. to automatically correct any out-of-trim conditions);
- by manipulating the main electrical trim switches on the pilots' control wheels (e.g. during manual flying); or
- by cranking the stabilizer trim wheels (e.g. when the main electrical trim fails).

Uncontrolled movement of the horizontal stabilizers could occur (e.g. a stabilizer run-away). If such a run-away occurs, in a normal situation, it can be overcome by moving the control column in the opposite direction.

To operate the horizontal stabilizer using the main electric trim system, the two switches on each of the control wheels have to be operated simultaneously, one to power the electric motor and two to release the brake and connect the clutch of the jackscrew. With such a switch arrangement, operation of one switch or a malfunction in one circuitry would not change the jackscrew position.

A malfunction affecting both trim switches on a control wheel could also cause a run-away. It was not possible to ascertain if such an occurrence took place. (But, at least one Service Bulletin reported a malfunction during an approach maneuver, see Appendix L.) However, had a run-away occurred due to a malfunction of the main electrical trim system, it would take about 10 seconds to change from 4.5 to 2.5 units (at a rate of trim change of 0.2 unit/sec at flaps retracted position). The trim wheel would turn continuously. The movement of the trim wheels and the sound produced would have been noticed by the pilots. Both pilots were trained to recognize such a condition and to take appropriate corrective actions.

The effect of a system run-away of the horizontal stabilizer trim was simulated in the Garuda Indonesia Training Simulator as well as Boeing M-Cab Simulator, see Appendix G. A trim change from 4.5 to 2.5 units changed the aircraft attitude from a nose-up to a nose-down attitude. The simulator results showed that, with such a trim change, it took 1 minute and 23 seconds to descend from 35,000 feet to 19,500 feet. However, the last five ATC radar points showed a much faster descent of the accident aircraft, i.e. 32 seconds from 35,000 feet to 19,500 feet. Therefore, if the simulation was correct, the change of horizontal stabilizer trim position alone would not have resulted in the fast descent after leaving FL350.

During autopilot operations, the trim operates automatically to correct changes in the center of gravity position due to fuel use or movements of people along the aisle. Had a run-away occurred during autopilot operations, the autopilot would disengage. The trim wheel would also turn continuously. The warning from the autopilot disengagement and the turning of the trim wheels would alert the pilots to this situation. Both pilots were trained to recognize such a condition and to take appropriate corrective actions.

The manual trim wheel is available as a back-up in case there is a malfunction in the main electrical trim system. It is possible to change the trim position using the trim wheel, but the pilot would have to crank the wheel in a prolonged manner to effect a large trim change. No evidence was found that the main electrical trim system had failed.

During normal operations, the main electrical trim switches on the control wheel are used to neutralize the force on the control columns. In this mode of operation, pushing the main electrical trim switches forward continuously would move the horizontal stabilizer to a limit of 2.5 units when the flaps are retracted. The horizontal stabilizer trim position was found in a 2.5 units position during the tear down examination. This matches the forward limit of the main electrical trim.

2.4.6 Other Actuators

During the tear down examination, the following components were found to be in the stowed or retracted position:

- Flight spoiler actuators
- Outboard ground spoiler actuators
- Inboard ground spoiler actuators
- Trailing edge flap ballscrews
- Leading edge flap actuators
- Leading edge slat actuators
- Mach trim actuator
- Thrust reverser actuators

The fact that these actuators were found in the stowed or retracted position does not necessarily suggest that their respective systems were not activated during the descent. If the respective systems remained in the stowed or retracted positions, they would not have been factors contributing to the accident.

2.5 Powerplant

In the examination of the recovered engine parts, main control units and throttle box, the following were found:

- There was no evidence found of melting or soot on recovered engine hardware, indicating that there was no pre or post impact engine fire.
- All major rotating engine hardware, i.e. fan, compressor, high pressure and low pressure turbine disks were recovered with no indications of high energy uncontained engine failures.

- Indications were found that both engines were operating at high engine rotation speed at the point of impact.

Therefore, the engines were considered to be not a factor contributing to the accident.

2.6 Stoppage of the CVR and FDR

2.6.1 CVR Stoppage

The CVR recording ended while the aircraft was still cruising at an altitude of 35,000 feet, about seven minutes before the last radar return. Up to the CVR stoppage, the conversation in the cockpit was consistent with normal flight operations.

The CVR stoppage could have occurred due to a malfunction of the unit itself or a loss of power to the unit. The loss of power to the unit could be due to power interruption to the Electronics Bus 1 that supplies power to the CVR, short circuit or overload, CVR circuit breaker pulling or break in the wiring.

The entire two-hour recording was found normal. There were no observed anomalies when power was transferred on the ground in Jakarta. It appeared that the recorder's internal energy storage capacitor was operating normally by providing continuous recorder operation in spite of momentary aircraft electrical power interruptions, [Reference 4].

The examination of the CVR unit performed by the manufacturer (Appendix F) confirmed that the CVR was functioning properly. The recording had characteristics that would be expected of a normal electrical power shutdown of the CVR. Therefore, the stoppage of the CVR could be a result of the loss of power to the unit.

According to the aircraft wiring diagram 24-58-11 (Figure 17) the power to the CVR was from the Electronics Bus 1 (Elex Bus 1). The Elex Bus 1 also supplies power to other systems, such as the FDR, DME-1, TCAS, ATC-1 etc. Parameters of DME-1 and TCAS were recorded in the FDR. Analysis of the FDR recording showed that six minutes after the CVR stopped, the FDR was still recording TCAS and DME-1 parameters. This indicates that the CVR stoppage was not due to power loss at Elex Bus 1.

The CVR is equipped with an energy storage capacitor. The function of this capacitor is to provide power for 250 milliseconds after electrical power is removed from the unit such as when the aircraft power is switched from ground power to APU generators or the engine generators. Another function of this capacitor is to enable continued recording for another 250 milliseconds after power loss to the unit.

Had there been an overload or short circuit, the resultant popping of the CVR circuit breaker in the cockpit would have been recorded as a unique and identifiable sound signature by the CVR (see Sections 1.11.3 and 1.16.1). Based on the examination of the results of the circuit breaker pull tests, there was no such sound signature in the MI 185 CVR recording found. This indicates that there were no short circuit or overload to cause the CVR circuit breaker to pop out.

The results of the CB pull tests showed that the sound signature associated with manual pulling of the circuit breaker is obscured by the cockpit ambient noise. Hence, no conclusion can be drawn whether the circuit breaker had been pulled manually.

A break in the wire supplying power to the CVR could also lead to CVR stoppage without any sound being recorded on the CVR. However, from the limited quantity of wiring recovered it could also not be determined if a break in the wiring had caused the CVR to stop.

Thus, the cause of the CVR stoppage could not be concluded.

2.6.2 FDR Stoppage

The FDR stopped recording at 09:11:33.7, or 6 minutes and 18.1 seconds after the CVR stoppage, and approximately 35.5 seconds before the aircraft started its descent, see Section 1.11.1 and Figure 2. Data recorded by the FDR indicates that the flight was normal until the FDR stoppage time. It was concluded that until the stoppage of the FDR, there were no indications of unusual disturbance (e.g. atmospheric turbulence, clear air turbulence, or jet stream upsets, etc.) or other events affecting the flight.

The FDR stoppage could have occurred due to a loss of power supply to the FDR, or the malfunction of the unit itself.

The recording of the ATC radar plots during the descent of the aircraft until 19,500 ft indicated that the aircraft ATC transponder continued operating after the FDR had stopped recording. SilkAir stated that generally flight crews use ATC-1 flying outbound from Singapore, and ATC-2 inbound. ATC-1 is on the same bus as the FDR, while ATC-2 is powered from Elex Bus 2, i.e. a different power source. No conclusion could be drawn as to the reasons for the CVR and FDR stoppage at different times.

The FDR was determined to be functioning normally until it stopped. The stoppage of the FDR could not be determined from the available data.

There were no evidence found that could explain the six-minute time difference between stoppage of the CVR and FDR.

2.7 Radio Transmission Voice Recognition

The last radio transmission on VHF from MI 185 was at 09:10:26 when it acknowledged ATC's call that MI 185 was abeam Palembang, to maintain FL350, and to contact Singapore Control at PARDI, by responding "SilkAir one-eight-five roger, 134.4 before PARDI". Voice spectrum analysis identified that the F/O made this last radio transmission, see Section 1.16.3. This information reveals that the F/O was in the cockpit about 1.5 minutes prior to the descent.

2.8 Maintenance Aspects

2.8.1 Aircraft Maintenance

The aircraft and the engines were found to be properly maintained by SIA Engineering Company (SIAEC) in accordance with the Maintenance Schedule ref. MI/B737-300 Issue No.1 and approved by the Civil Aviation Authority of Singapore (CAAS). The maintenance task cards and inspection reports were reviewed. The required checks were carried out within the stipulated period. There were no adverse findings on any matter/defect that would contribute to the accident.

A review was carried out of the aircraft technical logbooks, deferred defect logbooks and in-flight log defects. It did not reveal any defects that could have affected the airworthiness of the aircraft.

Therefore, the inspection of the maintenance records did not reveal any defects that may have contributed to the occurrence.

2.8.2 Patch Repair

On 24 April 1997 the aircraft was damaged in a ground incident, resulting in a dent to the fuselage skin. The patch repair, designed and performed according to Boeing Structure Repair Manual (SRM), was carried out by SIA Engineering Company on 28 April 1997.

The patch repair was recovered from the riverbed. A damage to the upper forward corner of the patch repair was concluded to be the result of impact. Examination of the patch revealed no evidence of material or workmanship abnormalities.

Therefore the possibility that the patch repair was a factor contributing to the accident can be ruled out.

2.9 General Operational Issues

Both pilots were properly trained, qualified and licensed to conduct the flight in accordance with the Singapore Air Navigation Order. The pilots received sufficient rest before the flight and had no medical history that would adversely affect their performance.

The security checks of passengers, baggage and cargo were conducted in accordance with standard procedures. The results of the checks were all normal. No dangerous goods were carried on board.

The aircraft was dispatched and operated within the certified weight and balance limits.

At the time of the accident it was daylight. Weather observations around Palembang indicated no adverse weather in the vicinity near that time. There were several flights in the vicinity at different flight levels and the en-route weather experienced by these flights was isolated in nature. Generally, flights that were affected by the weather would have requested for deviation before the flight encountered the weather. The Sempati 134 flight from Jakarta to Batam flying at FL310 approximately 2 minutes ahead of MI 185 reported that due to weather conditions en-route he requested to fly direct PARDI. The Qantas 41 flight at FL410 about 8 minutes behind MI 185 did not report adverse weather over Palembang except for two or three isolated thunderstorms about ten miles to the east of track near Palembang.

All navigational aids and facilities of the Jakarta airport, and other en-route navigation aids between Jakarta and Singapore were fully serviceable. The flight was cleared to route from a point near Jakarta direct to Palembang, then to PARDI.

Up to 09:10:26 the Jakarta Air Traffic Controller was communicating normally with the cockpit crew on frequency 132.70 MHz. From then on, no distress call was received from the crew, no distress signal was received from the aircraft transponder, and no emergency locator beacon transmissions were detected from the crash site.

2.10 Simulated Descent Profile

The last five ATC radar points recorded represent the flight trajectory of the aircraft from the cruise altitude 35,000 feet to approximately 19,500 feet. Each point consisted of data relating to time, altitude and geographical coordinates.

Simulator tests and computer simulation fly-out studies were done to determine failures or combination of failures of the flight control and autopilot systems that could result in the extreme descent trajectory. Aircraft flight data were not available for the time period after the stoppage of the FDR. The initial condition for these tests and studies was cruise configuration at 35,000 feet based on the last known FDR data. The altitude range for the simulations was from 35,000 feet to approximately 19,500 feet.

The results of these simulation studies (Appendix G) are summarized as follows:

- Any single failure of the primary flight controls such as hard-over or jamming of aileron, rudder or elevator did not result in a descent time history similar to that of the last ATC radar points. In simulations of these flight control failure conditions the aircraft could be recovered to normal flight manually.

- Any single failure of the secondary flight controls such as hard over or jamming of yaw damper, or runaway of the stabilizer trim would not result in a descent time history similar to that of the last ATC radar points. In simulations of these flight control failure conditions the aircraft could be recovered to normal flight manually.

- Manipulation of the primary flight controls without horizontal stabilizer trim would result in a descent time history similar to that of the last ATC radar points. But this required large control column input forces and the aircraft was subjected to a loading exceeding 2 G. However, if the control column input forces were relaxed, in the simulations the aircraft would recover from the steep descent due to its inherent stability.

- Among other possibilities, a combination of changing the stabilizer trim from about 4.5 to 2.5 units and an aileron input could result in a descent time history similar to that of the last ATC radar points. This simulated descent trajectory would result in the aircraft entering an accelerating spiral and being subjected to a loading of less than 2 G. Furthermore, the aircraft would continue in the spiral even when the control forces were relaxed. This would result in a descent at a speed exceeding 1.2 V_d, in agreement with the analysis on the break up of the empennage as discussed in Section 2.3.

2.11 High Speed Descent Issues

2.11.1 Mach Trim System and its Function

The aircraft was equipped with a Mach Trim system to provide stability at the higher operating speeds, i.e. higher Mach numbers. Mach trim is automatically accomplished above Mach 0.615. When the Mach Trim system is operative it will normally compensate for trim changes by adjusting the elevator with respect to the stabilizer, as the speed increases. With the Mach Trim inoperative, the aircraft could exhibit a nose down tendency ("Mach Tuck") as speed increases**.** However, the expected control forces to overcome the "Mach Tuck" are light. Additionally when the speed exceeds the maximum limit, audible overspeed warnings are activated.

Since the aircraft was cruising at subsonic speed (Mach 0.74) and trimmed for level flight, the aircraft will eventually return to the trimmed condition after a minor speed disturbance.

For the aircraft to dive, a significant disturbance resulting in an increasing speed must have taken place. Such a disturbance could be initiated by changing aircraft elevator or stabilizer trim. Should the airspeed increase to the point where it becomes transonic, and as the lift resultant moves aft and local supersonic flow develops, the nose-down pitching moment could be sufficiently large that the aircraft becomes speed unstable, i.e. continuing speed increase of the aircraft. Once the aircraft is in a transonic dive, a recovery from the dive becomes more difficult because of an increase in control column forces, due to the aircraft's increasing nose down pitching moment, as well as a large reduction of elevator effectiveness due to the formation of shock induced air flow separation in front of the elevator.

It is possible to recover from a transonic dive by timely action of the pilot, by reducing thrust and deploying the speed brakes. Should the pilot not initiate a prompt recovery action, the recovery becomes more difficult.

During the tear down examination, the mach trim was found in the fully retracted position. The fact that this actuator was found in the retracted position may not necessarily indicate that the mach trim system is a factor contributing to the accident.

2.11.2 Emergency Descent due to Fire, Smoke or Depressurization

An emergency descent is necessary when there is a rapid cabin depressurization or when a fire or smoke occurs in flight. The procedure is to simultaneously retard the thrust levers, deploy the speed brakes and initiate the descent[12] (Appendix K). Some forward stabilizer trim is applied to attain a dive that will accelerate the aircraft towards the maximum speed limit. Once the maximum speed is reached aircraft is re-trimmed to maintain the speed. This facilitates a limit on maximum rate of descent to the minimum safe altitude.

The last pilot radio transmission about two and a half minutes before the descent sounded normal and there was no mention of any in-flight fire or smoke. Furthermore, examination of the wreckage showed no evidence of in-flight fire or explosion.

Examination of the recovered oxygen generators showed that they were not activated. This indicated that there was no rapid depressurization at high altitude.

Based on the above findings, there was no indication of an emergency descent due to fire, smoke or rapid depressurization.

2.12 General Human Performance Issues

This section analyses the general human performance issues such as medical, professional qualification, training, fatigue, impairment, improper in-flight management, etc.

- The flight-crew's medical background and recent activities were examined. All medical files reviewed showed no significant medical history. Medical personnel, family, and friends reported both pilots to be in good health. Neither pilot flew in the two days before the crash. Family and friends reported routine activities and rest during that time period. Evidence from the CVR and the conduct of the flight (based on FDR and ATC communications) indicated that neither pilot experienced any medical difficulties in flight. Further, there was no evidence found of incapacitation or impairment. Therefore, the investigation concludes that until the stoppage of the flight recorders there was no evidence found to indicate that the performance of either pilot was adversely affected by any medical, psychological or physiological condition.

- Both pilots held valid airman licenses and medical certification. They had received all required training, including unusual attitude recovery training. At the time of the crash both pilots were within duty-time limits. Peers, instructors, and supervisors described both pilots as competent pilots with good airplane handling skills. It was concluded that both pilots were properly trained, licensed and qualified to conduct the flight.

- The relationship between the PIC and the F/O was examined. There were no reports of any conflict or difficulties between the pilots prior to the occurrence and before the day of the crash. Based on the available recorded data of the CVR, there was no evidence of any conflict or difficulties between the pilots during the approach and landing into Jakarta, on the ground at Jakarta, and during the accident flight. The infrequent non-flight related conversations between the pilots were also cordial. It was concluded that the investigation did not find any evidence of difficulties in the relationship between the two pilots either during or before the accident flight.

[12] Amended based on suggestion in Appendix N.

- During their career in SilkAir, the PIC and the F/O received training in recovery from unusual flight attitudes. The PIC was a member of the RSAF "Black Knights" aerobatic team in the 1970s. The F/O was reported to be sought after as co-pilot by other SilkAir pilots who were undergoing command upgrade training. This training typically includes scenarios which require handling of system failures or other abnormal flight situations. Therefore both pilots were familiar with recovery from unusual flight attitudes.

2.13 Human Factors Aspects of the CVR and ATC Recordings

2.13.1 CVR

(a) The conversations and sounds recorded by the CVR before it stopped were examined. The CVR transcript (Appendix A) showed that at 09:04:57 the PIC indicated his intention to go to the passenger cabin, "go back for a while …. finish your plate….". At 09:05:02 the PIC offered water to the F/O, and at about the same time, several metallic snapping sounds were recorded. Thirteen seconds later, at 09:05:15.6 the CVR ceased recording. Analysis of the recording indicated that the metallic snapping sounds were made by a seatbelt buckle striking the floor. (See Section 1.16.2)

(b) During the period recorded by the CVR, all door openings or closings were related to pre-departure activities, in-flight meal service and normal pilot-cabin crew interaction. In the four minutes following the last meal service, there were no sounds associated with cockpit door opening or closing. After takeoff from Jakarta, conversations within the flight deck were between pilot-to-pilot, pilot-to-flight attendants, and normal pilot-to-ATC radio communications. During the flight, except for cabin attendants serving meals and drinks to the pilots, there were no indications of any other person(s) in the cockpit. It is concluded that after the last meal service and until the stoppage of the CVR, the recording did not reveal any indications that person(s) other than the flight crew and cabin attendants attending to their duties were in the cockpit.

(c) Analysis of the CVR stoppage indicated that the failure of the CVR could not have been caused by a short circuit or overload. This is because either occurrence would have resulted in the CVR recording a "pop" sound which was heard on the test recording but not on the accident recording.

The CVR in-flight tests could not identify the sound of the CVR circuit breaker being manually pulled as the ambient noise obscured the sound made. The accident tape did not contain any identifiable sound attributable to manual pulling of the CVR circuit breaker. It was not possible to determine from the CVR tests if there was a pulling out of the CVR circuit breaker.

2.13.2 ATC Recordings

The data transcribed from the ATC communications recording of the air-to-ground conversation indicates that at 09:10:26, or 5 minutes and 10.4 seconds after the CVR stoppage, the F/O acknowledged the "abeam Palembang" call from the ATC. The F/O was positively identified by voice analysis examination. This confirms that the F/O was in the cockpit when the aircraft was abeam Palembang. However, it is not possible to conclude whether the PIC was in the cockpit at the time. It was also not possible to determine events or persons present in the cockpit from the time of the last transmission to ATC.

The absence of a distress call could suggest that the pilots were preoccupied with the handling of an urgent situation. However, it is not possible to conclude on the reason for the absence of a distress call.

2.14 Specific Human Factors Issues

In this section, the specific, personal, financial backgrounds and recent behaviour of the PIC and the F/O are examined.

2.14.1 Personal Relationships

Evidence obtained from family and friends of both the PIC and F/O reported no recent changes or difficulties in personal relationships.

It was concluded there was no evidence that either pilot was experiencing difficulties in any personal relationships.

2.14.2 First Officer (F/O)

The investigation into the F/O's personal and professional history revealed no unusual issues. No records of incidents or unusual events were found, and no career setbacks or difficulties were experienced. Financial records showed no evidence of financial problems. Interviews with family, close friends and relations seem to indicate that the F/O was a well-balanced and well-adjusted person, and keen on his job, and planning to advance his a flying career. There were no reports on recent changes in his behaviour.

2.14.3 Pilot-in-Command (PIC)

The investigation into the personal and professional career revealed that the PIC was considered to have been a good pilot, making his transition from a military pilot to commercial pilot smoothly. His career at SilkAir showed that he was well accepted and given higher responsibilities. He was considered to be a leader among the Singaporean pilot community in SilkAir.

During his professional career at SilkAir, he was involved in a few work-related events, which were in general considered minor operational incidents by the management. However in one particular event, for non-technical reasons the PIC infringed a standard operating procedure, i.e. with the intention to preserve a conversation between the PIC and his copilot, the PIC pulled out the CVR circuit breaker, but the PIC reset the circuit breaker in its original position before the flight. This was considered a serious incident by the management, and the PIC was relieved of his LIP appointment. The PIC was known to have tried through existing company procedures to reverse the management decision. Although there were some indications of the PIC being upset by the outcome of the events, the magnitude of the psychological impact on the PIC performance could not be determined.

The PIC's financial history was investigated for the period from 1990-1997. Based on the data available to the NTSC it was noted that the PIC's accumulated losses in share trading increased between 1993 and 1997, with moderate gains in 1997. There was no period of negative net worth. His trading activity was stopped on two occasions due to non-settlement of his share trading debt.

In the independent review of the NTSC's findings concerning financial background of the PIC by PricewaterhouseCoopers, the available information in regard to the assets, liabilities, income, expenditure, and share trading were incorporated into a net worth analysis. This analysis reveals the following:

- The PIC's net worth (known assets less known liabilities) deteriorated over the period of 1994 to 1996, however it grew marginally during 1997.
- Between 31 December 1994 and 31 December 1996 his known assets declined, while his known liabilities increased resulting in a net decline in the value of the PIC's known net worth.
- Between 31 December 1996 and 19 December 1997, the PIC's known net worth increased again.

Analysis of the net monthly income available for discretionary and general out-of-pocket expenses, based on a monthly combined gross income (including the PIC and his wife's salaries), indicated that the PIC had a relatively minor monthly cash shortfall at around the time of the accident. This should be considered in light of the PIC's positive net worth at the time of the accident.

2.14.3.1 Recent Behaviour

The PIC's recent behaviour was analysed from statements made by family members, friends and peers during interviews. The PIC's family reported no recent changes in his behaviour. Work associates who observed the PIC on the day of the accident and on his most recent flights, reported nothing odd or unusual in his behaviour.

2.14.3.2 Insurance

Based on the data available, it was found that at the time of the accident, the PIC had a number of life insurance policies. The majority of these were taken up earlier in his life. The most recent policy was a mortgage policy which was required by the financial institution from which he took the loan for his house in line with normal practice for property purchases in Singapore. The PIC applied for the mortgage policy on 27 November 1997. The insurance company approved the policy on 12 December 1997 pending payment of the first premium. The PIC submitted a cheque dated 16 December 1997 for the first premium payment. The commencement or the inception date of the policy was set by the insurance company to be 19 December 1997. This information was not conveyed to the PIC. The cheque was cleared on 22 December 1997. From the data available to the NTSC there was no evidence to indicate if this mortgage policy has any relevance to the accident.

2.14.3.3 Overall Comments on the Pilot-in-Command

NTSC concluded that the combination of financial situation and his work related events could be stressors on the PIC. However, NTSC could not determine the magnitude of these stressors and its impact on the PIC's behaviour.

3 CONCLUSIONS

3.1 Findings

Engineering and Systems

- There was no evidence found of in-flight fire or explosion.
- From flutter analysis and wreckage distribution study, the empennage break-up could have occurred in the range between 5,000 and 12,000 feet altitude.
- Examination of engine wreckage indicated that the conditions of the engines at impact were not inconsistent with high engine rotation speed. No indications were found of in-flight high energy uncontained engine failures. Therefore, the engines were considered to be not a factor contributing to the accident.
- Examination of the actuators of flight and ground spoilers, trailing and leading edge flaps, as well as engine thrust reversers indicate retracted or stowed positions of the respective systems.
- Examination of the main rudder power control unit (including the servo-valve), the yaw damper modulating piston, the rudder trim actuator, the rudder trim and feel centering unit, the standby rudder PCU, the aileron PCUs, the elevator PCUs, and the horizontal stabilizer jack-screw components, revealed no indications or evidence of pre-impact malfunctions.
- Examination of the 370 kg of recovered electrical wires, connectors and circuit boards showed no indication or evidence of corrosion, shorting, burning or arcing in these wires or parts.
- The CVR stopped recording at 09:05:15.6 and the FDR stopped recording at 09:11:33.7. The examination of the CVR and FDR showed no malfunction of the units. The stoppages could be attributed to a loss of power supply to the units. However, there were no indications or evidence found to conclude on the reason for the stoppages due to the loss of power. The cause of the CVR and FDR stoppages and the reason for the time difference between the stoppages could not be concluded.
- The inspection of the aircraft maintenance records did not reveal any defects or anomalies that could have affected the airworthiness of the aircraft or that may have been a factor contributing to the accident.
- The horizontal stabilizer trim was found to be in the 2.5 units position which matched the forward limit of the manual electrical trim.

Flight Operations

- Weather and Air Traffic Control were not factors contributing to the accident.
- Audio spectral analyses on Air Traffic Control communications and the accident CVR indicate that the last communication from the MI 185 at 09:10:26, occurring at a position approximately abeam Palembang was performed by the F/O.
- The examination of the flight deck noise and sounds concludes that the metallic snap recorded on the CVR was made by a seatbelt buckle hitting against a metal surface.

- Based on flight simulations, it was observed that the simulated descent trajectory resulting from any single failure of flight control or autopilot system would not match the radar data.
- Based on the same flight simulations, it was also observed that the trajectory shown by the radar data could have been, among other possibilities, the result of the combination of lateral and longitudinal inputs together with the horizontal stabilizer trim input to its forward manual electrical trim limit of 2.5 units.

Human Factors

- Both pilots were properly trained, licensed, and qualified to conduct the flight.
- There was no evidence found to indicate that the performance of either pilot was adversely affected by any medical or physiological condition.
- Interviews with respective superiors, colleagues, friends and family revealed no evidence that both the flight crew members had changed their normal behaviour prior to the accident.
- There was no evidence found to indicate that there were any difficulties in the relationship between the two pilots either during or before the accident flight; or had been experiencing noteworthy difficulties in any personal relationships (family and friends).
- Until the stoppage of the CVR, the pilots conducted the flight in a normal manner and conformed to all requirements and standard operating procedures.
- Although a flight attendant had been in the cockpit previously, after the last meal service and until the stoppage of the CVR there was no indication that anyone else was in the cockpit other than the two pilots.
- In the final seconds of the CVR recording the PIC voiced his intention to leave the flight deck, however there were no indications or evidence that he had left.
- Interviews and records showed that in 1997 the PIC had experienced a number of flight operations related events, one of which resulted in his being relieved of his LIP position.
- The PIC was involved in stock-trading activities, but no conclusions could be made indicating that these activities had influenced his performance as a pilot.
- From the data available to the NTSC there was no evidence found to indicate if the mortgage policy taken out by the PIC in connection with his housing loan has any relevance to the accident.

3.2 Final Remarks

- The NTSC investigation into the MI 185 accident was a very extensive, exhaustive and complex investigation to find out what happened, how it happened, and why it happened. It was an extremely difficult investigation due to the degree of destruction of the aircraft resulting in highly fragmented wreckage, the difficulties presented by the accident site and the lack of information from the flight recorders during the final moments of the accident sequence.

- The NTSC accident investigation team members and participating organizations have done the investigation in a thorough manner and to the best of their conscience, knowledge and professional expertise, taking into consideration all available data and information recovered and gathered during the investigation.
- Given the limited data and information from the wreckage and flight recorders, the NTSC is unable to find the reasons for the departure of the aircraft from its cruising level of FL350 and the reasons for the stoppage of the flight recorders.
- The NTSC has to conclude that the technical investigation has yielded no evidence to explain the cause of the accident.

4 RECOMMENDATION

Recommendations to manufacturers

- It is recommended that the ICAO FLIREC Panel undertake a comprehensive review and analysis of flight data recorders and cockpit voice recorders systems design philosophy be undertaken by aircraft and equipment manufacturers. The purpose of the review and analysis would be to identify and rectify latent factors associated with stoppage of the recorders in flight, and if needed, to propose improvements to ensure recording until time of occurrence.
- It is recommended that, to facilitate the recovery of flight recorders after impact into water, a review of the flight recorders design philosophy be undertaken by the equipment manufacturers to ensure that the underwater locator beacons (ULB) are fitted to the flight recorders in such a manner that the ULB would not be separated from the recorders in an accident.
- It is recommended that the ICAO FLIREC Panel recommend aircraft and equipment manufacturers to include recording of actual displays as observed by pilots in particular for CRT type of display panels.
- It is recommended that a review of the flight crew training syllabi be undertaken by aircraft manufacturers to include recovery from high speed flight upsets beyond the normal flight envelope. The purpose of developing the additional training is to enhance pilot awareness on the possibility of unexpected hazardous flight situations.
- It is recommended that a review of aircraft auto-flight systems be undertaken by aircraft and equipment manufacturers to provide all passenger aircraft with auto flight systems that could prevent an aircraft from flying beyond the high speed limit of its flight envelope. It is also recommended that such auto flight systems limit the rate of descent of the aircraft to a certain value that operationally safe.

General recommendation

- It is recommended that a regional investigation framework for co-operation in aircraft accident investigations be established to enable fast mobilization of resources and coordination of activities to support those states that do not have the resources and facilities to do investigations on their own.

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11. *Chemical Analysis of SilkAir Investigation Sample*, Analytical Engineering Report, No. 9-5576-WP-98-195, 27 August 1998
12. *Wreckage Trajectory Studies*, BASI Report, 16 April 1998
13. NTSB Report DCA98RA013, 27 April 1999
14. *Structures Analysis of Empennage Failure*, NTSB Report DCA-98-RA-013, 2 May 1999
15. SilkAir Flight Administration Manual + Organization Diagram
16. B737 Rudder Conference, April 1997
17. B737 Training Manual on Stabilizer Trim Unit
18. Cassandra Johnson, *Recorded Radar Study*, Specialist’s Report of Investigation, NTSB Report DCA98RA013, 2 November 1998.

Figure 1a - Route from Jakarta to Singapore over Sumatra, Indonesia

Figure 1b - Route from Jakarta to Singapore over South Sumatra, Indonesia

Figure 1c - Route over Palembang, Sumetera Selatan Province, Indonesia (Crash Site)

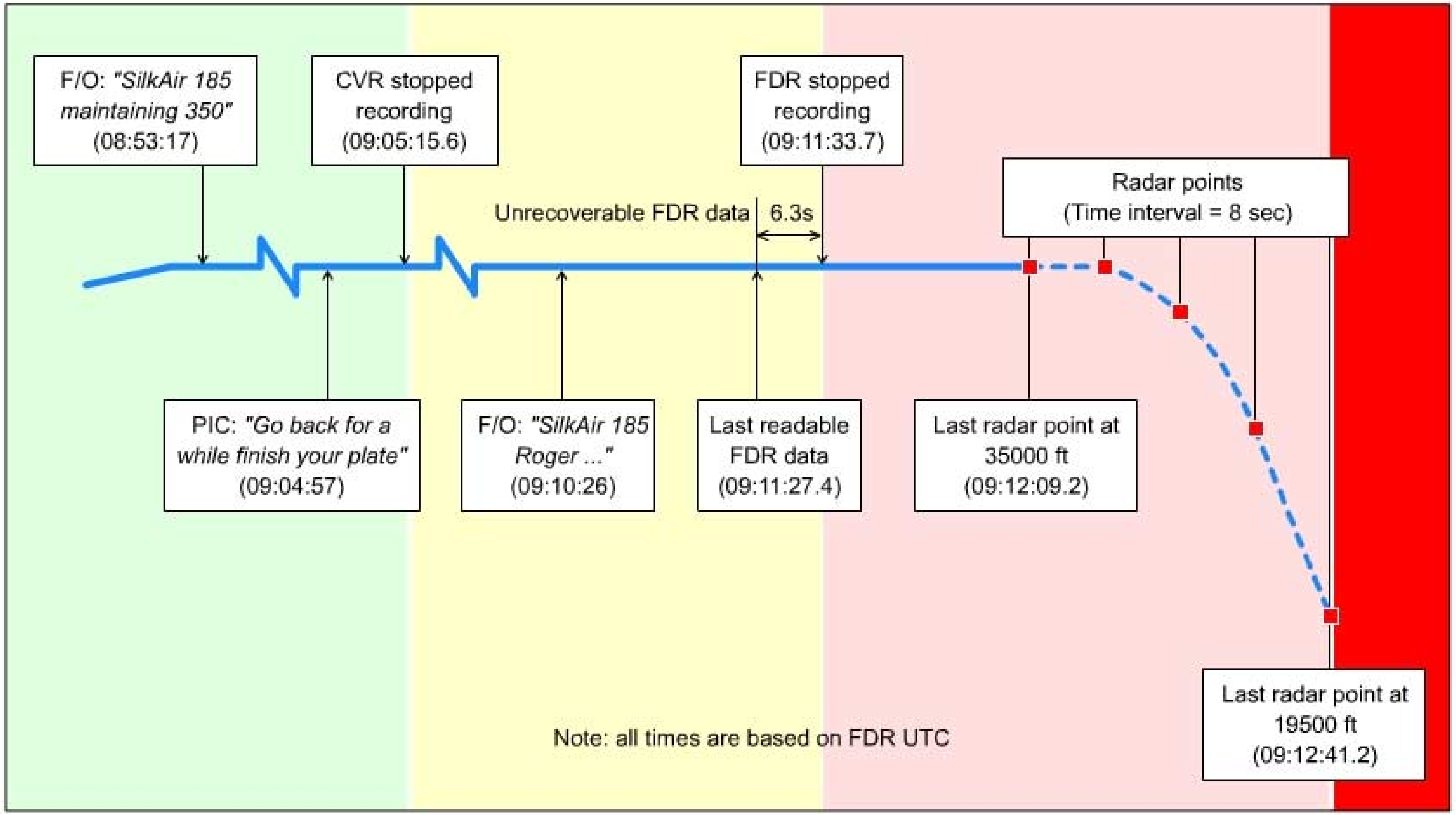


Figure 2 - Sequence of Events

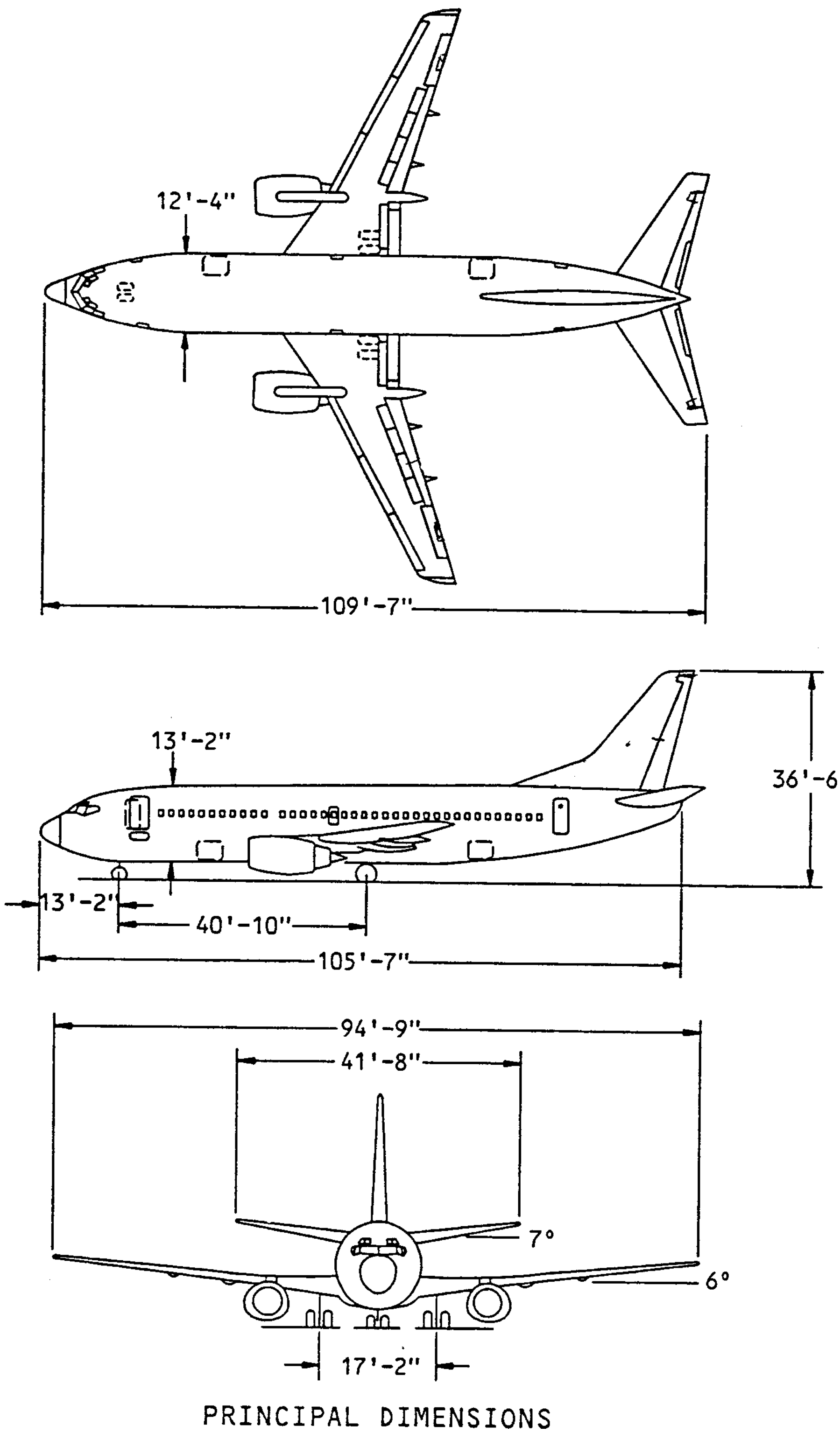


Figure 3 Boeing B737-300 – Three view drawing

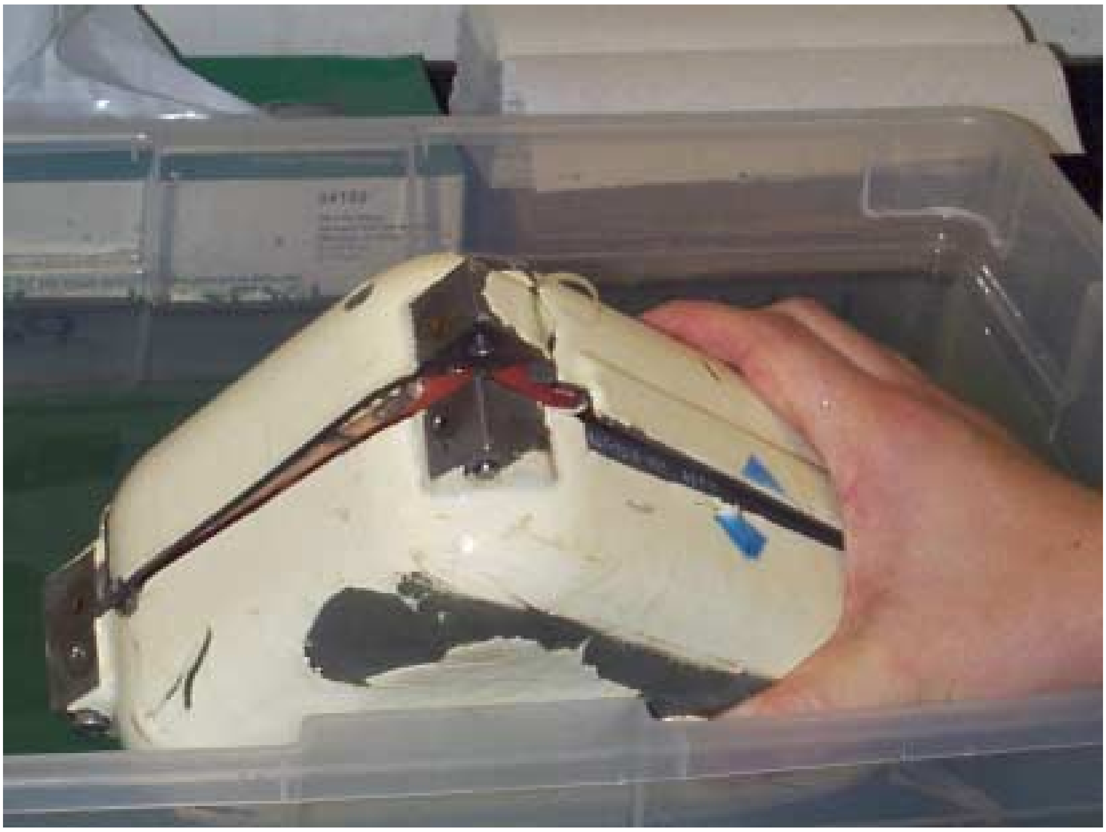


Figure 4.a Flight Data Recorder with an opening corner

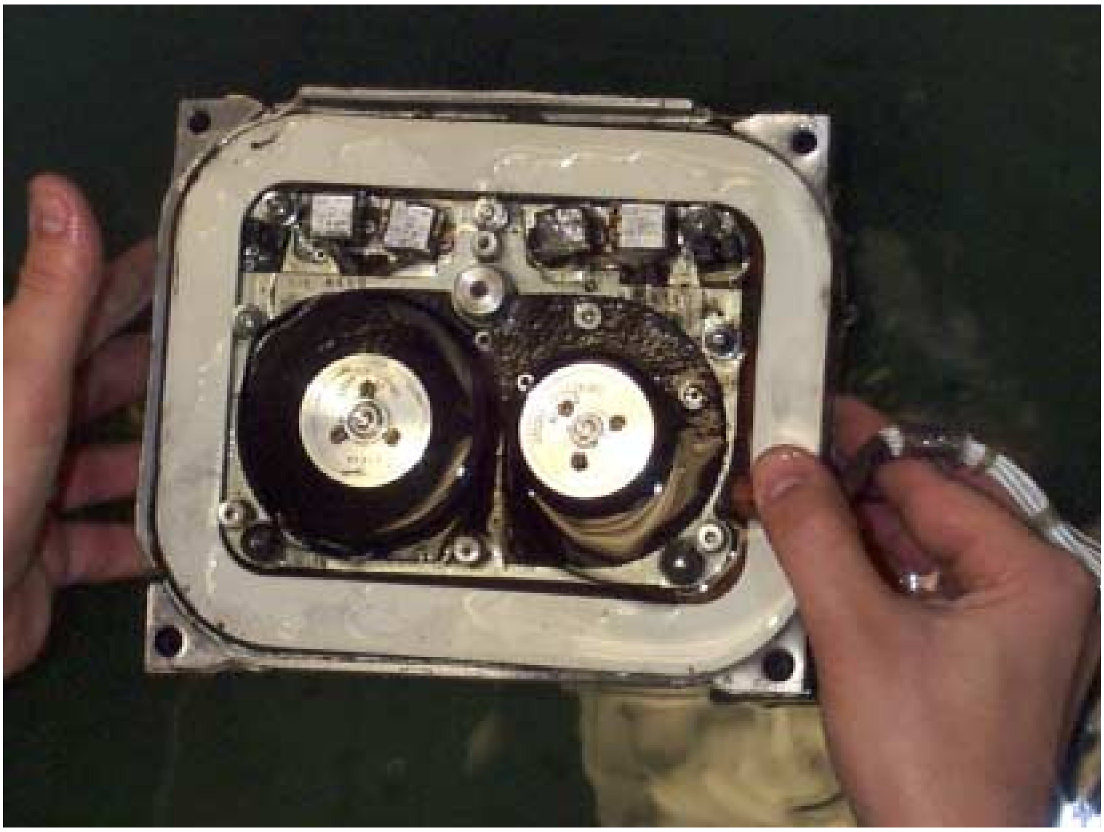


Figure 4.b The tape inside FDR

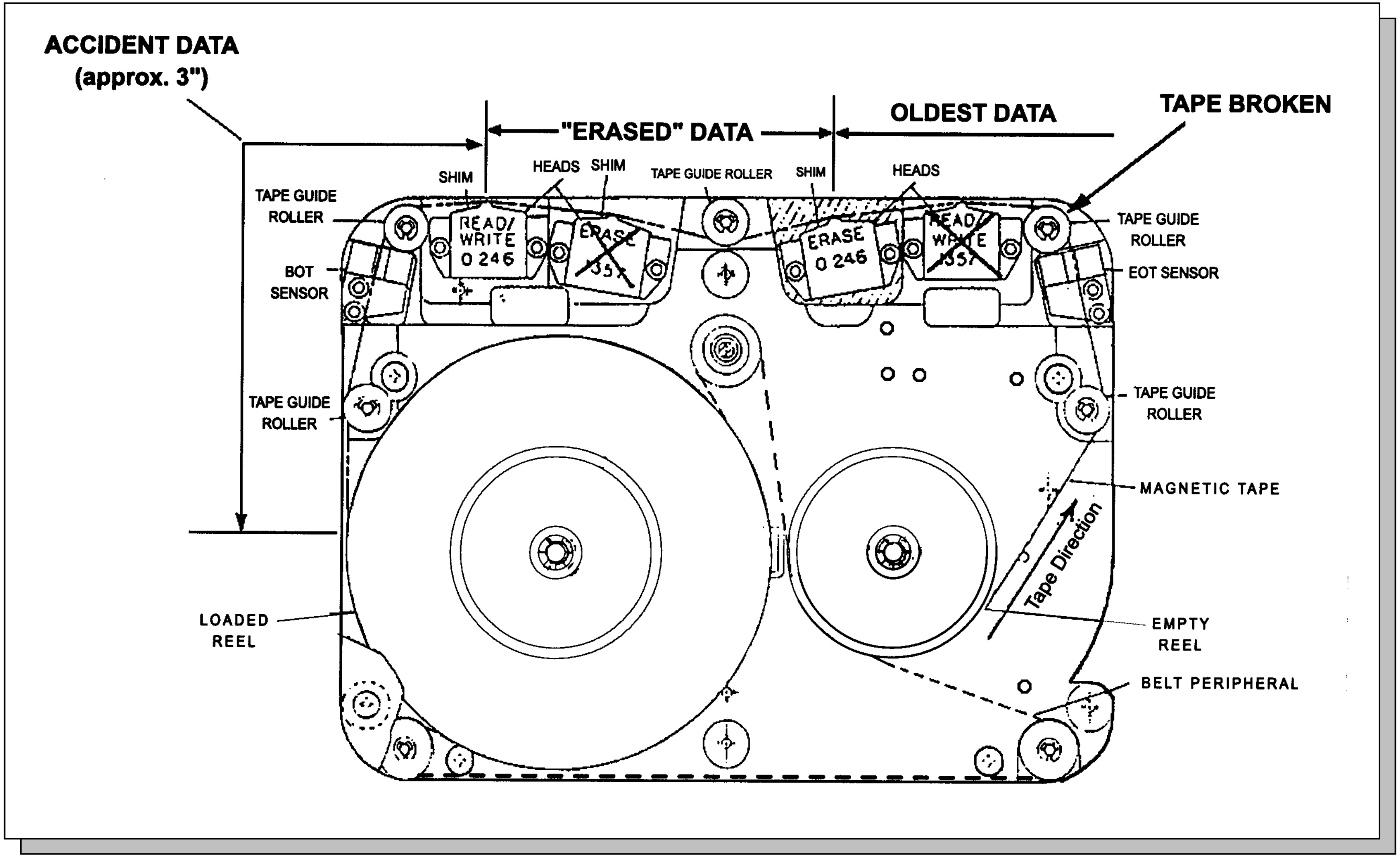


Figure 4.c Sketch of FDR tape layout

Figure 5.a Solid State CVR Module immersed in the river water

Figure 5.b Memory module of the Solid State CVR

Figure 6.a Early stage of debris recovery (by divers)

Figure 6.b Debris recovery using dredge

Legend:

A	**Engine parts**
B	**Tail sections**
C	**Wing sections**
D	**Fuselage parts**
E	**Human remains**
F	**Documents**
H	**Cockpit Voice Recorder (CVR)**
I	**Avionics equipment/parts**

Figure 6.c Sonar photo of the debris distribution buried in the river bottom

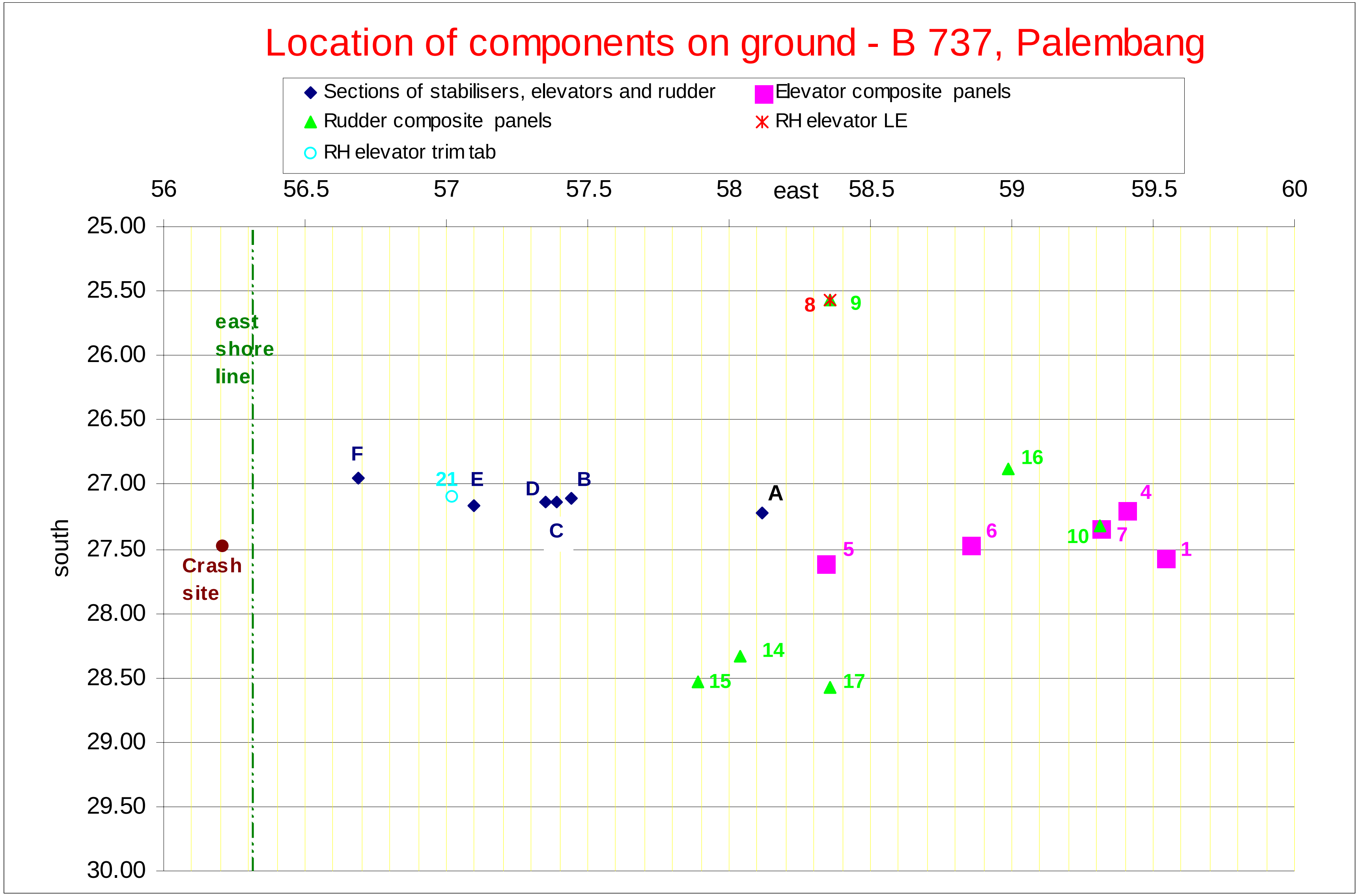


Figure 7 Sketch of the wreckage pieces found on land

(a)

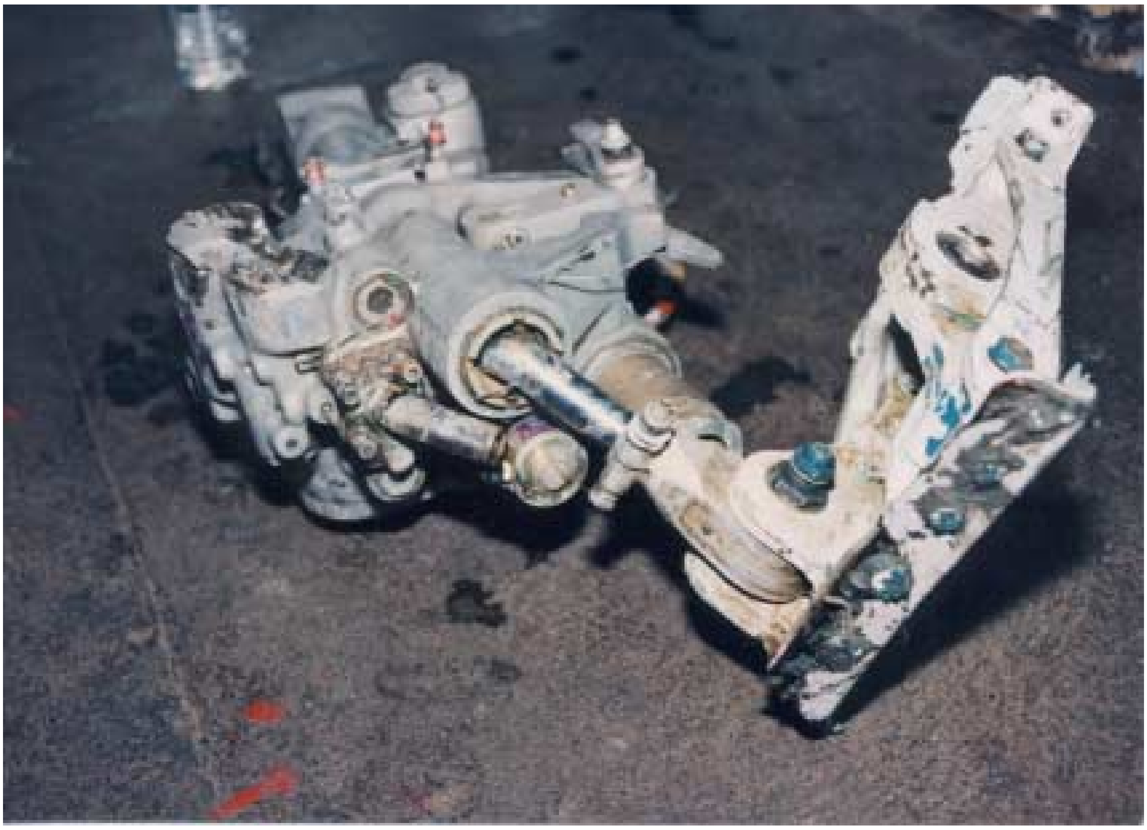
(b)

Figure 8 Picture of the wreckage recovered from the river

(c)

(d)

Figure 8 Picture of the wreckage recovered from the river (continued)



(e)

(f)

Figure 8 Picture of the wreckage recovered from the river (continued)

(g)

(h)

Figure 8 Picture of the wreckage recovered from the river (continued)

(a)

(b)

Figure 9 Picture of wreckage of the fuselage skin patch repair

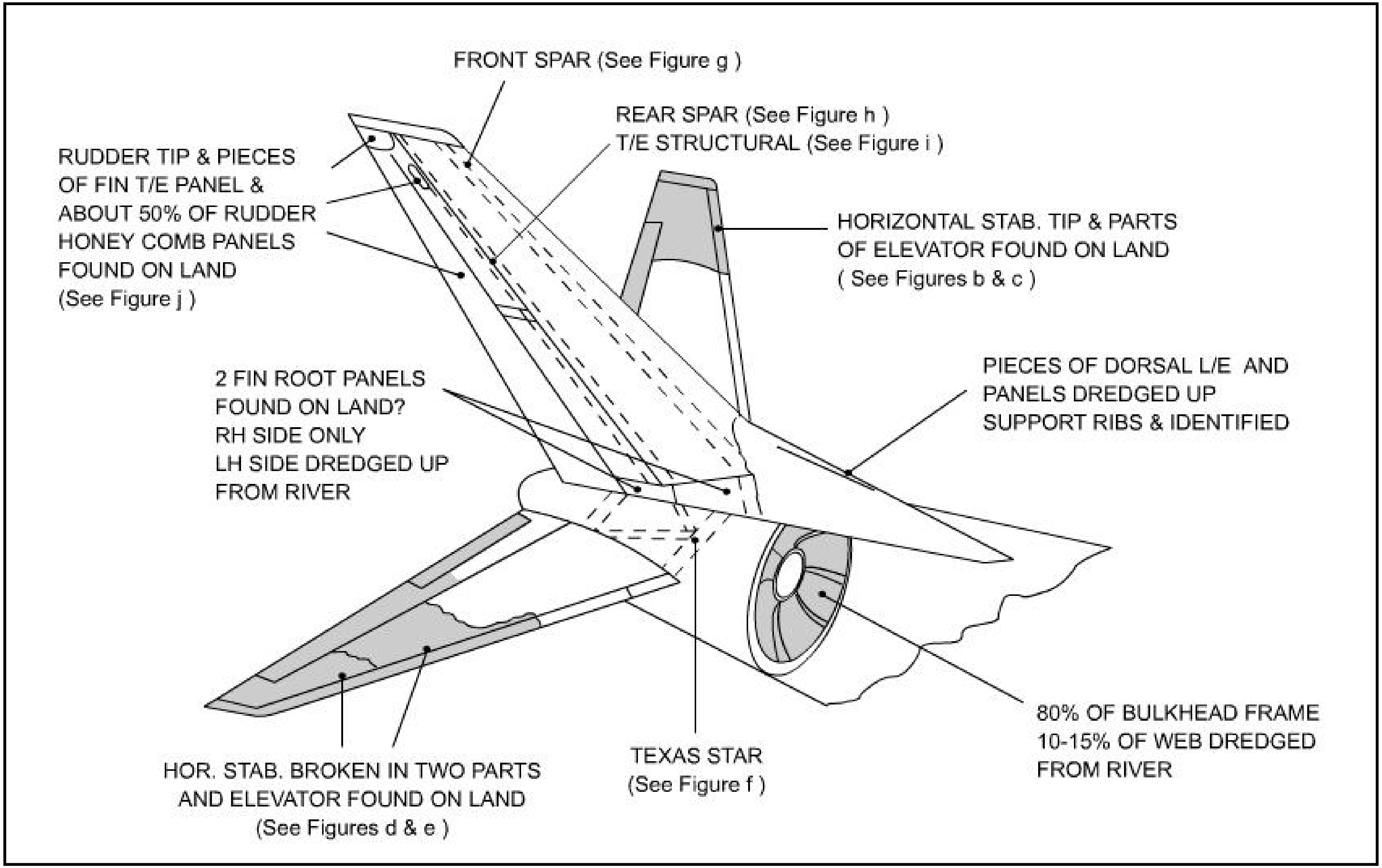


Figure 10.a Section 48 and Empennage

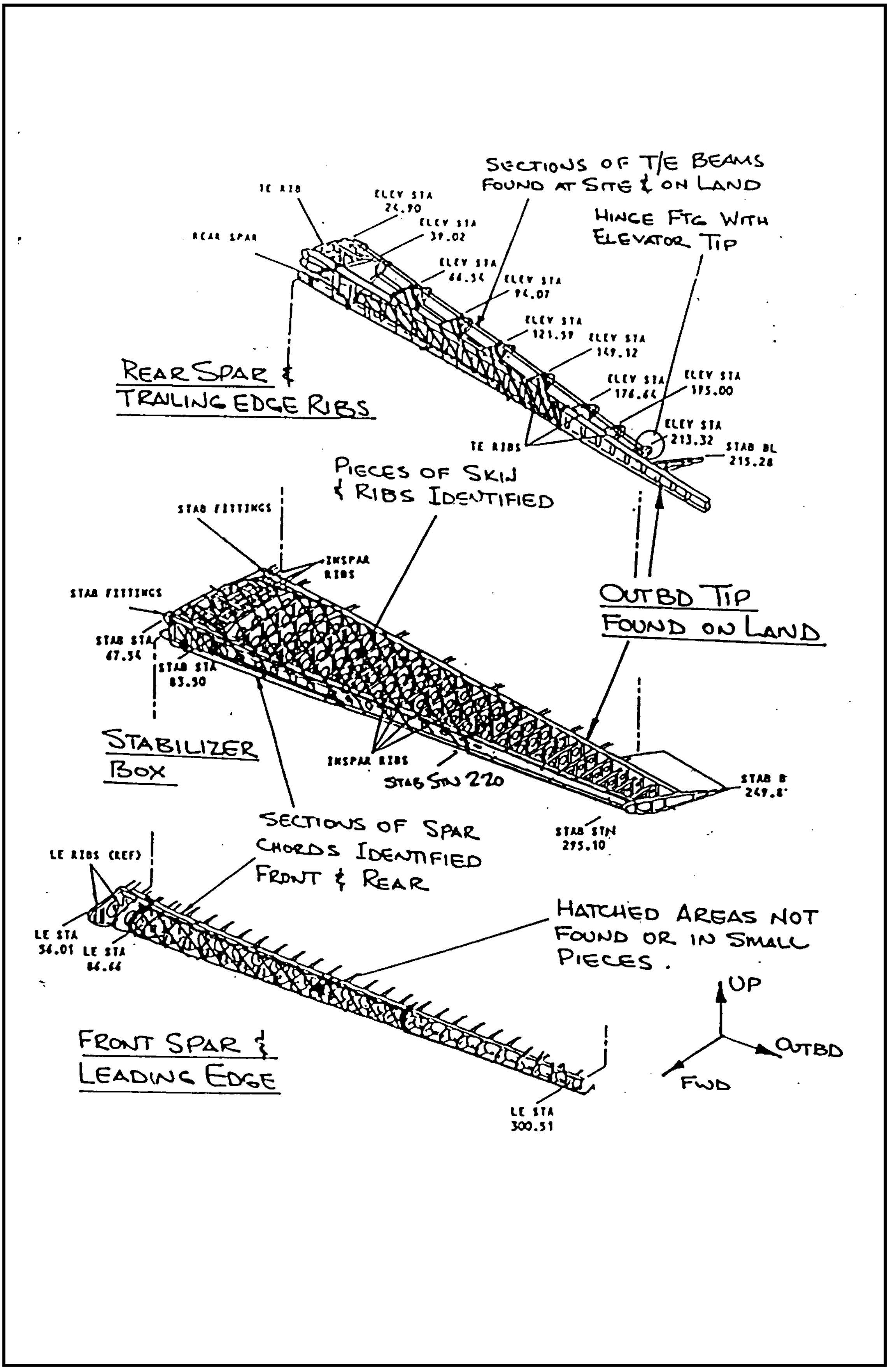


Figure 10.b Horizontal Stabilizer L.H. Side

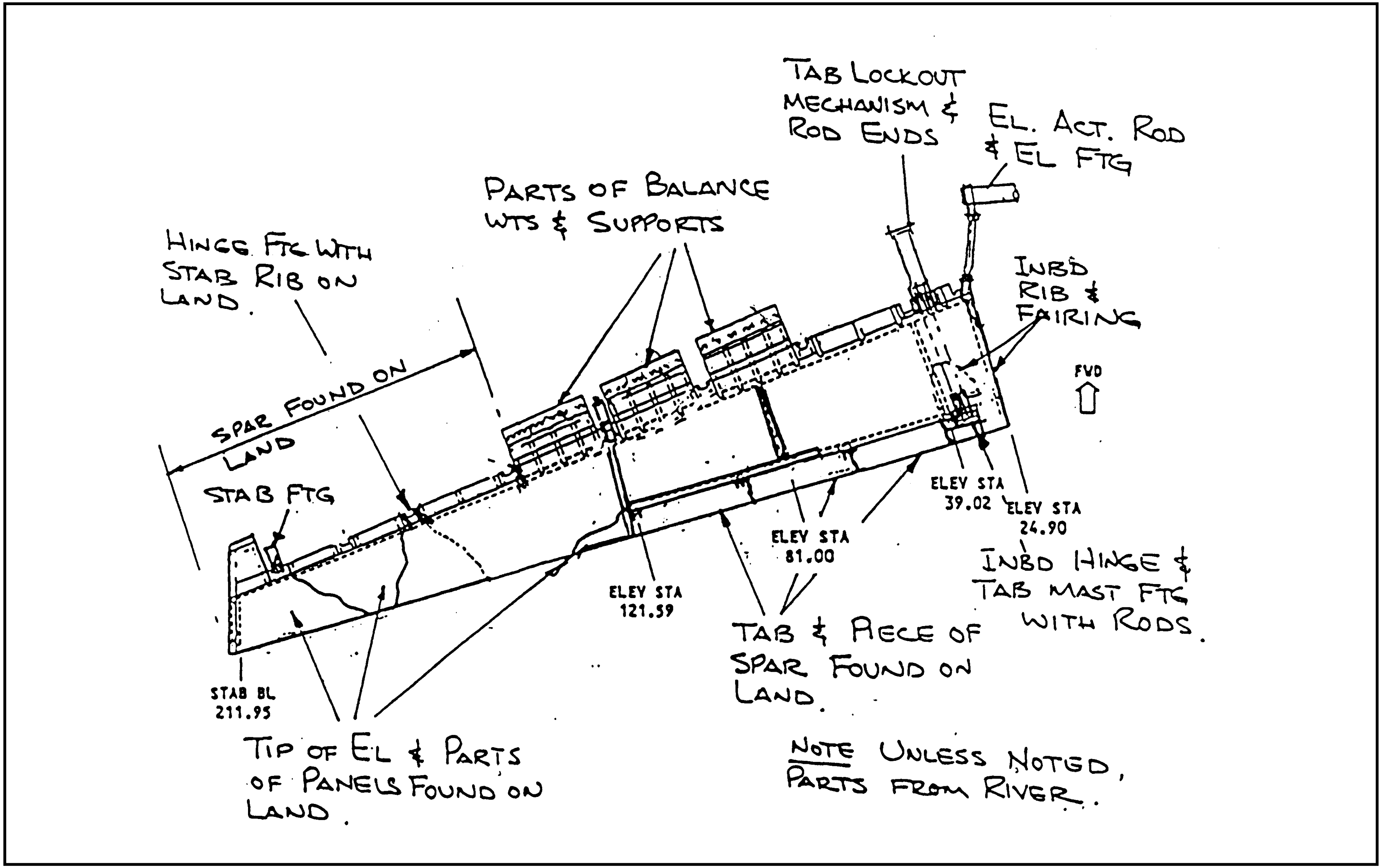


Figure 10.c L.H. Side Elevator

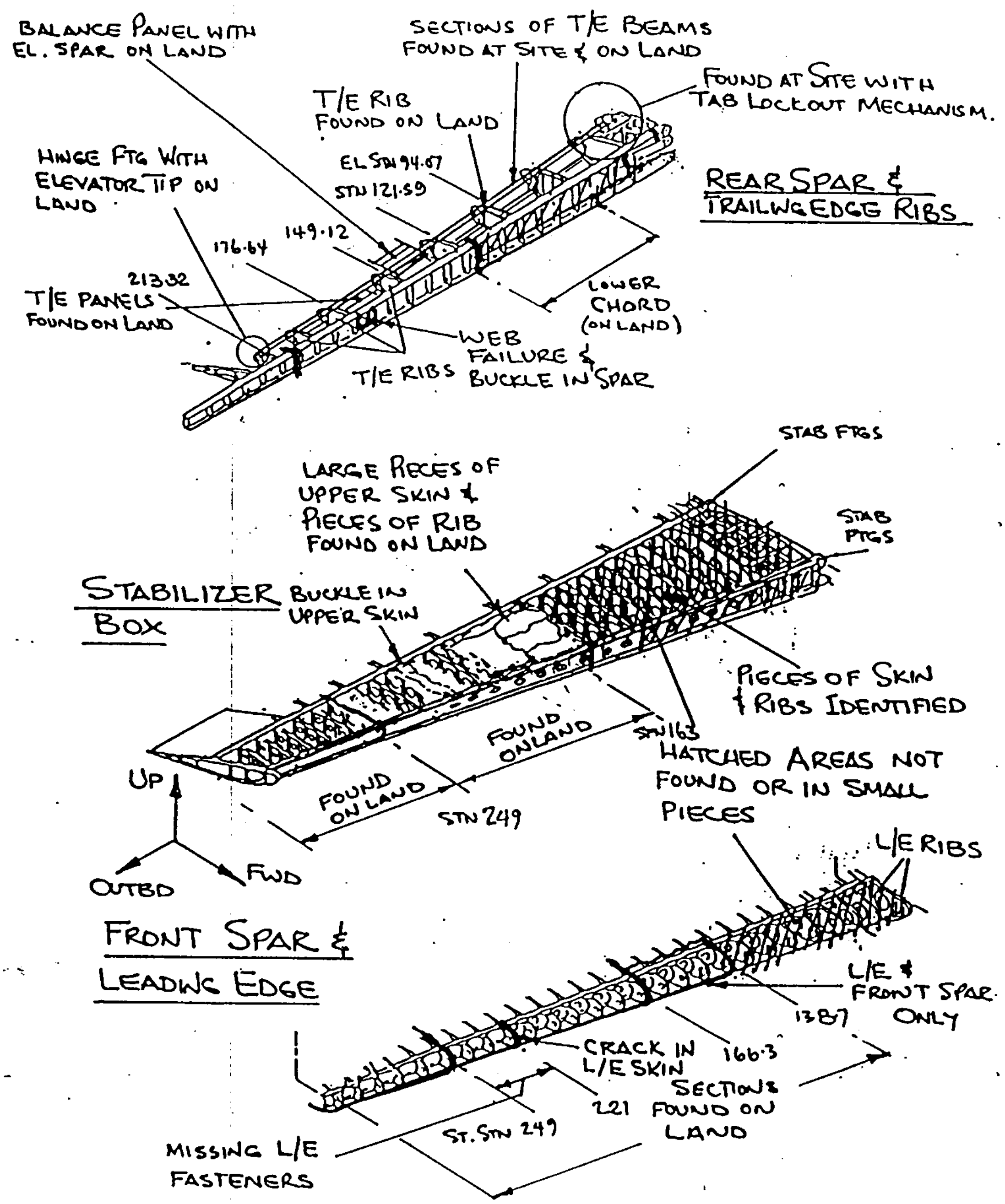


Figure 10.d Horizontal Stabilizer R.H. Side

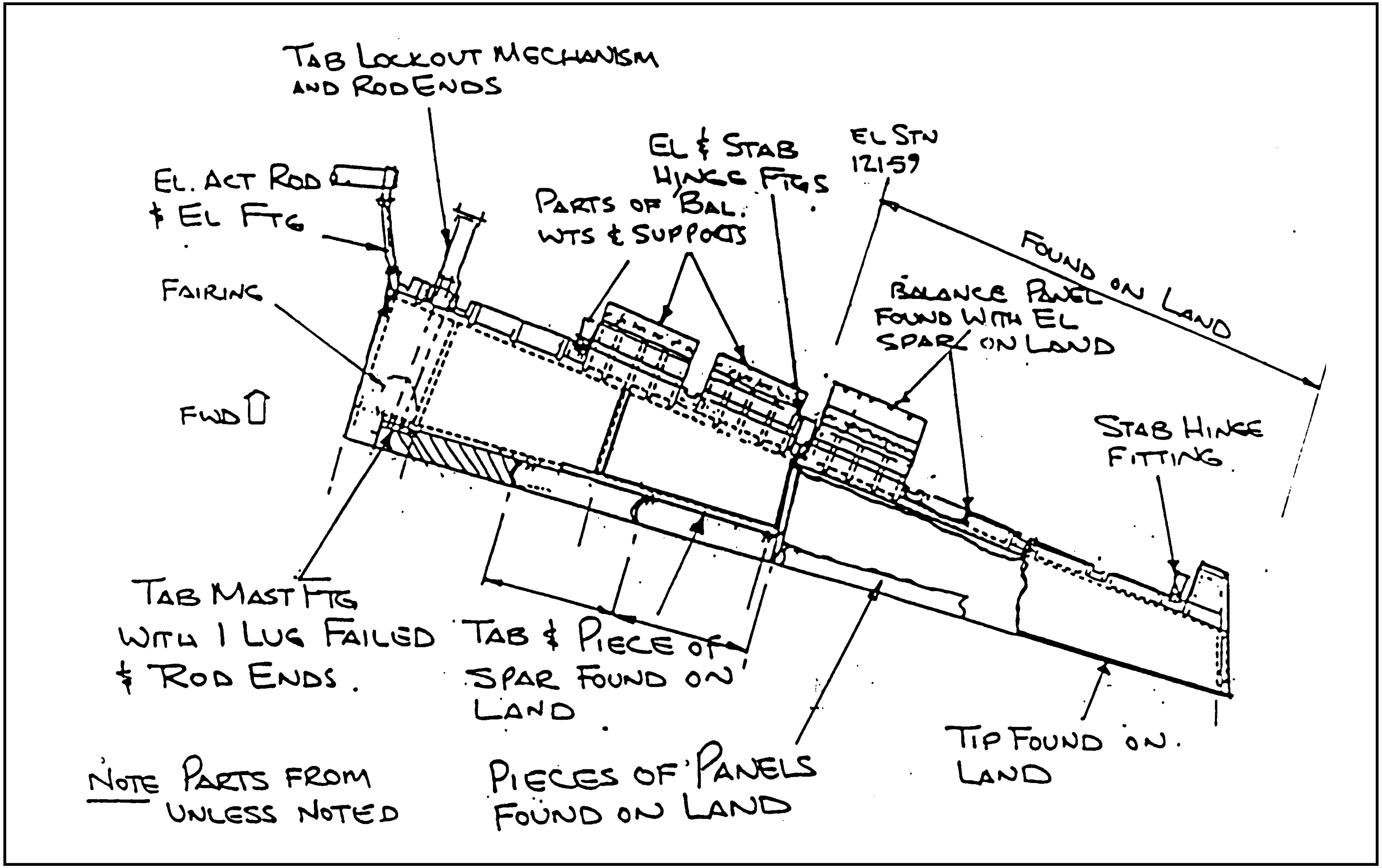


Figure 10.e R.H. Side Elevator

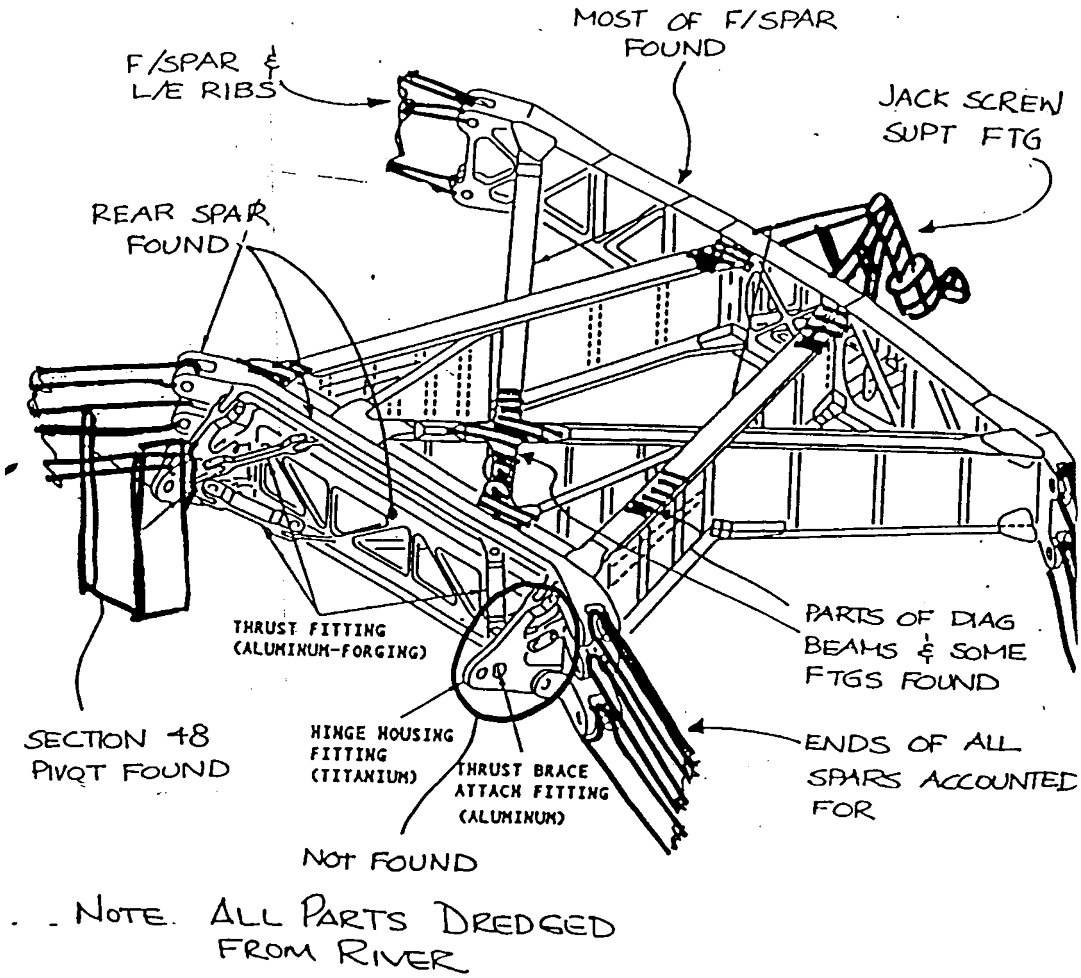


Figure 10.f Horizontal Stabilizer Center Section

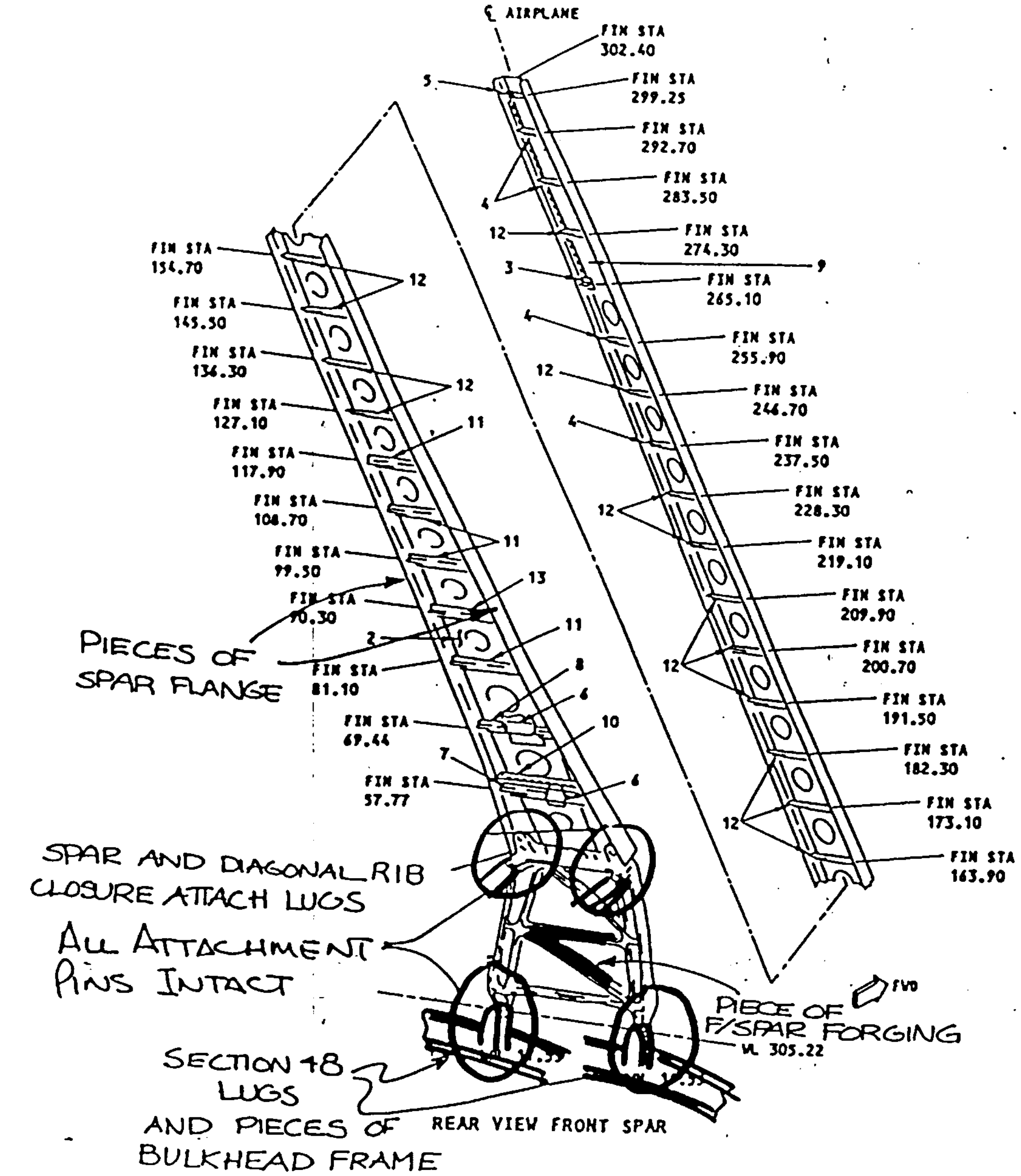


Figure 10.g Front Spar Vertical Stabilizer

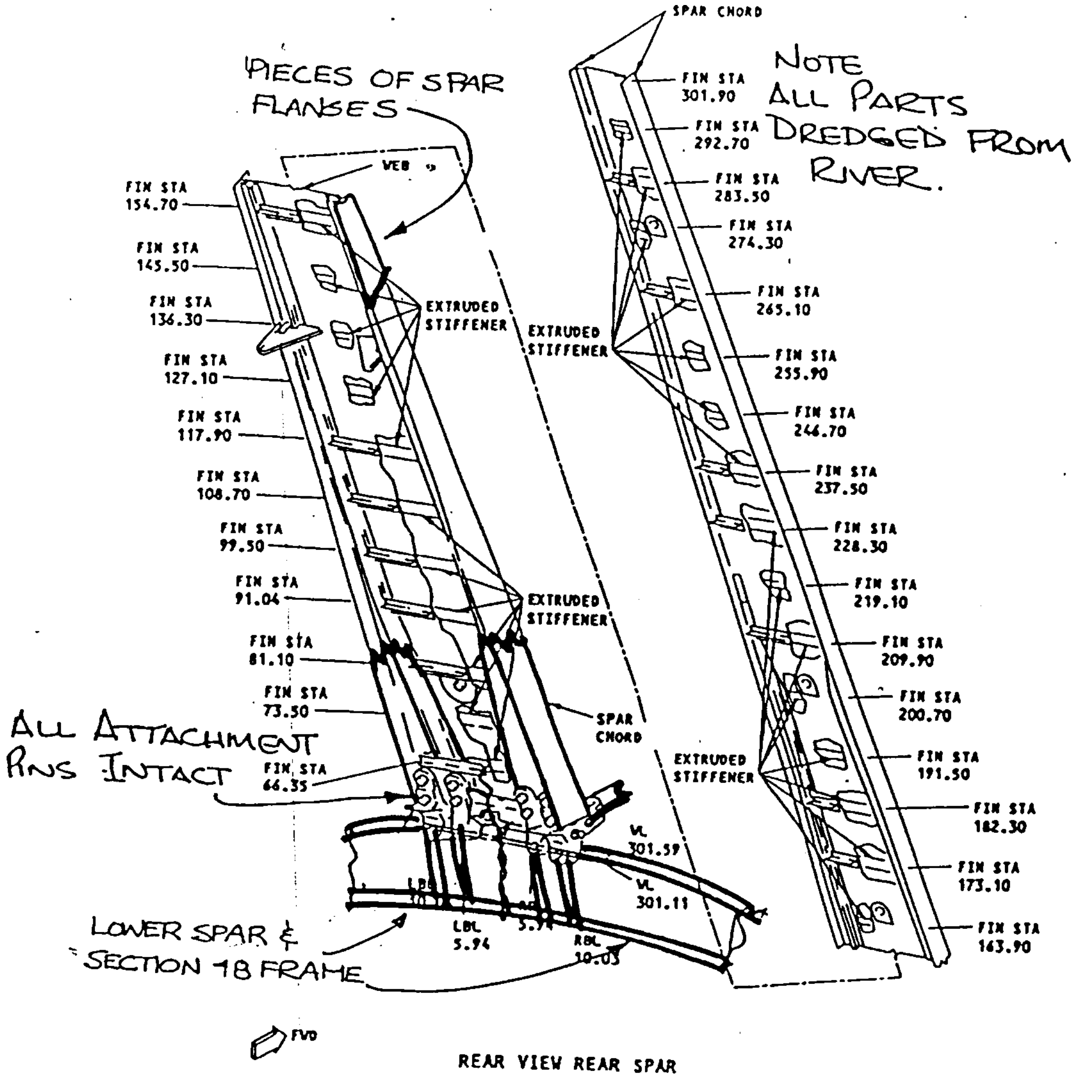


Figure 10.h Rear Spar Vertical Stabilizer

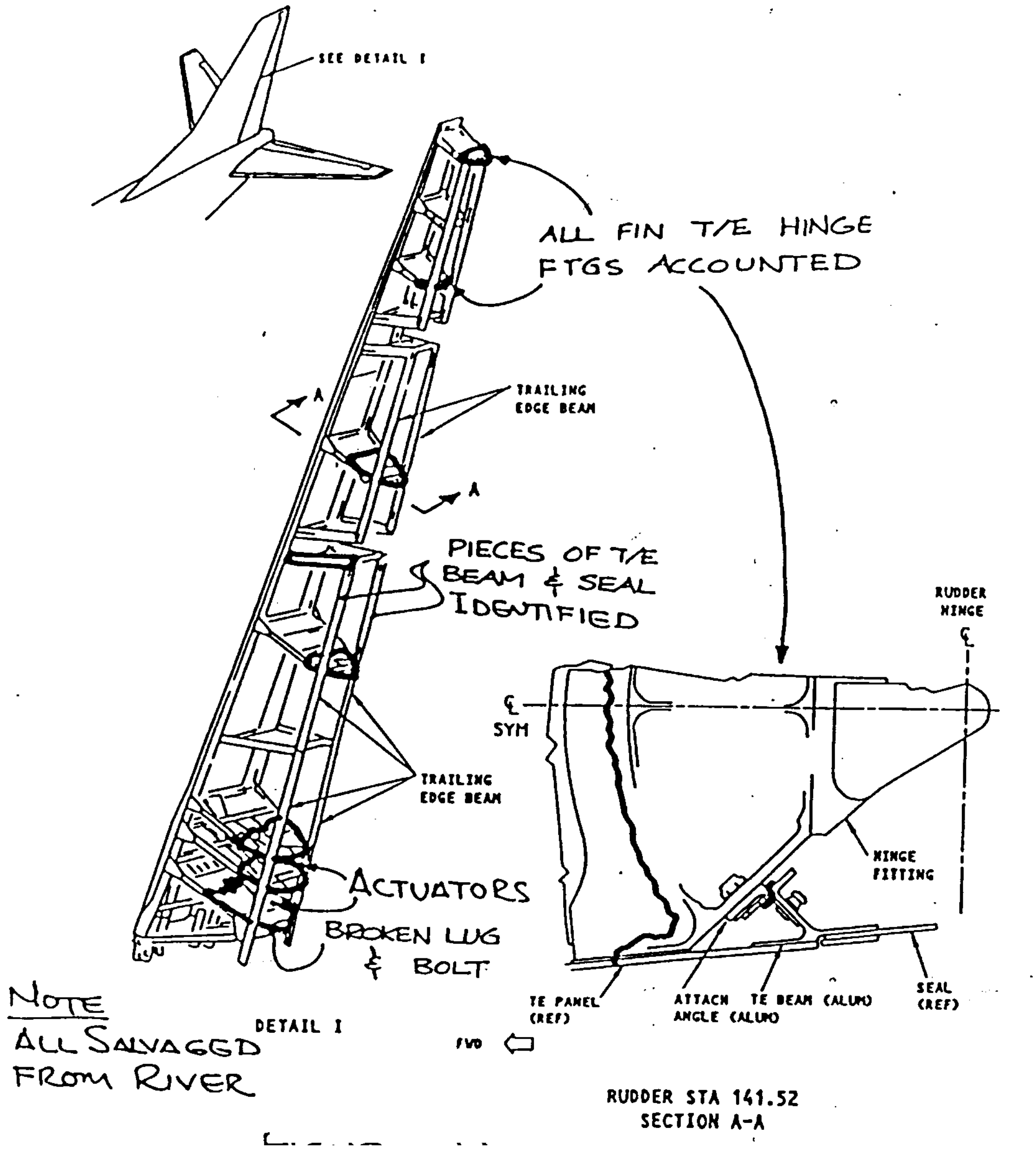


Figure 10.i Trailing Edge Beam Vertical Stabilizer

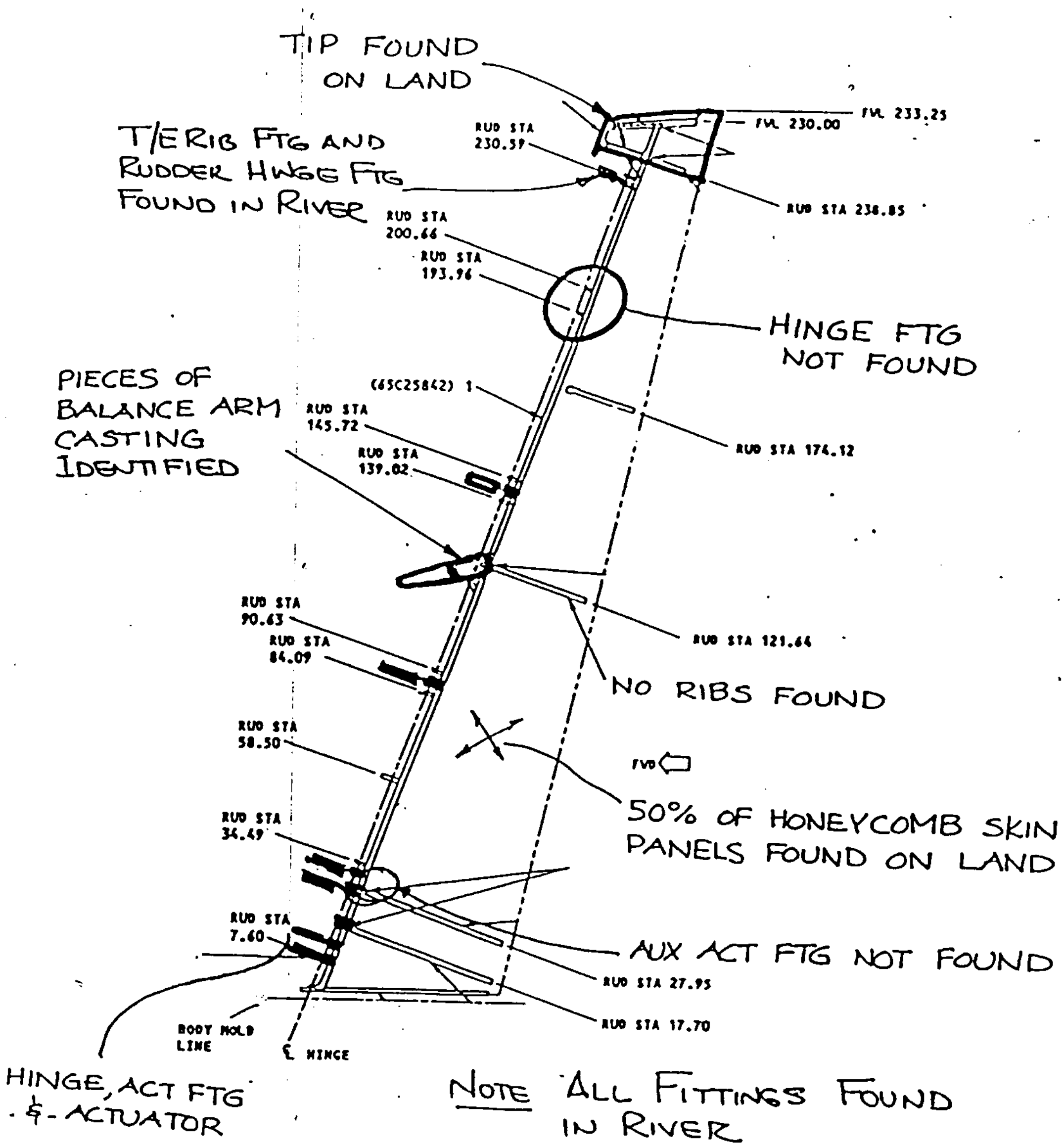
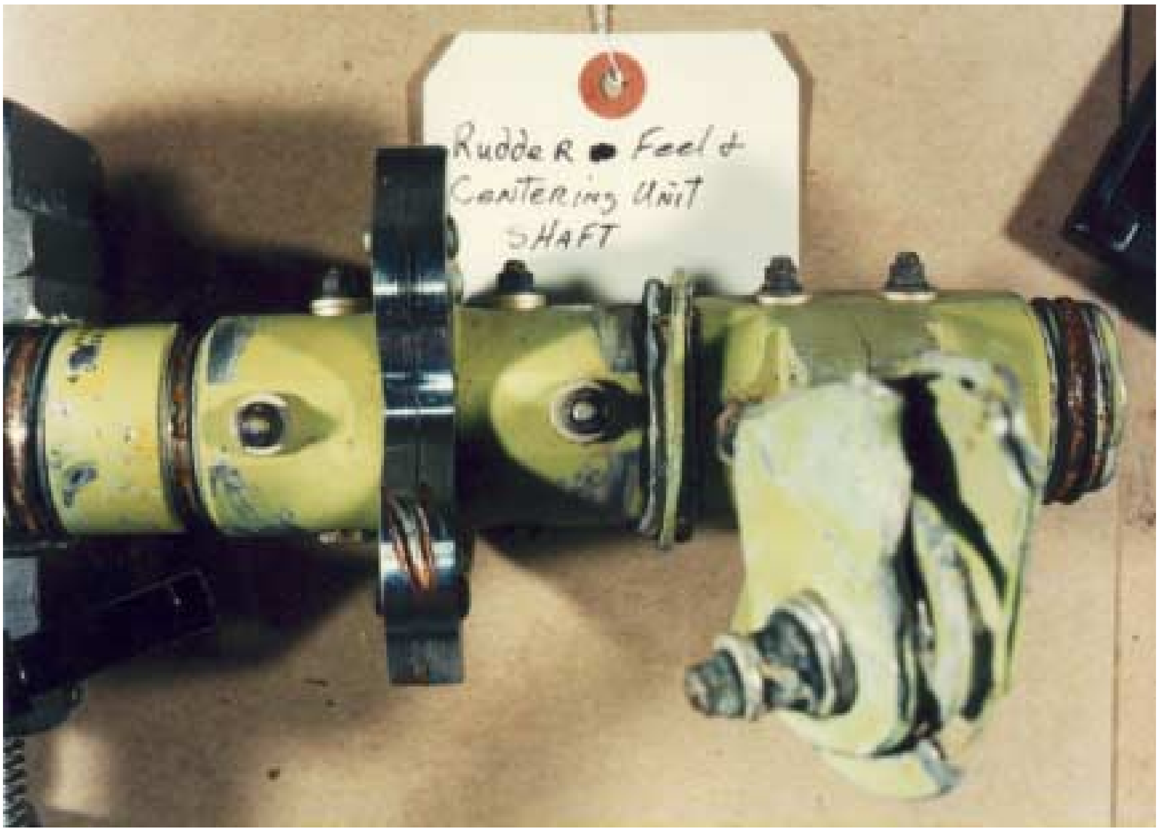


Figure 10.j Rudder Honeycomb Panels

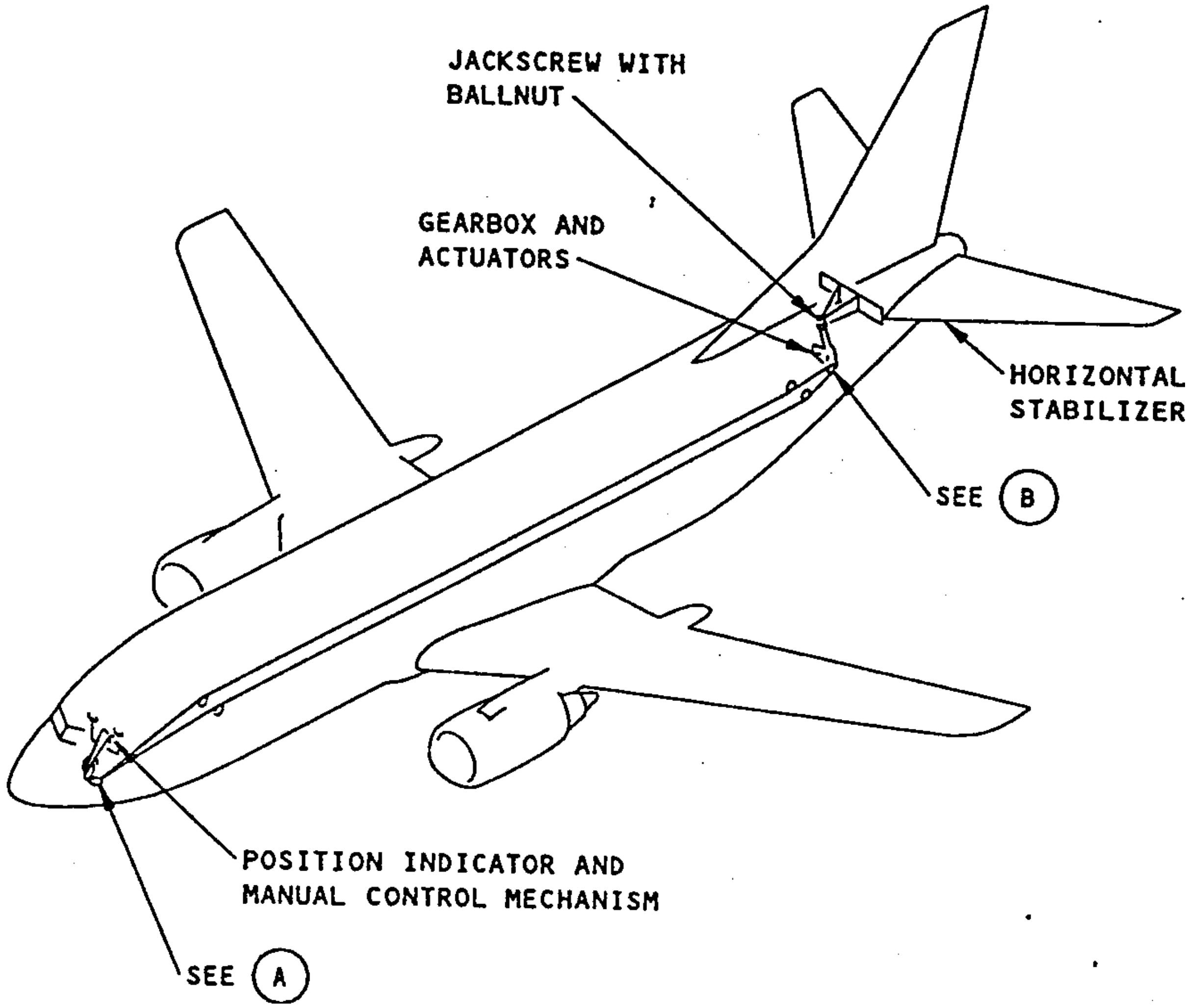
Figure 11 Picture of the reconstructed empennage



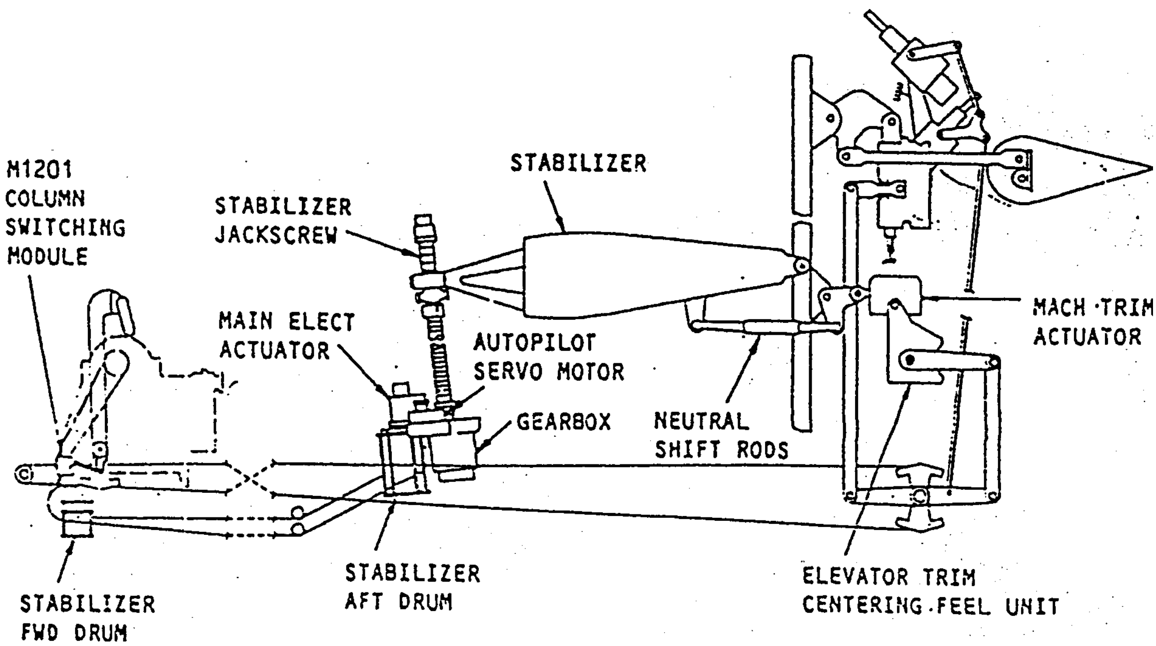
(a)

(b)

Figure 12 Picture of the impact marks at the cam feel centering unit

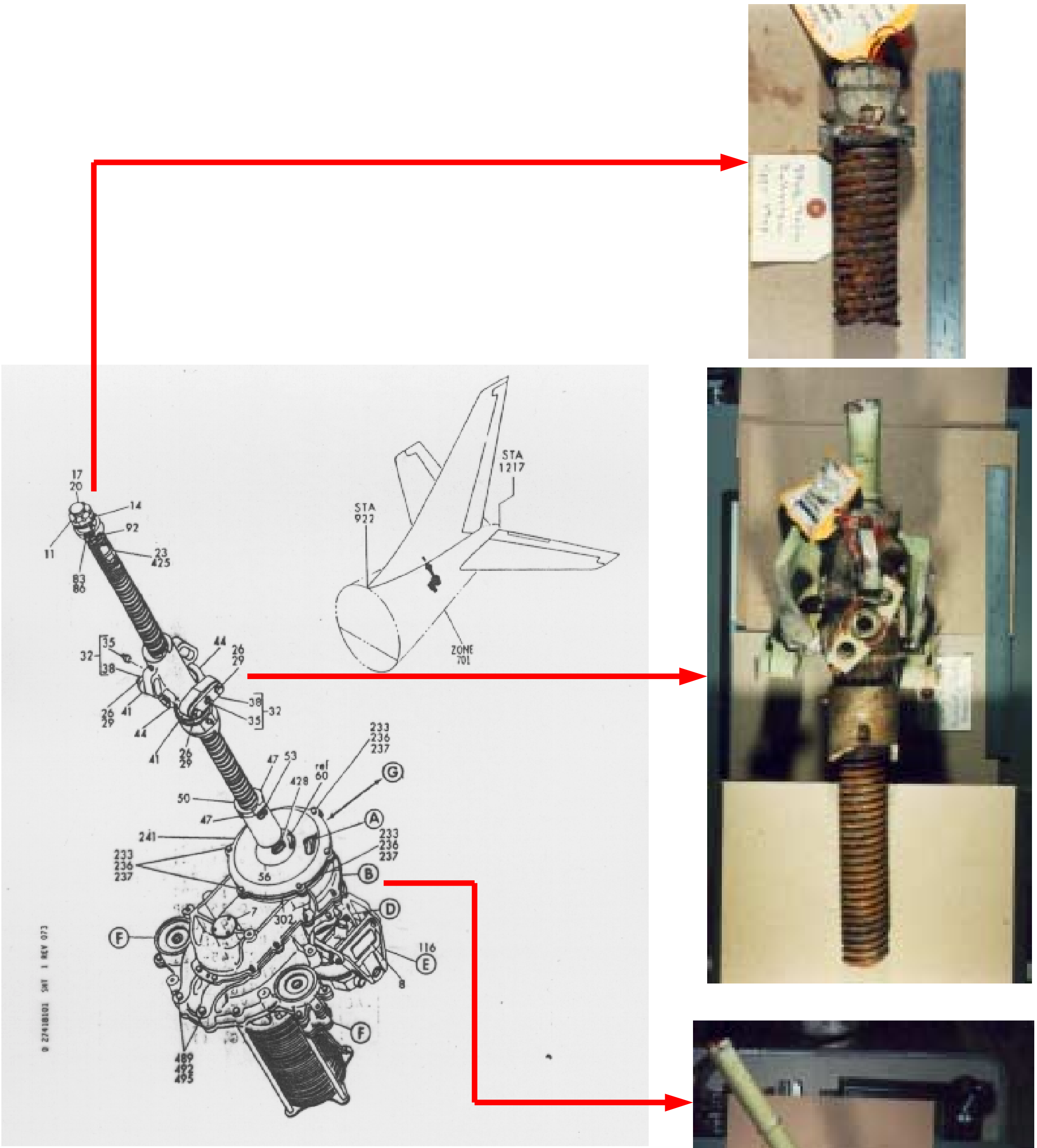


(a) Position of the Stabilizer Control System



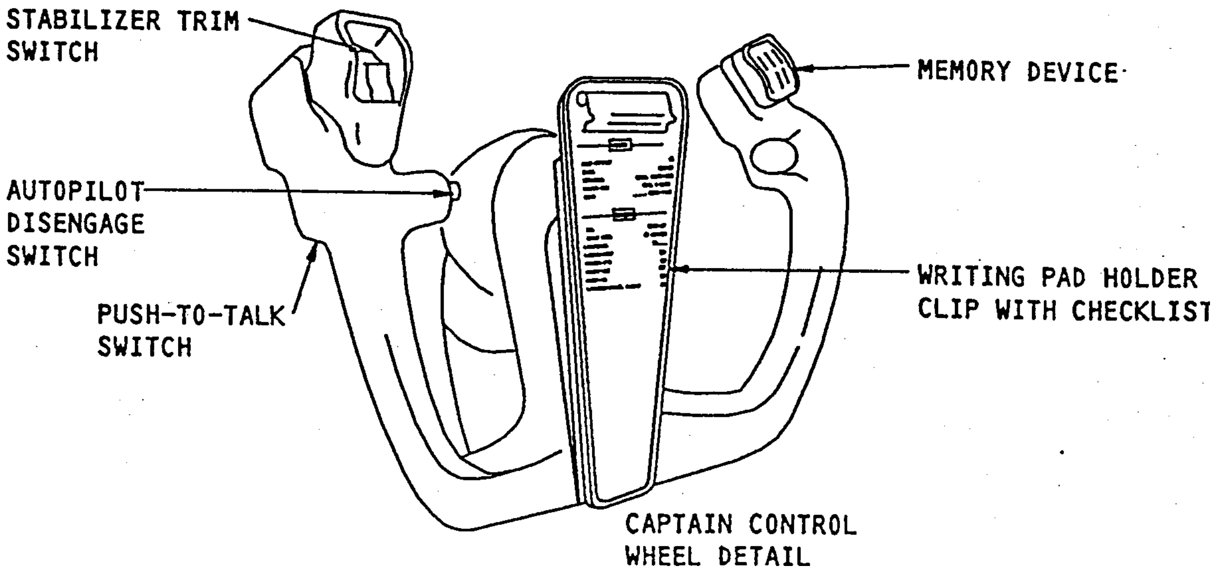
(b) Schematic Diagram of the Horizontal Stabilizer Trim

Figure 13 Horizontal Stabilizer Trim

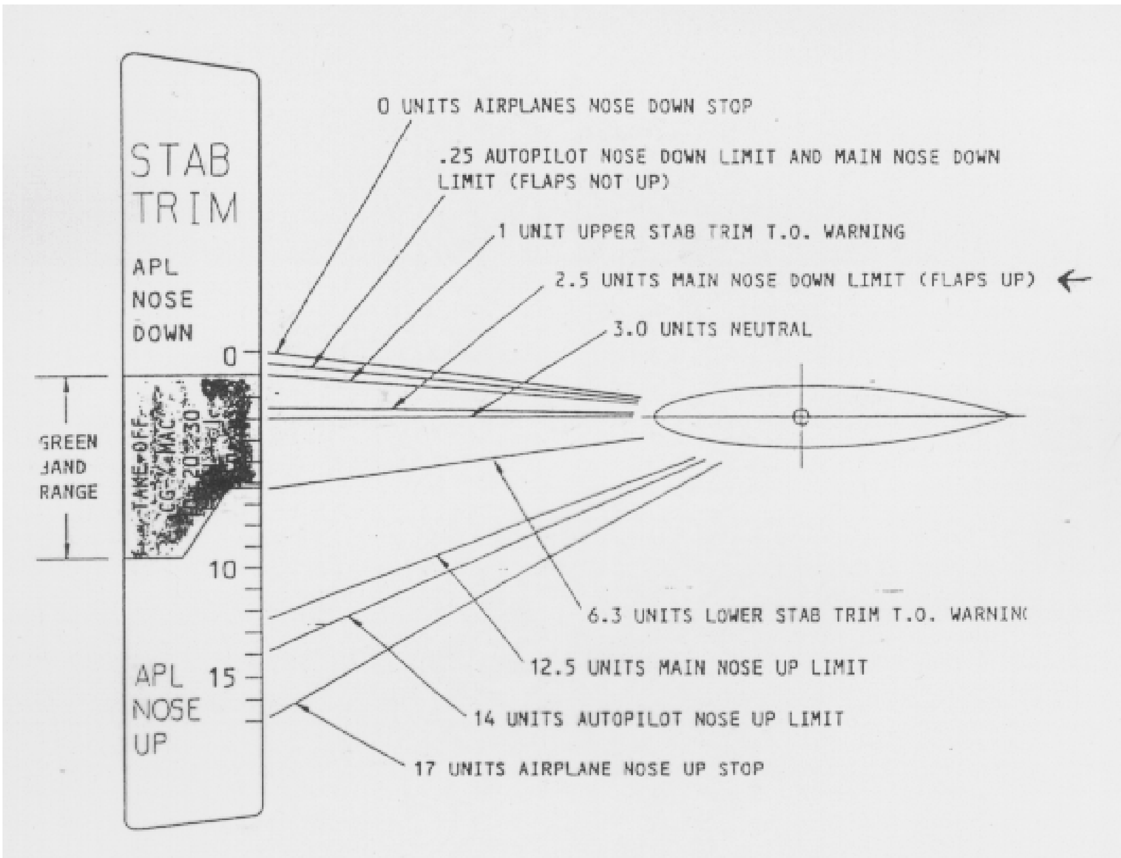


(c) Stabilizer Jackscrew

Figure 13 Horizontal Stabilizer Trim (Continued)

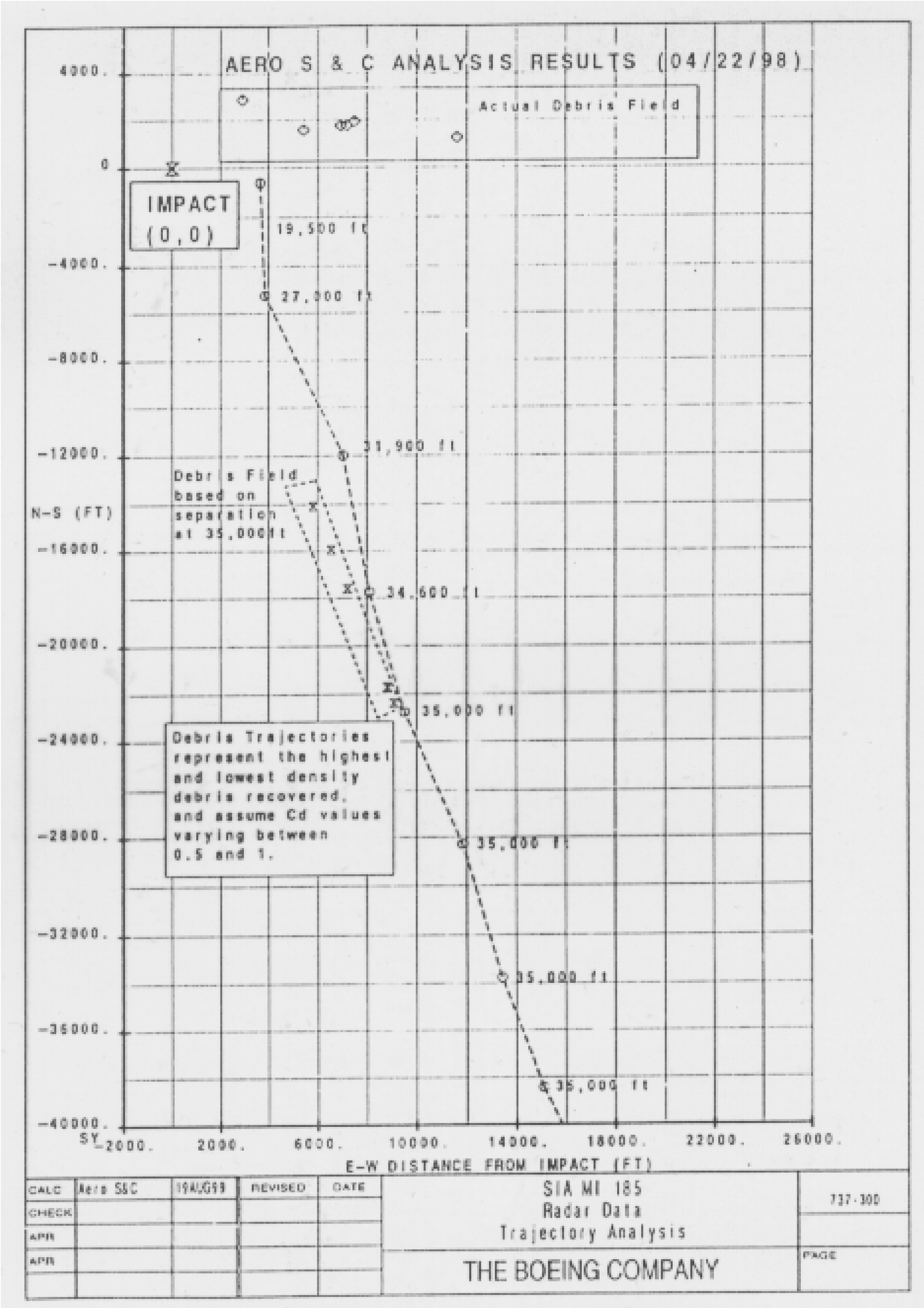


(d) Captain Control Wheel



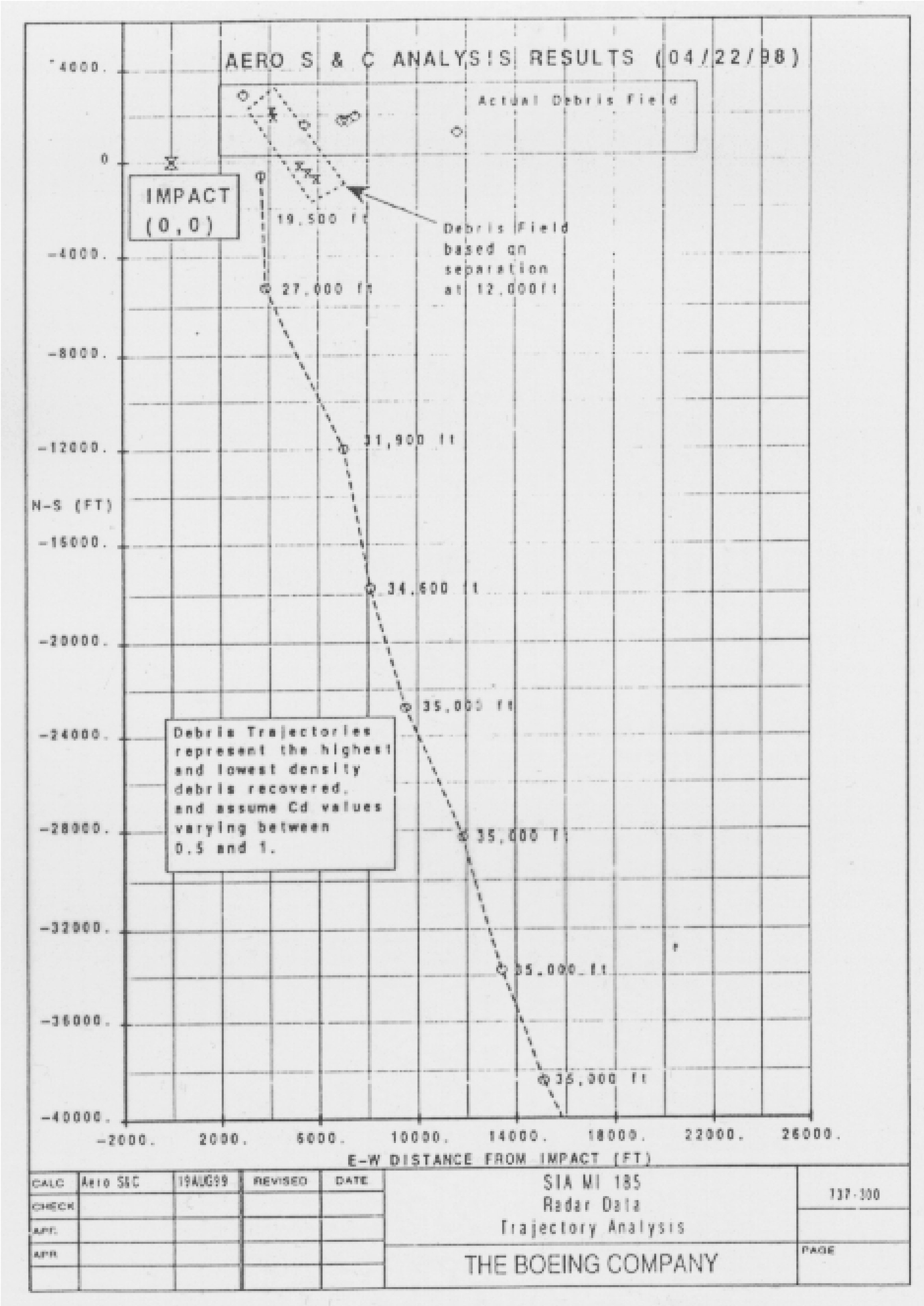
(e) Stabilizer Trim Deflection Scale

Figure 13 Horizontal Stabilizer Trim (Continued)



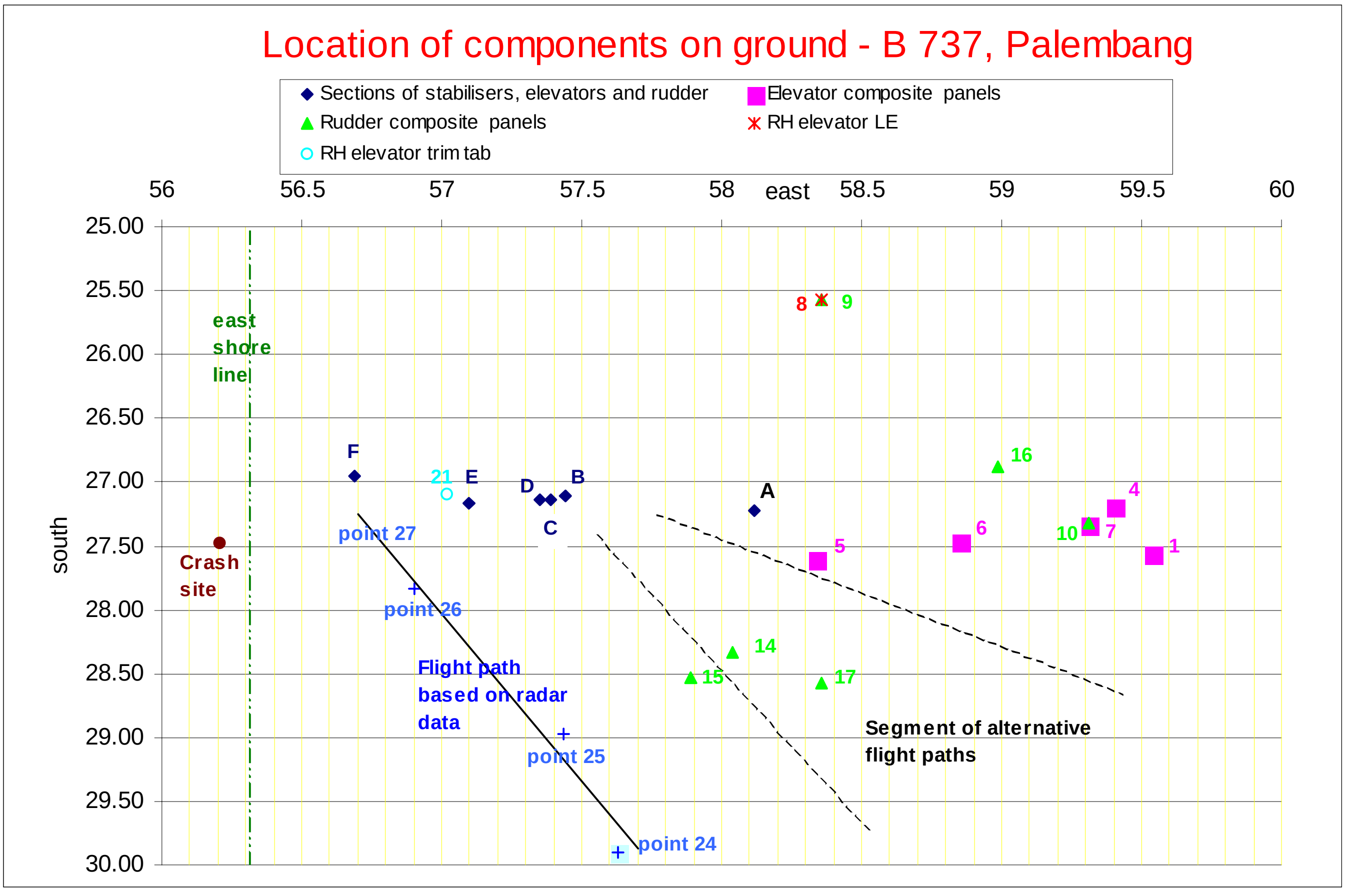
(a) NTSB Results based on separation at 35 000 ft

Figure 14 Diagram of debris distribution analysis



(b) NTSB Results based on separation at 12 000 ft

Figure 14 Diagram of debris distribution analysis (Continued)



(c) BASI Results

Figure 14 Diagram of debris distribution analysis (Continued)

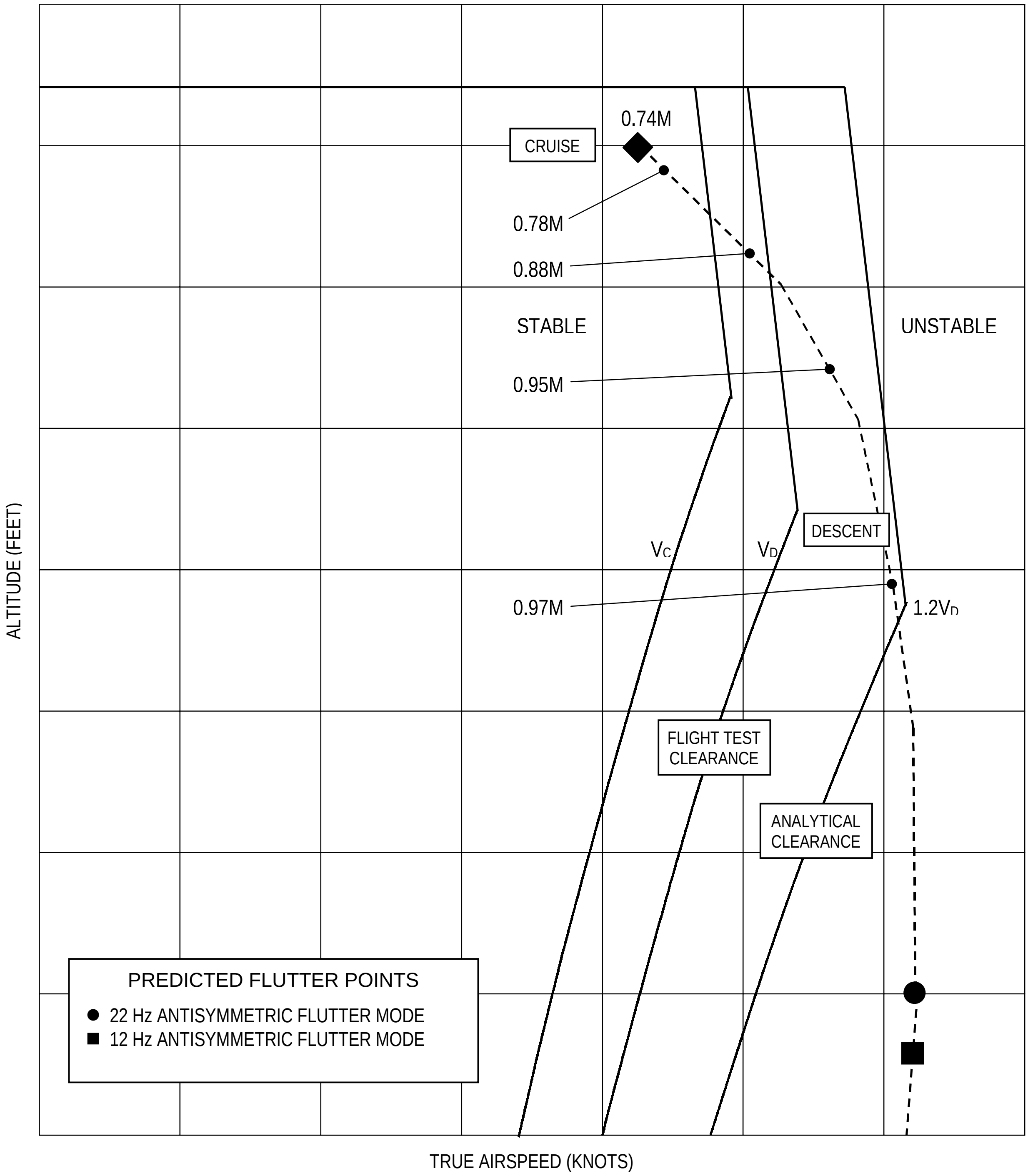
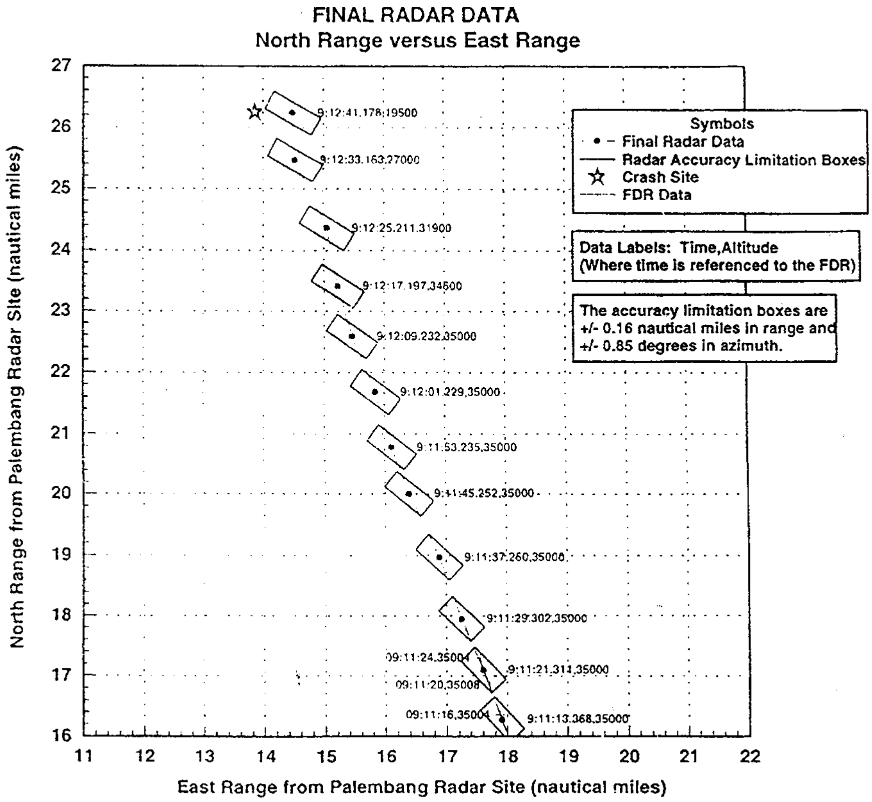
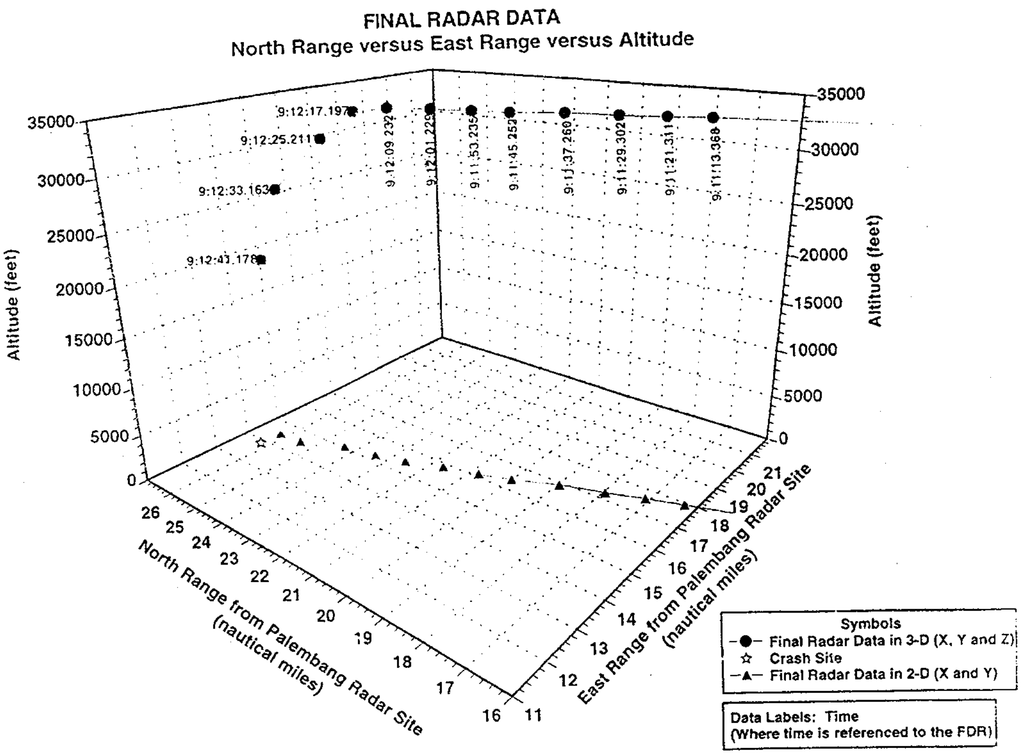


Figure 15 Diagram of Boeing B737 Flutter Flight Envelope

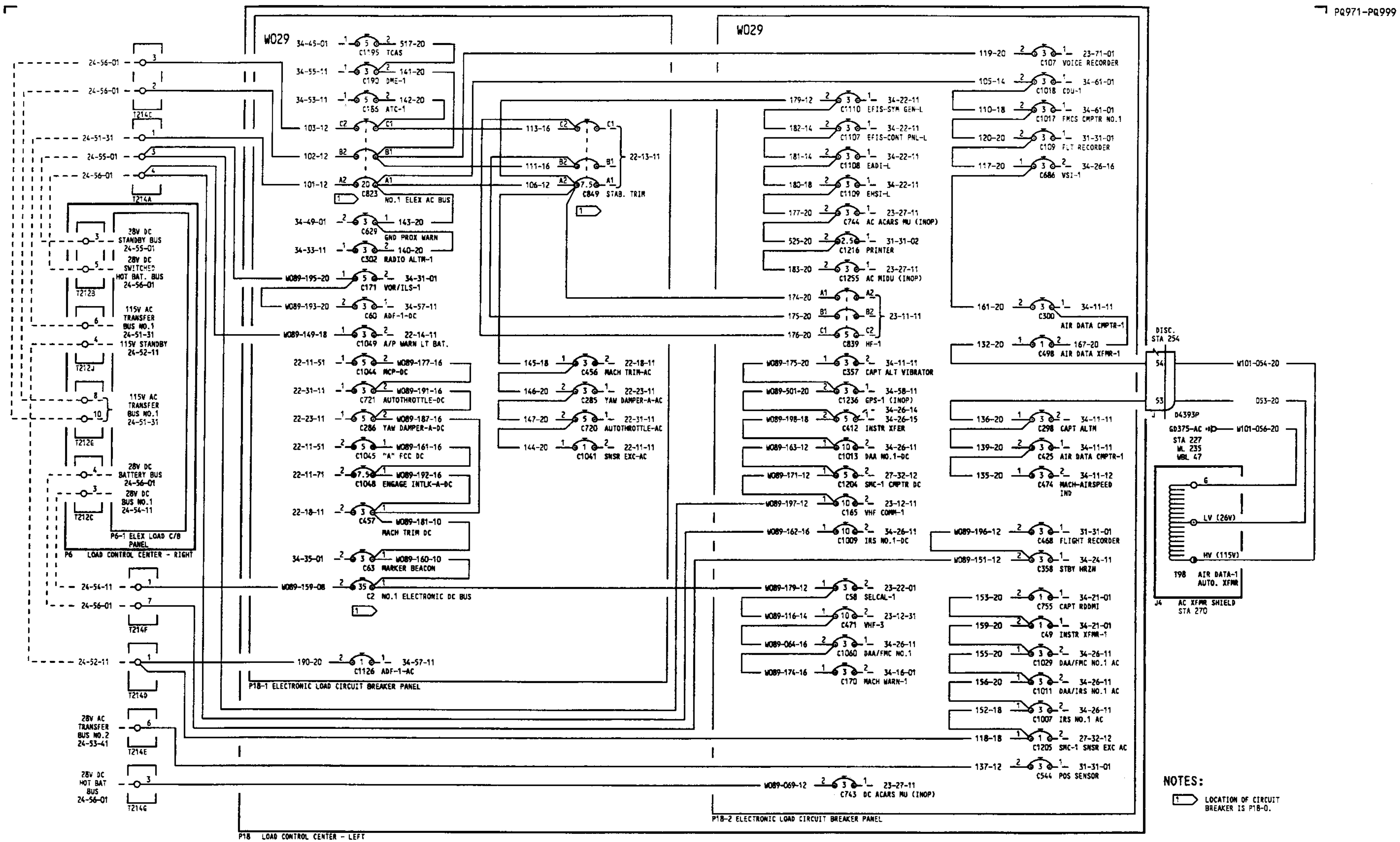


(a)



(b)

Figure 16 Corrected Radar Data



	ELECTRONIC POWER DISTRIBUTION NO.1

USED-ON: 61-71000
GRAPHICS DCN: -A

24-58-11

24-58-11

SH CONF 0431

SH CONF 0431
SH RI 0001

PHONE: 237-0736 DESIGNER: Huy Quang Nguyen
GCO: 23-AUG-96

Figure 17 Wiring Diagram 24-58-11

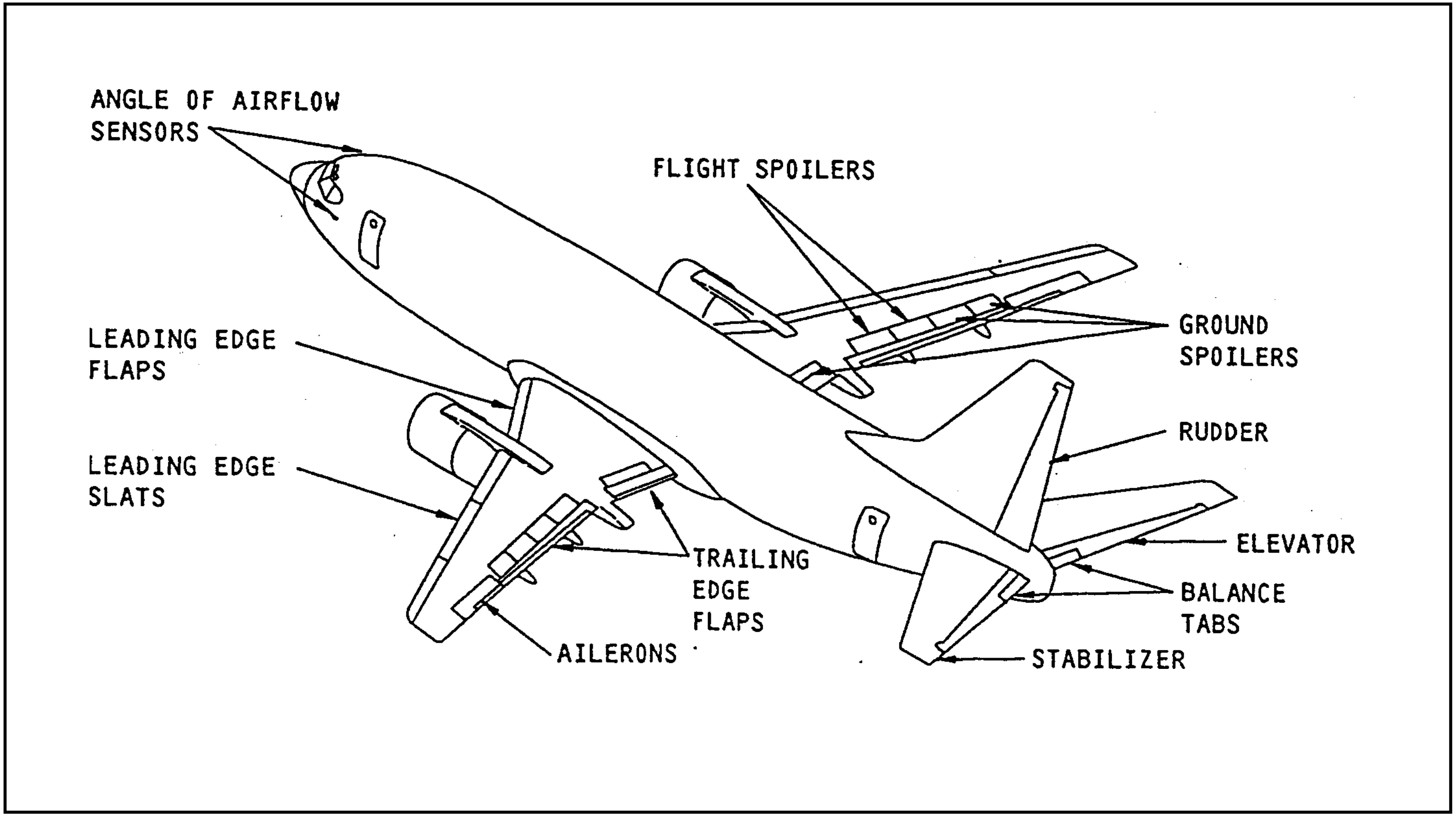


Figure 18   Flight Control Surfaces Location

Appendix A

Transcript of the Last Portion of CVR Recording

(CVR time is FDR UTC time – 2 seconds)

INTRA-COCKPIT COMMUNICATION | **AIR-GROUND COMMUNICATION**

TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0829:23 {25:29} CAM-1	checked.		
0829:24 {25:30} CAM-2	checked, flaps?		
0829:25 {25:31} CAM-1	five degrees, green light.		
0829:28 {25:34} CAM-2	five green, rudder, aileron stab trim?		
0829:29 {25:35} CAM-1	zero, zero and four point seven units checked.		
0829:35 {25:41} CAM-2	zero zero four point seven checked, takeoff briefing.		
0829:37 {25:43} CAM-1	complete.		
0829:38 {25:44} CAM-2	it's complete to the line.		
0829:40 {25:46} CAM-1	okay.		
0829:50 {25:56} CAM	((sound of door opening)).		
0829:51 {25:57} CAM-1	all set.		
0829:52 {25:58} CAM-5	yeah just give me one one five seconds to put on the infant seatbelt you know.		

INTRA-COCKPIT COMMUNICATION

TIME and SOURCE	CONTENT
0829:57 {26:03} CAM-1	never mind lah you can take quite some time you can take up to 3 seconds.
0829:59 {26:05} CAM-5	okay.
0830:00 {26:06} CAM-1	(sound of laugh) five seconds (sound of laugh) * * give me five seconds to put -.
0830:03 {26:09} CAM	((sound of door closing)).

AIR-GROUND COMMUNICATION

TIME and SOURCE	CONTENT
>0830:44 {26:50} GND	Silk Air one eight five continue taxi on alpha contact tower one one eight point seven five.
>0830:48 {26:54} RDO-2	one one eight seven five Silk Air one eight five.
>0831:34 {27:40} RDO-2	Tower selamat sore Silk Air one eight five on alpha.
>0831:38 {27:44} TWR	Silk Air one eight five number two for departure two five right.
>0831:41 {27:47} RDO-2	Silk Air one eight five.
>0834:00 {30:06} TWR	Silk Air one eight five line up and wait two five right.
>0834:03 {30:09} RDO-2	line up and wait Silk Air one eight five.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0834:06 {30:12} CAM-1	sit the girls thanks, below the line.		
0834:09 {30:15} PA-2	cabin crew take off positions please.		
0834:17 {30:23} CAM-2	cabin announcement complete, engine start switches?		
0834:20 {30:26} CAM-1	on.		
0834:21 {30:27} CAM-2	transponder?		
0834:22 {30:28} CAM-1	TA only.		
0834:23 {30:29} CAM-2	strobe lights?		
0834:25 {30:31} CAM-1	on.		
0834:26 {30:32} CAM-2	holding at takeoff clearance.		
0834:28 {30:34} CAM-1	thank you.		
0835:22 {31:28} CAM-1	*.		
0835:25 {31:31} CAM-2	sorry?		
0835:28 {31:34} CAM-1	this guy is also going papa lima bravo.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0835:30 {31:36} CAM-2	yeah.		
0835:32 {31:38} CAM-1	Sempati is turning right.		
0835:37 {31:43} CAM-1	we're waiting for him to cross before he can let us go.		
0835:40 {31:46} CAM-2	yeah.		
0835:55 {32:01} CAM-2	they turned around that triple seven fast.		
0835:57 {32:03} CAM-1	yeah.		
0835:59 {32:05} CAM-2	that SQ one.		
>0836:30 {32:38} CAM-1	come on.		
		>0836:35 {32:41} TWR	Silk Air one eight five cancel SID after airborne turn right direct papa lima bravo cleared for takeoff.
		>0836:41 {32:47} RDO-2	airborne right turn papa lima bravo cleared for takeoff Silk Air one eight five.
0836:44 {32:50} CAM-2	takeoff clearance.		

INTRA-COCKPIT COMMUNICATION | **AIR-GROUND COMMUNICATION**

TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0836:45 {32:51} CAM-1	obtained.		
0836:47 {32:53} CAM-2	before takeoff checklist's complete.		
0836:48 {32:54} CAM	((sound of increasing engine noise)).		
0836:50 {32:56} CAM-1	ninety one five.		
0836:55 {33:01} CAM-2	ninety one five thrust is set.		
0836:58 {33:04} CAM-2	eighty knots.		
0836:59 {33:05} CAM-1	my control.		
0837:00 {33:06} CAM-2	you have control.		
0837:12 {33:18} CAM-2	V-one rotate.		
0837:14 {33:20} CAM-2	V-two.		
0837:17 {33:23} CAM-2	positive climb.		
0837:18 {33:24} CAM-1	gear up thanks.		
0837:28 {33:34} CAM-1	heading select right turn three three zero yeah.		

INTRA-COCKPIT COMMUNICATION TIME and SOURCE	INTRA-COCKPIT COMMUNICATION CONTENT	AIR-GROUND COMMUNICATION TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
0837:32 {33:38} CAM-2	it's all clear.		
0837:33 {33:39} CAM-1	okay.		
0837:36 {33:42} CAM-1	N-one, two ten, flaps one.		
		>0837:48 {33:54} TWR	Silk Air one eight five contact departure one one nine seven five.
		>0837:52 {33:58} RDO-2	one one nine seven five Silk Air one eight five terima kasih pak.
		>0837:55 {34:01} TWR	*.
		>0837:58 {34:04} RDO-2	ah arrival Silk Air one eight five airborne one thousand six hundred.
		>0838:09 {34:14} RDO-2	Jakarta approach Silk Air one eight five.
0838:10 {34:16} CAM-1	flaps up.		
		>0838:12 {34:18} DEP	Silk Air one eight five identified on departure climb to three five zero turn right heading three four zero report passing one five zero.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		>0838:21 {34:27} RDO-2	climb three five zero right turn heading three four zero Silk Air one eight five roger.
0838:27 {34:33} CAM-2	flaps are up.		
0838:32 {34:38} CAM-1	V-Nav thanks.		
0838:47 {34:53} CAM-2	TCAS twenty.		
0838:48 {34:54} CAM-1	okay it's set.		
0839:15 {35:21} CAM-1	((sound of humming)).		
0839:21 {35:27} CAM-1	request high speed thanks.		
		>0839:24 {35:30} RDO-2	Silk Air one eight five request high speed climb.
		>0839:27 {35:33} DEP	Silk Air one eight five approved.
		>0839:29 {35:35} RDO-2	thank you.
0839:30 {35:36} CAM-1	okay delete th- start switches off, seatbelt sign off, after takeoff checklist thanks.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0839:43 {35:49} CAM-2	transponder TA-RA twenty miles, air-con and pres is set climbing start switches off, landing gear up and off, flaps up no lights, landing lights on until ten thousand, fasten belt's off, after takeoff complete.		
0839:56 {36:02} CAM-1	thank you.		
0840:50 {36:56} CAM-1	V-Nav heading select.		
0840:51 {36:57} CAM-2	checks.		
0840:52 {36:58} CAM-1	auto-pilot A engaged.		
0840:59 {37:05} CAM-1	we probably get direct Pardi eh probably.		
		>0841:15 {37:21} DEP	Silk Air one eight five take up heading three three zero.
		>0841:20 {37:26} RDO-2	heading three three zero Silk Air one eight five.
0841:31 {37:37} CAM-1	ten thousand checked one zero one three and ah.		
0841:38 {37:44} CAM-2	set.		
0841:53 {37:59} CAM-1	forty miles.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0843:20 {39:26} CAM-1	*.		
0843:21 {39:27} CAM-2	yeah.		
0843:22 {39:28} CAM-1	* for the next two days *.		
		>0843:35 {39:41} RDO-2	Silk Air one eight five pass one five zero.
		>0843:38 {39:44} DEP	control one two four three five.
0843:40 {39:46} CAM-1	I'll be off here.		
		>0843:43 {39:49} DEP	Silk Air one eight five contact one two four three five.
		>0843:46 {39:52} RDO-2	twenty four three five Silk Air one eight five.
		>0843:53 {40:00} RDO-2	ah Jakarta control Silk Air one eight five climbing three five zero.
		>0844:00 {40:06} CTRL	Silk Air one eight five maintain heading climb three five zero report passing two four zero.
0844:05 {40:11} CAM-2	want direct Pardi.		
0844:06 {40:12} CAM-1	huh.		

INTRA-COCKPIT COMMUNICATION

TIME and SOURCE	CONTENT
0844:06 {40:12}	
CAM-2	direct Pardi.
0844:10 {40:16}	
CAM-1	call two four zero.
0844:29 {40:35}	
CAM-1	I'll be off the air for a while.

AIR-GROUND COMMUNICATION

TIME and SOURCE	CONTENT
>0844:10 {40:17}	
RDO-2	flight level three five zero wilco Silk Air one eight five request direct Pardi.
>0844:15 {40:21}	
CTRL	all right stand-by.

INTRA-COCKPIT COMMUNICATION

TIME and SOURCE | **CONTENT**

0844:37 {40:43}
PA-1 good afternoon ladies and gentleman this is your Captain my name is Tsu Wai Ming on the flight deck this afternoon with me is first officer Duncan Ward we'd like to welcome you aboard and ah we are now climbing through nineteen thousand feet we'll be cruising today at thirty five thousand heading towards the north west tracking initially towards the eastern cost of Sumatra towards the town of Palembang before turning right towards Singapore flight time one hour twenty minutes you can expect ah to arrive at Singapore at about six o'clock in the evening Singapore time which is one hour ahead of Jakarta time, time in Singapore is now four forty five in the afternoon this is about five minutes ahead of schedule. weather conditions clear skies out of Jakarta very hot afternoon and at the moment we are still in good weather however toward Singapore we can expect a bit of showers thunderstorm towards the southern part of Singapore arrival at Singapore should be fine with a temperature of about twenty eight degrees Celsius the seatbelt sign is now off feel free to move around the cabin however while seated for your own safety have your seatbelt fastened sit back and relax enjoy the services provided today on Silk Air one eight five and I'll get back to you just before our descent into Singapore with a updated weather forecast thank you.

0846:04 {42:10}
CAM-1 I'm back with you.

0846:05 {42:11}
CAM-2 okay.

AIR-GROUND COMMUNICATION

TIME and SOURCE | **CONTENT**

>0847:01 {43:08}
RDO-2 Silk Air one eight five passing two four zero.

>0847:07 {43:13}
CTRL Silk Air one eight five contact Jakarta upper one three two decimal seven.

INTRA-COCKPIT COMMUNICATION

TIME and
SOURCE **CONTENT**

0847:50 {43:56}
CAM-1 *.

0847:52 {43:58}
CAM-5 * would you like to have some sandwich.

0847:55 {44:01}
CAM-1 drinks ah.

0847:56 {44:02}
CAM-5 *.

0847:57 {44:03}
CAM-1 tau hueh chui. ((soya drink))

AIR-GROUND COMMUNICATION

TIME and
SOURCE **CONTENT**

>0847:13 {43:19}
RDO-2 one three two seven Silk Air one eight five.

>0847:21 {43:28}
RDO-2 Jakarta Silk Air one eight seven climbing passing two five five two four five correction.

>0847:30 {43:36}
CTRH Silk Air one eight five confirm.

>0847:31 {43:38}
RDO-2 affirm Silk Air one eight five climbing three five zero requesting direct Pardi.

>0847:38 {43:44}
CTRH one eight five stand-by direct Pardi direct papa lima bravo report three five zero.

>0847:43 {43:49}
RDO-2 direct Palembang wilco Silk Air one eight five.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0847:57 {44:03} CAM-5	tau hueh chui.		
0847:59 {44:05} CAM-2	I'll have a ice lemon tea.		
0848:00 {44:06} CAM-5	ice lemon tea do you want the sandwich too.		
0848:03 {44:09} CAM-2	what kind.		
0848:04 {44:10} CAM-5	we have egg mayonnaise and chicken *.		
0848:08 {44:14} CAM-2	just a couple thanks nice clear day.		
0848:12 {44:18} CAM	((sound of door closing)).		
0848:16 {44:22} CAM-1	yeah.		
0848:33 {44:39} CAM-1	((sound of singing)).		
0848:49 {44:55} CAM-1	some water you want?		
0848:51 {44:57} CAM-2	ah fine thanks.		
0849:48 {45:54} CAM-1	just go level change and get up.		
0849:50 {45:56} CAM-2	yup.		

INTRA-COCKPIT COMMUNICATION		**AIR-GROUND COMMUNICATION**	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0849:51 {45:57} CAM-1	so we can go direct Pardi.		
0850:17 {46:23} CAM-2	thirty for thirty five.		
0850:52 {46:58} CAM-1	on speaker.		
0852:18 {48:24} CAM-1	a thousand to three five zero.		
0852:40 {48:46} CAM-1	*.		
0852:49 {48:55} CAM	((sound of altitude alert tone)).		
0853:08 {49:14} CAM-1	*.		
		>0853:15 {49:22} RDO-2	Silk Air one eight five maintaining three five zero.
		>0853:20 {49:26} CTRH	silk one eight five maintain three five zero cleared direct to Pardi report abeam papa lima bravo.
		>0853:25 {49:31} RDO-2	three five zero direct Pardi wilco Silk Air one eight five.
0853:51 {49:57} CAM-1	that's him behind us.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0853:52 {49:58} CAM-2	yup.		
0853:53 {49:59} CAM-1	very fast.		
0857:25 {53:31} CAM-1	he'll be ahead of us arriving in Singapore.		
0857:28 {53:34} CAM-2	yeah.		
0857:28 {53:34} CAM-1	he is he is speeding, shit.		
0857:35 {53:41} CAM-1	at least point eight *.		
0857:52 {53:58} CAM-2	he'll be above the weather as well.		
0900:48 {56:54} CAM	((sound of door opening)).		
0900:51 {56:57} CAM-5	tau huey chui.		
0900:56 {57:02} CAM-1	thanks.		
0901:01 {57:07} CAM-5	I was so busy I keep two pieces of sandwich for him then this coming in as well (sound of laugh).		
0901:12 {57:18} CAM	((sound of door closing)).		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0904:09 {00:15} CAM	((sound of rustling papers)).		
0904:55 {01:01} CAM-1	go back for a while, finish your plate.		
0904:56 {01:02} CAM-2	I am.		
0905:00 {01:06} CAM-1	some water.		
0905:01 {01:07} CAM-	((sound of several metallic snap)).		
0905:03 {01:09} CAM	((sound of snap)).		
0905:05 {01:11} CAM-2	no thanks.		
0905:13.6 {01:19.6 C	(end of recording)		

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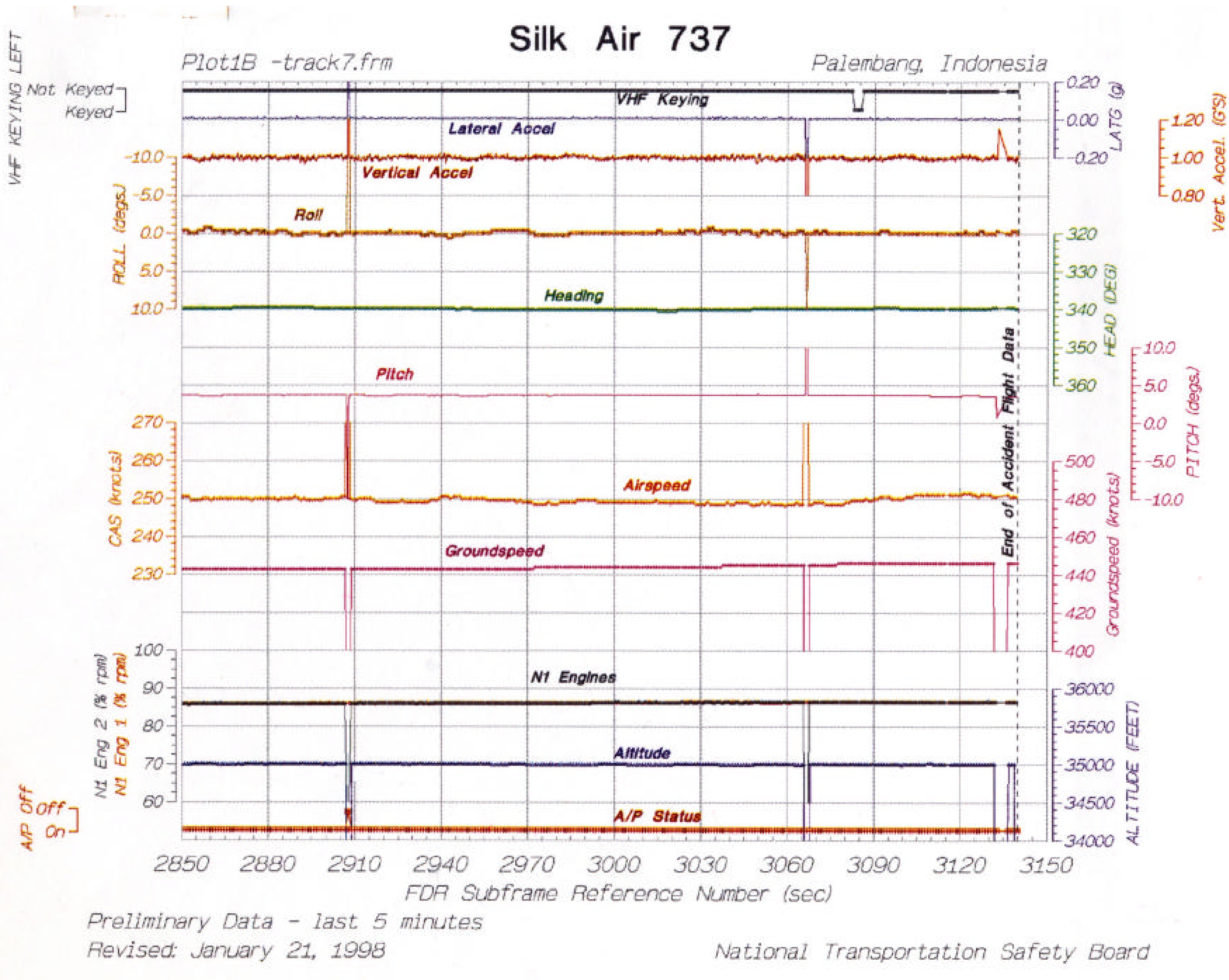
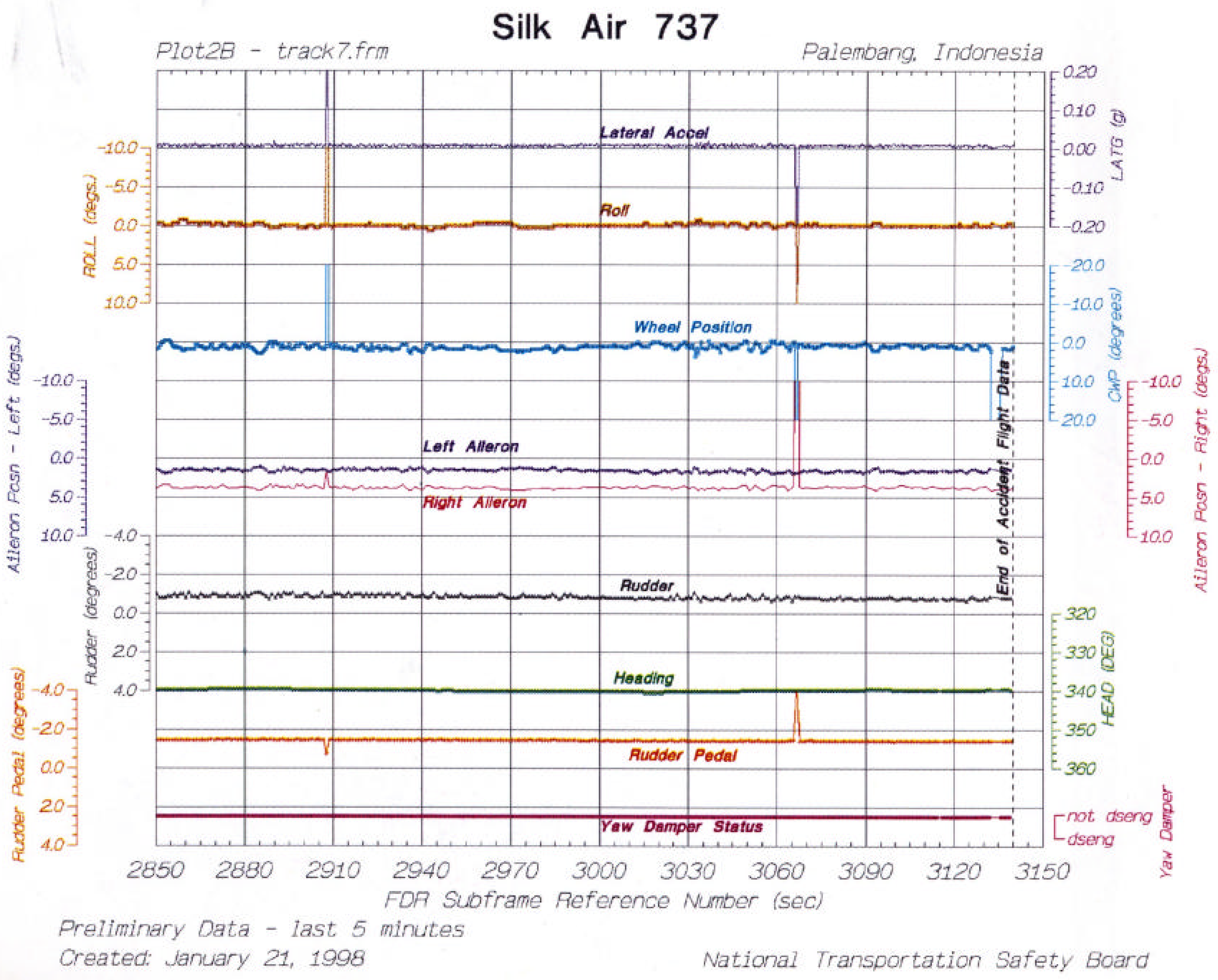
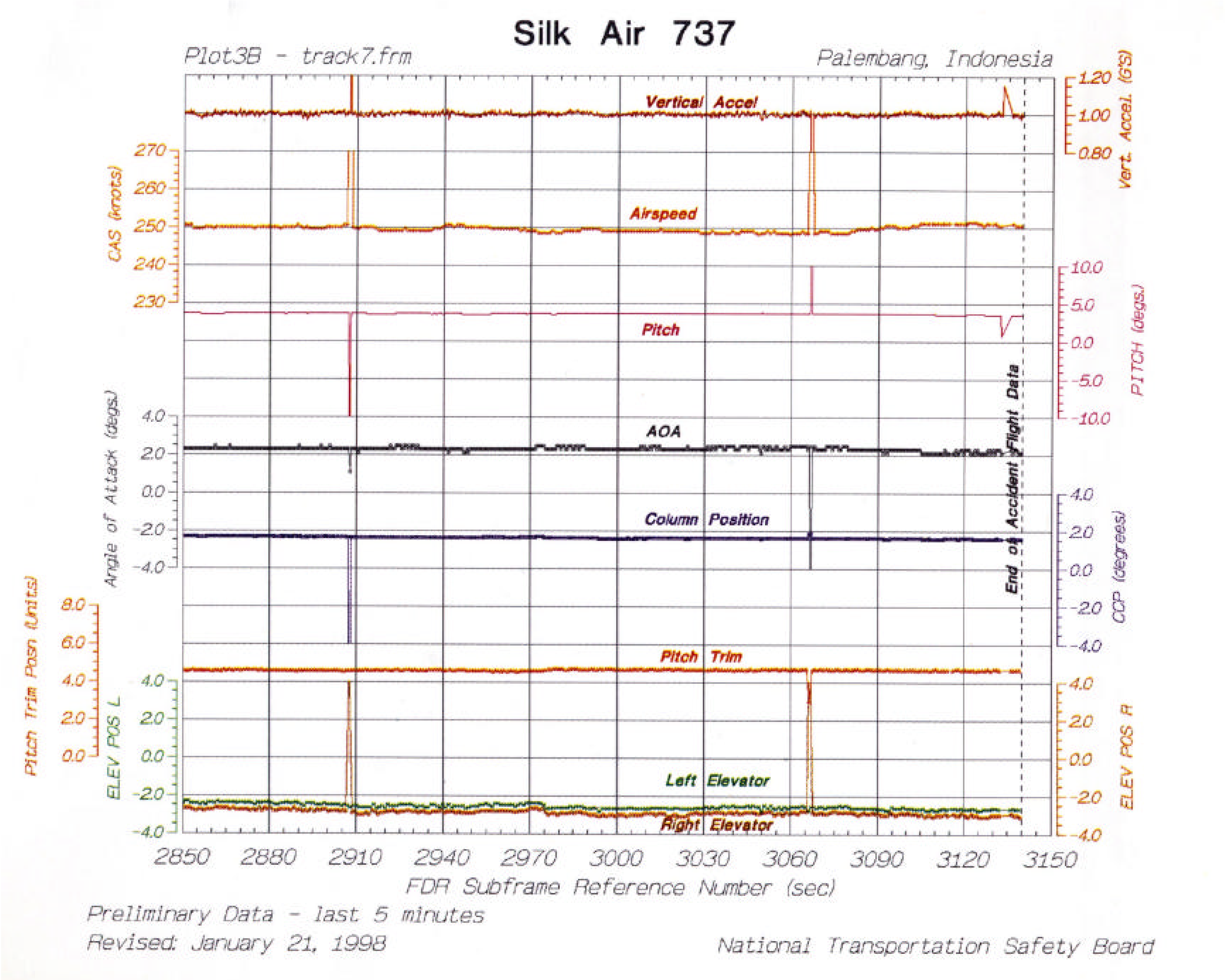
Appendix B

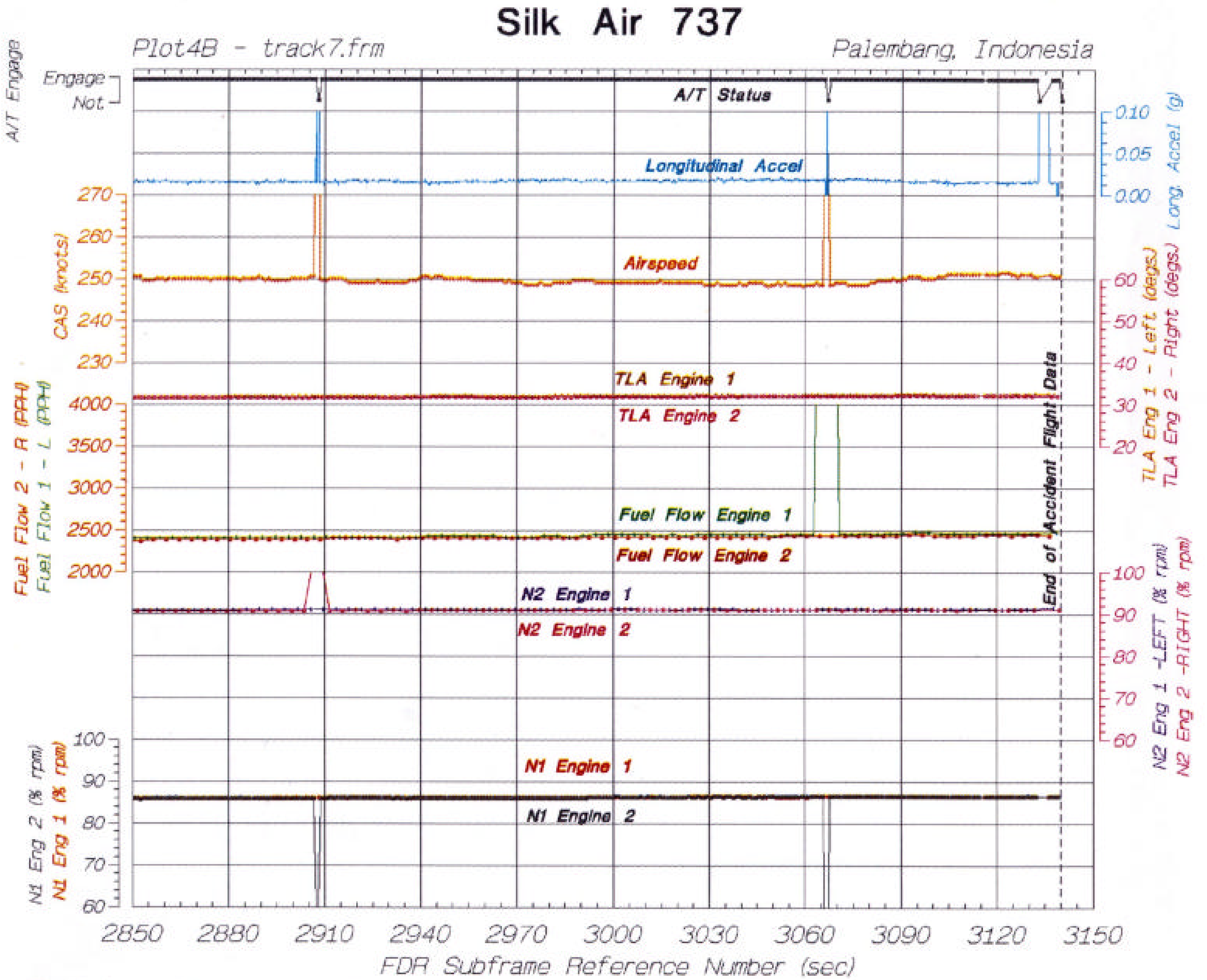
FDR Plots



Silk Air 737
Plot1B -track7.frm
Palembang, Indonesia
VHF KEYING LEFT
Not Keyed
Keyed
VHF Keying
Lateral Accel
Vertical Accel
Roll
Heading
Pitch
Airspeed
Groundspeed
N1 Engines
Altitude
A/P Status
End of Accident Flight Data
ROLL (degs.)
-10.0
-5.0
0.0
5.0
10.0
CAS (knots)
270
260
250
240
230
N1 Eng 2 (% rpm)
N1 Eng 1 (% rpm)
100
90
80
70
60
A/P Off
Off
On
0.20
0.00
-0.20
LATG (g)
1.20
1.00
0.80
Vert. Accel. (G'S)
320
330
340
350
360
HEAD (DEG)
10.0
5.0
0.0
-5.0
-10.0
PITCH (degs.)
500
480
460
440
420
400
Groundspeed (knots)
36000
35500
35000
34500
34000
ALTITUDE (FEET)
2850
2880
2910
2940
2970
3000
3030
3060
3090
3120
3150
FDR Subframe Reference Number (sec)
Preliminary Data - last 5 minutes
Revised: January 21, 1998
National Transportation Safety Board


Silk Air 737
Plot2B - track7.frm
Palembang, Indonesia
Lateral Accel
Roll
Wheel Position
Left Aileron
Right Aileron
Rudder
Heading
Rudder Pedal
Yaw Damper Status
End of Accident Flight Data
LATG (g)
ROLL (degs.)
CWP (degrees)
Aileron Posn - Left (degs.)
Aileron Posn - Right (degs.)
Rudder (degrees)
HEAD (DEG)
Rudder Pedal (degrees)
not dseng
dseng
Yaw Damper
2850
2880
2910
2940
2970
3000
3030
3060
3090
3120
3150
FDR Subframe Reference Number (sec)
Preliminary Data - last 5 minutes
Created: January 21, 1998
National Transportation Safety Board


Silk Air 737
Plot3B - track7.frm
Palembang, Indonesia
Vertical Accel
1.20
1.00
0.80
Vert. Accel. (G'S)
270
260
250
240
230
CAS (knots)
Airspeed
10.0
5.0
0.0
-5.0
-10.0
PITCH (degs.)
Pitch
4.0
2.0
0.0
-2.0
-4.0
Angle of Attack (degs.)
AOA
Column Position
CCP (degrees)
End of Accident Flight Data
8.0
6.0
4.0
2.0
0.0
Pitch Trim Posn (Units)
Pitch Trim
ELEV POS L
ELEV POS R
Left Elevator
Right Elevator
2850
2880
2910
2940
2970
3000
3030
3060
3090
3120
3150
FDR Subframe Reference Number (sec)
Preliminary Data - last 5 minutes
Revised: January 21, 1998
National Transportation Safety Board



Preliminary Data - last 5 minutes

Revised: January 21, 1998

National Transportation Safety Board

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Appendix C

Transcript of ATC Recording

(ATC time is FDR UTC time + 37 seconds)

TAPE TRANSCRIPT OF TRAFFIC COMMUNICATION WITH JAKARTA ATC (CLEARANCE DELIVERY (CLR), TOWER (TWR), GROUND CONTROL (GND), APPROACH CONTROL (APP) AND AREA CONTROL (ACC)) ON DECEMBER 19,1997

From	To	Time	Communications	Doubtful Words	Obs.
SLK 185	*CLR*	08:17:50	Delivery clearance selamat sore Silk Air 185		
CLR	*SLK 185*	08:17:54	Good afternoon Silk Air 185 Soekarno Hatta delivery go ahead		
SLK 185	*CLR*	08:17:59	Silk Air 185 D 11 requesting FL 350 to Singapore		
CLR	*SLK 185*	08:17:14	Silk Air 185 350 is already occupied do you accept FL 390 clearance		
SLK 185	*CLR*	08:17:21	Negative FL 310 please		
CLR	*SLK 185*	08:17:27	Roger Silk 185 you are cleared to Singapore via G 579 FL 310 squawk 2344 expect Cengkareng 2 G departure for runway 25 R		
SLK 185	*CLR*	08:18:38	Roger Singapore G 579 FL 310 squawk 2344 Cengkareng 2 G 25 R Silk Air 185		
CLR	*SLK 185*	08:18:47	Silk Air 185 that is correct when ready to start and push back contact ground 121.6		
SLK 185	*CLR*	08:18:52	121.6 Silk Air 185 good day		
SLK 185	*GND*	08:22:51	Soetta ground Silk Air 185 selamat siang		
SLK 185	*GND*	08:23:00	Soetta ground Silk Air 185		
GND	*SLK 185*	08:23:04	Silk Air 185 go ahead		
SLK 185	*GND*	08:23:07	Selamat sore Silk Air 185 D 11 request pushback and start		
GND	*SLK 185*	08:23:10	Silk Air 185 cleared to pushback and start facing Hotel		
SLK 185	*GND*	08:23:15	Facing Hotel Silk Air 185		
GND	*SLK 185*	08:26:54	Silk Air 185 are you able level 350		
SLK 185	*GND*	08:26:58	Silk Air 185 affirmative		
GND	*SLK 185*	08:27:01	Silk Air 185 are you able level 350		
SLK 185	*GND*	08:27:03	350 thank you Silk Air 185		
SLK 185	*GND*	08:27:40	Silk Air 185 taxi		
GND	*SLK 185*	08:27:43	OK runway 25 R via Hotel and Alpha		
SLK 185	*GND*	08:27:47	OK 25 R Silk Air 185		
GND	*SLK 185*	08:29:20	Silk Air 185 you are no.2 after aircraft Fokker 28 out Lima joining Alpha for runway 25R		
SLK 185	*GND*	08:29:27	Silk Air 185 copied		
GND	*SLK 185*	08:31:21	Silk Air 185 continue taxi on A contact tower 118.75		
SLK 185	*GND*	08:31:26	118.75 Silk Air 185		

From	To	Time	Communications	Doubtful Words	Obs.
SLK 185	*TWR*	08:32:12	Tower selamat sore Silk Air 185 On Alpha		
TWR	*SLK 185*	08:32:15	Silk Air 185 you are no.2 departure 25 R		
SLK 185	*TWR*	08:32:18	Silk Air 185		
TWR	*SLK 185*	08:34:38	Silk Air 185 line up and wait		
SLK 185	*TWR*	08:34:41	Line up and wait Silk Air 185		
TWR	*SLK 185*	08:37:13	Silk Air 185 cancel SID after airborne turn right direct PLB clear for take off		
SLK 185	*TWR*	08:37:18	Airborne right turn PLB clear for take off Silk Air 185		
TWR	*SLK 185*	08:38:26	Silk Air 185 contact departure 119.75		
SLK 185	*TWR*	08:38:30	119.75 Silk Air 185 terima kasih pak		
TWR	*SLK 185*	08:38:33	Sama – sama		
SLK 185	*APP*	08:38:36	Arrival Silk Air 185 airborne one thousand six hundred		
SLK 185	*APP*	08:38:47	Jakarta approach Silk Air 185		
APP	*SLK 185*	08:38:50	Silk Air 185 identified on departure climb to 350 turn right heading 340 report passing 150		
SLK 185	*APP*	08:38:59	Climb to 350 right turn heading 340 Silk Air 185 roger		
SLK 185	*APP*	08:40:03	Silk Air 185 request high speed climb		
APP	*SLK 185*	08:40:06	Silk Air 185 approved		
SLK 185	*APP*	08:40:09	Thank you		
APP	*SLK 185*	08:41:53	Silk Air 185 pick up heading 330		
SLK 185	*APP*	08:41:58	330 Silk Air 185		
APP	*SLK 185*	08:44:15	Silk Air 185 contact control 124.35		
SLK 185	*APP*	08:44:21	Silk Air 185 contact 124.35		
SLK185	*APP*	08:44:21	124.35 Silk Air 185		
SLK 185	*ACC*	08:48:00	Jakarta Control SLK 185 climbing 255 2344		
ACC	*SLK 185*	08:48:08	SLK 185 confirm?		
SLK 185	*ACC*	08:48:11	Affirm SLK 185 climbing 350 requesting direct Pardi		
ACC	*GLK 185*	08:48:17	SLK 185 stand by direct Pardi, direct to PLB report 350		
SLK185	*ACC*	08:48:21	Direct Palembang wilco SLK 185		

From	To	Time	Communications	Doubtful Words	Obs.
SIA 157	*ACC*	08:49:55	Jakarta Control SIA 157 selamat siang		
ACC	*SIA 157*		Selamat siang SIA 157 report the present heading		
SIA 157	*ACC*		SIA 157 we cleared to PLB now maintaining heading 330		
ACC	*SIA 157*		SIA 157 for avoiding traffic left heading 325 climb to level 390		
SIA 157	*ACC*		Climb on heading 325 FL 390 SIA 157		
SSR 134	*ACC*	08:51:40	Jakarta…..Jakarta control this is SSR 134		
ACC	*SSR 134*		SSR 134 climb and maintain 310 proceed to PLB		
SSR 134	*ACC*		Climb and maintain 310, request direct to Pardi at present due to weather		
ACC	*SSR 134*		Stand by for direct Pardi due to traffic		
SSR 134	*ACC*		Roger SSR 134		
SLK 185	*ACC*	08:53:54	SLK 185 maintaining 350		
ACC	*SLK 185*	08:53:58	SLK 185 maintain 350 clear direct to Pardi report abeam PLB		
SLK 185	*ACC*	08:54:04	350 direct Pardi, wilco SLK 185		
SIA 157	*ACC*	08:54:10	SIA 157 Jakarta Control		
ACC	*SIA 157*		Go ahead SIA 157		
ACC	*SIA 157*		Okay after passing 350 clear direct Pardi report reaching 390 after passing 350 sir		
SIA 157	*ACC*		Roger after passing FL 350 cleared direct Pardi, SIA 157 call you reaching 390		
QFA 41	*ACC*	08:57:26	Jakarta Control, QFA 41 is heading 360 on climb FL 410		
ACC	*QFA 41*		QFA 41 turn left heading 350 climb to FL 410		
QFA 41	*ACC*		Heading 350, QFA 41		
QFA 41	*ACC*		QFA 41, how long on this heading ?		
ACC	*QFA 41*		Roger 3 minutes Sir, for avoiding traffic, your traffic now about 2 o'clock 18 miles 265 climbing to 350		
QFA 41	*ACC*		Confirm it's about 2 o'clock?		
ACC	*QFA 41*		Until 3 minutes heading		

From	To	Time	Communications	Doubtful Words	Obs.
QFA 41	*ACC*	08:58:15	Confirm the traffic is now 2 o'clock ?		
ACC	*QFA 41*		Negative, your traffic is 11 o'clock, sorry 11 o'clock		
QFA 41	*ACC*		Roger, QFA 41.		
ACC	*QFA 41*	08:58:55	QFA 41 left now heading 330, continue climb to FL410.		
QFA 41	*ACC*		Roger, turning 330, continue climb to 410, QFA 41.		
SIA 157	*ACC*	08:59:20	Jakarta Control SIA 157 reaching FL390 request direct - PARDI.		
ACC	*SIA 157*		Cleared direct PARDI report abeam PLB.		
SIA 157	*ACC*		Report abeam PLB, SIA 157.		
ACC	*QFA 41*		QFA 41 you're passing the traffic, now direct to PLB.		
QFA 41	*ACC*		Direct PLB, QFA 41.		
SSR 134	*ACC*	09:00:20	Jakarta control SSR 134 reaching 310 request direct – PARDI		
ACC	*SSR 134*		SSR 134 roger, maintain 310 cleared direct PARDI, report abeam PLB.		
SSR 134	*ACC*		Maintain 310 cleared direct PARDI report abeam PLB abeam SSR 134.		
ACC	*QFA 41*	09:09:40	QFA 41, Jakarta Control……		
QFA 41	*ACC*		QFA 41…..		
ACC	*QFA 41*		Cleared direct to PARDI report abeam PLB……..cleared-direct PARDI report reaching 410.		
QFA 41	*ACC*		Cleared direct to PARDI, call you reaching 410, QFA 41		
SIA 157	*ACC*	09:10:33	Jakarta Control SIA 157 abeam PLB/10 FL390 and estimate PARDI at 27.		
ACC	*SIA 157*		Copied 27, maintain 390 at PARDI contact Singapore 134.4		
SIA 157	*ACC*		Maintain 390, PARDI 134.4 SIA 157 Selamat siang.		

From	To	Time	Communications	Doubtful Words	Obs.
ACC	*SLK 185*	09:10:55	SLK 185 you just passing abeam PLB, maintain 350 at PARDI contact Singapore 134.4		
SLK 185	*ACC*	09:11:03	SLK 185 roger 134.4 before PARDI.		
ACC	*SSR 134*	09:11:25	SSR 134 maintain 310 just leaving PLB, now contact Singapore 134.4 at PARDI SSR 134 at PARDI.		
SSR 134	*ACC*		134.4 at PARDI SSR 134.		
QFA 41	*ACC*	09:12:34	QFA 41 maintaining FL410.		
ACC	*QFA 41*		QFA 41 maintaining 410 direct PARDI, report abeam PLB.		
QFA 41	*ACC*		Roger, report abeam PLB, direct PARDI, QFA 41.		
		09:13:33	(sound off………..Husssssssss……………for a few second)		
ACC	*QFA 41*	09:16:38	QFA41 you position abeam PLB, maintain 410, at PARDI contact Singapore 134.4		
QFA 41	*ACC*		Roger 134.4 confirm………..?		
ACC	*QFA 41*		Affirmative, Singapore Radar		
QFA 41	*ACC*		Roger good day …….		
GIA 238	*ACC*	09:20:01	Jakarta Control good afternoon GIA 238 passing 250.		
ACC	*GIA 238*		GIA 238 climb and maintain 280, proceed PLB		
GIA 238	*ACC*		Proceed PLB maintain 280, GIA 238		
SIA 157	*ACC*	09:20:31	Jakarta Control SIA 157		
ACC	*SIA 157*		SIA 157 Go-ahead ………		
SIA 157	*ACC*		SIA 157 any objection to descend before Pardi ?		
ACC	*SIA 157*		SIA 157 say again your last message		
SIA 157	*ACC*		Is there any objection if we descend before Pardi?		
ACC	*SIA 157*		Affirmed, Jakarta no objection, contact Singapore for traffic below		
SIA 157	*ACC*		Roger, thank you, SIA 157		

From	To	Time	Communications	Doubtful Words	Obs.
ACC	*GIA 238*	09:36:26	GIA 238 Jakarta …….		
GIA 238	*ACC*		Go-ahead, GIA 238		
ACC	*GIA 238*	09:36:31	Please relay to SLK 185 …….SLK 185 to contact Singapore 134.4 sir		
GIA 238	*SLK 185*		Roger, GIA 238 . ……..SLK 185, GIA 238. ………..		

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Appendix D

Wreckage Weight

SILKAIR WRECKAGE WEIGHT

Box Number	Box Size	Description	Full Box Weight (kg)	Empty Box Weight (kg)	Weight of Contents (kg)
1	Full	Misc. Cabin and Interior Items/Cargo Liners/Galley - Box #1	690	130	560
2	Full	Misc. Fragments – Bits and Pieces - Box #1	1670	130	1540
3	Full	Misc. Fragments – Bits and Pieces - Box #2	1460	130	1330
4	Full	Misc. Fragments – Bits and Pieces - Box #3	1250	130	1120
5	Full	Misc. Fragments – Bits and Pieces - Box #4	1220	130	1090
6	Full	Misc. Fragments – Bits and Pieces - Box #5	1350	130	1220
7	Full	Misc. Fragments – Bits and Pieces - Box #6	1070	130	940
8	Full	Misc. Fragments – Bits and Pieces - Box #7	880	130	750
9	Full	Misc. Fragments – Bits and Pieces - Box #9 (Note: No Box #.8)	960	130	830
10	Full	Misc. Fuselage Parts and Fragments - Box #1	600	130	470
11	Full	Wing Skin Parts Upper and Lower - Box #1	1260	130	1130
12	Full	Wing Control Surfaces and Associated Parts - Box #1	720	130	590
13	Full	Wing Skin Parts Upper and Lower - Box #2	1200	130	1070
14	Full	Fuselage Skin Parts with Identification Markings, Door Parts - Box #1	580	130	450
15	Full	Landing Gear Parts Wheel Hub and Associated Parts LPT No.2, Exhaust Sleeve - Box #1	830	130	700
16	Full	Aft Fuselage Skin Section 46, 48 - Box #1	450	130	320
17	Full	Misc. Fuselage Part and Fragments - Box #2	660	130	530
18	Half	Pumps; Valves; Motors/APU + Associated Parts/Fit Control Comps.	700	110	590
19	Half	Flap Tracks Carriages Transmission and Associated Parts – Box #1	700	110	590
20	Half	Thrust Reverser Parts- Box #1	500	110	390
21	Half	No.1 Engine	810	110	700
22	Half	No.2 Engine	1030	110	920
23	Half	Connectors Circuit Boards/Wires – Box #1	480	110	370
24	Quarter	Control Actuation – Box #1	70	50	20
25	Quarter	Control Actuation – Box #2	80	50	30
26	Quarter	Control Actuation – Box #3	150	50	100
27	Quarter	Control Actuation – Box #4	120	50	70
28	Quarter	Control Actuation – Box #5	110	50	60
29	Quarter	Control Actuation – Box #6	110	50	60
30	Half (tall)	Engine Parts	750	120	630
31	Half (tall)	Landing Gear, APU engine diffuser	560	120	440
32	Half	Landing Gear Parts/Support Beam/Pylon/Mid Spar Fitting/A.C. Comps.	830	110	720
33	Half	Aircraft Documents, Aircraft Manuals	N.A.	N.A.	N.A.
34	Full	Parts from Empennage/Rudder, Elevator – Box #1	520	130	390
35	Full	Texas Star/Pressure Bulkhead/Fin Spar ends/Patch	570	130	440
36	Quarter Sm	Engine Part	350	40	310
37	Flat	Right Hand Horizontal Stabiliser Tip	160	110	50
38	Quarter Sm	Wheel Assembly	190	40	150
39	Flat	Right Hand Horizontal Stabiliser Piece	190	110	80
40	Flat	Left Hand Horizontal Stabiliser Tip	220	110	110
41	Half (tall)	Misc. Fragments Bits and Pieces – Box #10	410	120	290

Total Weights (kg)	26460	4310	22150
Total Weights (lb)	58212	9482	48730
Total Weight Excluding Cabin and Interior Items – Box #1 (kg)	25770	4180	21590
Total Weight Excluding Cabin and Interior Items – Box #1 (lb)	56694	9196	47498

Manufacturing Empty Weight PQ973 (no seats, galleys, lav) (lb)	64924
Percentage of Aircraft Recovered	**73.2%**

Appendix E

Actuator Matrix

No.	Actuator/Part Name	Measured Position	Nominal/ Neutral Position	Actuator Extend or Retract Direction	Electrical, Hidraulic, Mechanical control input Engaged or Disengaged	Expected Unpowered State	Equivalent Surface Position	Remarks
1a	Main Rudder PCU Piston	1.79"; 2.21"	1.97"	0.2"; Extend	Follows command input (always engaged)	Last powered position	3 deg left	Main and Standby tied to same torque tube (therefore Main and Standby can not disagree)
1b	Main Rudder Servo Valve	Primary: 1/2 rate; Secondary: Neutral	Primary: Neutral; Secondary: Neutral	**	Follows command input (always engaged)	Primary: Neutral; Secondary: Neutral	N/A	** When unit is physically disconnected from input linkage, bias spring moves Primary to 1/2 PCU rate (unit was physically disconnected)
2	Standby Rudder PCU Piston	3.1"	~ 3.17"	0.07"; Retract	Follows command input (always engaged)	Last commanded position	1 deg right	Main and Standby tied to same torque tube (therefore Main and Standby can not disagree)
3	Aileron PCU - Piston - 3529	1.39" extend cyl.; 2.07" retract cyl	1.72"	0.33" retract; 0.35" retract	Follows command input (always engaged)	Last commanded position	3.5 deg left aileron down or right aileron up	Rod bent
4	Aileron PCU - Piston - 3509	1.83" extend cyl; 1.60" retract cyl	1.72"	0.11" extend; 0.12" extend	Follows command input (always engaged)	Last commanded position	1.2 deg left aileron up or right aileron down	Rod bent

No.	Actuator/Part Name	Measured Position	Nominal/ Neutral Position	Actuator Extend or Retract Direction	Electrical, Hidraulic, Mechanical control input Engaged or Disengaged	Expected Unpowered State	Equivalent Surface Position	Remarks
5	Elevator PCU - Piston - 3559	1.59" extend cyl; 1.87" retract cyl	1.72"	0.13" retract; 0.15" retract	Follows command input (always engaged)	Last commanded position	1.5 deg trailing edge up	
6	Elevator PCU - Piston - 3560	Piston missing	1.72"	N/A	Follows command input (always engaged)	Last commanded position	Not measurable (piston missing)	
7	Flight Spoiler Actuator - 8312A	0.410" **	.4-.5"	Full Retract	N/A - No servos	Retracted/Down	Down	** Measured Cap to Rod end
8	Flight Spoiler Actuator - 8339A	0.410" **	.4-.5"	Full Retract	N/A - No servos	Retracted/Down	Down	** Measured Cap to Rod end
9	Flight Spoiler Actuator - 8271A	0.465" **	.4-.5"	Full Retract	N/A - No servos	Retracted/Down	Down	** Measured Cap to Rod end
10	Flight Spoiler Actuator - 8379A	0.410" **	.4-.5"	Full Retract	N/A - No servos	Retracted/Down	Down	** Measured Cap to Rod end
11a	Aileron Autopilot Servo - A7072	.103" off center	Centered	Centered	Disengaged *	Disengaged *	No input command to Ail PCUs	* Disengagement of detent pistons prevents mod piston inputs to PCU
11b	Aileron Autopilot Servo - A7017	Centered	Centered	Centered	Disengaged *	Disengaged *	No input command to Ail PCUs	* Disengagement of detent pistons prevents mod piston inputs to PCU

No.	Actuator/Part Name	Measured Position	Nominal/ Neutral Position	Actuator Extend or Retract Direction	Electrical, Hidraulic, Mechanical control input Engaged or Disengaged	Expected Unpowered State	Equivalent Surface Position	Remarks
12a	Elevator Autopilot Servo - A7076	.25" off center	Centered	Centered	Disengaged *	Disengaged *	No input command to Elev PCUs	* Disengagement of detent pistons prevents mod piston inputs to PCU
12b	Elevator Autopilot Servo - A6995	.20" off center	Centered	Centered	Disengaged *	Disengaged *	No input command to Elev PCUs	* Disengagement of detent pistons prevents mod piston inputs to PCU
13	Mach Trim	Fully retracted	Centered	Full Retract	Follows command input (on demand system)	Last commanded position	4.2 degrees elevator trailing edge up	Provides input into Elevator PCUs
14	Rudder Trim	1.4"	~ 1.44"	~ 0.04" retract	~ 0.06" retract	Last commanded position	Min right rudder trim	Provides input into Rudder PCUs
15	Outboard Ground Spoiler Actuator	0.0" (Flush) **	~ 0"	Locked/Retracted	Follows command input (on demand system)	Piston retracted	Down	** rod end to end cap
16	Outboard Ground Spoiler Actuator	0" **	~ 0"	Locked/Retracted	Follows command input (on demand system)	Piston retracted	Down	** rod end to end cap
17	Outboard Ground Spoiler Actuator	0" **	~ 0"	Locked/Retracted	Follows command input (on demand system)	Piston retracted	Down	** rod end to end cap

No.	Actuator/Part Name	Measured Position	Nominal/ Neutral Position	Actuator Extend or Retract Direction	Electrical, Hidraulic, Mechanical control input Engaged or Disengaged	Expected Unpowered State	Equivalent Surface Position	Remarks
18	Inboard Ground Spoiler Actuator (A)	~ 9.26" **	~ 9.25"	Full Extended/ Locked	Follows command input (on demand system)	Piston extended	Down/Locked	** in total length
19	Inboard Ground Spoiler Actuator (B)	~ 9.26" **	~ 9.25"	Full Extended/ Locked	Follows command input (on demand system)	Piston extended	Down/Locked	** in total length
20	Inboard Ground Spoiler Actuator (C)	~ 9.26" **	~ 9.25"	Full Extended/ Locked	Follows command input (on demand system)	Piston extended	Down/Locked	** in total length
21	Inboard Ground Spoiler Actuator (D)	~ 9.26" **	~ 9.25"	Full Extended/ Locked	Follows command input (on demand system)	Piston extended	Down/Locked	** in total length
22	Feel & Centering Unit	** Impact marks on CAM	Centered	N/A	N/A	N/A	Rudder Left	** Measured rudder left based on impact marks

No.	Actuator/Part Name	Measured Position	Nominal/ Neutral Position	Actuator Extend or Retract Direction	Electrical, Hidraulic, Mechanical control input Engaged or Disengaged	Expected Unpowered State	Equivalent Surface Position	Remarks
23	Stab Jackscrew	2.5 units *	3 units **	Cruise Condition (*1)	Follows command input	Last commanded position	0.5 deg Leading Edge Up	* These units are pilot units on the control stand; ** 0 deg Horizontal Stab; (*1) Verify Cruise Condition; Check FDR data; Note: 2.5 units correspond to Airplane Nose down Electric Limit
24	T E Flap Ballscrew	Fully retracted	Fully retracted	Fully Retracted	N/A	Last commanded position	Fully retracted	Flap Ballscrew position 2 or 7; outboard flap, inboard track
25	T E Flap Ballscrew	Fully retracted	Fully retracted	Fully Retracted	N/A	Last commanded position	Fully retracted	Flap Ballscrew position 4 or 5; inboard flap, inboard track
26	T E Flap Ballscrew	Fully retracted	Fully retracted	Fully Retracted	N/A	Last commanded position	Fully retracted	Flap Ballscrew position 1, 2, 7 or 8; Either outboard flap, either track
27	Locking T/R Actuator (LA)	Stowed	Stowed	Locked/Stowed	N/A	Stowed	Stowed	
28	Locking T/R Actuator (LB)	Stowed	Stowed	Unlocked/Stowed	N/A	Stowed	Stowed	Unlocked actuator piston was approximately 1/8" extended

No.	Actuator/Part Name	Measured Position	Nominal/ Neutral Position	Actuator Extend or Retract Direction	Electrical, Hidraulic, Mechanical control input Engaged or Disengaged	Expected Unpowered State	Equivalent Surface Position	Remarks
29	Locking T/R Actuator (LC)	Stowed	Stowed	Locked/Stowed	N/A			
30	Sync Lock T/R (LC)	Stowed	Stowed	Locked	N/A	Locked	N/A	
31	Sync Lock T/R (Z)	Stowed	Stowed	Locked	N/A	Locked	N/A	Broken Sync shaft
32	Center Non-Lock T/R	Stowed	Stowed	Stowed	N/A	Stowed	Stowed	
33	Center Non-Lock T/R	Stowed	Stowed	Stowed	N/A	Stowed	Stowed	
34	Center Non-Lock T/R	Stowed	Stowed	Stowed	N/A	Stowed	Stowed	
35	Lower Non-Lock T/R (A)	Stowed	Stowed	Stowed	N/A	Stowed	Stowed	Piston Stowed; Rod broken & extended 4"
36	Lower Non-Lock T/R (B)	Stowed	Stowed	Stowed	N/A	Stowed	Stowed	
37	Lower Non-Lock T/R (C)	Stowed	Stowed	Stowed	N/A	Stowed	Stowed	
38	Lower Non-Lock T/R (D)	Stowed	Stowed	Stowed	N/A	Stowed	Stowed	
39	Throttle Box	High power fwd thrust; Fuel Shut off Lever in run position	Idle/minimum fuel flow	N/A	Follows Command input	Last commanded position	N/A	Thrust Control rack apparently pulled out by impact forces (missing)
40	LE Flap Act - 0271	Extended 1.84"	Retracted	Extend = Flap Down	No Locking Mechanism	Retracted	Slightly Extended	Marks in bottom of bore near retract position
41	LE Flap Act - 0745	Retracted	Retracted	Extend = Flap Down	No Locking Mechanism	Retracted	Retracted	
42	LE Flap Act - 0095	Retracted	Retracted	Extend = Flap Down	No Locking Mechanism	Retracted	Retracted	
43	LE Slat Act - YL768 #1	Fully retracted	Retracted	Retracted	Lock stud, no damage, 1 finger broken	Retracted	Slats retracted	

No.	Actuator/Part Name	Measured Position	Nominal/ Neutral Position	Actuator Extend or Retract Direction	Electrical, Hidraulic, Mechanical control input Engaged or Disengaged	Expected Unpowered State	Equivalent Surface Position	Remarks
44	LE Slat Act - YL509	Inner Piston Extended .5"	Retracted	Retracted	No damage to fingers, Lock stud deformed	Retracted	Slats retracted	
45	LE Slat Act - B-401 #2	Fully retracted	Retracted	Retracted	Not torn down	Retracted	Slats retracted	
46	LE Slat Act - B-401 #1	Fully retracted	Retracted	Retracted	Lock stud, fingers intact	Retracted	Slats retracted	
47	LE Slat Act - YL689	Fully retracted	Retracted	Retracted	Lock stud, fingers intact	Retracted	Slats retracted	
48	LE Slat Act - YL768 #2	Fully retracted	Retracted	Retracted	Lock stud, fingers intact	Retracted	Slats retracted	

Appendix F

Letters from AlliedSignal

AlliedSignal

AEROSPACE

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Switchboard 206/885-3711 TWX 910/449-2860

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Date:	January 22, 1998	Delivery:	Normal X
Cover Sheet = Page 1 of	2		URGENT

To:	From:
Hyatt Regency – Bellevue	Greg Francois
PLEASE DELIVER TO YOUR HOTEL GUEST	AlliedSignal Aerospace
Captain Santoso Sayogo	Electronic and Avionics Systems
Room 1904	15001 NE. 36th Street, P.O. Box 97001
	Redmond, WA 98073-9701
Phone:	Phone: (425) 885-8500
Fax: (425) 646-7587	Fax: (425) 885-1098
CC: D. Schofield, G. Kersten, M. Thompson	email: greg.francois@alliedsignal.com

Subject: Summary from AlliedSignal Discussion/Analysis of Silk Air Recorders, 22 January, 1998

MESSAGE:

Dear Captain Santoso,

Thank you for the visit today at our facility. It is not often that we are involved in accident investigation and recovery of information from our flight data recorders. It gives us all here a great deal of pride in being able to assist you in this most important work.

I'd like to therefore summarize the findings we made today as well as to provide you some recommendations for possible future analysis of the data obtained from both the UFDR and SSCVR recovered from the Silk Air incident.

UFDR TAPE:

1) It is AlliedSignal's belief that the recovery measure taken to date by your team, carried out at the NTSB Laboratories in Washington, D.C., are exactly the same measures we would have done to recover the data from the UFDR tape. AlliedSignal does not know of any additional "tape" recovery techniques.
2) If the tape was indeed damaged due to contact with the solution (i.e. river water, silt, and mud) at the crash site, this would be the first instance that we know about where data has not been recovered from a mylar tape recorder manufactured by AlliedSignal due to contamination from liquids. A report performed by AlliedSignal on mylar tape contamination with typical fluids found from an aircraft has been given to you and your team.

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3) Furthermore, from magnified analysis of the mylar tape taken from that UFDR, it does appear that the oxide coating from the tape in the "area of interest" has been eroded by what appears to be some sort of chemical process. AlliedSignal also concludes from this information, as well as the fact that the rest of the data obtained from the UFDR was normal, that the erosion of the oxide from this portion of the tape is the reason why data has not been recovered from it, and not from any magnetic erasure or degaussing of the UFDR tape
4) AlliedSignal recommends that the tape be further examined/analyzed by the tape manufacturer (Quantegy) in order to ascertain if they have any techniques to be able to recover any more data from this portion of the tape and if indeed any erosion of the oxide has taken place.
5) The silt, mud, and water from the crash site should be analyzed in detail to ascertain the chemical properties of this composition.
6) Additionally, a test of this basic composition should also be made with the same mylar tape used in the UFDR to validate and/or deny the possibility that the environment at the accident site where the UFDR was recovered could have caused the possible erosion of the oxide from the tape.

SSCVR:

The SSCVR memory contents were analyzed in detail and no anomolies were found. The SSCVR appears to have been recording normally and retained all 2+ hours of audio data. The unit did not have any BITE faults and the memory was verified to have stopped recording at the exact location as given by the internal memory pointers of the unit.
2) The termination of the recording appears to be a result of power loss to the unit.
3) The last 500 milliseconds of the recording will be analyzed further, but the preliminary results indicate that the power to the SSCVR was lost, but the wiring of the SSCVR to the CVR Control Panel (located in the cockpit) was NOT the cause of this power loss (only power to the unit was lost).
4) Power loss to the recorder was most likely NOT due to any crew action of pulling the circuit breaker to the unit (no audio indication of this action being taken).
5) After power was lost to the SSCVR, it was not restored. There were no power "brown-outs" or any other indications of intermittent power to this unit.

AlliedSignal will verify the last 500 milliseconds in greater detail to substantiate item (3) above. AlliedSignal has no ready explanation as to why the SSCVR power was lost. It is AlliedSignal's belief that our latest Solid-State Recorder Products provide a 50-100% improvement in crash survivability over our older tape units (such as the tape-based UFDR). This improvement has been primarily driven by more stringent standards in the requirements for impact and penetration resistance as well as the high and low-intensity fire requirements of ED-56 Revision A and the new TSOs (TSO-C123a/124a).

We will forward any additional information and/or suggestions to you from further analysis on our side. Please, feel free to contact me at the numbers shown above if you require any additional information, or have any questions.

Sincerely,

Greg Francois
Product Manager, Data Mangement and Recorder Products
AlliedSignal Electronic and Avionics Systems

AlliedSignal

A E R O S P A C E

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Date: May 1, 1998 Delivery: Normal X

Cover Sheet = Page 1 of 3 URGENT

To:
Professor Oetarjo Diran
Investigator in Charge, SilkAir MI185
Aircraft Accident Investigation Commission

Phone: 62 21 341 7690
Fax: 62 21 3[illegible]2 2336
CC:

From:
Greg Francois
AlliedSignal Aerospace
Electronic and Avionics Systems
15001 NE. 36th Street, P.O. Box 97001
Redmond, WA 98073-9701

Phone: (425) 885-8500
Fax: (425) 8[illegible]-1[illegible]
email: greg.francois@alliedsignal.com

Subject: SilkAir MI185 Accident, AlliedSignal SSCVR (2-Hour, 980-6022-001), Ref. Your FAX of 27 April

Dear Professor,

As requested, attached is our final report on the findings from the SilkAir Solid-State Cockpit Voice Recorder (SSCVR, 2-Hour Recording Duration, Part Number 980-6022-001, Serial Number 0305.

Sincerely,

Greg Francois
Product Manager, Data Management and Recorder Products
AlliedSignal Electronic and Avionics Systems

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1

February 4, 1998

Final Report, SilkAir 2-Hour SSCVR Analysis
Part Number 980-6022-001, Serial Number 0308

AlliedSignal was asked to analyze the subject recorder (which was manufactured in September of 1996) during the visit from the National Transportation Safety Board and representatives from both Indonesia and Singapore.

1) The fault memory of the subject SSCVR was interrogated and there were no BITE Faults recorded (note that all AlliedSignal Solid-State Recorders store any detected BITE Fault conditions in non-volatile crash survivable memory).

2) The entire contents of the crash survivable memory were downloaded using the AlliedSignal Playback And Test System (PATS) for the SSCVR. The recorded duration was as expected (just over 2 hours) and no anomalies were noted.

3) There were no indications of interruption of power in the final 2-hours of recording (note that the AlliedSignal SSCVR provides an indication in crash survivable memory when power is turned on the unit. No such indications were noted in the final 2-hours of recording from the SilkAir SSCVR which indicates no disruption of power, until the end of the recording).

(Note that the power source for the AlliedSignal SSCVR is from 115 VAC, 400 Hz in a Boeing 737 installation.)

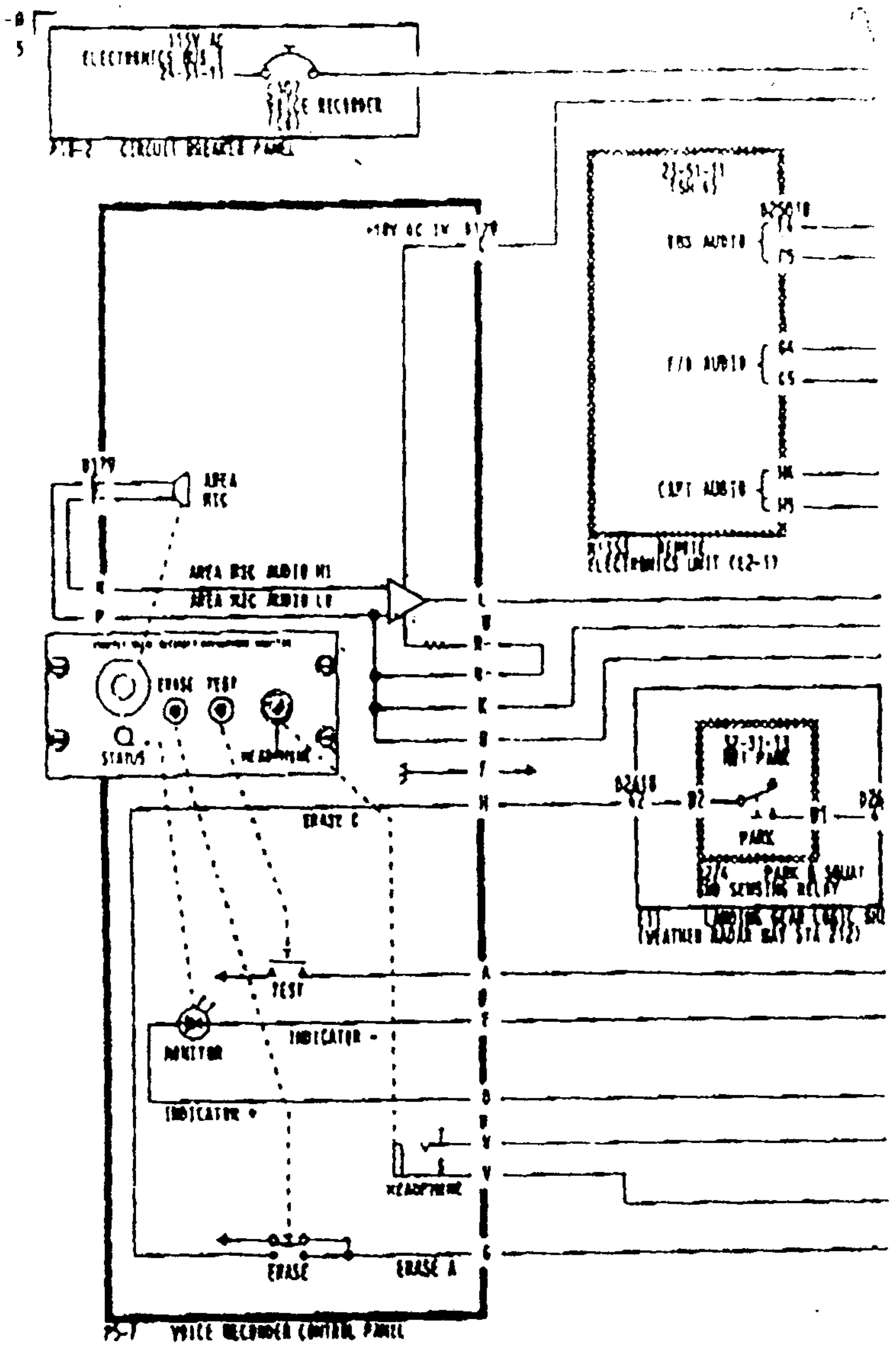
4) The wiring from the SSCVR to the Microphone Monitor (the control unit of the SSCVR located in the overhead panel in the cockpit of the Boeing 737) remained intact throughout the final 2-hours of recording. The SSCVR supplies power to the cockpit area microphone pre-amplifier located in the Microphone Monitor. The final seconds of the recording indicates that the cockpit audio environment was recorded until the removal of power. In addition, the AlliedSignal SSCVR will record in crash survivable memory the audio inputs received 200 milliseconds after power has been removed from the unit. No disruption in the cockpit audio environment was noted (even in the 200 milliseconds after power to the SSCVR was lost), indicating that the wiring between the SSCVR and the Microphone Monitor in the cockpit remained intact.

5) The final 500 milliseconds (1/2 second) of the recording was analyzed in further detail to see if there were any indications of "unusual" audio signals (e.g. high-level and/or high frequency signals, short duration pulses, etc.). No indication was noted in these final 500 milliseconds of recording other than the ambient cockpit audio environment which was present in the final seconds of the recording. As such, AlliedSignal is not able to ascertain if the loss of power to the SSCVR was a result of a manual (or electronic) break of the SSCVR circuit breaker (which is also located in the overhead panel of the Boeing 737 cockpit), or by any other means. In other words, there is not any recorded audio signal to explain the loss of power to the SSCVR.

Based upon the final seconds of recorded audio from the SilkAir SSCVR coupled with our knowledge of operation of the 980-6022-001, 2-Hour Solid-State Cockpit Voice Recorder, we cannot provide a definitive statement as to why the power to the SSCVR was lost at that time.

Submitted By,

Greg Francois
Product Manager, Data Management and Recorder Products
AlliedSigned Air Transport and Regional Avionics



PQ971-PQ995 PW831-PW850	VOICE RECORI

MANUAL NO:

Follow-up Explanation
From
Greg Francois
June 23, 2000

I had told the professor that from the information that was provided to us, there was no evidence on the SSCVR recording itself that the breaker had been pulled. I explained the way that the SSCVR worked (with the capacitive “battery”), such that the SSCVR recorder would STILL record (to the Crash Survivable Memory) after power had been removed for a minimum of 200 milliseconds. I said that there would then have been plenty of time for the audio indication (if any) from the CVR breaker to be recorded by the SSCVR (I had personally done this in demonstrations and ground tests).

There was no evidence on the recording itself. The only reason I know this is that the team came to Redmond (I know someone from the NTSB was there, but I can’t remember who) and we did play back the recording and listened to the last portion (and even captured the last few hundred milliseconds of the recording on an oscilloscope). There was no indication of any change whatsoever in cockpit audio signal (no sound of the breaker, no muffling of the area microphone, no change in the audio waveform, etc.).

What I did tell the Professor was that there should be a TEST conducted to attempt to duplicate the cockpit conditions and verify if the pulling of the breaker (the audio indication that is) could or could not be heard. It was my understanding that a test was conducted by Boeing, but I never heard the results.

What I think I also said was that the most probable cause of the recorder going off was indeed power being removed. I think that I may have also said that another way to remove power to the recorder (other than pulling the breaker in the cockpit) was to cut the power wire (I’m pretty sure that this was also testing) or pull the recorder out of the mounting tray.

Sorry that this is causing so much trouble. I just knew that the area microphone used on the SSCVR was pretty sensitive (especially within a few feet) and that the breaker wasn't too far away from it (on the overheard panel) and that I would have THOUGHT that if the breaker had been pulled, an AUDIO indication on the SSCVR recording itself would have been likely and that this should be verified (or refuted) by actual testing (ground and flight tests), which again I believe were conducted.

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Appendix G

Results of Flight Simulation Exercises

1. First Simulation Test

This simulation test was conducted on 23 January 1998 at Boeing M-Cab engineering flight simulator, Seattle - USA. The M-Cab is a full motion, multi-purpose flight simulator which is used to simulate various types of Boeing aircraft. In the case of B737-300, the nonlinear mathematical software has been validated using flight test data up to Mach 0.89, and extrapolated using aerodynamics data based on transonic wind tunnel data from 0.89 to 0.99 mach.

The objective of the test was to explore and understand the various possible combination of one or more malfunctions of flight controls, aircraft systems and power plants that would result in the extreme descent flight trajectory as suggested by the radar plots.

There were 21 scenarios performed as follows:

1. Autopilot (A/P) ON, Auto Throttle (A/T) ON and One engine FAIL
2. A/P OFF, A/T OFF and One engine FAIL
3. A/P ON, Yaw Damper (Y/D) FAIL and A/P was disconnected after 80 seconds
4. Repeat of scenario 3 with A/P OFF
5. A/P ON, Rudder INPUT simultaneously A/P disconnected, aircraft rolled to 120 degrees bank. Manual recovery.
6. A/P OFF, Rudder INPUT for 4 seconds (aircraft rolled right round) and manual recovery
7. A/P OFF, Rudder INPUT for 2 seconds (aircraft bank 85 degrees) and manual recovery
8. A/P ON, A/P hard over, A/P disconnected and manual recovery
9. A/P ON, A/P disconnected and push-over from level flight. The G's forces recorded at about 0.2 G.
10. A/P OFF, Repeat push-over (¼ column) and G's forces recorded at about 0.5 G until the aircraft descended to 30,500 feet.
11. A/P OFF, One Engine FAIL just before the last radar point at 35000 ft
12. A/P OFF, A/T ON (This session was aborted due to engine inadvertently left failed from the previous session.)
13. A/P OFF, A/T ON (to give max asymmetry with one Engine fail)
14. A/P ON, A/T ON and Y/D hard-over
15. A/P OFF, Yaw damper hard-over (manual recovery after 5 seconds)
16. A/P ON and A/T OFF, Rudder input (the aircraft descended to 33,700 feet at 270 knots with 90 degrees bank)
17. A/P OFF and A/T OFF, Rudder input
18. A/P ON and A/T ON, A/P hard over in lateral axis
19. A/P OFF and A/T OFF, control column pushed and held at 0.75 position down until speed reached Mach 1 (high control column force required)
20. A/P OFF and A/T OFF (try to show the locations of the radar points)
21. A/P OFF and A/T OFF. Rudder Input (aircraft allowed to spiral for much longer period than so far experienced).

Note: Scenarios 1 to 10 were conducted without simulator motion.

The results from the test indicated that none of the scenarios matched the flight trajectory as suggested by the radar points.

2. Second Simulation Test

The simulation test was conducted on 12 May 1998 at the same Boeing M-Cab facility, using corrected data provided by NTSB and Boeing.

The objective of the second test was to demonstrate aircraft responses to specific inputs with appropriate pilot actions to recover. Pilots were to apply appropriate recovery techniques after approximately 4 seconds per JAR ACJ 25.1329 sec 5.3.1 & 5.3.2.

The initial flight conditions of the simulation were based on approximate MI-185 cruise conditions: weight = 110,000 lbs., CG = 18% MAC, altitude = 35,000 feet, airspeed = Mach 0.74 and flaps up.

There were 20 scenarios performed in two sessions as follows:

Session One

1. A/P ON, one engine FAIL
2. A/P ON, one engine FAIL, recovery demonstrated after A/P disconnected
3. A/P ON, Yaw Damper FAIL
4. Yaw Damper FAIL with A/P disconnected after approximately 50 seconds
5. A/P hard over (A/P disconnected almost immediately due to aircraft monitoring system)
6. Attempts to replicate A/P hard over using manual inputs to simulate the monitors not functioning on the aircraft, A/P OFF
7. A/P ON. Full right pedal input, recovery demonstrated after A/P disconnected
8. A/P OFF. Full pedal input recovery demonstration
9. A/P ON. Full pedal input. Recovery after aircraft inverted with A/P disconnected.
10. Backdrive through radar points, demonstration 1
11. Backdrive through radar points, demonstration 2
12. Manual attempts to fly through radar points.

Session Two

1. Manual attempt to fly through radar points with full thrust and full pedal input.
2. Manual attempt to fly through radar points
3. Full right pedal input recovery demonstration
4. Full right pedal input and attempt to simulate an A/P type of response
5. Full right pedal input recovery demonstration
6. Manual attempt to fly through radar points
7. Manual attempt to fly through radar points
8. Full right pedal input with no pilot inputs to recover.

The results of the second simulation test were summarized as follows:

a) The descent trajectory resulting from any single failure would not fly through all the radar points.
b) Any single failure could be effectively recovered by the pilot.

c) The manual maneuvering of the aircraft by rudder/ailerons/elevators inputs would result in flying through some but not all of the radar points. The G load recorded was in excess of 2 G.

3. Third Simulation Test

The test was conducted on 17 February 1999 and 6 March 1999 by NTSC at the Garuda Indonesia B737-300 Training Flight Simulator facility in Jakarta. The test on 6 March was a repeat from the 17 February test with corrected weight & balance data.

The objective of the test was to verify certain findings by the Engineering and Operation groups regarding the horizontal stabilizer settings. The horizontal stabilizer screw jack was found at a position corresponding to a trim setting of 2.5 units. This coincides with the forward manual electric trim limit. However, FDR data shows that the horizontal stabilizer trim setting during cruise was at 4.61 units.

Based on radar data, a time factor of 32 seconds to descend from FL350 (35000 feet) to approximately FL195 (19500 feet) was targeted for this test. Radar points were not considered as they were not available in this simulator.

The test scenarios were:

1. Runaway horizontal stabilizer trim.
2. Rudder hard over.
3. Aileron hard over.
4. A combination of rudder hard over and runaway stabilizer trim.
5. A combination of aileron hard over and runaway stabilizer trim.
6. A combination of sustained manual inputs of rudder and/or aileron plus manipulation of elevator (push and pull).

The results of scenarios 1 to 5 showed that the descent time did not match the target. In scenario 6, the descent time matched the target. However, the g-factor could not be ascertained for all the scenarios.

4. Computer Simulation Fly-out Study

NTSB independently performed a simulation fly-out study of the MI-185 descent trajectory. The study was conducted using NTSB B737-300 NT Workstation based simulation. All simulations used the following cruise flight conditions: weight = 109,920 lbs., CG = 18% MAC, altitude = 35,000 feet, airspeed = Mach 0.74 and flaps up.

The simulation study used similar scenarios as in the second simulation test at the Boeing M-Cab facility.

From this study, NTSB reported on 6 May 1999 that airplane response to pitch control failures, rudder control failures and autopilot roll failures has been investigated. Pitch control failures and autopilot failures do not match the available radar data. Yaw Damper failures do not match the radar data. A rudder hard over failure will not match the radar data unless accompanied by adverse pilot action. Several scenarios have been identified in which active pilot control will produce a match with the radar data.

5. Fourth Simulation Test

This test was conducted on 13 July 1999 at the same Boeing M-Cab simulator facility as mentioned above. It incorporated scenarios from the second and third simulation tests.

The objective of the test was to review and reaffirm the results of the three simulation tests conducted so far, particularly with the effect of the manual electric horizontal stabilizer trim being at the full forward limit. Furthermore, emphasis was given to the value of load factor, airspeed, pitch angle and rate of descent.

The scenarios performed were as follows:

Case #4 Healthy aircraft, Pilot Control Inputs: Wheel, Pedal and Column
Case #5 Healthy aircraft, Pilot Control Inputs: Wheel and Column
Case #6 Full Rudder Input, Pilot Control Inputs: Wheel and Column
Case #7 Full Rudder Input, Pilot Control Inputs: Wheel and Column
Case #8 Full Rudder Input, Pilot Control Inputs: Wheel and Column
Case #9 Stab Trim Runaway, Pilot Control Inputs: Wheel and Column
Case #11 Stab Trim Runaway, Pilot Control Inputs: Wheel and Column
Case #12 Full Rudder Input, Pilot Control Inputs: Wheel and Column
Case #14 Full Rudder Input, Pilot Control Inputs: Wheel and Column
Case #15 Stab Trim Runaway, Pilot Control Inputs: Wheel only

Case #16 Stab Trim Runaway, Pilot Control Inputs: Wheel, Pedal and Column
Case #17 Stab Trim Runaway, Pilot Control Inputs: Wheel, Pedal and Column
Case #18 Healthy aircraft, Pilot Control Inputs: Wheel and Column
Case #21 Stab Trim Runaway, Pilot Control Inputs: Wheel, Pedal and Column
Case #23 Stab Trim Runaway, Pilot Control Inputs: Wheel, Pedal and Column

Case #30 Right Aileron Hard over (trailing edge up), Pilot Control Inputs: Wheel, Pedal and Column
Case #31 Right Aileron Hard over (trailing edge up), Pilot Control Inputs: Wheel, Pedal and Column
Case #32 Healthy aircraft, Pilot Control Inputs: Wheel, Pedal and Column
Case #33 Healthy aircraft, Pilot Control Inputs: Wheel, Pedal and Column
Case #34 Healthy aircraft, Pilot Control Inputs: Wheel, Pedal and Column
Case #35 Healthy aircraft, Pilot Control Inputs: Wheel, Pedal and Column
Case #36 Healthy aircraft, Pilot Control Inputs: Wheel, Pedal and Column
Case #37 Healthy aircraft, Pilot Control Inputs: Wheel, Pedal and Column

The results from the test indicated that for the scenarios that were flown with the Horizontal Stabilizer Trim in the normal cruise position (4.61 units) would generally produce a load factor higher than 2 G during the descent.

The scenarios flown with the Horizontal Stabilizer Trim in the manual electric forward limit (2.5 units) would generally produce a load factor lower than 2 G during the descent.

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Appendix H

Site Acceptance Certificate of The Hughes GUARDIAN System

SITE ACCEPTANCE

PROVISIONAL ACCEPTANCE

PROTOCOL

CONTRACT NO.	LI/89/VI/1994
CONTRACT NAME.	FAT-50

PROVISIONAL ACCEPTANCE SITE ACCEPTANCE PROTOCOL	CONTRACT NO. CONTRACT NAME. DATE:	LN89/VI/1994 FAT-50 JULY 31, 1997

PA SITE ACCEPTANCE PROTOCOL

(1) **PA SITE ACCEPTANCE PROTOCOL**

(2) **Consolidated Exception List (Annex A)**

(3) **Maintenance Actions Required (Annex B)**

(4) **References:**

- (a) **ORD Protocol**
- (b) **Physical Audit Protocol**
- (c) **ISAT Protocol**
- (e) **MSSR Civils Works Natuna Protocol**
- (d) **Natuna Cardion MSSR Equipment Protocol**
- (f) **AFTN ELSA Protocol**
- (g) **VHF Protocol**

PROVISIONAL ACCEPTANCE SITE ACCEPTANCE PROTOCOL	CONTRACT NO. CONTRACT NAME. DATE:	LN89/VI/1994 FAT-50 JULY 31, 1997

PROVISIONAL SITE ACCEPTANCE PROTOCOL

a. The undersigned agree that Hughes Aircraft of Canada Limited (HACL), International Airspace Management Systems Division (IAMS), has fully verified and demonstrated for FAT-50 as required by Paragraph 5.3 of the Technical Specification:

1. Satisfactory design, workmanship, material installation and functioning of all equipment;

2. Testing, Commissioning and performance on site to the satisfaction of the Employer in accordance with the specifications;

3. Satisfactory continuous operation over a period of 30 days without frequent adjustment, changes or part replacement of equipment;

4. Satisfactory completion of training courses for technical staff and controllers designated by DGAC/Employer;

5. Complete and satisfactory delivery of spares, tools, test equipment, etc.; and

6. Complete and satisfactory delivery of all documentation.

b. In recognition of the foregoing, it is agreed that HACL/IAMS has satisfied the contractual requirements for provisional site acceptance of FAT-50. Exceptions to the above mentioned requirements, which do not impair the normal operation of the site, for which the Contractor remains liable, are listed in attached Annex A and Annex B. Clearance of these exceptions will be accomplished prior to Final Site Acceptance (FSA)

c. Hughes agrees to provide one on-site representation to assist APII in carrying out its maintenance responsibilities for a period of one month.

d. Therefore, in accordance with the Terms and Conditions of the above contract, Provisional Acceptance for the FAT-50 Project is hereby granted. It is acknowledged that effective July 31, 1997:

(1) APII rights under the Contract for Liquidated Damages are hereby waived;

(2) APII assumes custody and responsibility, including all operation and maintenance responsibility, for the FAT-50 system and its subsystems;

(3) Warranty Period shall commence; and

(4) Hughes Aircraft of Canada is entitled to request payment from EDC for Installation and Site Acceptance Milestone.

This Protocol is signed and effective July 31, 1997.

For PT (PERSERO) ANGKASA PURA II **For HUGHES AIRCRAFT OF CANADA**

Mr. Risman Nuryadin, MEA,
APII Project Manager

Mr. Grant Rusconi
HACL Project Manager

Mr. Ir. Asrul Rapani,
Director of Engineering, APII

Mr. T.J. Levins
HACL Commercial Manager

Mr. Chusjairi, SE
President Director, APII

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Appendix I

Professional Events in the Flight Crew's Career during 1997

Professional Events in the Pilot-in-Command's Career During 1997

18 February	PIC attends base check. Performance rated as 'above average'.
3 March	PIC was flying pilot on a flight from Singapore to Manado, Indonesia. During approach to runway 36, the crew conducted a go-around manoeuvre.
8 April	The PIC was selected as a line instructor pilot (LIP).
10 May	The PIC commenced line operations as an LIP.
3 June	The first officer on the 3 March flight was interviewed by the B737 Fleet Manager about the Manado incident.
6 June	The B737 Fleet Manager interviewed and obtained written statements from the PIC and the first officer on the 3 March flight, and wrote an initial report. He recommended that further investigation was required.
19 June	The Flight Operation Manager re-interviewed both pilots involved in the Manado incident (3 March).
24 June	The PIC and the first officer on the 3 March Manado flight were rostered to fly together. While preparing for the flight in the flightdeck, the PIC had asked the first officer some questions about the Manado incident.He then pulled the circuit breaker for the cockpit voice recorder (CVR) in order to preserve the previous conversation between the two pilots as evidence for the ongoing investigation into the Manado incident. The PIC decided to reset the circuit breaker before take off. The flight continued uneventfully.
25 June	Both pilots on the 24 June flight reported the CVR circuit breaker incident to management. The Flight Operations Manager decided to conduct a Divisional Inquiry into the incident.
3 July	The PIC was handed a letter summarizing the findings of the inquiry panel into the circuit breaker incident. The PIC was also informed that the company had decided to remove him from his LIP position immediately, and he was reprimanded for his actions. Attached to the letter was a form that asked the PIC whether or not he accepted the company's decision.
7 July	The PIC returned the form attached to the 3 July letter, and stated that he did not accept the company's decision. As a result, a Company Inquiry into the go-around and circuit breaker incidents was held.
15 July	The PIC was informed by letter that the Company Inquiry would take place on 28 July.
28 July	The Company Inquiry into the go-around and circuit breaker incidents took place. The panel recommended that the original penalty stands.
1 August	The PIC was informed of the Company Inquiry's decision by the Flight Operations Manager. During this meeting, the PIC indicated that he did not accept the decision and he inquired about further

	avenues of appeal.
7 August	The PIC completed a base check. Performance was rated ‘above average’.
19 August	The PIC had a meeting with the SilkAir General Manager about the inquiries.
16 December	The PIC last flight assignment was on this date
19 December	**Accident**

Professional Events in the First Officer’s Career During 1997

3 March	The F/O completed base check. Performance rated as “above average”.
4 June	The F/O was found fit during his last medical examination.
14 Sept.	The F/O completed his most recent recurrent training (included recovery from unusual attitude) and was found to be satisfactory.
15 Sept.	The F/O completed base check. Performance rated as “above average”.
10 October	The F/O completed a line check, and no problems were noted.
16 December	The F/O last flight assignment was on this date
19 December	**Accident**

Appendix J

History of FAA AD Related to Boeing 737 Rudder System

Appendix C
History of Federal Aviation Administration Airworthiness Directives Related to the Boeing 737 Rudder System

FAA records indicate that 10 airworthiness directives (AD) related to the Boeing 737 rudder system have been issued since 1980. Each of these ADs is described below and summarized in the table that follows.

On April 21, 1980, AD 80-07-02 became effective. It required a test on Boeing 737 airplanes within 3 days to determine if the main rudder power control unit (PCU) and other flight components could fail. The AD was prompted by a finding that components manufactured by a company other then Parker were installed in the PCU by a repair station or operator.

On March 3, 1994, AD 94-01-07 became effective. It required a test of the main rudder PCU every 750 flight hours until the PCU was replaced with a PCU incorporating a redesigned servo valve. This test was used to determine if the PCU servo valve was in proper operating condition by evaluating rudder system hydraulic flow or internal leakage within the servo valve resulting from improperly positioned servo valve slides. The 750-hour test requirement was removed when the PCU was replaced with a redesigned servo valve. The USAir flight 427 aircraft had been tested for compliance with the AD on March 21, June 18, and August 8, 1994. AD 94-01-07 was superceded by AD 97-14-04 (which became effective on August 4, 1997.

On March 14, 1995, telegraphic AD 95-06-53 was issued regarding certain 737s that had PCUs serviced by a repair station. The FAA determined that assembly methods for the PCU servo valve did not guarantee that the servo valve primary and secondary slides would be properly set, which could result in the servo valve not functioning properly. The AD required removing or testing of the suspect parts within the next five flights. This action affected approximately 50 airplanes.

On November 27, 1996, AD 96-23-51 became effective. It required all 737 series airplanes to be inspected within 10 days and every 250 flight hours afterward. This AD was the result of findings related to testing of the main rudder PCU during the USAir flight 427 accident investigation. These findings indicated that a jam of the secondary slide to the servo valve housing and subsequent rudder input could result in the rudder moving opposite of its intended direction. The AD required that a full rudder pedal displacement be made to the travel limit of the rudder and then a sudden full pedal command be made to the opposing direction. If the pedals moved normally, the test was successful; if they did not, the rudder PCU was required to be replaced immediately. The 250-hour test requirement was removed when the PCU was replaced with one that incorporated a redesigned servo valve. AD 96-23-51 was superceded by AD 97-14-04 (which became effective on August 4, 1997).

On January 17, 1997, AD 96-26-07 became effective. The AD required revising the airplane flight manual (AFM) for all 737 series airplanes within 30 days to include procedures that would enable the flight crew to take "appropriate action to maintain control of the airplane during an uncommanded yaw or roll condition" and "correct a jammed or restricted flight control condition." The FAA stated that the AD had been prompted because such procedures were not defined adequately in the existing version of the 737 AFM. The AD established a "recall" procedure to be performed by flight crews immediately, from memory, in the event of an uncommanded yaw or roll. The FAA specified that air carriers could comply with the AD by inserting a copy of it in the AFM.

On March 19, 1997, AD 97-05-10 became effective. It required certain 737 main rudder PCUs to be removed or tested within 90 days to determine if they had been assembled by a repair station with an incorrect fastener used to retain the summing levers. This anomaly was discovered when an operator noted cracking of the summing lever bearing. The FAA found that the fastener installed by the repair station caused the bearing to crack. This AD affected approximately 200 PCUs.

On June 9, 1997, AD 97-09-15 became effective. It required an inspection of the yaw damper engage solenoid. If the solenoid part number was within a specified range, the solenoid valve was required to be replaced with a redesigned valve. This AD resulted from Safety Board's test findings in connection with the investigation of USAir flight 427 accident, which indicated that hydraulic fluid was contaminating the coils of the valve and causing it to fail. The redesigned valve utilized sealed coils that were impervious to hydraulic fluid. The AD required that the valves be replaced within 5 years or 15,000 flight hours after the AD's effective date or the next time the PCU was sent to a repair facility, whichever was earlier.

On August 1, 1997, AD 97-14-03 became effective. It requires the installation, within 3 years, of a newly designed rudder surface limiting device that reduces the rudder authority at flight conditions in which full rudder authority is not required. It also required the installation of a redesigned yaw damper system with improved reliability and fault monitoring capabilities. These actions were the result of Safety Recommendations A-96-107 and -110, which were issued on October 18, 1996, in connection with the USAir flight 427 accident investigation.

On August 4, 1997, AD 97-14-04 became effective. It required that all actions included in ADs 94-01-07 and 96-23-51 be implemented and that, within 2 years, all main rudder PCUs be replaced with a PCU that has a redesigned servo valve. The AD also required that the PCU's vernier control rod bolts be replaced with bolts that are less likely to fail and that a leak test be performed on the PCU within 4,000 to 6,000 flight hours of the AD's effective date and at 6,400 hour intervals thereafter. This leak test was designed to detect latent jams of the servo valve slides.

On January 20, 1998, AD 97-26-01 became effective. It required an inspection to detect galling on the standby rudder actuator input bearing and shaft within 18 months or 4,500 flight hours. The shaft and bearing are to be replaced with a redesigned shaft and bearing within 3 years of the AD's effective date. This AD, which affected approximately

2,800 airplanes, was the result of findings related to the investigation of the United Airlines flight 585 accident and Safety Recommendation A-96-115, issued on October 18, 1996, in connection with the USAir flight 427 accident investigation.

AD number	Title	Affected airplanes	Effective date	Compliance deadline	Description
80-07-02	Flight Control Systems	All model 707, 720, 727, 737, and 747 series airplanes that contain specific hydraulic components manufactured by Fortner Engineering and Manufacturing.	04/21/80	3 days after the AD's effective date.	Conduct a one-time manual input hardover test on the flight control systems (including the rudder, elevators, and ailerons).
94-01-07	Main Rudder PCU	Model 737 series airplanes, line positions 1 through 2453 (inclusive).	03/03/94	Within 750 flight hours after the AD's effective date.	Perform a test of the main rudder PCU to detect internal leakage of hydraulic fluid. Repeat test at 750-hour intervals unless replaced with new main rudder PCU. Superseded by AD 97-14-04.
95-06-53	Rudder Actuator Piston	All model 737 series airplanes.	03/14/95	Within 5 flights after the AD's effective date.	Compare part and serial numbers of the main rudder PCU with those on a list of suspect parts. If applicable, remove and replace PCU with serviceable part or perform specified testing.
96-23-51	Main Rudder PCU	All model 737 series airplanes.	11/27/96	Within 10 days after the AD's effective date.	Perform testing of the main rudder PCU in accordance with Boeing Alert Service Bulletin 737-27A1202. Repeat test at 250-hour intervals unless replaced with new main rudder PCU. Superseded by AD 97-14-04.
96-26-07	737 AFM Revision	All model 737 series airplanes.	01/17/97	Within 30 days after the AD's effective date.	Revise the AFM to include procedures that would enable the flight crew to take appropriate action to maintain control of the airplane during an uncommanded yaw or roll and correct a jammed/ restricted flight control condition.

AD number	Title	Affected airplanes	Effective date	Compliance deadline	Description
97-05-10	Main Rudder PCU	Model 737 series airplanes with a main rudder PCU identified in Boeing Service Letter 737-SL-27-112-B, dated 02/06/97.	03/19/97	90 days after the AD's effective date.	Remove the main rudder PCU and replace the improper fastener with a correct fastener or perform specified testing.
97-09-15	Engage Solenoid Valve Inspection	All model 737-100 through -500 series airplanes.	06/09/97	5 years or 15,000 flight hours after the AD's effective date or the next time the PCU is sent to a repair facility.	Perform a one-time inspection of the engage solenoid valve of the yaw damper to determine the part number (P/N) of the valve. If the valve P/N falls within the range specified, replace the valve with a new one.
97-14-03	Rudder Authority and Yaw Damper System	All model 737-100 through -500 series airplanes.	08/01/97	Within 3 years of the AD's effective date.	Install a newly designed rudder limiting device that reduces the rudder authority during flight conditions for which full rudder authority is not required. Install a newly designed yaw damper system that improves reliability and fault monitoring capability.
97-14-04	Main Rudder PCU	All model 737-100 through -500 series airplanes.	08/04/97	Within 2 years after the AD's effective date.	Perform all actions required by ADs 94-01-07 and 96-23-51. Replace any main rudder PCU having Boeing P/N 65-44861 or P/N 65C37052 with a new main rudder PCU. Replace the vernier control rod bolts having Boeing P/N 69-27229 with new bolts. Perform a leak test of the main rudder PCU within 4,000 to 6,000 hours of the AD's effective date. Repeat the leak tests at 6,400-hour intervals.

AD number	Title	Affected airplanes	Effective date	Compliance deadline	Description
97-26-01	Standby Rudder PCU Input Shaft and Bearing Inspection	Model 737-100 through -500 series airplanes, line numbers 1 through 2814 (inclusive).	01/20/98	Within 18 months or 4,500 hours after the AD's effective date.	Perform an inspection to detect galling on the input shaft and bearing of the standby rudder PCU within 18 months or 4,500 hours after the AD's effective date, whichever occurs later. Replace the input bearing of the standby rudder PCU with an improved bearing within 3 years after the AD's effective date.

Appendix K

Boeing B737 Non-normal Procedures – Emergency Descent

RAPID DEPRESSURIZATION

With airplane altitude above 14,000 Feet MSL, rapid depressurization is a rapid loss of cabin pressure as evidenced by the Cabin Rate of Climb and Altitude Indicators rapidly increasing and prolonged ear distress.

OXYGEN MASKS AND REGULATORS ....ON, 100%

CREW COMMUNICATIONS .....ESTABLISH

Select interphone and the oxygen mask microphone.

PRESSURIZATION MODE SELECTOR ....MAN

OUTFLOW VALVE SWITCH ....CLOSE

Operate Outflow Valve Switch to maintain proper cabin altitude and cabin rate of change. If pressurization is restored, continue manual operation.

PASSENGER SIGNS ....ON

PASSENGER OXYGEN SWITCH (if required) ....ON

If cabin altitude exceeds or is expected to exceed 14,000 feet and the PASS OXY ON Light is not illuminated, move the Passenger Oxygen Switch to ON.

If required:

EMERGENCY DESCENT ......INITIATE

With the airplane above 14,000 feet MSL and control of the cabin pressure not possible, or pressure lost, initiate an emergency descent.

EMERGENCY DESCENT

EMERGENCY DESCENT.........ANNOUNCE

The Captain will advise the cabin crew, on the PA system, of impending rapid descent. First Officer will advise ATC and obtain the area altimeter setting.

ENGINE START SWITCHES...........ON
THRUST LEVERS ....CLOSE

Reduce thrust to minimum or as required for anti-ice.

SPEED BRAKE ....FLIGHT DETENT
TARGET SPEED ....Mmo/Vmo
If structural integrity is in doubt, limit speed as much as possible and avoid high maneuvering loads.
LEVEL-OFF ALTITUDE ....LOWEST SAFE ALTITUDE or 10,000 FT, whichever is higher

SPEED BRAKE ....DOWN DETENT

Smoothly lower the Speed Brake Lever and level off. Add thrust and stabilize on altitude at desired airspeed.

CREW OXYGEN REGULATORS ....NORMAL

Flight crew must use oxygen when cabin altitude is above 10,000 feet. To conserve oxygen, position the Normal/100% Selector to NORMAL.

ENGINE START SWITCHES ......AS REQUIRED

The new course of action is based on weather, oxygen, fuel remaining and available airports. Use of long range cruise may be appropriate.

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Appendix L

Boeing B737 Alert Service Bulletin, Subject on Flight Controls – Trailing Edge Flap and Horizontal Stabilizer Trim

BOEING

Commercial Airplane Group

26 JUL 1999.

737 Service Bulletin

ALERT

Number: 737-27A1227
Date: April 8, 1999
Revision 2: June 3, 1999
ATA System: 2741 2751

TO: Prof DIRAN & R. ZAINAL.
FROM: SOERTANTO

Revision Transmittal Sheet

SUBJECT: FLIGHT CONTROLS - Trailing Edge Flap and Horizontal Stabilizer Trim Systems - S245 Flap Limit Switch Inspection and R850 Relay Installation

This revision includes all pages of the service bulletin.

COMPLIANCE INFORMATION RELATED TO THIS REVISION

Federal Aviation Administration (FAA) Airworthiness Directive 99-10-13, Amendment 39-11166, is related to this service bulletin.

More work is necessary on airplanes changed as shown in Revision 1 of this service bulletin. Boeing recommends that you do the inspection and test of the S245 flap limit switch (Part 1 of this service bulletin) at intervals of no more than 300 flight hours until you do the R850 relay installation (Part 2 of this service bulletin). The R850 relay installation is terminating action for the inspection and test of the S245 flap limit switch.

Airplanes with line number 3109 and larger were removed from the service bulletin effectivity. These airplanes will have the R850 relay installed in production.

REASON FOR REVISION

This revision is sent to:

- Put Revision 1 dated April 13, 1999 into service bulletin format. Revision 1 was sent telegraphically in message M-7550-99-RWH-026.
- Make the inspection of the S245 flap limit switch Part 1 of the service bulletin.
- Add the data for the R850 relay installation (Part 2 of the service bulletin).
- Remove airplanes with line number 3109 and larger from the service bulletin effectivity. These airplanes will have the R850 relay installed in production.

Paragraph 1.A., Effectivity, shows changes of airplane operators. Each operator should examine the Effectivity paragraph for changes.

Vertical lines are put on the left edge of each page, except in Paragraph 1.A., Effectivity, to show the location of important changes.

Pages with no vertical lines have no important changes.

ALERT

Number: 737-27A1227
Date: April 8, 1999
Revision 2: June 3, 1999
ATA System: 2741 2751

Summary

SUBJECT: FLIGHT CONTROLS - Trailing Edge Flap and Horizontal Stabilizer Trim Systems - S245 Flap Limit Switch Inspection and R850 Relay Installation

CONCURRENT REQUIREMENTS

None

BACKGROUND

One operator had two occurrences of uncommanded, nose down, stabilizer trim during approach.

The S245 flap limit switch was removed from the operator's airplane and an analysis was done. The analysis showed that the switch had an electrical short because of corrosion. It is possible that water got into the switch and caused the corrosion. The electrical short in the switch gave an accidental signal to the stabilizer trim motor (STM). This caused the STM to move at the high-speed rate. This condition can occur with the autopilot on or off and can decrease the safe operation of the airplane.

The installation of a new relay in the trim system for the horizontal stabilizer will prevent this condition. The relay will prevent an accidental signal sent from the S245 flap limit switch to the STM if the switch has an electrical short.

Boeing Service Related Problem (SRP) 737-SRP-27-0114 is related to this service bulletin.

The Federal Aviation Administration (FAA) has issued an Airworthiness Directive (AD) which requires incorporation of this service bulletin.

ACTION (PRR38060-31)

Part 1 - Do an inspection and functional test of the S245 flap limit switch.

Part 2 - Install a new relay and the related wires. Do a functional test of the relay and a test of the stabilizer trim function of the S245 flap limit switch.

EFFECTIVITY

All 737-300, -400, and -500 airplanes before line number 2997 with a Vickers stabilizer trim motor (Boeing P/N 10-62233-5, Vickers P/N 6355B001-02) and all 737-300, -400, and -500 airplanes line numbers 2997 thru 3108.

COMPLIANCE

For airplanes with 1000 flight hours or more:

Boeing recommends that you do the inspection and test of the S245 flap limit switch (Part 1 of this service bulletin) in 5 days or less from when you receive this service bulletin. After the initial inspection and test, Boeing recommends that you do the inspection and test again at intervals of no more than 300 flight hours.

For airplanes with less than 1000 flight hours:

Boeing recommends that you do the inspection and test of the S245 flap limit switch (Part 1 of this service bulletin) in 10 days or less from when you receive this service bulletin. After the initial inspection and test, Boeing recommends that you do the inspection and test again at intervals of no more than 300 flight hours.

For all airplanes:

Boeing recommends that you do the R850 relay installation (Part 2 of this service bulletin) as soon as manpower and material are available. The R850 relay installation is terminating action for the inspection and test of the S245 flap limit switch (Part 1 of this service bulletin). Part 2 is approved as an Alternative Method of Compliance (AMOC) for

ALERT

Number: **737-27A1227**
Date: April 8, 1999
Revision 2: June 3, 1999
ATA System: 2741 2751

SUBJECT: FLIGHT CONTROLS - Trailing Edge Flap and Horizontal Stabilizer Trim Systems - S245 Flap Limit Switch Inspection and R850 Relay Installation

THIS SERVICE BULLETIN IS SENT TO THE OPERATORS OF RECORD OF THE AIRPLANES SHOWN IN PARAGRAPH 1.A., EFFECTIVITY. IF AN AIRPLANE HAS BEEN LEASED OR SOLD, SEND THIS SERVICE BULLETIN TO THE NEW OPERATOR. IF APPLICABLE SPARES HAVE BEEN SOLD, SEND THIS SERVICE BULLETIN TO THE NEW OWNER.

1. PLANNING INFORMATION

A. Effectivity

1. Airplanes

Refer to Service Bulletin Index Document D6-19567, Part 3 for Airplane Variable Number, Line Number, and Serial Number data.

This service bulletin is for all 737-300, -400, and -500 airplanes before line number 2997 with a Vickers stabilizer trim motor (Boeing P/N 10-62233-5, Vickers P/N 6355B001-02) and the airplanes shown below. 737-300, -400, and -500 airplanes before line number 2997 with a Vickers stabilizer trim motor are **NOT** shown below. An equivalent change is on subsequent production airplanes. Refer to PRR38060-31 for data about this change.

Airplane Models:
737-300 737-400 737-500

IDENTIFICATION BY CUSTOMER, CUSTOMER CODE, GROUP AND VARIABLE NUMBER

AEROFLOT (ARO)
PW441-PW450

AIR FRANCE (AFA)
PU311-PU313

AIR MALTA (MLT)
PS873-PS874

AIR NEW ZEALAND (ANZ)
PR009 PR014

AIR NIPPON (ANK)
PT881-PT884

Federal Aviation Administration (FAA) Airworthiness Directive 99-10-13, Amendment 39-11166.

Federal Aviation Administration (FAA) Airworthiness Directive 99-10-13, Amendment 39-11166, is related to this service bulletin.

INDUSTRY SUPPORT INFORMATION

Boeing warranty remedies are available for airplanes in warranty as of November 13, 1998. Please refer to Paragraph 2.B., Industry Support Information.

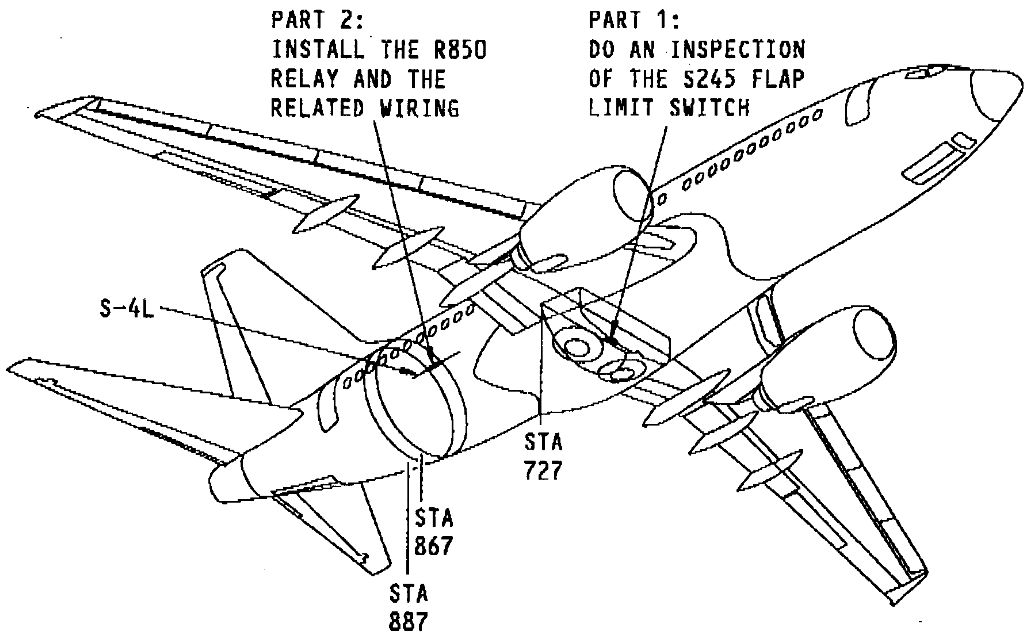
MANPOWER

	Total Man-Hours	Elapsed Time (Hours)
Part 1	3	1.5
Part 2	12	7.25

MATERIAL INFORMATION

Boeing Supplied Kits/Parts

Refer to Paragraph 2.A., Material - Price and Availability.



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Appendix M

Singapore Accredited Representative's Comments on Draft Final Report

Note: For ease of reference by readers, NTSC's comments (in `courier`) are printed onto the attached comments by the Singapore Accredited Representative.

MINISTRY OF COMMUNICATIONS AND INFORMATION TECHNOLOGY
460, Alexandra Road, #39-00,
PSA Building, Singapore 119963
Republic of Singapore
Tel: (65) 270 7988
Fax: (65) 375 7734
Website: http://www.mcit.gov.sg

Our ref: MCIT/CA/MI 185

Your ref:

8 December 2000

Prof Oetarjo Diran
Investigator-in-Charge
Chairman
National Transportation Safety Committee (NTSC)
Gedung Karsa Lt 2, Departmen Perhubungan
Jl. Medan Merdeka Barat No. 8
Jakarta 10110
Indonesia

Tel: (65) 5412481
Fax: (65) 5456519

Dear Prof Diran

MI 185 – DRAFT FINAL REPORT

Please refer to your letter dated 12 October 2000.

2 We are pleased that the NTSC has concluded the investigation. We appreciate the effort put in by your team in this difficult and painstaking investigation which had to be undertaken on the basis of extremely limited information.

3 As requested, our comments on the draft final report incorporating comments by SilkAir and CAAS are attached for your consideration. They also include comments from the Singapore Police, to whom you asked us to extend a copy of the draft final report.

4 Please do not hesitate to let me know if we may be of further assistance.

Thank you.

Yours sincerely

CAPT TAN WEE LEE
ACCREDITED REPRESENTATIVE
SINGAPORE

cc Permanent Secretary
Ministry of Communications & Information Technology
Republic of Singapore

MCIT 6/2000

COMMENTS ON DRAFT FINAL REPORT

1. For the benefit of most readers with little knowledge of aircraft accident investigations, the aim and nature of the technical investigation should be explained upfront in the final report and executive summary. For example, paragraph 3.1 of Annex 13 states that the sole objective of the investigation of an accident shall be the prevention of future accidents. Paragraph 5.4.1 of Annex 13 and ICAO Manual of Aircraft Accident and Incident Investigation Part I – Organisation and Planning (Doc 9756) state that any judicial or administrative proceedings to apportion blame or liability should be separate from any investigation conducted under the provisions of Annex 13.

2. The reason for informing the aviation security authorities should be explained in the final report as well as in its executive summary to avoid any possible misunderstanding by the public. It should explain that the NTSC had informed the relevant aviation security authorities in 1999 based on paragraph 5.11 of Annex 13[1]. As such, there is a separate investigation conducted by the aviation security authorities, i.e. the police. It should also explain that the final report of this technical investigation does not go in depth into the pilots' background as it is the subject of the separate investigation by the aviation security authorities.

NTSC'S COMMENTS:

The aviation security authorities were notified taking into account the findings of the Human Performance & Factors Group in July 1999.

3. The Singapore Police has commented that two statements in the report relating to the financial position of the pilot are inaccurate:

Page 25 paragraph 1.18.3.3

The statement "*During 1990-1997 the PIC traded over 10 million shares, where the value and the volume of the trading increased significantly every year*" should be corrected. The value and volume of the PIC's share trading did not increase every year but fluctuated during this period. Also, the two dates from which the PIC's trading activities were suspended should read as 9 April 1997 (not 15 April 1997) and 9 December 1997 (not 4 December 1997).

Page 43 para 2.14.3

The statement "*The data available also showed that his loans and debts were greater than his realizable assets*" is incorrect. The pilot's realizable assets were higher than his loans and debts.

[1] Para 5.11 of Annex 13 states that "If, in the course of an investigation it becomes known, or it is suspected that an act of unlawful interference was involved, the investigator-in-charge shall immediately initiate action to ensure that the aviation security authorities of the State(s) concerned are informed.

4. The Singapore Police also recommends that the report include mention of the capital gains made by the pilot over the years through the sales of his houses. In addition, it should also mention that the First Officer had another insurance bought in 1992.

NTSC'S COMMENTS:

The First Officer's insurance policy bought in 1992 was not relevant to the accident.

5. We suggest that the fact that only a relatively small amount of wreckage was recovered be reflected in the report. This will illustrate clearly the difficulties faced by the investigation team and enable readers to better appreciate the NTSC's tests (and hence its findings) as well as its constraints due to the extent of damage to the wreckage and the non-recovery of many critical parts of the aircraft. This would also give readers an understanding of why comprehensive tests using the recovered wreckage could not be conducted. As such, we propose the following:

Page 2 paragraph 1.3

There should be a more detailed description of the wreckage recovered. The report should also elaborate that the state in which the wreckage was found severely limited the extent to which meaningful reconstruction could be undertaken.

NTSC'S COMMENTS:

The report has stated that the wreckage was very fragmented. Section 1.12 contains details of wreckage recovered.

Page 7 & 8 paragraph 1.12

The report should state expressly that the cockpit and the circuit breaker panel were not recovered from the wreckage.

Page 9 paragraph 1.12.1.2 & Page 28 para 2.2

The report states that "*examination of the recovered passenger oxygen generators revealed no evidence of activation from which it concluded that the aircraft did not experience depressurization in flight*".

We suggest to insert a line before it, "*Not all of the passenger oxygen generators were recovered*."

Page 17 paragraph 1.12.4

The report states that *"Approximately 370 kg of electrical wires, connectors and circuit boards of the aircraft were recovered"*.
We suggest that the word "Approximately" be replaced by "Only" to avoid any misimpression that a very substantial part of the aircraft was recovered.

Page 6 Section 1.11.1

6. We propose to change the third paragraph to read as "The FDR module was first cleaned and then packed in a container filled with clean water (to prevent the tape medium from drying out and becoming brittle). It was hand-carried to the United States National Transportation Safety Board (NTSB) HQ's readout facility in Washington D.C., USA." This is to avoid readers having the misimpression that the FDR tape was damaged because the FDR module was carried to the NTSB immersed in river water.

Page 22 Section 1.17

7. In the third paragraph fifth sentence, it is incorrectly stated that "All managers are seconded from SIA." SilkAir's Engineering Manager (now titled Senior Manager Engineering) is a SilkAir employee and not on secondment from SIA. We suggest changing the sentence to "The majority of SilkAir's senior managers are seconded from SIA."

Page 23 Section 1.17

8. We suggest changing the existing sentence "Disciplinary inquiries are rare." to read as "As SilkAir is a small organisation, it is natural that disciplinary inquiries are rare."

Page 25 Section 1.18.3.2

9. In the third paragraph it is incorrectly stated that the PIC was appointed Captain on 26 January 1996. He was appointed on 27 January 1996. Also, SilkAir wishes to add that while the PIC was selected for command training on 22 October 1995, he was officially informed of his selection only on 20 November 1995. We suggest amending the third paragraph to read as "The PIC was selected for B737 command training on 22 October 1995. He was officially informed of his selection on 20 November 1995. He

was appointed Captain on 27 January 1996, and confirmed in that position on 27 July 1996."

Page 25 Section 1.18.3.2

10. In the fourth paragraph, SilkAir wishes to advise that the PIC was written to and advised that he had been selected for LIP training on 8 April 1997. Also, while SilkAir wrote to the PIC to advise him of his de-appointment as LIP on 3 July 1997, this was subsequently revised to 28 July 1997 following a company inquiry. We propose amending the fourth paragraph to read as "SilkAir wrote to the PIC on 8 April 1997 to advise him of his selection for LIP. He completed his training on 9 May 1997. He performed satisfactorily thereafter in this position. On 3 July 1997, SilkAir wrote to the PIC to advise him of his de-appointment as LIP. This was subsequently revised to 28 July 1997 following a company inquiry into an operational incident which occurred on 24 June (see Appendix 1 for details)."

Page 38 Section 2.9

11. In the earlier Section 1.7.4 (page 5) second bullet point, it was mentioned that Qantas 41 reported that "the weather was good except for two or three isolated thunderstorms about ten miles to the east of track near Palembang." On page 38 Section 2.9 the sentence about Qantas 41 stated that "Qantas 41 …. did not report adverse weather over Palembang." To be consistent with Section 1.7.4, we suggest that the sentence on Qantas 41 in Section 2.9 on page 38 be changed to "The Qantas 41 …. did not report adverse weather over Palembang except for two or three isolated thunderstorms about ten miles to the east of track near Palembang."

Page 43 Section 2.14.5

12. The last paragraph is intended to cover the whole of the preceding Sections 2.14.1 to 2.14.5 and not just the topic of "insurance". It may be misleading to put this paragraph immediately after Section 2.14.5 without another heading. We suggest adding a new heading "2.14.6 Overall Comments on Section 2.14 " before this paragraph.

Appendix I - Professional Events in the PIC's Career during 1997

13. In the item against the date of 1 August in this Appendix, it is stated that (on 1 August) the PIC met with the Flight Operations Manager and indicated then that he did not accept the decision of the company's inquiry and asked about further avenues of appeal. SilkAir wishes to state that both the Flight Operations Manager and the Fleet Manager B737 who met with the PIC on that day cannot recall him saying that he did not accept the decision. They do, however, recall that he was not happy with it and

asked if a meeting with the General Manager to appeal his case was appropriate. We propose to amend the second sentence of this item to read as "During the meeting, the PIC was not happy with the decision and asked if a meeting with the General Manager to appeal his case was appropriate."

<u>Recommendation</u>

14. We propose the addition of the following recommendation:

"To facilitate the recovery of flight recorders after impact into water, it is recommended that a review of the flight recorders design philosophy be undertaken by the equipment manufacturers to ensure that the underwater locator beacons (ULB) are fitted to the flight recorders in such a manner that the ULB would not be separated from the recorders in an accident."

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Appendix N

USA Accredited Representative's Comments on Draft Final Report

Note: - For ease of reference by readers, NTSC's comments (in `courier`) are printed onto the attached comments by the USA Accredited Representative.

- Legend :

  Times New Roman, Italics – Draft Final Report

  Times New Roman, Bold – NTSB's Comments

  Times New Roman, Normal – NTSB's Comments

  Courier New, Italics – NTSC's Comments

National Transportation Safety Board

Washington, D.C. 20594

Office of the Chairman

December 11, 2000

Professor Oetarjo Diran
National Transportation Safety Committee
Gedung Karsa Lt. 02
Departemen Perhubungan dan Telekomunikasi
JL. Medan Merdeka Barat No 08
Jakarta 10110
Indonesia

Dear Professor Diran:

The National Transportation Safety Board participated in the National Transportation Safety Committee's (NTSC) investigation of the December 19, 1997, accident involving SilkAir flight MI185 as the State of Design and Manufacture of the accident airplane, a Boeing 737, as provided in Annex 13 to the Convention on International Civil Aviation. The Safety Board provided a U.S. Accredited Representative and technical advisors from its investigative staff as resources to the investigation. Additionally, Boeing, the Federal Aviation Administration, and Pratt and Whitney provided technical advisors.

The Safety Board is pleased to provide comments on the NTSC's draft final report. Please note that our review of the draft final report revealed that several sections require correction, clarification, or the inclusion of additional information. Of greatest concern are the statements in the draft final report that the "NTSC is unable to find the reasons for the departure of the aircraft from its cruising level of FL350 and the reasons for the stoppage of the flight recorders" and the "investigation has yielded no evidence to explain the cause of the accident." Additionally, the draft final report contains recommendations that are not supported by the factual evidence.

The examination of all of the factual evidence is consistent with the conclusions that 1) no airplane-related mechanical malfunctions or failures caused or contributed to the accident, and 2) the accident can be explained by intentional pilot action; specifically, a) the accident airplane's flight profile is consistent with sustained manual nose-down flight control inputs, b) the evidence suggests that the cockpit voice recorder was intentionally disconnected, c) recovery of the airplane was possible but not attempted, and d) it is more likely that the nose-down flight control inputs were made by the captain than by the first officer

The detailed comments on the final report are enclosed. These comments are submitted pursuant to Section 6.9 of Annex 13 to the Convention on International Civil Aviation.

Sincerely,

Jim Hall
~~Acting~~ Chairman

Enclosure

Comments on Draft Final Report of Aircraft Accident Submitted by the Accredited Representative of the United States National Transportation Safety Board

SUMMARY

Introduction

As the state of Design and Manufacture of the Boeing 737 airplane, a United States Accredited Representative and advisors[1] participated in all aspects of the Republic of Indonesia's National Transportation Safety Committee (NTSC) investigation into the December 19, 1997, crash of SilkAir flight MI185 in the Musi River, Palembang, Indonesia. On October 17, 2000, the Safety Board received the NTSC's draft Final Report. These comments are submitted pursuant to Section 6.9 of Annex 13 to the Convention on International Civil Aviation, which provides that the State conducting the investigation "shall either amend the draft Final Report to include the substance of the comments received, or append the comments to the Final Report."

Review of the draft Final Report revealed that several sections require correction, clarification, or the inclusion of additional information. Of greatest concern are the statements in the draft Final Report that the "NTSC is unable to find the reasons for the departure of the aircraft from its cruising level of FL350 and the reasons for the stoppage of the flight recorders" and the "investigation has yielded no evidence to explain the cause of the accident."

A significant amount of pertinent factual information developed during the 3-year investigation is either not discussed in the draft Final Report or not fully considered in analyzing the cause of the accident. In particular, the draft Final Report does not take into account all of the investigative findings of the Human Performance Group (HPG), which were documented in a report produced July 30, 1999, and identified as version 6.0. This version of the HPG report was the only version that was developed through consensus agreement among the group members, which included representatives from the Indonesian AAIC (who served as Group Chairman), the Singapore CAA, the United States NTSB, and the Australian BASI.[2] Relevant content from version 6.0 of the HPG

[1] Advisors to the U.S. Accredited Representative included representatives from the Federal Aviation Administration, Boeing Commercial Airplane Group, United Technologies, and Pratt and Whitney.

NTSC'S COMMENTS:

The NTSC understood that the advisors to the US Accredited Representative included representatives from General Electric as the aircraft had GE CFM-56 engines. NTSC was not aware that the representatives included Pratt and Whitney's.

[2] The HPG provided version 6.0 of its report to the NTSC; however, the document that was designated by

report is provided later in this document in connection with specific comments on individual sections in the draft Final Report. Among other things, version 6.0 of the report contains comprehensive information about the flight crewmembers, including information about their professional, personal, and financial backgrounds. For example, substantial information was developed indicating that the captain's professional and financial situations had undergone negative changes in the months preceding the accident. It is disappointing that much of this information was either omitted from the draft final report or was not fully analyzed.

NTSC'S COMMENTS:

> *The Australian BASI (now ATSB) advisor is not an official representative. The Singapore Accredited Representative is from the Ministry of Communications and Information Technology and his advisors are from the Civil Aviation Authority of Singapore, SIA Engineering Company and SilkAir.*
>
> *The final draft is based on information that had since overtaken the HPG report version 6.0, for example the PricewaterhouseCoopers audit report. Hence, sole reliance on version 6.0 would lead to inaccurate conclusions.*
>
> *All group reports have been analysed and integrated into the final report. Specific details, such the pilots' personal details etc., were not deemed appropriate for inclusion in the final report.*

Following this summary, this document suggests specific corrections, clarifications, and/or additions for each section of concern. This summary provides an overview of the primary areas of concern and offers an explanation for the accident that is consistent with all of the evidence. As further discussed in this summary, when all of the investigative evidence is considered, it leads to the conclusions that: 1) no airplane-related mechanical malfunctions or failures caused or contributed to the accident, and 2) the accident can be explained by intentional pilot action. Specifically, a) the accident airplane's flight profile is consistent with sustained manual nose-down flight control inputs; b) the evidence suggests that the cockpit voice recorder (CVR) was intentionally disconnected; c) recovery of the airplane was possible but not attempted; and d) it is more likely that the nose-down flight control inputs were made by the captain than by the first officer.

---

the NTSC as the final HPG report (without consensus agreement from the HPG members) omits a significant amount of information that was included in version 6.0.

NTSC'S COMMENTS:

> *The NTSC is aware that others may draw different conclusions from the same set of facts. With reference to the conclusions referred to in the statement "when all of the investigative evidence is considered, it leads to the conclusions …", the NTSC has a set of different conclusions based on the evidence available.*

1. No airplane-related mechanical malfunctions or failures caused or contributed to the accident.

The investigation examined the aircraft structures, flight control systems, and powerplants extensively, and the results are presented in the NTSC draft Final Report. As stated in the conclusions in the draft Final Report, there was no evidence of any pre-impact mechanical malfunctions or failures. Further, the pilots did not report any problems with the airplane or make any distress calls to air traffic controllers throughout the duration of the flight, as would be expected if they had experienced a mechanical problem. Finally, engineering simulations of flightpath data (derived from pre-upset DFDR data, recorded radar information, and wreckage locations) were conducted to determine the motion of the airplane from the time it departed cruise flight until the end of recorded data indicated. As noted in the NTSC draft Final Report, analysis of these simulation results indicated that no single mechanical failure of the airplane structure or flight control systems would have resulted in movement of the airplane through recorded radar data points. Further, there was no evidence of any combination of systems failures.

Therefore, the evidence supports a conclusion that no airplane-related mechanical malfunctions or failures caused or contributed to the accident.

NTSC'S COMMENTS:

> *The evidence available does not rule out that there were no airplane-related mechanical malfunctions or failures as only 73% of the wreckage was recovered, most of which was highly fragmented. It is for this reason that NTSC has not made any conclusions on this. NTSC has taken the consistent position throughout the final report that conclusions must be backed by evidence.*

2. The accident can be explained by intentional pilot action.

a) The accident airplane's flight profile is consistent with sustained nose-down manual flight control inputs.

The engineering simulations just discussed indicated that manual manipulation of the primary flight controls in multiple axes would result in a descent time history that was similar to the last recorded radar points. Without the use of horizontal stabilizer trim, this would require control column forces greater than 50 pounds and large control column inputs; if those forces were relaxed, the airplane would have initiated a return to a nose-up attitude due to its inherent stability. However, the simulations indicated that a combination of either control column inputs and/or changing the stabilizer trim from about 4.5 to 2.5 units nose-down trim (which would have "unloaded" the high control forces) in conjunction with aileron inputs, would result in a descent time history similar to that of the last recorded radar points. It is important to note that the physical evidence indicated that the horizontal stabilizer trim was set at the maximum airplane nose-down main electric trim limit (2.5 units) at the time of impact.

Therefore, on the basis of the engineering simulations, it is very likely from the time it departed from cruise flight until the end of the recorded data, that the airplane was responding to sustained flight control inputs from the cockpit.

NTSC'S COMMENTS:

There is no evidence to conclude that there was manual intervention. After the stoppage of the FDR, which occurred before the airplane started its descent, there was no data available on the inputs made to flight control surfaces or engine thrust levers up to the point of impact.

b) The evidence suggests that the CVR was intentionally disconnected.

The NTSC draft Final Report states that no reason could be found for the stoppage of the flight recorders and recommends that "a comprehensive review and analysis of [FDR and CVR] systems design philosophy by undertaken . . . to identify and rectify latent factors associated with the stoppage of the recorders in flight." This recommendation implies that the NTSC believes the flight recorders stopped because of mechanical malfunction. However, this implied conclusion is not supported by the evidence. Rather, the evidence suggests that the CVR was intentionally disconnected. There is also no evidence to indicate that the digital flight data recorder (DFDR) stopped as a result of mechanical malfunction.

NTSC'S COMMENTS:

Although it may be possible that the CVR was intentionally disconnected, there is no evidence to suggest as such. The evidence only showed that the stoppage was not caused by an over load or short circuit.

The first indication of an anomaly in the flight occurred at 09:05:15.6, when the CVR ceased recording. As further discussed later in this document in detailed comments on section 2.6.1 of the draft Final Report, evidence (including the sound signature at the end of the recording) indicated that the stoppage of the CVR was consistent with the removal of power going to the unit through activation ("pulling") of the circuit breaker, rather than the CVR stopping as a result of a mechanical malfunction or a short circuit or other electrical condition.[3] Further, the evidence from the last recorded minutes on the CVR indicates that during the 4 minutes that elapsed after the last meal service and before the recording stopped, only the captain and first officer were present in the cockpit. The HPG determined that the captain's statement at 0904:55, "go back for a while, finish your plate," indicated that he was leaving the cockpit and told the first officer to finish eating. In addition, the CVR also recorded sounds that were consistent with seat movement and removal of a seat belt just before the captain offered the first officer water at 0905:00. This sequence of events is consistent with the captain preparing to leave the cockpit.

The circuit breaker panel located directly behind the captain's seat contains the circuit breakers for both the CVR and FDR. It was determined that the cockpit door did not open before the CVR ceased recording at 0905:15.6, thus it is evident that the captain would have been in the best position to manually pull the CVR circuit breaker at the time that it stopped. (It should be noted that the captain had pulled a CVR circuit breaker on a previous occasion.[4])

The DFDR stopped recording approximately 6 minutes after the CVR stopped recording. There was no evidence of any malfunction of the DFDR until the moment it stopped recording. Examination of other aircraft systems and the review of the air traffic control radar tapes revealed that the DFDR is powered through the same electrical bus (Electronics Bus 1) as ATC-1 (one of the airplane's two radar transponders) and the Mach trim actuator. The radar transponder (which was likely ATC-1 during the accident flight) continued to operate and return data for a short time after the DFDR stopped. In

[3] The DFDR gave no indication of any other electrical problems associated with the cessation of the CVR or electrical problems preceding the subsequent cessation of the DFDR.

[4] The NTSC draft Final Report acknowledges this incident in section 2.14.3, which describes the incident as follows: "for non-technical reasons the PIC infringed a standard operating procedure, i.e., with the intention to preserve a conversation between the PIC and his copilot, the PIC pulled out the CVR circuit breaker, but the PIC reset the circuit breaker in its original position before the flight."

addition, the Mach trim actuator was found at its high speed (not cruise speed) setting, indicating that it was powered and operational during the airplane's high-speed dive. It can be concluded that the absence of a malfunction of the DFDR up to the point at which it stopped, combined with the fact that the transponder continued to transmit and the Mach trim actuator continued to operate after the DFDR had stopped, indicates that the stoppage was not due to a loss of power to Electronics Bus 1. However, the stoppage could be explained by someone manually pulling the circuit breaker.

NTSC'S COMMENTS:

As mentioned above, although it may be possible that the CVR was intentionally disconnected, there is no evidence to suggest as such.

The NTSC draft Final Report suggests that the cessation of the CVR and DFDR could in each case be explained by a broken wire. Although this is technically correct, the probability of two such unrelated wire breaks occurring several minutes apart and affecting only the CVR and DFDR is so highly improbable that it cannot be considered a realistic possibility.

NTSC'S COMMENTS:

- *The draft final report stated that "A break in the wire supplying power to the CVR could also lead to CVR stoppage without any sound being recorded. However, from the limited quantity of wiring recovered, it could not be determined if a break in the wiring had caused the CVR to stop." The report did not conclude or rule out that the stoppage of the CVR was due to a broken wire.*
- *The draft final report did not make any statement linking FDR stoppage with wire breakage as implied by NTSB.*

c) Recovery of the airplane was possible but not attempted.

The NTSC draft Final Report contains a recommendation that flight crews be trained in "recovery from high speed flight upsets beyond the normal flight envelope…to enhance pilot awareness on the possibility of unexpected hazardous flight situations." This recommendation implies that the NTSC has concluded that the accident may have been caused by an unexpected unusual flight upset and that the flight crew was not properly trained to recover from such an upset. However, such a conclusion is not supported by the evidence.

NTSC'S COMMENTS:

The evidence showed that the airplane had exceeded its flight envelope during its high-speed transonic descent. The recommendation does not in any way imply that NTSC has concluded that the accident may have been caused by an unexpected unusual flight upset. This recommendation is to generate crew awareness of the narrow margin between the normal high-speed flight regime and the limits of the flight envelope, and the hazards of exceeding the normal flight envelope.

Regardless of the reason for the airplane's departure from cruise flight, it could have been easily recovered using conventional techniques that both pilots had received training for and that were within the capabilities of both pilots. Further, there was ample time for the pilots to take such corrective action to return the airplane to a straight and level attitude and flight. Both pilots had training in unusual attitudes, and the captain was an accomplished fighter pilot adept at aerobatic maneuvers as evidenced by his membership on the RSAF flight demonstration team, the "Black Knights." It is apparent that, had the pilot attempted to recover by initiating immediate corrective action using standard flight control inputs and techniques, the airplane would have recovered to a straight and level attitude with a minimum loss of altitude.

NTSC COMMENTS:

- *The NTSB statement is based on the assumption that the recovery was possible if recovery action was taken immediately (eg JAR ACJ 25.1329 gives a norm of 4 secs). Without such immediate recovery action the airplane could exceed the normal flight envelope. Airframe manufacturers have not specified to airline crew recovery techniques for flight outside the normal envelope.*
- *There was evidence indicating that the Captain had the intention to leave the cockpit.*
- *There was no evidence that the recovery of the airplane was not attempted. The fact that during impact the engine was in high power and that the undercarriage was*

retracted do not preclude the possibility of pilot attempts to recover from the steep dive by using flight controls and varying engine thrust.

As previously mentioned, the simulations indicate that from the time it departed cruise flight, a sustained nose-down flight control input was necessary to maneuver the airplane through the recorded radar points. Additionally, the impact damage to the engine was consistent with a higher-than-cruise power setting. (Without pilot input, the autothrottle system would have reduced engine power to idle when the descent began; therefore, the high power setting must have been input by the pilot.) Further, there was no evidence that any other measures were taken (such as deploying aerodynamic drag devices on the airplane) to slow the airplane's speed. The wing leading-edge devices and trailing-edge flaps, the "speed brakes" (in-flight spoilers) and the landing gear were found to have been in a position that was consistent with cruise flight.

NTSC'S COMMENTS:

There was no FDR recording to provide any data as to what actually happened from the time the recording stopped until impact.

The simulation results, in combination with the physical evidence of a high engine power setting, a horizontal stabilizer trim setting positioned for maximum nose-down attitude, and the absence of any indication of an attempt to reduce the airplane's speed, are clearly inconsistent with an attempt to a recover from a dive and return to cruise flight, and strongly suggest the maneuver was intentional.

NTSC'S RESPONSE:

As mentioned above, there was no FDR recording to provide any data as to what actually happened from the time the recording stopped until impact.

d) It is more likely that the nose-down flight control inputs were made by the captain than by the first officer.

The HPG evaluated the professional, personal, and financial backgrounds of the flight crew of flight MI185. The HPG findings are discussed in more detail in comments on individual sections of the draft Final Report later in this document. In summary, the HPG investigation revealed that both pilots were trained in accordance with applicable company and civil aviation authority regulations and were competent to promptly recognize, address, and manage an unanticipated in-flight situation using all resources available to them; there was no evidence to indicate that the performance of either pilot was adversely affected by any medical or physiological condition existing before the accident; there was no evidence to indicate that there were any difficulties in the relationship between the two pilots before or during the accident flight; and there was no evidence that either pilot was experiencing any significant difficulties in personal relationships involving family and friends.

Further, with respect to the first officer, the evidence developed by the HPG revealed the first officer was not experiencing any professional setbacks or difficulties at the time of the accident, nor was he experiencing any financial difficulties. Also, there was no evidence that he was experiencing any behavioral changes before the accident.

However, the investigation of the captain's background developed evidence that revealed he had experienced multiple work-related difficulties, particularly during the 6-month period before the accident. Additionally, the investigation found that the captain was experiencing significant financial difficulties about the time of the accident, and there were indications that the captain's behavior and lifestyle had changed before the accident.

NTSC'S COMMENTS:

> *The information obtained after HPG report version 6.0 showed that the captain had no significant financial difficulties at the time of the accident.*

It is not possible to determine with certainty which pilot made the manual flight control inputs. However, when the HPG findings are considered in the context of all the other investigative findings, they lead to the conclusion that the airplane departed cruise flight as a result of an intentional maneuver requiring sustained manual flight control inputs that were most likely performed by the captain.

NTSC'S COMMENTS:

> *There is no evidence to conclude that either of the pilots made any manual flight control inputs.*

In summary, the investigative findings strongly support the conclusions that no airplane-related mechanical malfunctions or failures caused or contributed to the accident, and the accident can be explained by intentional pilot action.

The remainder of this document sets forth detailed comments on individual sections in the draft Final Report.

1. FACTUAL INFORMATION

1.1 History of Flight

Sequence of Events

On 19 December 1997, a SilkAir Boeing B737-300 aircraft, registration 9V-TRF, was on a scheduled commercial international passenger flight under Instrument Flight Rules (IFR), routing Singapore – Jakarta – Singapore.

The flight from Singapore to Jakarta operated normally. After completing a normal turn-around in Jakarta the aircraft departed Soekarno-Hatta International Airport for the return leg.

At 08:37:13 (15:37:13 local time) the flight (MI 185) took off from Runway 25R with the Captain as the handling pilot. The flight received clearance to climb to 35,000 feet (Flight Level 350) and to head directly to Palembang[5]. At 08:47:23 the aircraft passed FL245. Ten seconds later, the crew requested permission to proceed directly to PARDI[6]. The air traffic controller instructed MI 185 to standby, to continue flying directly to Palembang and to report when reaching FL350. At 08:53:17, MI 185 reported reaching FL350. Subsequently, the controller cleared MI 185 to proceed directly to PARDI and to report when abeam Palembang.

At 09:05:15.6, the cockpit voice recorder (CVR) ceased recording. According to the Jakarta ATC transcript, at 09:10:18 the controller informed MI 185 that it was abeam Palembang. The controller instructed the aircraft to maintain FL350 and to contact Singapore Control when at PARDI. The crew acknowledged this call at 09:10:26. There were no further voice transmissions from MI 185. The last readable data from the flight data recorder (FDR) was at 09:11:27.4. Jakarta ATC radar recording showed that MI 185 was still at FL350 at 09:12:09. The next radar return, eight seconds later, indicated that MI 185 was 400 feet below FL350 and a rapid descent followed. The last recorded radar data at 09:12:41 showed the aircraft at FL195. The empennage of the aircraft subsequently broke up in flight and the aircraft crashed into the Musi River delta, about 28 kilometres north east of Palembang. The accident occurred in daylight and in good weather condition.

The route map and the crash site are depicted in Figures 1.a to c. The sequence of events is shown schematically in Figure 2.

---

[5] *Coordinates (02.52.7S, 104.39.2E)*
[6] *Air Traffic Control reporting point (00.34.0S, 104.13.0E) north of Palembang in the Jakarta FIR near the boundary with the Singapore FIR. At PARDI, flights are transferred over to Singapore ATC*

Section 1.1 in the NTSC's draft Final Report does not present all factual information necessary to portray a more complete picture of the flight crewmembers' interaction in the cockpit shortly after departure from Jakarta. It is strongly suggested that this section be revised to include information from the HPG Final report (dated June 8, 2000), which provides a time history of the captain's movements in the cockpit in relation to the time that the CVR stopped recording. Once this history is established, it provides a basis for analyzing the stoppage of the CVR and, possibly, the DFDR. The following text should be inserted immediately before the sentence, "At 09:05:15.6, the cockpit voice recorder (CVR) ceased recording":

> **At 0904:55, the PIC said "go back for a while, finish your plate." The co-pilot responded "I am." A series of metallic snaps started immediately prior to 0905:00, when the PIC said "some water." The co-pilot replied "no thanks."**

Further, the CVR transcript in Appendix A is not a complete factual record of CVR recording that was transcribed by the CVR group. Appendix A does not include the conversation that took place during preflight activities or the conversations that transpired between the flight crewmembers or between the flight crew and the cabin crew while the airplane was on the ground in Jakarta. This information is critical to the analysis of crewmembers' overall discipline and of comments that were made in conversation by the crewmembers. Seen in its entirety, the CVR transcript indicates that a cordial and professional atmosphere existed on the flight deck during the period of time the CVR was operating. Moreover, the publication of the entire CVR transcript is necessary to maintain consistency with the ATC communications transcripts.

1.5 Personnel Information

1.5.1 Pilot-In-Command (PIC)

Sex	*Male*
Age	*41 years*
Date of joining SilkAir	*1 March 1992*
Licence country of issue	*Singapore*
Licence type	*ATPL (Airline Transport Pilot Licence)*
Licence number	*501923*
Validity period of licence	*1 November 1997 to 30 April 1998*
Ratings	*Boeing B737; Airbus A310 (not current)*
Medical certificate	*First class – issued 10 October 1997*
Aeronautical experience	*7173.3 hours*
Experience on type	*3614.7 hours*
Last 24 hours	*1.6 hours*

Last 7 days	*20.1 hours*
Last 28 days	*56.8 hours*
Last 90 days	*216.7 hours*
Last line check	*25 January 1997*
Last proficiency check	*7 August 1997*
Instrument rating check	*7 August 1997*

1.5.2 First Officer (F/O)

Sex	*Male*
Age	*23 years*
Date of joining SilkAir	*16 September 1996*
Licence country of issue	*Singapore*
Licence type	*CPL (Commercial Pilot Licence)*
Licence number	*503669*
Validity period of licence	*1 July 1997 to 30 June 1998*
Ratings	*Boeing B737*
Medical certificate	*First class – Issued 4 June 1997*
Aeronautical experience	*2501.7 hours*
Experience on type	*2311.8 hours*
Last 24 hours	*1.6 hours*
Last 7 days	*21.4 hours*
Last 28 days	*69.8 hours*
Last 90 days	*217.6 hours*
Last line check	*10 October 1997*
Last proficiency check	*15 September 1997*
Instrument rating check	*15 September 1997*

Sections 1.5.1 and 1.5.2 do not contain any information about the captain's personal background. Although this is not a typical subheading for an accident report, the high probability of flight crew involvement in this accident makes it necessary to include this information to complete the factual record and provide the basis for a thorough analysis.

It is strongly suggested that the NTSC add a section pertinent to the captain's personal background information to the draft Final Report. This section should be identified as "1.5.1.1 Personal Background" and include the following information about the captain:

- **The captain was born June 17, 1956 in Singapore. His parents were Chinese immigrants, and he was the second of four children. He was of Buddhist faith, but he was not reported to be devoutly religious.**

- **He achieved his "O" level education in 1972 and an industrial technician certificate in electronics in 1974.**

- **The captain was married in July 1979, and his wife, also of Chinese descent, was born in Singapore. The captain and his wife had three sons, born in 1981, 1983, and 1989. In HPG interviews during the investigation, the captain was described as being a family man, who often spoke about his sons and spent a lot of time with them.**

- **The captain's family moved to a new house in August 1997 next to where the captain's brother and parents lived. He was reported to be interested in computers and financial markets.**

- **According to police representatives, he had no record of criminal activity in Singapore.**

It is also strongly suggested that the NTSC add a section pertinent to the first officer's personal background information. This section should be identified as "1.5.2.1 Personal Background" and include the following information:

- **The first officer was born in New Zealand on March 3, 1974. He was the second of four children. The first officer was not married but had a close personal relationship with a stewardess who worked at SilkAir. The first officer lived with another SilkAir first officer, a close friend who he also lived with when working for Garuda.**

- **The first officer was a Christian, and was described as being devout. He was described as being close to his family and had a number of close friends in Singapore. He was described as being very interested in flying and pursuing a flying career. His other interests were reported to include traveling, spending time with friends, and playing sport.**

- **Police representatives reported that the first officer had no record of criminal activity in Singapore.**

1.16 Tests and Research

1.16.1 CVR Circuit Breaker Actuation Test

Upon the completion of data readout by NTSB, the CVR was taken to AlliedSignal on 22 January 1998 for further testing. This testing was an attempt to verify if the termination of the CVR recording was due to loss of power by the pulling of the CVR circuit breaker or other means. The result was inconclusive. Therefore other tests had to be performed, see Appendix F.

There were three tests conducted in a B737-300 aircraft to investigate the CVR circuit breaker actuation sound signature.

The first test

The first test was carried out on the ground by NTSB and Boeing on 5 February 1998. The reason for this test was to have quiet ambient condition to provide the best opportunity for detection of circuit breaker actuation sound signature. The result showed that the CVR cockpit area microphone did record the CVR circuit breaker actuation. Actuation of a circuit breaker nearby gave a similar result.

The second test

The test (consisting of on-ground and in-flight tests) was conducted on 14 May 1998 and 15 May 1998 by NTSB.

The purpose of the ground test was to obtain an on-plane, on-ground CVR recording of the CVR circuit breaker actuation, and the purpose of the flight test was to obtain an on-plane, in-flight CVR recording of the CVR circuit breaker opening. In both tests the circuit breaker was actuated manually and through the introduction of faults to the aircraft's wiring, i.e. short circuit and overload.

The results of these tests were compared with the accident CVR recording sound signatures. In the short circuit tests a distinctive 400 Hz tone is recorded on one or more of the CVR channels. No corresponding signatures could be identified on the accident recording. The same tests found that the area microphone is able to pick up a distinctive and identifiable snap sound that the circuit breaker makes when it is violently tripped by a short circuit. (Note: The CVR continues to run for 250 milliseconds before it runs out of power from the capacitor. As sounds travel about one foot per millisecond, it would take only six milliseconds to travel the approximately six feet distance from the circuit breaker to the area microphone. Hence the CVR is able to record the snap sound of the circuit breaker.)

The overload tests yielded similar results as the short circuit tests except that there was a slight time delay for the circuit breaker to trip and the snap sound was quieter but still identifiable. No corresponding sound signatures could be found in the accident recording.

The last set of tests was to examine the sound signatures when the CVR circuit breaker was manually pulled. The snap sound was identifiable on the ground without engines and air-conditioning operating. However in the flight tests, the addition of the background cockpit noise present during normal cruise obscures the sounds associated with the manual in-flight pulling of the cockpit circuit breaker. No corresponding sound signatures could be found in the accident recording.

The summaries of the results of the second tests are as follows:

- *During an overload and a short circuit, the sound of the circuit breaker popping is loud enough to be identified on the CVR's area microphone channel, both on the ground and in-flight.*
- *During an overload and a short circuit, the CVR records unique and identifiable sound signature on one or more of the channels, both on the ground and in-flight.*
- *During the manual pull test on the ground, the sound of the circuit breaker is loud enough to be identified on the CVR recording.*
- *In cruise flight, normal cockpit background noise obscured the manual circuit breaker pull sounds. There are no unique electronic identifying sound signature recorded on the CVR.*

The third test

The test was conducted in-flight using a B-737 SilkAir sister aircraft in Singapore on 16 October 1998 and supervised by the Indonesian NTSC, an FAA avionic inspector (representing NTSB) and Singapore MCIT representatives.

In the third test, several scenarios were performed where the CVR circuit breaker in the cockpit was manually pulled. The manual pulls were categorized as "soft", "hard" and "string" pull. The soft pull was by pulling the circuit breaker with minimum noise. The hard pull was by pulling the circuit breaker normally. The string pull was by pulling on a string that was attached to the circuit breaker. This was to simulate a short circuit causing the circuit breaker to pop out.

All the tests were conducted with an identical AlliedSignal SSCVR 2-hours recorder as installed in the accident aircraft.

All four channels of the CVR recordings of the above three tests were analyzed using the same NTSB signal processing software that was used to analyze the accident CVR recording.

Several tests were done to document the sound that were recorded on the CVR during a soft, hard and string pull of the CVR circuit breaker. The test closely matched the data obtained from the second test (NTSB in-flight test above).

The NTSC draft Final Report's discussion about the CVR (and DFDR later in the report) requires a correction of terms so as to avoid confusion when referencing the electrical power that is being supplied to both recorders. The "power source" is where the CVR and DFDR receive their respective electrical power from within the aircraft whereas the "power supply" is a component that is integral to the CVR and DFDR units. The use of "power supply" when describing a power interruption from the aircraft power source is incorrect because it implies that an internal failure occurred or may have occurred within a respective recorder.

To eliminate any potential confusion regarding the electrical power being supplied to the CVR and DFDR, the draft Final Report should be reviewed and the term "electrical power source" inserted where the term "power supply" is currently used.

NTSC'S COMMENTS:

> *The term "electrical power source" is meant to include the external as well as the internal power supply to the individual units.*

In addition, examination and testing requested by the NTSC revealed no evidence to suggest that a mechanical malfunction or failure of either the CVR or DFDR caused either recorder to stop recording data.

The discussion of the postaccident CVR testing does not address the distinctive 400 Hz tone (or "hum") that was recorded on the CVR tape. For purposes of clarity, the following information (an excerpt summary from the February 20, 1998, Boeing test report) should be added to this section to discuss the basis for the 400 Hz tone:

> **Power line hum components, located at multiples of 400 HZ were evident in the CVR area microphone signal. The level of some of these hum components increased when the overload was applied until the circuit breaker popped. These levels were even more dramatic during the ground fault conditions….It should be noted that some of these hum components persisted in the signal, after the breaker has opened, to the very end of the recorded data. Tones are good candidates for detection amongst broadband boundary layer excitation. Tracking the amplitude of a particular power-line hum component may indicate circuit overload or faults.**

NTSC'S COMMENTS:

> *It has been adequately covered in the report that failure of the CVR is not due to an overload or a short circuit condition.*

1.18.3 PIC's Background and Training

1.18.3.1 Professional Background in RSAF

The PIC joined the Republic of Singapore Air Force (RSAF) as a pilot trainee on 14 July 1975. He obtained his 'wings' (fully operational) on 25 March 1977. During his RSAF career, the PIC flew many different types of fighter and training aircraft. He held senior flying and instructing positions. In 1970s, the PIC was selected to joint the RSAF's Black Knights aerobatic team. He reached the rank of Captain in 1980 and was promoted to

Major in 1989. In 1991, the PIC applied to leave the RSAF under a voluntary early release scheme. The PIC met the eligibility requirements for the early release scheme as he was 35 years old and had at least six years in his immediate preceding rank. His application was accepted.

The PIC's reason to leave RSAF and join SilkAir was to keep flying and to spend more time with his family.

The PIC obtained a US Federal Aviation Administration (FAA) Commercial Pilot Licence on 19 November 1991 and an Air Transport Pilot Licence on 26 November 1991 in Benton Kansas. He left full-time employment in the RSAF on 29 February 1992. He had approximately 4,100 hours flying experience at that time. The PIC served as a squadron pilot in the RSAF on a part-time basis from 1 March 1992 to 30 April 1993. He subsequently served in the military reserve, as a Major, in a non-flying capacity. In January 1997, the PIC was promoted to Deputy Director Air Liaison Officer in his reserve unit.

The NTSC draft Final Report's description of the captain's "Professional Background in RSAF" should be expanded to include information developed by the HPG regarding his military service or significant events that occurred during his service period. It is strongly recommended that section 1.18.3.1 be revised to include the following information:

The captain joined the RSAF as a pilot trainee on July 14, 1975. He obtained his "wings" (fully operational) on March 25, 1977. During his RSAF career, the captain flew many different types military fighter and training aircraft. He held senior flying and instructing positions and reached the rank of captain (military) in 1980 and was promoted to the rank of major in 1989. The captain became a member of the RSAF Black Knights in 1990 [not 1970s as stated in the NTSC draft Final Report].

NTSC'S COMMENTS:

Factually correct however it is felt that there is no need to include such specific details in the final report.

In December 1979, when five RSAF pilots (including the captain) and four T/A-4S aircraft were temporarily stationed in the Philippines for training, the captain experienced the first of three significant events during his service in the military. On December 19, the captain was forced to withdraw from a scheduled training mission because of a mechanical problem with his aircraft. The other three aircraft continued with the training mission and collided with terrain after encountering bad weather in a mountainous area. All of the pilots on

board the aircraft were killed. Although the HPG investigation obtained information about this event, it was not possible for the group to determine the extent to which the captain had been affected by this event.

On September 6, 1981, the captain took off in an SF 260 training aircraft as the instructor pilot with a student pilot conducting the flying duties. During the takeoff roll, the aircraft crashed. The student was fatally injured. The RSAF investigation found the circumstances of the accident were not the responsibility of the captain.

On March 3, 1986, the T/A-4S in which the captain was acting as an instructor pilot during a training flight experienced loss of control because of a mechanical malfunction. Both crewmembers ejected safely from the aircraft. The RSAF investigation found the captain was not responsible for the event.

During HPG interviews, RSAF personnel described the captain as being a highly skilled pilot. According to the RSAF, there were no records of the captain receiving disciplinary action or having any major setbacks in his career. It was also reported that the captain did not have a history of disagreements with other personnel while serving in the RSAF. However, several pilots who worked with the captain at SilkAir and who were in the RSAF at the same time as the captain reported that he had disagreements with his commander while serving with the Black Knights. The RSAF reported that these disagreements were related to flying maneuvers. The disagreements were characterized as minor and were reported to have been resolved. It was reported that the squadron was under a great deal of pressure and that there were disagreements between many pilots.

In 1991, the captain applied to voluntarily leave the RSAF under an early release program. The captain met the eligibility requirements for the early release (he was 35 years old and had at least 6 years in his immediate preceding rank), and his application was accepted shortly thereafter.

The captain obtained a United States Federal Aviation Administration (FAA) Commercial Pilot Certificate on November 19, 1991, and an Airline Transport Pilot Certificate on November 26, 1991, in Benton Kansas. He left the full-time employment of the RSAF on February 29, 1992, at which time he had accumulated approximately 4,100 hours flying experience.

The HPG investigation found during an interview with the captain's wife that he separated from the RSAF because he wanted to spend more time with his family. A person considered to be a flying associate of the captain reported that the captain probably left the RSAF in order to remain in a flying position because his next job would have likely been in a nonflying capacity if he remained enlisted. Under the early release scheme, the captain had the choice of joining either Singapore Airlines (SIA) or SilkAir. Several SilkAir personnel who knew the captain reported that he preferred to join SilkAir rather than SIA because he could be promoted to a command pilot position at SilkAir within 3 years whereas he would likely have to wait at least 5 years to achieve the same position at SIA.

Although the captain was flying full-time for SilkAir in March 1992, he served as a squadron pilot in the RSAF on a part-time basis from March 1, 1992, to April 30, 1993. He subsequently served in the military reserve, as a major, in a nonflying capacity and in January 1997 was promoted to Deputy Director Air Liaison Officer in his reserve unit.

NTSC'S COMMENTS:

The above details are deemed not relevant to the accident.

1.18.3.2 Professional Background with SilkAir

The PIC formally joined SilkAir on 1 March 1992. He was initially employed as a Cadet pilot under a training program for pilots that did not have a Boeing 737 (B737) type rating and had no previous airline experience.

The PIC was assigned to the Airbus A310 fleet and commenced training on 30 May 1994. He was appointed First Officer on the aircraft on 15 August 1994. When SilkAir discontinued A310 operations, the PIC was re-qualified on the B737 in March 1995.

The PIC was selected for B737 command training on 22 October 1995. He was appointed Captain on 26 January 1996, and confirmed in that position on 27 July 1996.

He was selected as LIP in March 1997[7] and completed his training on 9 May 1997. He performed satisfactorily thereafter in this position. On 3 July 1997, the PIC was de-appointed from his LIP position following an investigation into an operational incident which occurred on 24 June (see Appendix I for details).

7 The LIP position was seen as a requirement for further promotion to instructor pilot or into management. The position also gave a pilot additional allowance of S$ 750 monthly.

The PIC had no problems with regard to his professional licence medical requirements. His last licence renewal medical examination was on 2 December 1997.

Section 1.18.3.2 does not provide a complete factual record regarding the captain's career at SilkAir nor does the referenced Appendix I (the chronology presented in Appendix I does not list any professional events that occurred after August 19, 1997). The addition of a complete career chronology is necessary to accomplish a thorough analysis of the accident. Thus, it is strongly recommended that the NTSC include the following information (from version 6.0 of the HPG report) in section 1.18.3.2 to present a complete chronology of the captain's airline history:

> **The captain was formally employed with SilkAir on March 1, 1992, as a "cadet" pilot under a special training program for pilots who did not have a Boeing 737 (B737) type rating and had no previous airline experience. The captain signed a 7-year training bond agreement with SilkAir (then known as Tradewinds) that required the captain to pay the company on a prorated schedule for his training if he should leave the employ of SilkAir for any reason.**
>
> **After completing B737 ground school, the simulator checks, and base checks, the captain was appointed as a second officer on June 26, 1992. At SilkAir, the second officer position is typically identified with a copilot who requires a mandatory period of supervision before promotion to first officer. It was a standard appointment for someone with the captain's background at the time he joined the airline. He was appointed as a first officer for a 6-month probation period on October 14, 1992, commenced line operations in that position, and completed his probation period on April 14, 1993.**
>
> **The captain was selected for a conversion to the Airbus 310 (A310) fleet on April 14, 1994, and commenced training activities on May 30, 1994. He was appointed as a first officer on the aircraft on August 15, 1994. When SilkAir phased out its A310 fleet, the captain was eligible to leave SilkAir and join SIA. However, he decided to remain with SilkAir and subsequently completed B737 reactivation training in March 1995.**
>
> **After obtaining sufficient flight time to convert his FAA issued Airline Transport Pilot License (ATPL) to a Singaporean license, the captain took a written examination (Special Assessment Paper for a Foreign License Conversion) on July 25, 1995. This examination was administered by the United Kingdom (UK) CAA under a contract with the Singaporean CAAS. Candidates are only given one opportunity to take this examination for which a passing score was 75**

percent. The captain initially scored 68 percent but a subsequent rescoring elevated his score to 71 percent. On August 1, 1995, the captain made a special appeal to the UK CAA, citing that there were "imperfections" in the exam paper. His appeal was accepted and he was given a passing grade. He applied for a Singapore ATPL on October 11, 1995, and received a letter 7 days later from the SilkAir B737 Fleet Manager congratulating him on achieving his Singapore ATPL and 3 years of service at SilkAir.

The captain was selected for B737 command training on October 22, 1995,[8] and commenced training for this position on January 22, 1996. This training included both simulator and line training, with the simulator training consisting of five line-oriented flight training (LOFT) sessions. The captain signed a 3-year bond agreement with SilkAir for the training. He was appointed to captain on January 26, 1996, and confirmed (after probation) in that position on July 27, 1996.

In March 1997, three management pilots in SilkAir[9] met to discuss the captain's suitability for a line instructor pilot (LIP) position.[10] Although the captain met the minimum requirements for the position, the managers initially had reservations about the captain's suitability as they thought he may have been too reserved, regimented, or strict. After interviewing the captain, they selected him for the position and he completed the required training between April 30, and May 9, 1997. He also conducted line operations as a LIP between May 10 and June 13, 1997. There were no problems reported concerning the captain's LIP performance.

During his career at SilkAir, the captain received training in unusual attitudes, flight control malfunctions, and flight instrument malfunctions on several occasions. No significant problems were noted regarding the captain's abilities to accomplish this training. During his last training session in these areas (February 17 to 18, 1997), his performance was rated as "sound." In May 1997, the captain participated in the Aircrew Resource Management course conducted within SIA for aircrews.

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[8] Pilots are not eligible for command selection in SilkAir before they have served 3 years in the company, flown a total of 4,400 hours, and completed 300 sectors as pilot flying.

[9] These management pilots were the Flight Operations Manager, B737 Fleet Manager, and the F-70 Fleet Manager. The B737 fleet manager was the PIC's immediate supervisor.

[10] In SilkAir, a captain is eligible to be considered for an LIP position after serving as a captain for 1 year. In addition to regular duties as commander, LIPs at SilkAir give instruction and guidance to command candidates or first officers in the final stages of their training. At SilkAir, the LIP position was considered a requirement for further promotion to instructor pilot or into management. The position also gave a pilot additional pay of S$750 monthly.

During 1992 to 1996, the captain was not involved in any known operational incidents. However, he was involved in three non-operational incidents that SilkAir management described as minor and as having no effect on the captain's chances of career progression. These events involved missing a security briefing, forgetting his passport for an international flight, and attempting to cash a cheque at an inappropriate facility.

Between January 1997 and the time of the accident, the captain was involved in the following four operational events:

- **On March 3, 1997, a go-around was performed on an approach into Manado, Indonesia;**

- **On May 17, 1997, a flight was conducted with a dispatch authorization for an inoperative parking brake;**

- **On June 24, 1997, the captain pulled, and then reset, the CVR circuit breaker before a flight; and**

- **On November 20, 1997, an overweight landing occurred in Singapore.**

As a result of the CVR circuit breaker incident, the captain was removed from his LIP position on July 3, 1997, after a Divisional Inquiry. Although he subsequently appealed this decision, a Company Inquiry upheld the original decision. During the accident investigation, the HPG found through interviews with several SilkAir personnel that the captain was upset by the events that resulted in the loss of his LIP position. The events surrounding the four incidents are summarized in Appendix I of the draft Final Report (Appendix H1 of the HPG version 6.0 report).

During interviews conducted by the HPG, SilkAir instructors reported that the captain's transition from military fighter aircraft to a commercial airliner was average but that his performance soon improved with experience. He adapted quickly and generally had no problems with any period of training. Further, SilkAir evaluates each pilot's operational performance every 6 months. These base checks are performed in a simulator, and the pilot's performance is rated in a number of key performance areas. The captain's performance on almost all base checks from March 1993 to his last check on August 7, 1997, was rated as "above average." His performance on the annual line checks was consistent with his performance on base checks.

Interviews conducted by the HPG with instructors and other pilots at SilkAir indicated that the captain's ability as a pilot was above average and that he was a competent operator. He was commonly described as being very highly skilled in handling an aircraft and as having fast reaction times. It was reported that he appeared to maintain good situation awareness and that he made decisions quickly, firmly, and confidently. He also appeared to be able to handle any flight-related pressures quite calmly.

The captain was described by other SilkAir pilots as a good cockpit manager. They indicated that he provided clear instructions, kept first officers informed of his decisions, and let first officers make their own decisions. He was quick to spot copilot mistakes or problems with the flight. However, he was not known for criticizing copilots, and liked to teach and show them new ways of doing things.

The HPG interviews of SilkAir pilots also revealed the captain to be someone who operated "by the book" and who would not exceed aircraft limitations. However, many pilots also indicated the captain would vary from normal practices at times. For example, several copilots reported the captain would often push the aircraft's speed beyond the economy speed of .74 mach.[11] There were also several reports of the captain performing higher than normal approaches[12] and, unlike other company captains, exploring ways of varying normal practices to reduce flight durations. Although the captain was not generally regarded as an unsafe pilot, he was regarded as a pilot who made his own decisions as to what was and was not safe.

Over a period of 2 years, the captain received several letters of appreciation from the SilkAir B737 Fleet Manager for being on standby. Such letters were standard for such events.

In addition, it is strongly suggested that the following events, which were presented in the HPG report (version 6.0) be added to Appendix I:

24 August: The captain and the first officer who had been involved in the go-around incident in March and the circuit breaker incident in June flew together as a result of a

[11] Economy speed is a speed that is supposed to optimize the relationship between time enroute and fuel burn. It is a speed calculated to reduce the cost of operating the flight for the airline considering several economic factors and not a manufacturer-imposed operating limitation on the aircraft.
[12] A high approach means that during the descent from cruise, an airplane is at an altitude higher than the typical altitude for a given distance from an airport.

roster change that the captain had requested for personal reasons.

20 November: The captain was involved in an event that resulted in an overweight landing. There was an engine power problem noted during takeoff and climbout. After discussion with an engineer on board, the flight crew decided to return to Singapore instead of continuing to the destination airport. The subsequent overweight landing was not noted in the voyage report and technical log as was specifically required by company procedures. The crew also did not complete other paperwork associated with the flight including calculating the landing speeds, flight time, and fuel flight plan. The B737 Fleet Manager noted the discrepancies and sent both pilots letters the next day, instructing them to "please be more mindful."

10 December: The captain was flying with close friends, one was the first officer and the other was riding in the jump seat. During the flight, the captain complained about the B737 Fleet Manager and the letter he had received about the overweight landing incident on November 20. A variety of other topics were discussed (see recommended additions to section "1.18.3.4 Recent Behaviour").

11 December: The captain visited the Flight Operations Manager to discuss the letter about the overweight landing. The captain was concerned that he had been sent a negative letter about a minor issue and no mention had been made about the significant good work he had done to return the airplane to Singapore (according to the first officer on that flight, the captain effectively managed the increased workload that was associated with this air-turn back to Singapore including troubleshooting, making the necessary notifications to ensure that passengers' needs were met, and moving the airplane to the maintenance area). The Flight Operations Manager reported that he told the captain to send him a letter outlining his concerns and he would then consider whether to send him a "thank you" letter. The Flight Operations Manager did not receive a letter from the PIC outlining his concerns.

Finally, information in Appendix I regarding certain events in the captain's professional history that occurred before August 19, 1997, is noticeably condensed when compared to the discussion of the same events in the HPG report (version 6.0). Some of these events were addressed and acknowledged publicly by SilkAir following the AAIC interim report that was released in August 1999. Although this information may have been pared down for the sake of brevity, the NTSC should provide more information about the March 3, 1997, Manado event and the June 4, 1997, CVR circuit breaker event and the associated inquiries and appeals.

NTSC'S COMMENTS:

All group reports have been analysed and integrated into the final report. Specific details such as those stated above were not deemed necessary for inclusion in the final report.

1.18.3.3 Financial Background Information

The financial background data of the PIC was gathered to determine whether financial factors could have affected the performance of the PIC.

PricewaterhouseCoopers was appointed by the NTSC to conduct an independent review of the preliminary findings of the NTSC's Human Factors Group concerning the financial background of the PIC. PricewaterhouseCoopers was not involved in the investigation itself. Based on the review, PricewaterhouseCoopers made certain recommendations to the NTSC in order for the NTSC to refine its findings.

At the time of the accident, the PIC operated a securities trading account in Singapore. This account was operated from June 1990 until the time of the accident. During 1990 – 1997 the PIC traded over 10 million shares, where the value and the volume of the trading increased significantly every year. The PIC's accumulated total losses from share trading increased between 1993 and 1997, with moderate gains during 1997. There was no period of the PIC negative net worth. The PIC's trading activities was stopped on two occasions due to the non-settlement of his debt, i.e. from 15 April to 15 August 1997 and again from 4 December 1997 until the time of the accident. On the morning of 19 December 1997, the PIC promised the remisier to make a payment when he returned from his flight.

The PIC had several loans and debts at the time of the accident. The PIC's (and immediate family's) monthly income was calculated to be less (about 6%) than their monthly expenditure at the time of the accident.

The probate document indicates that the PIC had a number of insurance policies which provided benefits on the event of his death. Most of these policies were taken out many years prior to the accident. In December 1997 he was required by the financial institution granting the property loan to take a mortgage insurance policy. The PIC underwent medical tests for the policy on 1 December 1997 and followed this with a formal application of 5 December 1997. The PIC did not specify the commencement date for the policy. On 12 December 1997 the insurance company informed the PIC that his application was accepted pending payment of the insurance premium. A cheque dated 16 December 1997 was sent to the insurance company by the PIC being payment for the premium. The commencement or the inception date of the policy was set by the insurance company to be 19 December 1997. This information was not conveyed to the PIC. The cheque was cleared on 22 December 1997.

The HPG's examination and evaluation of the captain's and first officer's overall financial status was understood to be sensitive and confidential for the purpose of publication, and the NTSC's decision not to present the actual financial numbers in the report is respected. However, this section's brevity is of concern because it does not present the totality of information evaluated and analyzed by the HPG.

All of the participants in the HPG (representing Indonesia, Singapore, the United States and Australia) were involved with almost every aspect of the fact-gathering process regarding the captain's financial status, which spanned a period of more than 8 years before the accident. The HPG evaluated this aspect of the captain's life and in July 1999, determined through consensus of all members that at the time of the accident, the captain was experiencing significant financial difficulties (conclusion 14 in the HPG report version 6.0) The NTSC contracted Price-Waterhouse-Coopers (an auditing company) to conduct an audit of financial information that had been gathered during the investigation by the HPG and the NTSC in the latter stages of the investigation. Although the audit was completed, HPG members were not provided a copy for its review and evaluation. Given the significance of this information, the report and its content should be discussed in greater detail.

The review of section 1.18.3.3, revealed inaccuracies and exclusion of relevant information. The NTSC draft report briefly summarized the captain's stock trading over a period of 7 years. Although the actual number of stock shares that the captain traded is not relevant, the monetary value of the stocks traded, even approximated, is significant in that it demonstrates the financial burden that he was incurring in the later years. In addition, the NTSC draft report should contain specific information regarding the type of trading performed by the captain (that is, contra-trading versus buying normal shares) because it establishes that contra-trading, which the captain had been conducting for approximately 8 years, is a high-risk activity. Further, a complete discussion of the captain's trading activities would provide a basis for explaining his loss of trading privileges on two occasions because

of nonpayment (the first time requiring a repayment plan that spanned months).

NTSC'S COMMENTS:

> *The information in 1.18.3.3 is accurate based on the findings of the HPG report version 6.0 completed in July 1999 with corrections by PricewaterhouseCoopers in October 2000.*

The NTSC draft Final Report misstates factual information developed by the AAIC HPG as of July 1999 concerning the mortgage insurance policy that became effective on the date of the accident. The NTSC draft Final Report states that mortgage insurance was "required" by the mortgage lender. However, the HPG found that mortgage insurance, which is purchased voluntarily, is generally recommended by the lender. Also, it should be noted that the loan secured for the purchase of this insurance had been established for at least 3 months before the policy was issued.

It is suggested that the following revisions be made to the draft Final Report to clarify existing information:

> **The mortgage insurance application was submitted November 27, 1997. The insurance was recommended and not required as part of the loan taken by the captain in August 1997.**

NTSC'S COMMENTS:

> *This information was updated after the HPG report version 6.0 was completed.*
>
> **The captain had two training bonds that were in effect at the time of the accident, which required repayment had the captain voluntarily separated from SilkAir or was dismissed.**
>
> **The statement that "The PIC's accumulated total losses from share trading increased between 1993 and 1997, with moderate gains during 1997," should be clarified to indicate that the captain had experienced net losses during this period.**

NTSC'S COMMENTS:

> *The information is based on the findings of the HPG report version 6.0 completed in July 1999 with corrections by PricewaterhouseCoopers in October 2000.*

In addition, the NTSC draft Final Report does not adequately present sufficient information regarding the captain's liquidity of assets at the time of the accident.

Finally, the statement, "The PIC had several loans and debts at the time of the accident" does not provide the specificity that is necessary to demonstrate the significant debt. Also, this statement does not address the significant amount of money that was due to be paid to the stock remiser at the time of the accident or the fact that there were no known liquid assets from which to pay this loan. Further, the draft Final Report does not address the credit cards debt that had been incurred by the captain at the time of the accident. A more thorough description of this information, even in general terms, is necessary to demonstrate that the captain's debts exceeded his assets. In addition, for clarity that maintains confidentiality of specific financial amounts, the report should be modified to characterize the magnitude of the captain's stock losses and debts about the time of the accident in terms of his average annual income.

NTSC'S COMMENTS:

> *Additional evidence not previously available to the HPG provided a more accurate estimate of the PIC's monthly expenditures. As stated in 1.18.3.3 of the final report, the PIC had no period of negative net worth.*

1.18.3.4 Recent Behavior

The PIC's family reported that events and activities were normal in the days before the accident. The PIC was reported to have slept and eaten normally. There were no reported changes in his recent behavior. He was organizing his father's birthday party that was planned for 21 December 1997. No medical problems were reported or noted by airline's appointed medical clinics.

Work associates who observed the PIC on the day of the accident and on his most recent flights, reported nothing odd or unusual in his behavior.

The NTSC draft Final Report provides very brief information about the captain's activities in the days preceding the accident; however, excerpted information from the HPG report (final report and version 6.0) cites other pertinent information that documents the captain's behavior during the 45-day period prior to the accident. It is suggested that NTSC draft Final Report be revised to include the following information:

> **The PIC's family reported that events and activities were normal in the days before the accident. The PIC was reported to have slept and eaten normally. No recent changes in his behavior were reported by his family. It was also reported that the PIC was assisting in preparations for his father's birthday party, which was to occur on December 21.**

Several work associates who observed the PIC on the day of the accident reported nothing odd or unusual in his behavior. One associate noted that the PIC was quite reserved in the briefing room but that he had behaved that way on some occasions.

In the month prior to the accident, the PIC conducted flights on November 21, 22, 23, 28, 29 and 30, and December 10, 11, 12, 13 and 16. Some company personnel on these flights reported nothing unusual or noteworthy in the PIC's behavior. Some personnel reported that the PIC was quieter than normal, and other personnel reported that he complained about company management and its maintenance of aircraft. The following specific events were recounted:

On December 10, the PIC was flying with close friends, one was the first officer and the other was riding in the jump seat. During the flight, the PIC complained about the B737 Fleet Manager and the letter he received about the overweight landing incident. A variety of other topics were also discussed. The PIC asked one of the other pilots about a crash involving a Malaysian Airlines B737 at Gelang Patah in 1984.[13] The PIC was also reported to have discussed the TWA800 B747 accident and mentioned the helplessness of a pilot in such an accident.

The captain took leave from December 1 to 7, 1997. He applied for this leave on November 26, which coincided with school holidays.

In addition, the NTSC draft Final Report does not include factual information related to the behavioral characteristics of both pilots that was developed by the HPG. The information is necessary for a complete understanding of the human factors aspects of the investigation and critical to a complete and proper analysis being accomplished.

Therefore, it is strongly recommended that the NTSC add a section that describes the behavioral characteristics of the captain and first officer. The new section for the captain should precede "section 1.18.3.4 Recent Behaviour" in the draft Final Report (thereby making "Recent Behaviour" section 1.18.3.5) and be identified as "1.18.3.4 Behavioral Characteristics." This section should contain the following information:

The HPG found during its investigation regarding the captain that the RSAF did not require any psychological assessment during his career nor

[13] The crash was determined to be the result of a hijacking. Information recorded on the CVR assisted authorities in making this determination. This information was told to the PIC during this flight.

was such an assessment required or conducted for his employment with SilkAir.

HPG interviews with a variety of people who worked with the captain revealed that he was generally a quiet and reserved person. He would not initiate conversation with casual acquaintances but would talk if asked questions or shared a common interest with the other person. Some people described him as distant and difficult to get to know while other people described him as friendly and easy-going.

The captain's wife described him as a perfectionist and others who knew him in the RSAF described him as a typical fighter pilot. He was also described by people in the RSAF and SilkAir as a very assertive person; he would state his opinion if he disagreed with some professional issue, often in an undiplomatic manner. The interviews revealed that he was very confident and proud of his flying skills and was very proud of his RSAF experience. The captain was described as motivated to obtain the best for himself and it was reported that his career was important to him.

The HPG did find through interviews that there were no reports of the captain having any unusual or abnormal personal habits in the cockpit during flights and that it was routine for him to leave the cockpit to use the toilet, get a drink, or chat with the flight attendants.

The relationships between the captain and the three management pilots in SilkAir were reported to be quite cordial. It was reported that when he joined the company, management regarded him as a pilot who would have no trouble reaching a command position and who had the potential to become a management pilot. The managers were impressed with the captain's performance during his time as a first officer and as a captain. HPG interviews revealed that during this period, the captain often visited the Flight Operations Manager or the B737 Fleet Manager to offer suggestions to improve the company's operations. However, following the incidents and subsequent investigations in 1997, the captain's relationship with the B737 Fleet Manager became less amicable. Although there were no reported arguments, there was little interaction between them. The captain continued to visit and communicate with the Flight Operations Manager but this relationship became somewhat strained after the captain lost his LIP status.

The captain was well respected by other Singaporean pilots in the company, was one of the first two Singaporeans to join SilkAir, and was one of the first two Singaporeans to be selected for command training. As such, he was regarded as a natural leader to the Singaporeans who subsequently joined the airline. The captain was one of several pilots

who were involved in efforts to improve the employment conditions of Singaporean pilots. He was also known to defend other Singaporean pilots or encourage them to question any unfair treatment.

During the accident investigation, the HPG received reports that the captain did not have a good relationship with some of the expatriate pilots in the airline. Some of the pilots stated that the captain did not accept advice or criticism well from other captains. Further, some pilots also stated that that the captain had been promoted to LIP over more experienced captains who had airline instructional experience before coming to SilkAir. The Flight Operations Manager said that the captain was promoted because he had previous training experience in the RSAF, had a good record, and had all the markings of a good instructor. It was also stated that because he was Singaporean, he was preferred over expatriates.

The captain was generally popular among flight attendants and it was reported that he was typically easy-going and often joked with them. He never made any special demands, and he often completed sectors faster than other captains. Flight dispatchers also reported that the captain was easy-going and sociable. Line engineers reported that the captain was friendly, helped when there were engineering problems, and was quite reasonable about accepting any defects.

The HPG also received reports during its investigation that during the latter part of 1997, the captain criticized or complained about SilkAir management and the B737 Fleet Manager during flights. It was reported that he appeared to be upset about the inquiries that had taken place and his loss of LIP status and that he believed he had been unfairly treated. However, there were also reports that the captain had accepted his demotion.

It is also suggested that the appropriate section of NTSC draft Final Report be revised to include the information regarding the captain's use of medical leave to demonstrate a change in his behavior in the 3 months before the accident. For example, during his 6-year career at SilkAir, the captain visited the airline's preferred medical group on 31 occasions. No major, excessive, or extra-ordinary medical problems were ever reported or noted. The PIC submitted six medical certificates, each requiring a day off flying duties during his SilkAir career. These occurred on August 1, 1995, July 23, 1996, August 10, 1997, October 1, 1997, and November 12 and 24, 1997. All certificates were associated with temporary conditions such as upper-respiratory tract infection, flu, or gastroenteritis.

As previously stated, a section describing the first officer's behavioral characteristics should be added to the draft Final Report. This section should

precede "section 1.18.4.3 Recent Behaviour" in the draft Final Report (thereby making "Recent Behaviour" section 1.18.4.4) and be identified as "1.18.4.4 Behavioral Characteristics." The following information should be included:

> **During HPG interviews, the first officer was described as a quiet and reserved person. However, it was reported that if something needed to be said, he would say it. He was described as being mature for his age, confident, and likeable. The HPG received no reports of any interpersonal problems between the first officer and other pilots or other employees at SilkAir. There were no indications that he was experiencing any personal problems.**
>
> **While at Massey University, the first officer completed a California Personality Inventory. The results indicated that the he was well-adjusted, conservative, stable, and confident. There were no reports that the first officer had any unusual or abnormal habits in the cockpit during flights.**

The NTSC draft Final Report should also be revised to include information about the first officer's medical history while at SilkAir. Specifically, the first officer visited the airline's preferred medical group on three occasions, and no medical certificates were submitted requiring time off of work due to illness.

NTSC'S COMMENTS:

> *All group reports have been analysed and integrated into the final report. Specific details such as those stated above were not deemed necessary for inclusion in the final report.*

Additional Comments on NTSC Factual Section

Page 15, 1.12.3.2, Flight control surface diagrams should accompany the discussion of the spoiler actuators, leading edge flaps, etc., to facilitate the reader's understanding of these mechanisms.

Page 16, 1.12.3.3f, The statement, "As the actuator is of the piston type, the position may be indicative of the last position at impact", should be changed to read "As the actuator is of the piston type, the position may not be indicative of the last position at impact." This change would make the statement consistent with a similar statement made in section 1.12.3.3.a.

Pages 16 and 17, 1.12.3.3.g and 1.12.3.3.h, The heading for each paragraph should be changed to read "Aileron Power Control Units and Autopilot Servos" and "Elevator Power Control Units and Autopilot Servos" respectively.

Page 21, 1.16.4, Paragraph 3, The statement that the rudder balance weight separation did not occur "…while the aircraft was cruising at FL350 but at a lower altitude" is correct. However, it should be emphasized that the balance weight separated after the airplane departed cruise flight. Thus, it is suggested that the sentence be revised to read "The rudder balance weight did not separate while the aircraft was in cruise flight at FL350 but at a significantly lower altitude, after the airplane departed cruise flight."

Page 21, 1.16.4, This section only discusses the BASI trajectory study. The NTSB performed a "desktop" simulation that is referenced as Appendix G. The results of this simulation should be included in this section to provide a complete picture of the aircraft trajectory and break-up after departure from cruise flight.

Page 24, 1.18.2.3, There is no "Figure 15" as referenced in this paragraph.

NTSC'S COMMENTS:

> *Figure 15 is included in the final report. It was not ready at the draft report stage.*

Page 25, 1.18.3.2, Paragraph 4, It is suggested that instead of using the word "de-appointed" to describe the captain's loss of his LIP status, the words "demoted" or "removed" be used.

NTSC'S COMMENTS:

> *The word "de-appointed" is appropriate. The LIP status is not a promotion position but an additional lateral appointment.*

2. ANALYSIS

2.1 Introduction

The following statement in section 2.1 should be clarified:

In accordance with Annex 13, a report was made to the relevant aviation security authorities in late 1999. While the technical investigation continued, aviation security authorities conducted a separate investigation, which is not covered in this report.

Currently there is no support text in the factual part of the NTSC draft Final Report that explains why the contents of the investigative report were made available to the relevant aviation security authorities. In accordance with ICAO Annex 13 requirements regarding suspicion or evidence that an accident was the result of a criminal act, paragraph 5.11 states "If, in the course of an investigation it becomes known, or it is suspected, that an act of unlawful interference was involved, the investigator-in-charge shall immediately initiate action to ensure that the aviation security authorities of the State(s) concerned are so informed." In the case of MI 185, this notification was necessary because the technical examination of the aircraft wreckage revealed there was no evidence of a mechanical malfunction of the aircraft structure, systems or powerplants that would have caused the aircraft to depart cruise flight. Further, the HPG developed sufficient personal background data pertaining to the captain to warrant the "relevant aviation security authorities" to conduct a further investigation of the captain.

NTSC'S COMMENTS:

The notification to the relevant aviation security authorities was not made because there was no evidence of a mechanical malfunction of the aircraft structure, systems or powerplants. The findings of the HPG at that time (July 99) was taken into consideration in the notification.

2.3.3 Explanation to the Break Up of the Empennage

Close examination of the wreckage (Section 1.22) supports the results of the flutter analysis (Section 2.3.2) and the trajectory analysis (Section 2.3.1).

The above results suggest that the separation of the empennage parts could have had occurred at an altitude near or below 12,000 ft, due to an unstable flutter as the aircraft exceeded 1.2 Vd.

These two sentences may be misleading. To provide clarification, the NTSC draft Final Report should be revised to state that evidence indicates that the separation of the empennage components/parts was not the cause of the departure from cruise flight or the accident but was the result of an overspeed condition that occurred after the airplane departed cruise flight.

NTSC'S COMMENTS:

The two sentences are satisfactory.

2.4 Power Control Units and Actuators

2.4.1 Main Rudder PCU

In the controlled laboratory test condition [Reference 16], it was found that problems due to thermal shock can arise. This can happen if the warm hydraulic fluid (at +77°C) rushes into a cold-soaked servo valve (at -40°C) causing the slides to expand against the valve housing. In such a temperature difference, a valve jamming could occur causing the rudder to move uncommanded or in a direction opposite to the rudder pedal command (rudder reversal). In real flight, the hydraulic temperature would not reach that high (+77°C) a level.

An introductory paragraph should be included in section 2.4.1 that explains why the rudder PCU was examined and described in greater detail than the other actuators/PCUs. This introduction would provide the reader with a brief background about the known rudder PCU anomalies identified in previous accidents and the reason for the additional examination.

Further, for clarification, the last two sentences in this section should be revised to read, "In such a temperature difference, if the valve jams and the pilot commands additional rudder input, the result could be an unintended rudder movement in a direction opposite to commanded input (rudder reversal). However, the temperature of the hydraulic fluid rising to +77°C is not likely in normal in-flight operations.

Finally, this section should contain a conclusion statement that indicates that the investigation determined that the rudder PCU was not a cause or contributing factor in the accident.

NTSC'S COMMENTS:

In view of the FAA 737 Flight Controls Engineering Test and Evaluation Board Report and the FAA AD --- which recommends that -- , the NTSC is of the view that this section should not contain a conclusion statement on whether the rudder PCU was or was not a cause or contributing factor in the accident.

2.4.5 Horizontal Stabilizer Jackscrew

A malfunction affecting both trim switches on a control wheel could also cause a run-away. It was not possible to ascertain if such an occurrence took place. However, had a run-away occurred due to a malfunction of the main electrical trim system, it would take about 10 seconds to change from 4.5 to 2.5 units (at a rate of trim change of 0.2 unit/sec at flaps retracted position). The trim wheel would turn continuously. The movement of the trim wheels and the sound produced would have been noticed by the pilots. Both pilots were trained to recognize such a condition and to take appropriate corrective actions.

This paragraph should be modified to include a conclusion that based on the evidence derived from the last recorded FDR position, the NTSB simulation and the physical evidence found during the wreckage examination, the stabilizer trim was moved to the full nose-down limit through pilot input to the main electric trim system and not due to an "uncommanded" or "runaway" trim condition.

NTSC'S COMMENTS:

There is no evidence to conclude that pilot input was responsible for the final position of the stabilizer.

The effect of a system run-away of the horizontal stabilizer trim was simulated in the Garuda Indonesia Training Simulator as well as Boeing M-Cab Simulator, see Appendix G. A trim change from 4.5 to 2.5 units changed the aircraft attitude from a nose-up to a nose-down attitude. The simulator results showed that, with such a trim change, it took 1 minute and 23 seconds to descend from 35,000 feet to 19,500 feet. However, the last five ATC radar points showed a much faster descent of the accident aircraft, i.e. 32 seconds from 35,000 feet to 19,500 feet. Therefore, if the simulation was correct, the change of horizontal stabilizer trim position alone would not have resulted in the fast descent after leaving FL350.

The phrase in the preceding paragraph, "if the simulation was correct" should be removed unless there are specific doubts regarding the accuracy of the simulation. If there is evidence to support the accuracy or inaccuracy of the simulation, this information should be discussed in detail in the factual and the analysis. Further, Boeing does not have any additional qualifiers about the simulation accuracy other than the verification by flight test to .89 Mach and extrapolation to .99 Mach.

NTSC'S COMMENTS:

This qualifying phrase recognises that simulation tests cannot fully replicate actual flight conditions especially flight conditions beyond the normal flight envelope.

2.4.6 Other Actuators

During the tear down examination, the following components were found to be in the stowed or retracted position:

- *Flight spoiler actuators*
- *Outboard ground spoiler actuators*
- *Inboard ground spoiler actuators*
- *Trailing edge flap ballscrews*
- *Leading edge flap actuators*
- *Leading edge slat actuators*
- *Mach trim actuator*
- *Thrust reverser actuators*

The fact that these actuators were found in the stowed or retracted position does not necessarily suggest that their respective systems were not activated during the descent. If the respective systems remained in the stowed or retracted positions, they would not have been factors contributing to the accident.

There was sufficient evidence to indicate that the actuators had performed as intended. Thus, this section should be modified to include a conclusion that there was no evidence of a mechanical malfunction or failure of any flight control PCU or actuator that either caused or contributed to MI 185's departure from cruise flight or the resulting accident.

NTSC'S COMMENTS:

> *As only 73% of the highly fragmented wreckage was recovered, airplane-related mechanical malfunctions or failures can not be totally ruled out.*

2.6 Stoppage of the CVR and FDR

2.6.1 CVR Stoppage

The CVR recording ended while the aircraft was still cruising at an altitude of 35,000 feet, about seven minutes before the last radar return. Up to the CVR stoppage, the conversations in the cockpit was consistent with normal flight operation.

The CVR stoppage could have occurred due to a malfunction of the unit itself or a loss of power to the unit. The loss of power to the unit could be due to power interruption to the Electronics Bus 1 that supplies power to the CVR, short circuit or overload, CVR circuit breaker pulling or break in the wiring.

The entire two-hour recording was found normal. There were no observed anomalies when power was transferred on the ground in Jakarta. It appeared that the recorder's internal energy storage capacitor was operating normally by providing continuous *recorder operation in spite of momentary aircraft electrical power interruptions, [Reference 4].*

The examination of the CVR unit performed by the manufacturer (Appendix F) confirmed that the CVR was functioning properly. The recording had characteristics that would be expected of a normal electrical power shutdown of the CVR. Therefore, the stoppage of the CVR could be a result of the loss of power to the unit.

According to the aircraft wiring diagram 24-58-11 (Figure 16) the power to the CVR was from the Electronics Bus 1 (Elex Bus 1). The Elex Bus 1 also supplies power to other systems, such as the FDR, DME-1, TCAS, ATC-1 etc. Parameters of DME-1 and TCAS were recorded in the FDR. Analysis of the FDR recording showed that six minutes after the CVR stopped, the FDR was still recording TCAS and DME-1 parameters. This indicates that the CVR stoppage was not due to power loss at Elex Bus 1.

The CVR is equipped with an energy storage capacitor. The function of this capacitor is to provide power for 250 milliseconds after electrical power is removed from the unit such as when the aircraft power is switched from ground power to APU generators or the engine generators. Another function of this capacitor is to enable continued recording for another 250 milliseconds after power loss to the unit.

Had there been an overload or short circuit, the resultant popping of the CVR circuit breaker in the cockpit would have been recorded as a unique and identifiable sound signature by the CVR (see Section 1.11.1). Based on the examination of the results of the circuit breaker pull tests, there was no such sound signature in the MI 185 CVR recording found. This indicates that there were no short circuit or overload to cause the CVR circuit breaker to pop out.

The results of the CB pull tests showed that the sound signature associated with manual pulling of the circuit breaker is obscured by the cockpit ambient noise. Hence, no conclusion can be drawn whether the circuit breaker had been pulled manually.

A break in the wire supplying power to the CVR could also lead to CVR stoppage without any sound being recorded on the CVR. However, from the limited quantity of wiring recovered it could also not be determined if a break in the wiring had caused the CVR to stop.

Thus, the cause of the CVR stoppage could not be concluded.

The conclusions presented by the NTSC regarding the stoppage of the CVR are not in full agreement with the evidence. As previously stated in the comments to the factual portion of the draft Final Report, postaccident examination and testing proved that there were no mechanical malfunctions or failures of either the CVR or DFDR that would have caused the recorders to stop recording data.

Further, it is highly unlikely that the CVR lost power because of a broken wire, as the NTSC's analysis suggests, without a related "short circuit" or power loss to other systems in a related wiring bundle or electrical bus, which likely would have been reflected on the DFDR. If the short circuit had occurred, the circuit breaker would have popped, which would have been recorded on the CVR. NTSB tests established that if an "overloaded and a short circuit" condition had occurred, the sound of the circuit breaker popping is unique and loud enough to be identified on the CVR area microphone channel on the ground and in flight. No such sound was recorded on the CVR from MI 185.

Sufficient evidence has been documented, based on postaccident testing and examination, to conclude that the failure was not the result of a "fault" or the CVR "internal power supply and "hold up" capacitor, which appeared to be operating normally. Additionally, postaccident examination and testing revealed that the CVR recording exhibited characteristics that would be expected of a normal electrical power shutdown of the CVR.

NTSC'S COMMENTS:

The evidence indicates that the stoppage of the CVR was not due to a short circuit or an overload condition. As only a limited amount of electrical wires was found, the failure of the CVR as a result of a broken wire cannot be completely ruled out.

2.6.2 FDR Stoppage

The FDR stopped recording at 09:11:33.7, or 6 minutes and 18.1 seconds after the CVR stoppage, and approximately 35.5 seconds before the aircraft started its descent, see Section 1.11.1 and Figure 2. Data recorded by the FDR indicates that the flight was normal until the FDR stoppage time. It was concluded that until the stoppage of the FDR, there were no indications of unusual disturbance (e.g. atmospheric turbulence, clear air turbulence, or jet stream upsets, etc.) or other events affecting the flight.

The FDR stoppage could have occurred due to a loss of power supply to the FDR, or the malfunction of the unit itself.

The recording of the ATC radar plots during the descent of the aircraft until 19,500 ft indicated that the aircraft ATC transponder continued operating after the FDR had stopped recording. SilkAir stated that generally flight crews use ATC-1 flying outbound from Singapore, and ATC-2 inbound. ATC-1 is on the same bus as the FDR, while ATC-2 is powered from Elex Bus 2, i.e. a different power source. No conclusion could be drawn as to the reasons for the CVR and FDR stoppage at different times.

The FDR was determined to be functioning normally until it stopped. The stoppage of the FDR could not be determined from the available data.

There were no evidence found that could explain the six-minute time difference between stoppage of the CVR and FDR.

The NTSC draft Final Report's discussion regarding the stoppage of the FDR needs to be revised to indicate that in addition to the possibilities mentioned, the DFDR's stoppage can also be explained by someone manually pulling the circuit breaker. This discussion should also be revised to reflect that the DFDR is powered through the same electrical bus (Electronics Bus 1) as ATC-1 (one of the airplane's two radar transponders) and the Mach trim actuator. The radar transponder (which was likely ATC-1 during the accident flight) continued to operate and return data for a short time after the DFDR stopped. In addition, the Mach trim actuator was found at its high speed (not cruise speed) setting, indicating that it was powered and operational during the airplane's high-speed dive. It can be concluded that the absence of a malfunction of the DFDR up to the point at which it stopped, combined with the fact that the transponder continued to transmit and the Mach trim actuator continued to operate after the DFDR had stopped, indicates that the stoppage was not due to a loss of power to Electronics Bus 1. However, the stoppage could be explained by someone manually pulling the circuit breaker.

The NTSC draft Final Report's discussion of the SilkAir practice of flight crews using ATC-1 when flying outbound from Singapore and ATC-2 when returning to Singapore is not documented in either the AAIC Operations or HPG reports. Further, this statement is contrary to information provided to the HPG group that the transponder in use during a flight typically corresponds to the pilot flying. Therefore, in the case of the accident flight, ATC-1 would have been selected. It is suggested that this statement be corrected.

Finally, the NTSC draft Final Report should include a discussion of human actions as a possible cause of the CVR and DFDR stoppage.

NTSC'S COMMENTS:

As the data pertaining to the use of the ATC-1 and ATC-2 is not captured by the FDR, it cannot be confirmed for the accident flight, whether ATC-1 or ATC-2 had been selected. The NTSC draft Final Report contains a discussion of the human aspects of stoppage of the CVR recording. Discussion of the human aspects of stoppage of the FDR recordings was not meaningful as there was no available CVR recording to assist in the discussion.

2.10 Simulated Descent Profile

The last five ATC radar points recorded represent the flight trajectory of the aircraft from the cruise altitude 35,000 feet to approximately 19,500 feet. Each point consisted of data relating to time, altitude and geographical coordinates.

Simulator tests and computer simulation fly-out studies were done to determine failures or combination of failures of the flight control and autopilot systems that could result in the extreme descent trajectory. Aircraft flight data were not available for the time period after the stoppage of the FDR. The initial condition for these tests and studies was cruise configuration at 35,000 feet based on the last known FDR data. The altitude range for the simulations was from 35,000 feet to approximately 19,500 feet.

The results of these simulation studies (Appendix G) are summarized as follows:

- *Any single failure of the primary flight controls such as hard-over or jamming of aileron, rudder or elevator did not result in a descent time history similar to that of the last ATC radar points. In simulations of these flight control failure conditions the aircraft could be recovered to normal flight manually.*

- *Any single failure of the secondary flight controls such as hard over or jamming of yaw damper, or runaway of the stabilizer trim would not result in a descent time history similar to that of the last ATC radar points. In simulations of these flight control failure conditions the aircraft could be recovered to normal flight manually.*

- *Manipulation of the primary flight controls without horizontal stabilizer trim would result in a descent time history similar to that of the last ATC radar points. But this required large control column input forces and the aircraft was subjected to a loading exceeding 2 G. However, if the control column input forces were relaxed, in the simulations the aircraft would recover from the steep descent due to its inherent stability.*

- *Among other possibilities, a combination of changing the stabilizer trim from about 4.5 to 2.5 units and an aileron input could result in a descent time history similar to that of the last ATC radar points. This simulated descent trajectory would result in the aircraft entering an accelerating spiral and being subjected to a loading of less than 2 G. Furthermore, the aircraft would continue in the spiral even when the control forces were relaxed. This would result in a descent at a speed exceeding 1.2 Vd, in agreement with the analysis on the break up of the empennage as discussed in Section 2.3.*

Bullet 3 should be modified as follows for correctness and clarity:

Although manipulation of the primary flight controls without horizontal stabilizer trim would result in a descent time history similar to that of the last ATC radar points, this would and large control require control column forces greater than 50 pounds column inputs. However, the simulations indicated that if the control column input forces had been relaxed, the aircraft would have initiated a return to a nose-up attitude due to its inherent stability.

Bullet 4 should be modified as follows for correctness and clarity:

Among other possibilities, a combination of either control column inputs and/or changing the stabilizer trim from about 4.5 to 2.5 units, in combination with aileron inputs could result in a descent time history similar to that of the last ATC radar points. This simulated descent trajectory would result in the aircraft entering an accelerating spiral and being subjected to a loading of less than 2 G. Furthermore, the aircraft would continue in the spiral even when the control forces were relaxed. This would result in a descent at a speed exceeding 1.2 Vd, which is in agreement with the analysis of the breakup of the empennage as discussed in section 2.3.

Based on the data derived from the simulations, the following conclusion can be made regarding the maneuvers necessary for the airplane to fly a profile similar to that of MI 185:

No single mechanical failure of the airplane structure or flight control systems was found that would have resulted in movement of the airplane that matched the recorded radar data points. Further, there was no evidence of any combination of systems failures. Thus, no known or postulated mechanical failure was found that resulted in a flight profile that matched the radar data. However, changing the flight control input manually in multiple axes did provide a flight profile that matched the last recorded ATC radar data points. Therefore, it is probable that the airplane was likely responding to sustained flight control inputs from the cockpit.

NTSC'S COMMENTS:

As there was no FDR data available from before the commencement of descent up to time of impact, it is not possible to conclude that the airplane was responding to sustained flight control inputs from the cockpit.

2.11 High Speed Descent Issues

2.11.1 *Mach Trim System and its Function*

The aircraft was equipped with a Mach Trim system to provide stability at the higher operating speeds, i.e. higher Mach numbers. Mach trim is automatically accomplished above Mach 0.615. When the Mach Trim system is operative it will normally compensate for trim changes by adjusting the elevator with respect to the stabilizer, as the speed increases. With the Mach Trim inoperative, the aircraft could exhibit a nose down *tendency ("Mach Tuck") as speed increases. However, the expected control forces to overcome the "Mach Tuck" are light. Additionally when the speed exceeds the maximum limit, audible overspeed warnings are activated.*

Since the aircraft was cruising at subsonic speed (Mach 0.74) and trimmed for level flight, the aircraft will eventually return to the trimmed condition after a minor speed disturbance.

For the aircraft to dive, a significant disturbance resulting in an increasing speed must have taken place. Such a disturbance could be initiated by changing aircraft elevator or stabilizer trim. Should the airspeed increase to the point where it becomes transonic, and as the lift resultant moves aft and local supersonic flow develops, the nose-down pitching moment could be sufficiently large that the aircraft becomes speed unstable, i.e. continuing speed increase of the aircraft. Once the aircraft is in a transonic dive, recovery from the dive becomes more difficult because of an increase in control column forces due to the aircraft's increasing nose down pitching moment as well as a large reduction of elevator effectiveness due to the formation of shock induced air flow separation in front of the elevator.

It is possible to recover from a transonic dive by timely action of the pilot, by reducing thrust and deploying the speed brakes. Should the pilot not initiate a prompt recovery action, the recovery becomes more difficult.

During the tear down examination, the mach trim was found in the fully retracted position. The fact that this actuator was found in the retracted position may not necessarily indicate that the mach trim system is a factor contributing to the accident.

Because the Mach Trim system was not implicated as a cause or contributing factor in the accident, the discussion regarding this system is irrelevant. Therefore, it is strongly suggested that the discussion in this section be substantially reduced and that a definitive conclusion be included indicating that there was no evidence of a Mach Trim system failure that would have been causal or contributing to the accident.

2.11.2 Emergency Descent due to Fire, Smoke or Depressurization

An emergency descent is necessary when there is a rapid cabin depressurization or when a fire or smoke occurs in flight. The procedure is to simultaneously retard the thrust levers, deploy the speed brakes and bank the aircraft to initiate the descent. (Appendix K). Some forward stabilizer trim is applied to attain a dive which will accelerate the aircraft towards the maximum speed limit. Once the maximum speed is reached aircraft is re-trimmed to maintain the speed. This facilitates a limit on maximum rate of descent to the minimum safe altitude.

The last pilot radio transmission about two and a half minutes before the descent sounded normal and there was no mention of any in-flight fire or smoke. Furthermore, examination of the wreckage showed no evidence of in-flight fire or explosion.

Examination of the recovered oxygen generators showed that they were not activated. This indicated that there was no rapid depressurization at high altitude.

Based on the above findings, there was no indication of an emergency descent due to fire, smoke or rapid depressurization.

The first paragraph in this section is not a statement of analysis but of fact. The information presented refers to procedures (included in the NTSC draft Final Report as appendix K) to be employed by the flight crew in the event that an emergency descent is necessary. Moreover, the statement that the emergency descent procedures call for the pilot to "bank the aircraft to initiate the descent" is incorrect. The procedures do not specify banking the aircraft as the method to be used to initiate the descent. Because this information has no relationship to the accident and implies that a true emergency descent profile is similar to the derived profiles used in the simulator to match the accident descent profile, this statement should be removed. However, if it is to remain in the analysis, it must be corrected by removing the statement "banking the aircraft to initiate descent."

2.13 Human Factors Aspects of the CVR and ATC Recordings

2.13.1 CVR

(a) The conversations and sounds recorded by the CVR before it stopped were examined. The CVR transcript (Appendix A) showed that at 09:04:55 the PIC indicated his intention to go to the passenger cabin " .… go back for a while …. finish your plate….". At 09:05:00 the PIC offered water to the F/O, and at about the same time, several metallic snapping sounds were recorded. Thirteen seconds later, at 09:05:13.6 the CVR ceased recording. Analysis of the recording indicated that the metallic snapping sounds were made by a seatbelt buckle striking the floor. (See Section 1.16.2)

(b) During the period recorded by the CVR, all door openings or closings were related to pre-departure activities, in-flight meal service and normal pilot-cabin crew interaction. In the four minutes following the last meal service, there were no sounds associated with cockpit door opening or closing. After takeoff from Jakarta, conversations within the flight deck were between pilot-to-pilot, pilot-to-flight attendants, and normal pilot-to-ATC radio communications. During the flight, except for cabin attendants serving meals and drinks to the pilots, there were no indications of any other person(s) in the cockpit. It is concluded that after the last meal service and until the stoppage of the CVR, the recording did not reveal any indications that

person(s) other than the flight crew and cabin attendants attending to their duties were in the cockpit.

(c) Analysis of the CVR stoppage indicated that the failure of the CVR could not have been caused by a short circuit or overload. This is because either occurrence would have resulted in the CVR recording a "pop" sound which was heard on the test recording but not on the accident recording.

The CVR in-flight tests could not identify the sound of the CVR circuit breaker being manually pulled as the ambient noise obscured the sound made. The accident tape did not contain any identifiable sound attributable to manual pulling of the CVR circuit breaker. It was not possible to determine from the CVR tests if there was a pulling out of the CVR circuit breaker.

The information presented in paragraph (c) regarding the CVR is redundant. Because no conclusions are drawn, it is not necessary to discuss this information again.

In addition, as noted in the summary, this section should address the fact that the captain was in the process of leaving the cockpit at the time the CVR stopped recording. It should provide a description of the position of the CVR and DFDR circuit breakers in relation to the captain's seat, the door, etc. Finally, the information about the captain's previous CVR event (in June 1997) should be emphasized.

NTSC'S COMMENTS:

The PIC's previous CVR event has no bearing on this accident. The location of the CVR circuit breaker is provided in in-flight documentation.

2.13.2 ATC Recordings

The data transcribed from the ATC communications recording of the air-to-ground conversation indicates that at 09:10:26, or 5 minutes and 10.4 seconds after the CVR stoppage, the F/O acknowledged the "abeam Palembang" call from the ATC. The F/O was positively identified by voice analysis examination. This confirms that the F/O was in the cockpit when the aircraft was abeam Palembang. However, it is not possible to conclude whether the PIC was in the cockpit at the time. It was also not possible to determine events or persons present in the cockpit from the time of the last transmission to ATC.

The absence of a distress call could suggest that the pilots were preoccupied with the handling of an urgent situation. However, it is not possible to conclude on the reason for the absence of a distress call.

The NTSC's conclusion that the absence of a distress call likely indicates that the pilots were attempting to "handle an urgent situation" is misleading because it implies that the pilot(s) perceived the situation as an emergency. The discussion in this section should be modified to make clear the possibility that the absence of a distress call could suggest that the pilot(s) did not consider the situation a condition of distress, that is, the airplane was doing what a pilot commanded it to do.

NTSC'S COMMENTS:

> *Just as it is not possible to conclude that the pilots perceived the situation as an emergency, it is also not possible to conclude that the airplane was doing what a pilot commanded it to do.*

2.14 Specific Human Factors Issues

In this section, the specific, personal, financial backgrounds and recent behavior of the PIC and the F/O are examined.

2.14.1 Personal Relationships

Evidence obtained from family and friends of both the PIC and F/O reported no recent changes or difficulties in personal relationships.

It was concluded there was no evidence that either pilot was experiencing difficulties in any personal relationships.

2.14.2 First Officer (F/O)

The investigation into the F/O's personal and professional history revealed no unusual issues. No records of incidents or unusual events were found, and no career setbacks or difficulties were experienced. Financial records showed no evidence of financial problems. Interviews with family, close friends and relations seem to indicate that the F/O was a well-balanced and well-adjusted person, and keen on his job, and planning to advance his a flying career. There were no reports on recent changes in his behavior.

2.14.3 Pilot-in-Command (PIC)

The investigation into the personal and professional career revealed that the PIC was considered to have been a good pilot, making his transition from a military pilot to commercial pilot smoothly. His career at SilkAir showed that he was well accepted and given higher responsibilities. He was considered to be a leader among the Singaporean pilot community in SilkAir.

During his professional career at SilkAir, he was involved in a few work-related events, which were in general considered minor operational incidents by the management. However in one particular event, for non-technical reasons the PIC infringed a standard operating procedure, i.e. with the intention to preserve a conversation between the PIC and his copilot, the PIC pulled out the CVR circuit breaker, but the PIC reset the circuit breaker in its original position before the flight. This was considered a serious incident by the management, and the PIC was relieved of his LIP appointment. The PIC was known to have tried through existing company procedures to reverse the management decision. Although there were some indications of the PIC being upset by the outcome of the events, the magnitude of the psychological impact on the PIC could not be determined.

The PIC's financial history was investigated for the period from 1990-1997. Based on the data available to the NTSC it was noted that the PIC's accumulated losses in share trading increased between 1993 and 1997 and his trading activity was stopped on two occasions due to non-settlement of his share trading debt. The data available also showed that his loans and debts were greater than his realizable assets and his monthly income (including his immediate family's income) was less (about 6%) than his estimated monthly expenses at the time of the accident.

2.14.4 Recent Behaviour

The PIC's recent behaviour was analysed from statements made by family members, friends and peers during interviews. The PIC's family reported no recent changes in his behaviour. Work associates who observed the PIC on the day of the accident and on his most recent flights, reported nothing odd or unusual in his behaviour.

2.14.5 Insurance

Based on the data available, it was found that at the time of the accident, the PIC had a number of life insurance policies. The majority of these were taken up earlier in his life. The most recent policy was a mortgage policy which was required by the financial institution from which he took the loan for his house in line with normal practice for property purchases in Singapore. The PIC applied for the mortgage policy on 27 November 1997. The insurance company approved the policy on 12 December 1997 pending payment of the first premium. The PIC submitted a cheque dated 16 December 1997 for the first premium payment. The commencement or the inception date of the policy was set by the insurance company to be 19 December 1997. This information was not conveyed to the PIC. The cheque was cleared on 22 December 1997. From the data available to the NTSC there was no evidence to indicate if this mortgage policy has any relevance to the accident.

NTSC concluded that the combination of financial situation and his work related events could be stressors on the PIC. However, NTSC could not determine the magnitude of these stressors and its impact on the PIC's behavior.

The deficiencies, inaccuracies, and omissions of relevant information pertaining to the captain's and first officer's personal, career, and financial backgrounds have been previously discussed. It is imperative that complete and accurate factual information be presented for analysis so that a proper and thorough analysis can be accomplished. The factual information suggested for inclusion will serve as the basis for revising the analytical discussion and conclusions of the human factors issues in this section.

Finally, it should be noted in this section that the captain had been told that the insurance policy would go into effect upon receipt of the first premium payment.

NTSC'S COMMENTS:

NTSC notes that the above details about the crew's personal background, the PIC's professional background in RSAF and SilkAir and financial background information and the crew's recent behaviour which are proposed to be included in the final report are taken from the HPG Report version 6.0. As explained earlier, the HPG Report version 6.0 was overtaken by information from the PricewaterhouseCoopers Audit. Relevant information from the HPG Report version 6.0 which had or might have a bearing on the accident were integrated into the final report. Whatever had no bearing was not included.

In accordance with 5.12 of Annex 13 to the Convention on International Civil Aviation, private information regarding persons involved in the accident shall be included in the final report or its appendices only where pertinent to the analysis of the accident. Parts of the private information not relevant to the analysis shall not be included.

3. CONCLUSIONS

3.1 Findings

Engineering and Systems

- *There was no evidence found of in-flight fire or explosion.*
- *From flutter analysis and wreckage distribution study, the empennage break-up could have occurred in the range between 5,000 and 12,000 feet altitude.*
- *Examination of engine wreckage indicated that the conditions of the engines at impact were not inconsistent with high engine rotation speed. No indications were found of in-flight high energy uncontained engine failures. Therefore, the engines were considered to be not a factor contributing to the accident.*
- *Examination of the actuators of flight and ground spoilers, trailing and leading edge flaps, as well as engine thrust reversers indicate retracted or stowed positions of the respective systems.*
- *Examination of the main rudder power control unit (including the servo-valve), the yaw damper modulating piston, the rudder trim actuator, the rudder trim and feel centering unit, the standby rudder PCU, the aileron PCUs, the elevator PCUs, and the horizontal stabilizer jack-screw components, revealed no indications or evidence of pre-impact malfunctions.*

Based on the evidence and postaccident testing, a definitive conclusion can be made regarding the flight control systems. Therefore, it is suggested that the NTSC's draft Final Report be modified to include the following:

> **There was no evidence of a mechanical failure of any of the flight control systems or related components that would have been causal or contributing to the accident.**

Also, it is suggested that the following conclusion be added for completeness:

> **Separation of the empennage components/parts were not the cause of the departure from cruise flight or the resulting impact with terrain but, rather, were the result of an overspeed condition that occurred after the airplane departed cruise flight.**

- *Examination of the 370 kg of recovered electrical wires, connectors and circuit boards showed no indication or evidence of corrosion, shorting, burning or arcing in these wires or parts.*
- *The CVR stopped recording at 09:05:15.6 and the FDR stopped recording at 09:11:33.7. The examination of the CVR and FDR showed no malfunction of the units. The stoppages could be attributed to a loss of power supply to the units. However, there were no indications or evidence found to conclude on the reason for the stoppages due to the loss of power. The cause of the CVR and FDR stoppages and the reason for the time difference between the stoppages could not be concluded.*

The NTSC draft Final Report suggests that the cessation of the CVR and DFDR could in each case be explained by a broken wire. Although this is technically correct, the probability of two such unrelated wire breaks occurring several minutes apart and affecting only the CVR and DFDR is so highly improbable that it cannot be considered a realistic possibility.

- *The inspection of the aircraft maintenance records did not reveal any defects or anomalies that could have affected the airworthiness of the aircraft or that may have been a factor contributing to the accident.*
- *The horizontal stabilizer trim was found to be in the 2.5 units position which matched the forward nose-down limit of the manual electrical trim.*

This conclusion should be expanded to include a definitive statement that the 2.5 units of nose-down trim was the result of a sustained manual input and not attributed to a malfunctioning system resulting in a "runaway."

Flight Operations

- *Weather and Air Traffic Control were not factors contributing to the accident.*
- *Audio spectral analyses on Air Traffic Control communications and the accident CVR indicate that the last communication from the MI 185 at 09:10:26, occurring at a position approximately abeam Palembang was performed by the F/O.*
- *The examination of the flight deck noise and sounds concludes that the metallic snap recorded on the CVR was made by a seatbelt buckle hitting against a metal surface.*
- *Based on flight simulations, it was observed that the simulated descent trajectory resulting from any single failure of flight control or autopilot system would not match the radar data.*
- *Based on the same flight simulations, it was also observed that the trajectory shown by the radar data could have been, among other possibilities, the result of the*

combination of lateral and longitudinal inputs together with the horizontal stabilizer trim input to its forward manual electrical trim limit of 2.5 units.

To clarify the conclusion at bullet 5, it is suggested that the following sentence be added to the end:

Despite the stabilizer trim being at the 2.5 unit nose-down setting (its forward limit), the aircraft would have remained controllable and appropriate flight control input would return the airplane a normal flight attitude.

Additionally, the following should be added to the draft Final Report:

No single mechanical failure of the airplane structure or flight control systems was found that would have resulted in movement of the airplane that matched the recorded radar data points. Further, there was no evidence of any combination of systems failures. Thus, no known or postulated mechanical failure was found that resulted in a flight profile that matched the accident radar data. However, changing the flight control input manually in multiple axes did provide a flight profile that matched the last recorded ATC radar data points. Therefore, it is probable that the airplane was likely responding to flight control inputs from the cockpit."

Human Factors

- *Both pilots were properly trained, licensed, and qualified to conduct the flight.*
- *There was no evidence found to indicate that the performance of either pilot was adversely affected by any medical or physiological condition.*
- *Interviews with respective superiors, colleagues, friends and family revealed no evidence that both the flight crew members had changed their normal behaviour prior to the accident.*

This conclusion is not representative of the findings of the HPG investigation. Although consistent with the HPG's conclusion (in HPG report Version 6.0, July 30, 1999) regarding the first officer, the conclusion in the draft report is inconsistent with the HPG's conclusion regarding the captain. The HPG report states, "There were some indications that the captain's behavior or lifestyle changed prior to the accident." It is suggested that this conclusion be separated to accurately describe the captain's and first officer's behavior.

- *There was no evidence found to indicate that there were any difficulties in the relationship between the two pilots either during or before the accident flight; or had been experiencing noteworthy difficulties in any personal relationships (family and friends).*
- *Until the stoppage of the CVR, the pilots conducted the flight in a normal manner and conformed to all requirements and standard operating procedures.*
- *Although a flight attendant had been in the cockpit previously, after the last meal service and until the stoppage of the CVR there was no indication that anyone else was in the cockpit other than the two pilots.*
- *In the final seconds of the CVR recording the PIC voiced his intention to leave the flight deck, however there were no indications or evidence that he had left.*
- *Interviews and records showed that in 1997 the PIC had experienced a number of flight operations related events, one of which resulted in his being relieved of his LIP position.*

In its evaluation of the data collected, the HPG made a more definitive conclusion regarding the captain's career in the 6 months prior to the accident. The HPG conclusion, "During 1997 the PIC experienced multiple work-related difficulties, particularly during the last 6 months" should be used to modify the existing conclusion.

- *The PIC was involved in stock-trading activities, but no conclusions could be made indicating that these activities had influenced his personal behavior.*

The first part of this conclusion, "The PIC was involved in stock-trading activities" is a statement of fact and does not provide the basis for a conclusion. Further, the factual report substantiates that at the time of the accident, the PIC had been requested to pay a significant amount of money for outstanding debts and did not have liquid assets from which to pay these debts. This latter information forms the basis for a conclusion regarding the captain's financial stressors. In the HPG report, the conclusion was made that "At the time of the accident the PIC was experiencing significant financial difficulties." Also, this information was presented in the NTSC's interim report issued August 1999. Therefore, it is suggested that the NTSC revise this conclusion to be consistent with information cited in the AAIC HPG report and that was disseminated to the public in 1999.

- *From the data available to the NTSC there was no evidence found to indicate if the mortgage policy taken out by the PIC in connection with his housing loan has any relevance to the accident.*

Finally, the NTSC's conclusions do not address the crash of the three training aircraft from the captain's squadron while he was serving in the military. As discussed in the comments to section 1.18.3.1, the HPG examined the effect this event may have had on the captain but could not determine the extent to which he may have been affected. It is strongly suggested that the NTSC's draft Final Report include the conclusion from the AAIC HPG report that states, "The accident [in Palembang] occurred on the same date as the 1979 RSAF crash in the Philippines; the extent to which the PIC was affected by this event could not be determined."

3.2 Final Remarks

- *The NTSC investigation into the MI 185 accident was a very extensive, exhaustive and complex investigation to find out what happened, how it happened, and why it happened. It was an extremely difficult investigation due to the degree of destruction of the aircraft resulting in highly fragmented wreckage, the difficulties presented by the accident site and the lack of information from the flight recorders during the final moments of the accident sequence.*
- *The NTSC accident investigation team members and participating organizations have done the investigation in a thorough manner and to the best of their conscience, knowledge and professional expertise, taking into consideration all available data and information recovered and gathered during the investigation.*
- *Given the limited data and information from the wreckage and flight recorders, the NTSC is unable to find the reasons for the departure of the aircraft from its cruising level of FL350 and the reasons for the stoppage of the flight recorders.*
- *The NTSC has to conclude that the technical investigation has yielded no evidence to explain the cause of the accident.*

The technical investigation has, in fact, yielded sufficient information, which was derived through the on-scene and postaccident investigation activities, to definitively conclude that there were no mechanical anomalies with the aircraft, there were no environmental anomalies, nor were there any other significant technical factors that would have caused or contributed to the accident.

Additionally, the statement regarding the participating organizations in bullet 2 is made with a level of certainty that may not truly reflect the opinions of the "participating" organizations. Further, the remaining concluding statements do not necessarily reflect an analysis of all of the facts, conditions, and circumstances revealed during the course of this accident investigation.

NTSC'S COMMENTS:

With respect to the proposals relating to the conclusions of the final report, please refer to comments made at the relevant sections above.

4 RECOMMENDATIONS

TO MANUFACTURERS

1. *It is recommended that a comprehensive review and analysis of flight data recorders and cockpit voice recorders systems design philosophy be undertaken by aircraft and equipment manufacturers. The purpose of the review and analysis would be to identify and rectify latent factors associated with stoppage of the recorders in flight, and if needed, to propose improvements to ensure recording until time of occurrence.*

2. *It is recommended that a review of the flight recorders design philosophy be undertaken by aircraft and equipment manufacturers to include recording of actual displays as observed by pilots in particular for CRT type of display panels.*

3. *It is recommended that a review of the flight crew training syllabi be undertaken by aircraft manufacturers to include recovery from high speed flight upsets beyond the normal flight envelope. The purpose of developing the additional training is to enhance pilot awareness on the possibility of unexpected hazardous flight situations.*

GENERAL RECOMMENDATION

4. *It is recommended that regional investigation framework for co-operation in aircraft accident investigations be established to enable fast mobilization of resources and coordination of activities to support those states that do not have the resources and facilities to do investigations on their own.*

The factual evidence does not support recommendations 1 and 3 because the postaccident tests and examination suggest that the CVR stopped recording as a result of the unit's circuit breaker being pulled. This scenario also likely explains why the DFDR stopped recording.

The investigation did not reveal any evidence to suggest that a mechanical malfunction or failure of a particular system caused an unexpected upset. If such a scenario had occurred, the flight crew should have been able to take immediate corrective action because they had received training at SilkAir in the recovery from unusual attitudes. Based on the evidence, the departure from cruise flight was likely an intentional maneuver; therefore, recommendation 3 is without merit.

NTSC'S COMMENTS:

There was no evidence to positively conclude that the departure from cruise flight was an intentional maneuver. Present line crew training does not include recovery from high speed flight upset beyond the normal flight envelope from whatever cause. If such crew training is developed, it would enhance crew awareness on the possibility of unexpected hazardous flight situations and provide them with the necessary recovery techniques to handle any high speed flight upsets.

Errata

No.	Page, Section, Paragraph/Bullet, Line	Originally	It should be modified to
1	Page i, Abstract, Para 7, Line 2	Except parts of the empennage that ...	Except for parts of the empennage …
2	Page i, Abstract, Para 8, Line 3	… to what have happened, …	… to what had happened, …
3	Page i, Abstract, Para 10	… to make conclusions …	… to make any conclusions …
4	Page x, Glossary of Terms, Actuator	… into mechanical fore	… into mechanical force
5	Page x, Glossary of Terms, Control wheel steering mode, Lines 2 and 3	… allows the autopilot … … autofilight … … similar that …	… allows the pilot … … autoflight … … similar to that …
6	Page xi, Glossary of Terms, Hydraulic system A, Line 2	… engine-drive …	… engine-driven …
7	Page xi, Glossary of Terms, Hydraulic system B, Lines 2 and 5	… engine-drive … … thrust reverse, …	… engine-driven … … thrust reverser, …
8	Page 6, Section 1.11.1, Para 1, Line 1 and Para 5, Line 4	… Sunstrand … … damage tape, … … could have been stopped …	… Sundstrand … … damaged tape, … … could have stopped …
9	Page 7, Section 1.12, Para 3, Line 3	… and disinfections before …	… and disinfecting before …
10	Page 8, Section 1.12, Para 4, Line 1	… operation, including ten …	… operation, which included ten …
11	Page 8, Section 1.12, Para 6, Line 6	The cockpit instrumental panel and circuit breakers panel …	The cockpit instrument panel and circuit breaker panel …
12	Page 8, Section 1.12.1, Para 1, Line 1	… evidence of an in-flight fire …	… evidence of any in-flight fire …
13	Page 12, Section 1.12.1.5, Para 3, Line 5	… evidence of over-travels …	… evidence of over-travel …
14	Page 13, Section 1.12.2.2, Para 1, Line 2	… recovered MEC systems …	… recovered MEC units …
15	Page 22, Section 1.17, Bullet 4, Lines 1 & 3	… F70 reported … , … a labor …	… F70 report … , … a labour …
16	Page 26, Section 1.18.4.1, Para 1, Line 1	… 19 September 1996 …	… 16 September 1996 …
17	Page 33, Section 2.4.5, Para 6, Line 3	… and two to release …	… and the other to release …
18	Page 35, Section 2.6.1, Para 1, Line 2	… the last radar return …	… the aircraft started its descent …

19	Page 40, Section 2.11.2, Para 2, Line 1	… about two and a half minutes …	… about one and a half minutes …
20	Page 41, Section 2.12, Bullet 4, Line 3	… in the 1970s …	… in 1990 …
21	Page 42, Section 2.14.2, Para 1, Lines 5 & 6	… person, and keen on … … advance his a flying career.	… person, keen on … … advance his flying career.
22	Page 51 (Figure 1.c)	Pacific Ocean	Java Sea
23	Page 59 (Figure 7) &Page 82 (Figure 14)	Graph labels: South & East	South (minutes) & East (minutes)
24	Page N-38, Section 2.4.1, NTSC's Comments, Lines 2 & 3	… and the FAA AD --- which recommends that -- , …	… and the FAA AD 2000-22-02 which recommends essentially that the Airplane Flight Manual be revised to ensure that the flight crew is aware of the critical recall items to address a condition involving a jammed or restricted rudder.