Aviation Safety Council

Taipei, Taiwan

GE 791 Occurrence Investigation Report

VOLUME I

IN-FLIGHT ICING ENCOUNTER AND CRASH INTO THE SEA
TRANSASIA AIRWAYS FLIGHT 791
ATR72-200, B-22708
17 KILOMETERS SOUTHWEST OF MAKUNG CITY,
PENGHU ISLANDS, TAIWAN
DECEMBER 21, 2002

ASC-AOR-05-04-001

According to according to the Aviation Occurrence Investigation Act of The Republic of China, Article 5;

The objective of the ASC ‘s investigation of aviation occurrence is to prevent recurrence of similar occurrences. It is not the purpose of such investigation to apportion blame or liability.

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

The sole purpose 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.

Thus, based on Both the ICAO Annex 13, as well as the Aviation Occurrence Investigation Act of the Republic of China, this aviation occurrence investigation report, as the result of the investigation effort of GE791, shall not be used for any other purpose than to improve safety of the aviation community.

Executive Summary[1]

On December 21, 2002, at 0152[2] Taipei local time, TransAsia Airways (TNA) freighter GE791, aircraft type ATR72-200, registration No.B-22708, encountered a severe icing during its flight and crashed into the sea 17 kilometers southwest of Makung city, Penghu Islands. Both pilots (CM-1 and CM-2) on board were missing[3].

According to Article 84 of the ROC Civil Aviation Act, and Annex 13 to the Convention on International Civil Aviation (Chicago Convention), which is administered by the International Civil Aviation Organization (ICAO), the Aviation Safety Council (ASC), an independent agency of the ROC government responsible for civil aviation accidents and serious incidents investigation, immediately launched a team to conduct the investigation of this accident. The investigation team included members from the ROC Civil Aeronautical Administration (CAA) and CAL. Based on ICAO Annex 13, the Bureau D'enquetes et D'analyses pour la Securite de L'aviation Civile(BEA), the state of manufacture, was invited as the Accredited Representative (AR) of this investigation. The BEA team included members from the AVIONS DE TRANSPORT REGIONAL, which is the manufacturer of ATR-72.

After 10 months of factual data collection including wreckage recovery and examination, recorders recovery and readout, and other activities such as laboratory tests conducted in Chung-Shan Institute of Science and Technology (CSIST), and the 1st Technical Review Meeting, the Safety Council published the Factual Data Collection Report (ASC-AFR-03-10-001) on October 25, 2003.

The analysis portion of the investigation process was commenced immediately after the release of the Factual Data Collection Report. A Preliminary Draft of the investigation report was sent to the BEA, CAA, and TNA for their comments. Another Technical Review Meeting (TRM2) was held by the Safety Council on July 15, 2004 to discuss the preliminary analyses prior to the release of the Preliminary Report. The intent of both TRM2 and the Preliminary draft were to solicit early feedback from the stakeholders. Based on the comments from the BEA, CAA, and TNA, a final draft is prepared and presented.

This final report follows the format of ICAO Annex 13 with a few minor modifications. Firstly, in Chapter 3, Conclusions, the Safety Council decided in their 39th Board meeting that to further emphasize the importance that the

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[1] Note— If there are differences in interpretation the Chinese text prevails.

[2] All of the time shown herein represents local time in 24-hour system.

[3] The pilot-in-command was announced death by the court of law.

purpose of the investigation report is to enhance aviation safety, and not to apportion blame and responsibility, the final report does not directly state the “Probable Causes and Contributing Factors”, rather, it will present the findings in three categories: findings related to the probable causes of the accident, findings related to risks, and other findings. Secondly, in Chapter 4, in addition to the safety recommendations, the Safety Council also includes the safety actions already taken or in progress by the stakeholders. This modification follows the practices by both the Australian Transport Safety Bureau (ATSB) and Transportation Safety Board (TSB) Canada, as well as follows the guidelines of ICAO Annex 13. The Safety Council decided that this modification would better serve its purpose for the improvement of aviation safety.

The National Transportation Safety Board（NTSB）published an alert to pilots-Wing Upper Surface Ice Accumulation（See the Appendix 25）indicating “…*there are circumstances in which upper wing surface ice accumulation can be difficult to perceive visually. For example, depending on airplane’s design*（*size, high wing, low wing, etc.*） *and the environmental and lighting conditions*（*wet wings, dark night, dim light, etc*） *it may be difficult for a pilot see ice on the upper wing surface from the ground or through the cockpit or other windows. Further, frost, snow, and rime ice can be very difficult to detect on a white upper wing surface and clear ice can be difficult to detect on an upper wing surface of any color. However, it is critically important to ensure, by any means necessary, that the upper wing surface is clear of contamination before takeoff. That is why the Safety Board recently issued Safety Recommendation A-04-66, urging pilots to conduct visual and tactile inspections of airplane wing upper surfaces.*”

Therefore, based upon the analysis by the Safety Council, the following are the key findings of the GE791 accident investigation.

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

1. The accident flight encountered severe icing conditions. The liquid water content and maximum droplet size were beyond the icing certification envelope of FAR/JAR 25 appendix C.（2.2.1, 2.3.2.1, 2.4.2 and 2.4.4）

2. TNA’s training and rating of aircraft severe icing for this pilots has not been effective and the pilots have not developed a familiarity with the Note, CAUTION and WARNING set forth in Flight Crew Operating Manual and Airplane Flight Manual to adequately perform their duties.（2.3.3）

3. After the flight crew detected icing condition and the airframe de-icing system was activated twice, the flight crew did not read the relative Handbook, thereby the procedure was not able to inform the flight crew and to remind them of “be alert to severe icing detection”. （2.3.2.3）

4. The “unexpected decrease in speed” indicated by the airspeed indicator is

an indication of severe icing.（2.3.2.2）

5. The flight crew did not respond to the severe icing conditions with pertinent alertness and situation awareness that the aircraft might have encountered conditions which was “outside that for which the aircraft was certificated and might seriously degrade the performance and controllability of the aircraft”.（2.3.2.3）
6. The flight crew was too late in detecting the severe icing conditions. After detection, they did not change altitude immediately, nor take other steps required in the Severe Icing Emergency Procedures.（2.3.2.4.1）
7. The aircraft was in an “unusual or uncontrolled rolling and pitching” state, and a stall occurred thereafter.（2.3.2.4.2）
8. After the aircraft had developed a stall and an abnormal attitude, the recovery maneuvering did not comply with the operating procedures and techniques for Recovery of Unusual Attitudes. The performance and controllability of the aircraft may have been seriously degraded by then. It cannot be confirmed whether the unusual attitudes of the aircraft could have been recovered if the crew’s operation had complied with the relevant procedures and techniques.（2.3.2.4.2）
9. During the first 25 minutes, the extra drag increased about 100 counts, inducing a speed diminishing about 10 knots. (2.4.1)
10. During the airframe de-icing system was intermittently switched off, it is highly probable that residual ice covered on the wings of the aircraft. (2.4.2)
11. Four minutes prior to autopilot disengaged, the extra drag increased about 500 counts, and airspeed decayed to 158 knots, and lift-drag ratio loss about 64% rapidly. (2.4.2)
12. During the 10s before the roll upset, the longitudinal and lateral stability has been modified by the severe ice accumulated on the wings producing the flow separation. Before autopilot disengaged, the aerodynamic of the aircraft (lift/drag) was degraded of about 40%. (2.4.4)

The findings related to risk identify elements of risk that have the potential to degrade aviation safety. Some of the findings in this category identify unsafe acts, unsafe conditions, and safety deficiencies that made this accident more likely; however, they can not be clearly shown to have operated in the accident. They also identify risks that increase the possibility of property damage and personnel injury and death. Further, some of the findings in this category identify risks that are unrelated to the accident, but nonetheless were safety deficiencies that may warrant future safety actions.

1. The TAMC medium-level SIGWX chart indicated around Taiwan Strait cloudy areas and air temperature of minus 9°C at FL 180. The WAFC Washington wind/temperature chart provided to the crew by the FIS of CKS indicated that forecasted air temperature was minus 10°C at FL 180 around Taiwan Strait.（1.7.3, 1.7.4）

2. At the SOC the flight plan controller is in charge to prepare flight documents for international flights. The SOC Operations Manual only mentions SIGWX and upper wind charts at higher levels, above FL 250. It’s not applicable for ATR flights. （2.2.3）

3. An ATR pilot who had experienced severe icing indications did not write “Fight Crew Report”. （2.3.4.1）

4. Important WARNING and NOTE information are not adequately appearing in all of the relevant Chapter/Section of ATR’s Airplane Flight Manual and Flight Crew Operating Manual.（2.3.5.2）

5. There was no detection or warning equipment designed for detecting severe icing conditions on any type of turboprop aircraft. It totally relied on the flight crew to visually determine.（2.3.2.5）

6. It could be performed difficult to closely observe the indications of severe icing in an adverse weather environment at night.（2.3.2.5）

7. Recent ATR 72 incidents indicated that after prolonged exposure to severe icing conditions and continued activating the airframe de-icing, icing caused drag increased about 500 counts, and caused the aircraft upset or stall.（2.4.1）

8. The aircraft probably encountered icing condition at 0131. Flight crews perceived icing condition at 1.5 minutes later. Three minutes later, flight crews activated airframe de-icing system.（2.4.4）

9. The icing detection system was operating normally during flight, the flight crews were aware of the ice accretion and activated the airframe de-icing system**.** However currently there is no any on board system which is able to identify the severe icing condition and provide proactively sufficient information related to ice accretion and associated effects to the flight crews.（2.5.1）

10. The stall warning system was operating as designed. The Safety Council believes under severe icing condition and aircraft performance seriously degradation, the stall warning system could not provide adequate warning.（2.5.2）

Other findings identify elements that have the potential to enhance aviation safety, resolve an issue of controversy, or clarify an issue of unresolved ambiguity. Some of these findings are of general interest and are not necessarily analytical, but they are often included in ICAO format accident reports for informational, and safety awareness, education, and improvement purposes.

1. This accident bears no relationship with air traffic control services and communications.（2.1）

2. The pilots were properly certificated and qualified in accordance with applicable Civil Aviation Regulations.（2.1）

3. The flight crew’s duty and rest time was normal within the 72 hours prior to the accident. There was no evidence indicating the crew had any physical or psychological problems, nor the use of alcohol and drugs.（2.1）

4. According to the maintenance records, the aircraft was certified, equipped, and maintained in accordance with CAA regulations and approved procedures. There was no evidence of pre-existing mechanical malfunctions or other failures of aircraft structure, flight control systems, power plants or anti/de-icing systems that could have contributed to the occurrence. (1.6.9.1, 1.6.9.3)

5. The aircraft’s weight and balance were within the limitations.（2.1）

6. There is no evidence that the crew did not display on FIS computer any other updated weather information available for the flight.（1.7.4）

7. It would be difficult to visualize the propeller spinner from the ATR72’s cockpit, therefore the guidance “Accumulation of ice on the propeller spinner farther aft than normally observed” could not be performed difficult.（2.3.2.5）

8. The TAMC medium-level SIGWX charts stood on ICAO Annex 3, marking moderate or severe icing symbols in the non-CB clouds area when moderate or severe icing was forecasted. With regard to the clouds above freezing level which supercooled liquid water is possible to be existed, Hong Kong Observatory and Tokyo Aviation Weather Service Center would mark symbols for moderate icing on that charts. This is to emphasize the situation awareness of moderate icing en-route to dispatchers and pilots. (2.2)

9. CM-1did not follow reporting procedures manifested a flaw in flight operation management.（2.3.4.2）

10. The wings of the aircraft contaminated by severe ice caused asymmetric stall and left roll upset and stall warning which induced the disengagement of autopilot.（2.4.3）

11. Observation made by remote operating vehicle indicates that the wreckage including structure and components of accident aircraft are distributed within an area of 200 by 300 meter.（2.6）

12. The aircraft pitch down angle over 90° during the wing impact. （2.6）

13. The diving speed of the aircraft was very high during the water impact.（2.6）

14. There is no structure fatigue damage was found. All the structure failure was cause by over load damage and occurred during water impact.（2.6）

15. Before August 1997, TNA’s procedures to SB evaluation, to EO production and to maintenance record keeping system in General Maintenance Manual were not established very well. (1.6.9.2、1.6.10,、1.6.11、2.7.1、2.7.2)

16. Totally 6.8 hours data unrecoverable was found on the track 1 and track 2 of accident FDR which was a tape based recorder, model F800, but the unrecoverable data didn’t included the accident flight. (2.8)

Recommendation

Interim Flight Safety Bulletin

The Safety Council issued an Interim Flight Safety Bulletin (Issue No：ASC-IFSB- 03- 01- 001) on January 24, 2003. It is recommended that all operators with turboprop aircraft review their training programs to ensure the program contains the necessary training for pilots to recognize and effectively respond to all levels of "Icing Conditions." It is also recommended that operators emphasize additional training in pilot's situation awareness of icing conditions.

Safety Recommendations

To TransAsia Airways

1. Review the managing procedures for the SOC Operations Manual to revise that manual timely when related operation-factor variations existed.
2. Request to the flight crews to check the weather documentation they received from the dispatcher that it is applicable to the flight.
3. Review and improve the implementation and management of ground school courses, flight training and rating to ensure that all pilots are competent in performing their duties.
4. Require pilots to ensure that the adequacy of read and follow the checklist’s procedures in abnormal or emergency conditions.
5. Enhance pilots of the ATR aircraft fleet with their training and rating on areas such as awareness, observing indications of severe icing, briefings and workload sharing, emergency procedures, and unusual attitude recovery.
6. Review the relevant rules and procedures of Flight Crew Reports.
7. Evaluate the retrofit of all company aircraft to use of solid flight data recorders.

To ATR Aircraft Manufacturer

1. Evaluate to include Severe Icing Emergency Procedures as memory items when encountering severe icing condition.
2. Add WARNING remarks to all of the severe-icing-related Chapter/Section in ATR’s relative Manuals to remind flight crew.

3. Proactively develop a more sophisticated icing detection system to enhance the flight crews' understanding and awareness of icing condition. Evaluate a new system to provide flight crew additional warning when aircraft operates in icing environment with autopilot engaged to reduce the potential risk of pilot's failure of monitoring and maintaining airspeed. Continuously support and engage a research activity similar to Smart Icing System to reduce the accident s caused by severe icing.

To DGAC, France

1. Proactively develop a more sophisticated icing detection system to enhance the flight crews' understanding and awareness of icing condition. Evaluate a new system to provide flight crew additional warning when aircraft operates in icing environment with autopilot engaged to reduce the potential risk of pilot's failure of monitoring and maintaining airspeed. Continuously support and engage a research activity similar to Smart Icing System to reduce the accident s caused by severe icing.

To Civil Aeronautics Administration

1. In addition to ICAO's regulations, refer to the practices made by HKO and TAWSC. To emphasize the situation awareness of icing en-route to pilots by marking symbols for, at least, moderate icing on the SIGWX charts, where the non-CB clouds above freezing level with supercooled liquid water is possible to be existed.
2. Review the TNA's pilots training to perform their duties effectively.
3. Evaluate the retrofit of all civil aircraft to use of solid flight data recorders.
4. Continuously review and evaluate the icing detection related Advisory Circular and Airworthiness Directive.

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Abbreviations

AAI	Assistant Avionic Inspector
AAIB	Aircraft Accident Investigation Board
AAS	Anti-Icing Advisory System
AD	Airworthiness Directive
ADF	Automatic Direction-Finding Equipment
ADS	Air Data System
AFM	Airplane Flight Manual
AHRS	Attitude and Heading Reference System
AIP	Aeronautical Information Publication
AIREP	Air Report
AIRMET	Information concerning en-route weather phenomena which may affect the safety of low-level aircraft operations
AMCM	Aircraft Maintenance Control Manual
AMI	Assistant Maintenance Inspector
AOA	Angle of Attack
AP	Auto Pilot
ARAC	Aviation Rulemaking Advisory Committee
ASB	Alert Service Bulletin
ASC	Aviation Safety Council
ATC	Air Traffic Control
ATCAS	ATC Automation System
ATR	AVIONS DE TRANSPORT REGIONAL
BEA	Bureau Enquetes Accidents
BFU	Bundesstelle fur Flugunfalluntersuchung
CAA	Civil Aeronautics Administration
CCAS	Central Crew Alerting System
CCD	Control Column Deflection
CDR	Continuous Data Recording
CFIT	Controlled Flight Into Terrain
CG	Center of Gravity
CL	Coefficient of Lift
CRC	Continuous Repetitive Chime
CRM	Crew Resource Management
CSU	Crash Survivable Unit
CTA	Control Area
CVR	Cockpit Voice Recorder
CWB	Central Weather Bureau
CWD	Control Wheel Deflection
DAFCS	Digital Automatic Flight Control System
DGAC	Director General Civil Aviation
DME	Distance Measuring Equipment
EADI	Electronic Attitude Director Indicator

EFIS	Electronic Flight Instrument System
EO	Engineering Order
EO	Engineering Order
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCOM	Flight Crew Operation Manual
FDR	Flight Data Recorder
FGS	Flight Guidance System
FIR	Flight Information Region
FOM	Flight Operations Manual
FSK	Frequency Shift Key Modulation
FTM	Flight Training Manual
FTMM	Flight Training Management Manual
GPS	Global Positioning System
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
IEP	Ice Evidence Probe
JAA	Joint Aviation Authority
JAR	Joint Aviation Regulations
LOMS	Line Operations Monitor System
LWC	Liquid Water Content
MAC	Mean Aerodynamic Chord
MCT	Maximum Continuous Throttle
MEL	Minimal Equipment List
METAR	Meteorological Report
MFC	Multi Function Computer,
MMEL	Master Minimal Equipment List
NAGRA	Tape recorder manufacturer in Switzerland
NTAP	National Track Analysis Program
NTSB	National Transportation Safety Board
OAT	Outside Air Temperature
PAI	Principal Avionic Inspector
PMI	Principal Maintenance Inspector
PM	Pilot Monitor
PPC	Production Planning Control
QRH	Quick Reference Handbook
RAPS	Recovering Analysis and Presentation System
RCAU	Remote Control Audio Unit
RII	Required Inspection Item
ROV	Remote Operating Vehicle
SAT	Static Air Temperature
SB	Service Bulletins
SC	Single Chime
SCDD	Super Cooled Drizzle Drops
SCR	Special Certification Review
SEM	Scanning Electron Microscope
SFC	Surface
SIGMET	Significant Meteorological Information
SIGWX	Significant Weather
SIL	Service Information Letter

SIL	Service Information Letter
SL	Service Letter
SLD	Super-Cooled Large Droplets
SOP	Standard Operation Procedures
SPS	Stall Protection System
TACC	Taipei Area Control Center
TAF	Aerodrome Forecast
TAS	True Air Speed
TAT	Total Air Temperature
TCAS	Traffic Alert and Collision Avoidance System
ULB	Underwater Locator Beacon
UTC	Coordinated Universal Time
VFE	Flaps Extended Speed
VHF	Very High Frequency
VLE	Landing Gear Extented Speed
VMO	Maximum Operating Speed
VOR	VHF Omni-directional Radio Range
WAFC	World Area Forecast Centre
WX	Weather

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1 Factual Information

1.1 History of Flight

On December 21, 2002, at 0152[4] Taipei local time, TransAsia Airways (TNA) freighter GE791, aircraft type ATR72-200, registration No.B-22708, encountered a severe icing during its flight and crashed into the sea 17 kilometers southwest of Makung city, Penghu Islands. Both pilots (CM-1 and CM-2) on board were missing[5].

Around 2310, December 20, 2002, the flight crew arrived at TNA office at Chiang Kai-Shek (CKS) International Airport and was prepared to flight from CKS International Airport to Macau International Airport.

About 0056, December 21, 2002, GE791 started engines from cargo apron 508. It was airborne on Runway 06 at 0104 and via CANDY 1 departure (see Appendix 1). It reached the assigned flight level 180 (FL 180) at 0125 and joined A-1 when passing MKG VOR/DME.

According to the Meteorological Conditions data[6]: The ground temperature was 20 degrees Celsius when GE791 departed from CKS International Airport and the estimate temperature at the altitude of 18,000 ft of accident area was minus 9 degrees Celsius.

The Flight Data Recorder (FDR) parameters showed that the airframe de-icing system was activated during the periods of 0134 to 0137 and 0141 to 0152 (when the FDR stopped recording) respectively.

According to the Cockpit Voice Recorder (CVR) transcript:

0132 CM-2: Looks like it's iced up….look at my side your side is also iced up right

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[4] All of the time shown herein represents local time in 24-hour system.

[5] The pilot-in-command was announced death by the court of law.

[6] The validity of the Meteorological Conditions data was from 8pm Dec. 20 to 8am Dec. 21.

0134 CM-1: oh it is icing up

0144 CM-1: it's iced up quite a huge chunk

0150:29[7] CM-1: Wow it's a huge chunk

CM-2: what an ice

0150:55 CM-1: This speed is getting slower it was a hundred two hundred one hundred and ninety now one hundred seventy

After discussed with CM-1 for a short while; at 0151:38, CM-2 said: you want high or ah, it is severe icing. After a discussion again, CM-2 at 0151:51 requested and approved from Air Traffic Control to descend to FL 160. FDR data showed: GE791 began to descent at 0151:56

0152:02 CM-1: do you see that

0152:08 CM-1: it's severe icing up

0152:10 CM-2: Captain

The CVR has recorded various warning sounds during the 40 seconds from 0152:11 to 0152:51 (when the CVR stopped recording).

0152:25 CM-2: Captain pull up. (This was the last dialogue between them.)

Furthermore, the FDR has shown:

- When the aircraft reached and maintained FL180, the lowest indicated airspeed recorded was 157knots at 0151:12 and the highest was 436knots at 0152:50 when the FDR stopped recording.
- At 0152:12, the aircraft began pitching down. Starting from 0152:23.5 till the stop of FDR, the pitch angle exceeded 50 degrees all the time with 85.9 degrees the biggest one. At 0152:09, a left bank developed and reached up to 48.9 degrees two seconds later. From then on, the bank degrees were constantly changing until the FDR stopped with the biggest one exceeding 90 degrees.
- The maximum vertical acceleration speed was 4.02G at 0152:45.375.
- A disengage of the autopilot was recorded at 0152:11.

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[7] 0150:29 means 1 o'clock 50 minutes 29 seconds, and this apply to the time referred hereinafter.

1.2 Injuries to Persons

Injuries	Flight Crew	Passengers	Others	Total
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	0	0	0	0
Missing	2	0	0	2
Total	2	0	0	2

1.3 Damage to Aircraft

Aircraft destroyed.

1.4 Other Damage

None.

1.5 Personnel Information

1.5.1 Backgrounds and Experiences of Flight Crew Members

1.5.1.1 CM-1

The nationality of CM-1 is Republic of China who had served in military, as a freighter pilot and his total flight time was 3,638:45 during his military service. He joined in TNA in February 1991 as a first officer of ATR42. In May of the same year, he completed ATR42/72 differential training and was promoted as a captain of ATR42/72 in September 1993. His total flight time was 14,247:33 which included 10,608:48 on ATR42/72 as of the accident.

1.5.1.2 CM-2

The nationality of CM-2 is Republic of China who completed his ATR42/72 initial type training in Flight Safety International U.S. from June 1996 to July 1997 with 307 total flight hours at that time. He joined in TNA in September 1997 and completed ATR42/72 differential training on November 27. In July next year, he completed required training courses and quality as a first officer of ATR42/72. His total flight time was 4,578:48 as of the accident.

Table 1.5-1 Basic Information of Pilots

Item	CM-1	CM-2
Gender	Male	Male
Age as of accident	53	34
Date of joining in TNA	February 20, 1991	September 15, 1997
License type	Airline Transport Pilot No.101096	Airline Transport Pilot No. 102065
Type rating Expire date	ATR42/72 August 31, 2003	ATR42/72 F/O January 6, 2004
Medical class Expire date	1st class airman March 31, 2003	1st class airman April 30, 2003
Latest flight check	July 25, 2002	June 23, 2002
Total flight time	14,247 hrs 33min.	4,578 hrs 48 min.
Flight time in last 12 months	887 hrs 37 min.	873 hrs 14 min.
Flight time in last 90 days	201 hrs 14 min.	178hrs 44 min.
Flight time in last 30 days	59 hrs 46 min.	42 hrs 11 min.
Flight time in last 7 days	8 hrs 52 min.	11 hrs 05 min.

ATR42/72 flight time	10,608 hrs 48 min.	4,271 hrs 48 min.
Flight time on the day of accident	0	0
Rest time period before accident	Over 24 hrs	Over 24 hrs

1.5.2 Training and Rating Records of Flight Crew

1.5.2.1 CM-1

Initial training

Completing ground academic courses training of ATR42 flight crew at ATR Training Center, France on March 29, 1991; passing the rating of first officer on performance and takeoff/landing skills on April 22; completing differential training of ATR42/72 aircraft on May 16; and passing the first officer flight route check on May 21.

Up-grade training

Finishing ground academic courses training of ATR42/72 pilot; passing the rating of captain on performance and takeoff/landing skills on August 13, 1993; and passing the captain flight route check on August 27.

Recurrent training

Simulator recurrent training of TNA pilots had been conducted at Flight Safety International, U.S.A., between 1991 and 1997, and has changed to at Asian ATR Training Center, Bangkok, Thailand, since October 1997. The pilots are trained by TNA instructor pilots and examined by TNA designated examiners designated by CAA.

The recurrent training and rating records indicated:

1. In addition to the listed items of the ATR Recurrent Training Rating Record sheet filled out on October 18, 1998, the item “ICING CONDITION EXERCISES” was added on the Item column but its score column was remained blank.
2. On the Recurrent Training Record sheet of July 21 to 22, 1999, handwritten “+ ICING” were added to the “Approaches to Stalls” item column and an “S” (satisfactory) was shown in its score column. For this recurrent training, “WEAK SYSTEMS KNOWLEDGE BUT IS ABLE AND VERY WILLING TO LEARN” was put in the Remarks column of ATR Recurrent Training Rating Record sheet.

3. On the Recurrent Training Record sheet of March 17 to 18, 2000, handwritten “INCLUDE ICING” was added to the “Approaches to Stalls” item column and an “S” was shown in its score column. For this recurrent training, “TENDENCY TO LOSE SITUATION AWARENESS – AUTOPILOT NOT ENGAGED BUT NOT AWARE AND LEAD TO STICK SHAKER STALL, SEVERE BANK>45° WITH SINGLE ENG. RE-DID EXERCISE SEVERAL TIMES WAS OK. – BUT STILL UNSTEADY.” was put in the Remarks column of ATR Recurrent Training Rating Record sheet.
4. The score column of ATR Recurrent Training Rating Record sheet of July 9, 2001, showed “PASS.”
5. The score column of ATR Recurrent Training Rating Record sheet of February 20, 2002, showed “PASS.”

1.5.2.2 CM-2

Initial training

Finishing ground academic courses training of ATR42/72 pilot at FlightSafety International, U.S.A. in August 1997; starting ATR72 aircraft initial type training after joining in TNA in September 1997; completing differential training of ATR42/72 aircraft on November 27; passing the rating of first officer on performance and takeoff/landing skills on February 18, 1998; and passing the first officer route check on April 5.

Recurrent training

From completion of initial training till the occurrence of accident, CM-2 had successfully past all recurrent trainings and ratings without any unusual remarks in records.

1.5.3 TNA Flight Crew Members’ Ground School Recurrent Training

A ground school of recurrent training for TNA flight crew is conducted prior to the twice-per-year’s recurrent trainings. The curriculum of the one-day ground school training program includes:

1. Civil aviation regulations, one hour;
2. Crew resources management (CRM), one hour;
3. Controlled flight into terrain/approach and landing accident reduction/ground proximity warning system (CIFT/ALAR/GPWS), one

hour;

4. Abnormal operations of aircraft systems, two hours;
5. Instructor pilot’s briefing, one hour;
6. Traffic alert and collision avoidance system (TCAS) operation or cold weather operation including operations when passing through a thunderstorm and usage of weather radar--Traffic alert and collision avoidance system (TCAS) operation is conducted in between April and September; cold weather operation in between October and March; one hour.
7. Other curricula (such as Fleet Circular) that need to be replenished or reinforced; and
8. Tests; one hour.

According to interview records, the recurrent training curricula and tests under flight crew the instructor pilots of the type of aircraft fleet conduct member’s regular ground school recurrent training program.

1.5.3.1 CM-1

CM-1’s ground academic courses training records in recent two years provided by TNA showed the dates and tests scores as follows: 98 points on January 9, 2001; 100 points on July 2, 2001; 100 points on January 31, 2002; and 100 points on July 19, 2002.

1.5.3.2 CM-2

CM-2’s ground academic courses training records in recent two years provided by TNA showed the dates and tests scores as follows: 100 points on January 9, 2001; 98 points on May 17, 2001; 94 points on December 18, 2001; and 95 points on June 11, 2002.

1.5.4 Flight crew members’ physical conditions

1.5.4.1 CM-1

The item of limitations on the Airman Medical Certificate issued by CCA to CM-1 noted: “Holder shall wear correcting glasses”

1.5.4.2 CM-2

The item of limitations on the Airman Medical Certificate issued by CCA to CM-2 noted: “none”.

1.5.5 Flight Crew Members’ Activities in 72 hours prior to the Accident

1.5.5.1 CM-1

1. December 18: Stayed overnight at Kaohsiung after finishing previous day’s flight and reported to Kaohsiung Section company at 0720 to perform Kaohsiung→ Makung → Kaohsiung→ Makung→ Sungshan flights. He was off-duty after landing Sungshan Airport around 1200.
2. December 19: On furlough and took his family for an outing.
3. December 20: Spent leisure daytime at home and reported to TNA office at CKS International Airport around 2310, then implemented this flight.

1.5.5.2 CM-2

1. December 18: Stayed overnight at Hualien after finishing previous day’s flight and reported to Hualien Section company at 0650 to perform Hualien→ Sungshan flight. He was off-duty after landing Sungshan Airport at 0812.
2. December 19: On furlough and stayed at home.
3. December 20: Spent leisure daytime at home and reported to TNA System Operation Center at 2140. After receiving a flight crew briefing, he took a vehicle to CKS International Airport and then implemented this flight.

1.6 Aircraft information

1.6.1 Basic Information

According to maintenance records provided by TNA, the B-22708 maintenance works were completed in accordance with the TNA aircraft maintenance programs. All the Airworthiness Directives (AD) was completed in compliance with CAA regulation. Before the accident, there were no deferred items to the aircraft. The basic aircraft information was listed as table 1.6-1 below.

Table 1.6-1 Basic Information

No.	Item	Description
1	Registration Number	B-22708
2	Type	ATR-72-200
3	Manufacturer	Avions De Transport Regional, France
4	Serial Number	322
5	Manufacturing Date	The third quarter of 1992
6	Delivering Date	1992/08/25
7	Operator	TNA
8	Owner	TNA
9	Main Deck Design	Bulk Cargo
10	Airworthy until	2003/02/15
11	Total Fight Hours	19,254：27
12	Cycles	25,529
13	Type and Date of Latest Heavy Maintenance	7C 2001/06/17
14	Type and Date of Estimated Next Maintenance check	8C / Before 19,501 hours
15	Hours at Each C Check	3,600Hours

This aircraft was delivered from Toulouse, France to Taipei, Taiwan in August 1992. It had been used as domestic passenger flight for six years before leased to Gill Airways, United Kingdom on October 15, 1998. It was registered as G-BXYV to service as a "COMBI" for three years in United Kingdom. This aircraft ferried back to Taiwan after the leasing contract terminated and changed the type certificate to be a bulk cargo aircraft. It was registered as B-22708 again by CAA, Taiwan. The service history in Taiwan and UK was listed as Table1.6-2.

Table 1.6-2 Servicing history in Taiwan and UK

Description	Date
Manufactured Date	Third quarter of 1992
Date of Ferry flight from Toulouse	1992/09/24
Date of arrival at Taipei	1992/09 /28
Domestic flight in Taiwan	1992/10/06~1998/09/18
Date of ferry flight to Newcastle International Airport, UK	1998/09/22
Commercial Flight in Gill Airways	1998/10/15~2000/02/21
Date of ferry flight from UK to Taiwan	2001/12/30
Type certificate change in Taiwan to bulk cargo aircraft	2002/02/22~2002/12/21

Table 1.6-3 Heavy maintenance schedule Check

Types of check	Completed Date	Flight Hour	Flight Cycle	Done by
1C	1993/08/31	1862:20	2746	TNA
2C	1994/06/25	3569:46	5537	TNA
3C	1995/08/22	5320:15	8524	TNA
4C	1996/03/12	7048:49	11584	TNA
5C	1997/05/13	9212:19	15293	TNA
6C	1998/02/20	10784:03	17998	TNA
1CFH/2CFH/2CCA	1999/11/15	13854	21037	GILL
1CFH/2CFH	2000/06/28	15054	22103	GILL
1CFH/2CFH	2001/06/21	16808	23997	GILL
7C	2002/06/17	18088:08	24974	TNA

Table 1.6-4 Major Repair/Alternation List

Item	Date	Description
1	2002/02/22	ATR72 freighter conversion for class "E" freighter requirement
2	2001/03/17	Install Collins TCAS and 2 ATC mode S and Sextant VSI/TCAS on Collins radio NAV system
3	2002/10/07	Modification to passenger compartment interior

The aircraft is about 1068"（27 meters）long × 1064" （27 meters）wide × 143" （3.6 meters） wing height × 301" tail height（7.6 meters）（Figure 1.6-1）.

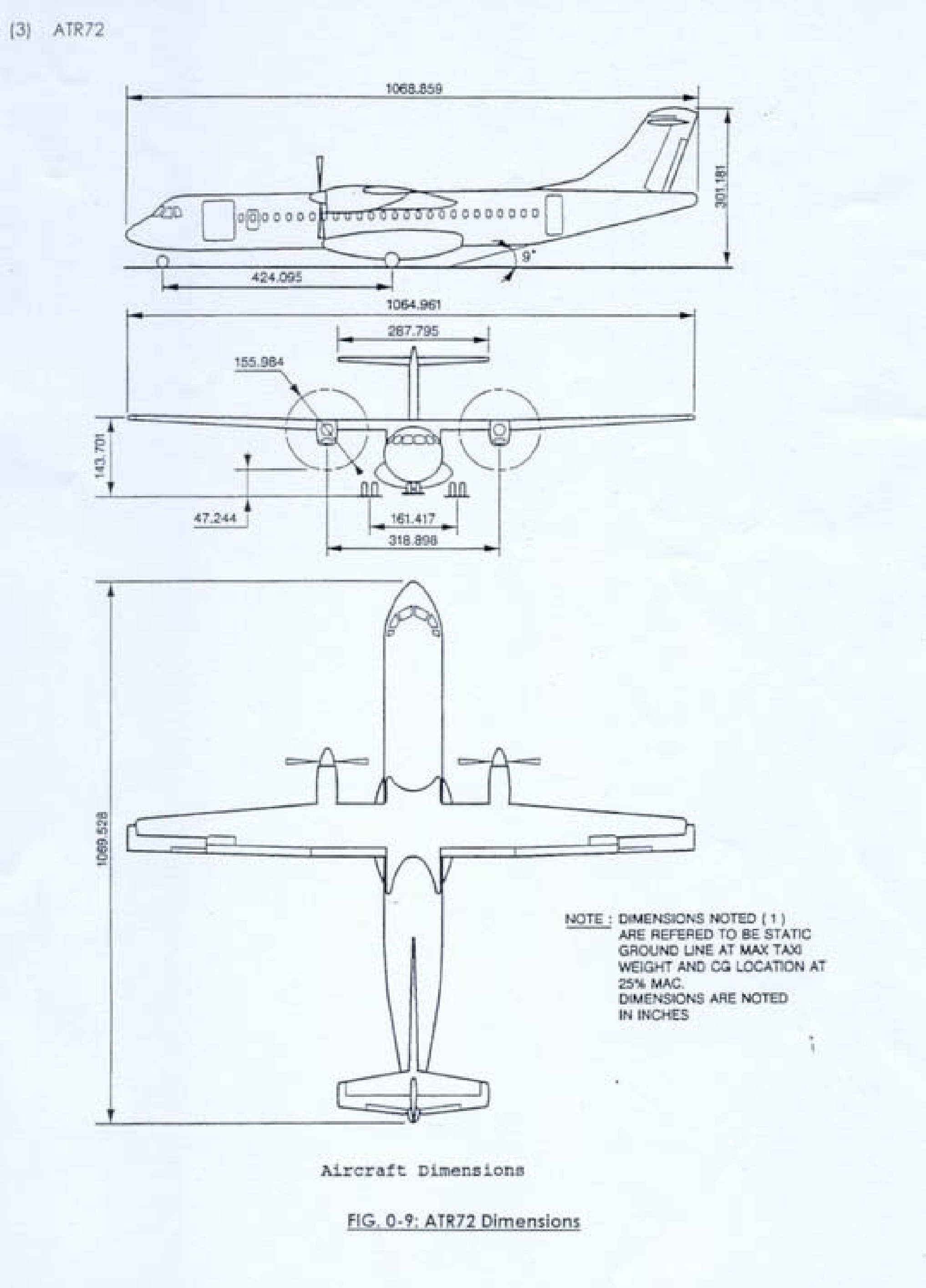

Figure 1.6-1 ATR72 dimensions

Reviewed routine maintenance records of year 2002, there is no major structure repair for B-22708.

1.6.2 Engine Information

This aircraft was operating with two PWC124B engines with the information as Table 1.6-5:

Table 1.6-5 PW124B Engine Information

Position	Serial No	Date of Manufacturing	Date of Installation	Flight Hours after installed	Total Flight Hours	Total cycles
1	124636	1993/03	2002/01/24	1,871:39	15,638:58	23,469
2	124420	1990/10	2002/08/26	693:05	18,605:52	29,076

1.6.3 Propeller Information

Two Hamilton Standard 14SF-11, 806660-1 propellers were installed and the basic information was listed as following：

Table 1.6-6 Basic information of propeller 806660-1

Position	Serial No	Manufactured by	Date of Installation	Time after Installation	Total Flight Hours	Total Cycles
1	MFG930320	Hamilton Standard, United Tech. Co.	2001/10/15	1,871:39	6,956:00	6,477
2	MFG930321	Hamilton Standard, United Tech. Co.	2001/10/15	1,871:39	1,901:51	917

1.6.4 ATR72 Ice Protection Systems

The ATR72 ice protection system provides the following functions：

- Pneumatic boots deicing system for leading edges of wing and empennage (figure 1.6-2);
- Pneumatic deicing system for engine air intakes;
- Electrical heating system for anti-icing of the propeller blades, the windshield and the side windows, the pitot tubes, static ports, TAT (total

air temperature) probe, and the AOA vanes;

- Electrical heating system for anti-icing of the aileron, elevator and rudder balance horns.

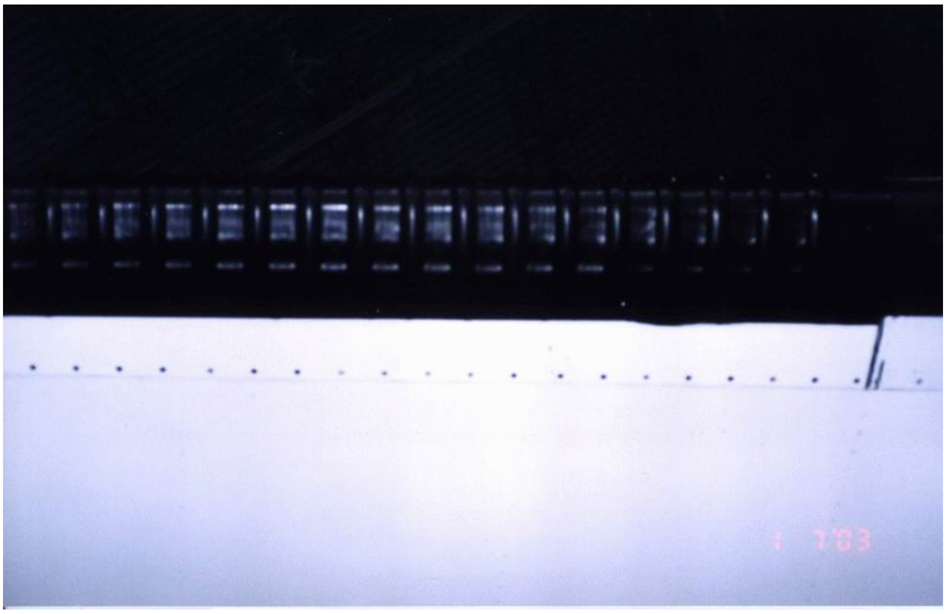

Figure 1.6-2 The inflating Deicing boot (wing and empennage)

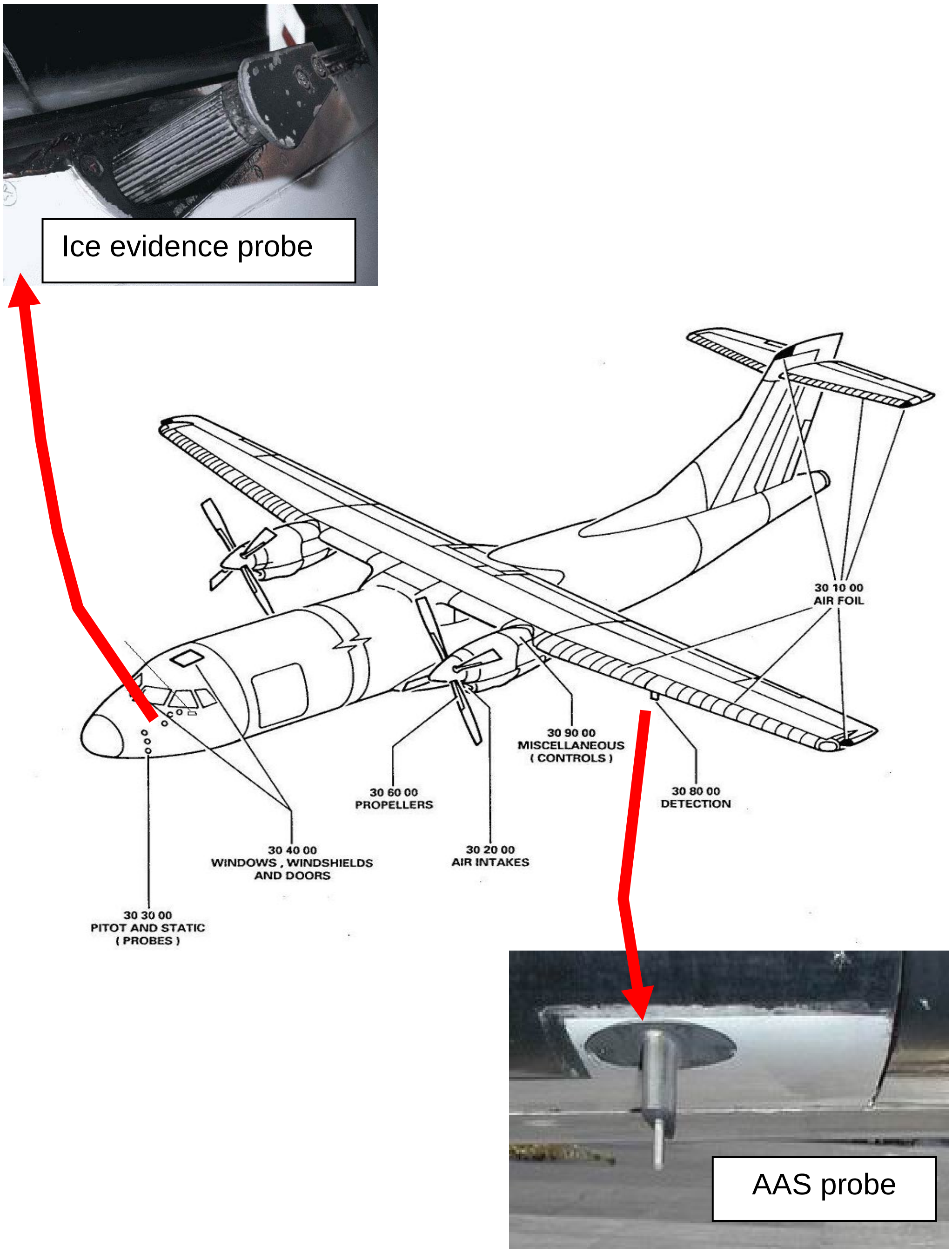

Figure 1.6-3 The Ice evidence probe & The Anti-Icing Advisory System (AAS) probe

The ice evidence probe (IEP) is located outside and below the captain's left side window (Figure 1.6-3). IEP has an integrated light, which is " ON " when the navigation lights are " ON ". The IEP that provides pilots with visual cue of ice formation is visible to both pilots and provides ice accretion condition. The probe is designed to retain ice but does not have the function of ice protection.

In addition to the IEP, ATR72 also equipped with Anti-Icing Advisory System (AAS) for the supplemental icing detection. The probe is located at the underside of the left wing leading edge and generates the AAS signal. The AAS provides both visual and aural warning to flight crew. The aural alert (chime) is inhibited when boots are activated. Visual alert light stays on as long as ice accretion is detected.

The AAS detects accretion-icing condition by using ultrasonic ice detector probe, which senses ice accretions. It is approximately 1/4 inch in diameter and 1 inch long and vibrates along its axis at a given (approx 40 KHz) frequency. The system detects changes in vibration frequency resulting from the increased mass of the accumulated ice. If the frequency drops below 39.867 Hz. It initiates a signal to the Central Crew Alerting System (CCAS) for 60 seconds and provides the amber flashing caution light. That reminds the flight crew that the aircraft is in icing accretion condition.

In accordance with ATR72 Aircraft Maintenance Manual chapter 30-81:

> *The purpose of Ice Detection System is to help crew to detect icing accretion conditions.*
>
> *However the primary mode of detection remains visual detection of ice formation by the flight crew.*

As long as ice is detected but the AIRFRAME de-icing has not selected ON, the following caution signals activate:

1. Flashing of ICING amber light
2. Flashing of master CAUTION light
3. Single chime aural signal

Whenever the ice accretion is detected and anti-icing/de-icing have selected ON, the ICING amber light stays on.

When ice is detected but the flight control surfaces and horns anti-icing/de-icing have not been selected ON, the ICING light flashes.

If the AAS probe has not detected ice accretion for more than 5 minutes the AIRFRAME DE-ICING is still “ ON “, the DE ICING blue light will flash.

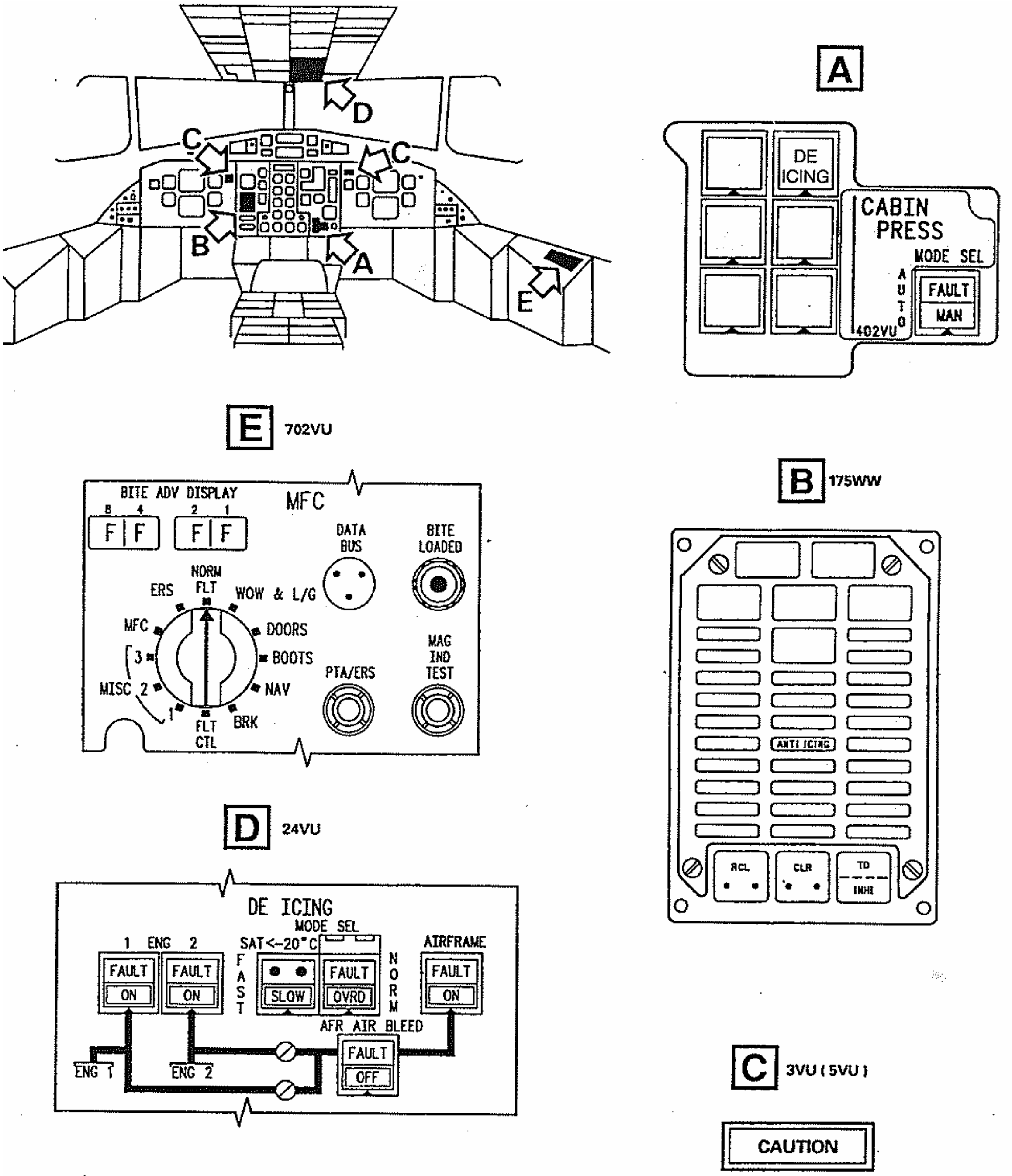

Figure 1.6-4 The location of airframe ice protection system instrument panels in the cockpit

Location of airframe ice protection system instrument panels for crew to monitor in the cockpit is shown as Figure1.6-4.

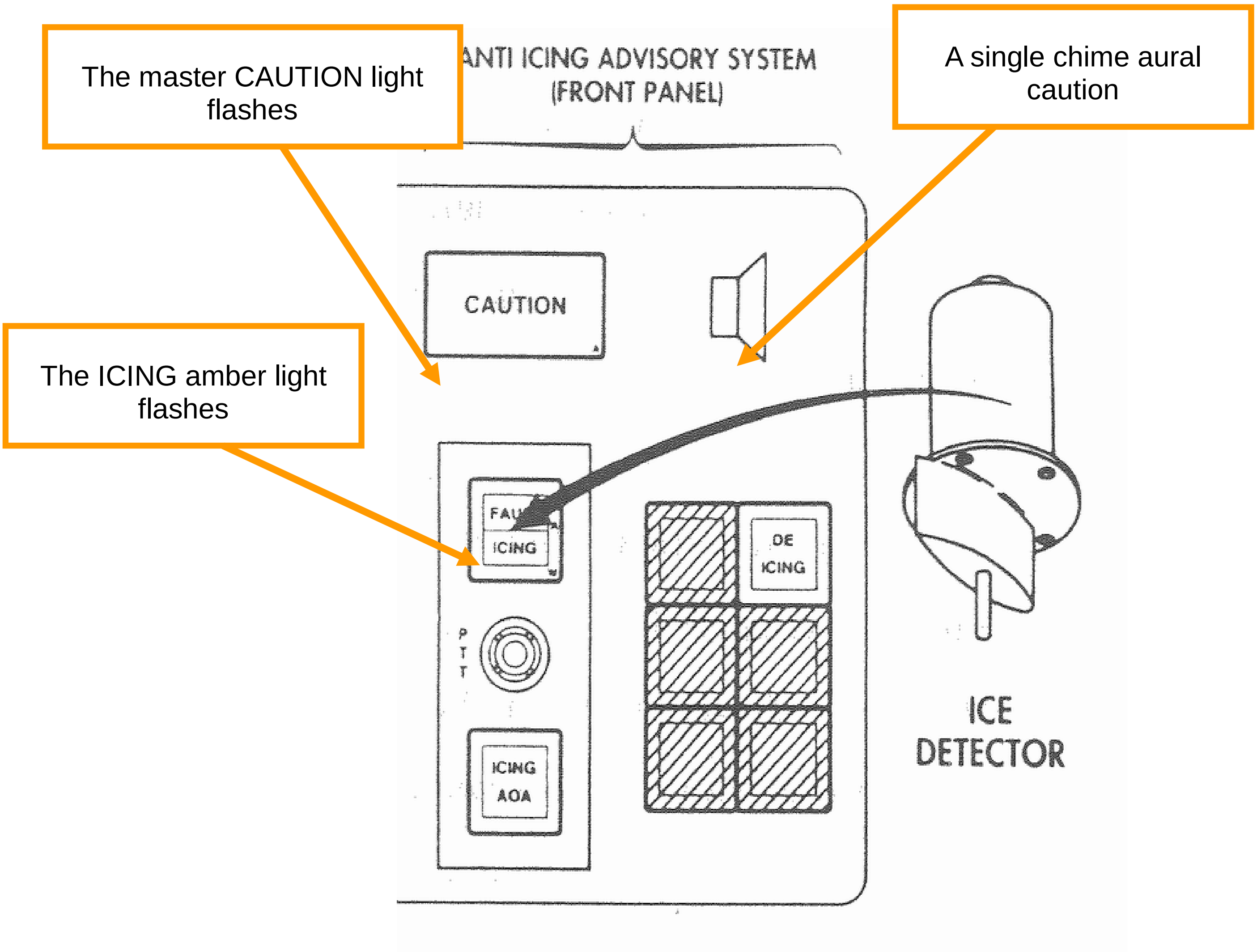

Figure 1.6-5 AAS visual and aural alert signals

1.6.5 Malfunction of the Ice Protection

When the crew activates the airframe, engines and propellers ice protection systems, two Multi Function Computers (MFCs) monitor and control the operation. There are 14 independent subsystems monitor the correct operation of the system. In the event of any subsystem malfunction, MFCs indicate the failure by the illumination of the FAULT legend on the de icing control panel push button switch and illuminate ANTI ICING alert on CCAS panel. See Figure 1.6-5. The single chime is activated and the master CAUTION lights flash. When the MFCs fail the system submit the alert to flight crew and remind them the override de-icing mode has to be activated.

The MFCs monitor the following malfunctions:

- Boots air supply fault engine 1-1
- Boots air supply fault engine 1-2
- Air bleed overheat engine 1-1

- Air bleed overheat engine 1-2
- Brush block supply fault propeller 1-1
- Brush block supply fault propeller 1-2
- Boots air supply fault airframe-1
- Boots air supply fault airframe-2
- Boots air supply fault engine 2-1
- Boots air supply fault engine 2-2
- Air bleed overheat engine 2-1
- Air bleed overheat engine 2-2
- Brush block supply fault propeller 2-1
- Brush block supply fault propeller 2-2

Heating of the rudder, elevators and aileron horns are controlled by two horn anti-icing controller. Any subsystem malfunction will trigger the horn anti-icing controller to activate the following alerts:

1. Illumination of ANTI ICING amber light on CCAS panel
2. Flashing of master CAUTION light
3. Single chime aural signal

1.6.6 ATR72 Lateral Control System

The ATR72 lateral control systems composed of movable cable loop driven ailerons and the hydraulically actuated wing spoilers (figure 1.6-6). The ailerons are aerodynamically balanced through the use of an offset hinge line, geared trailing edge balance tabs, and exposed horns (see figure1.6-7 and figure 1.6-8)

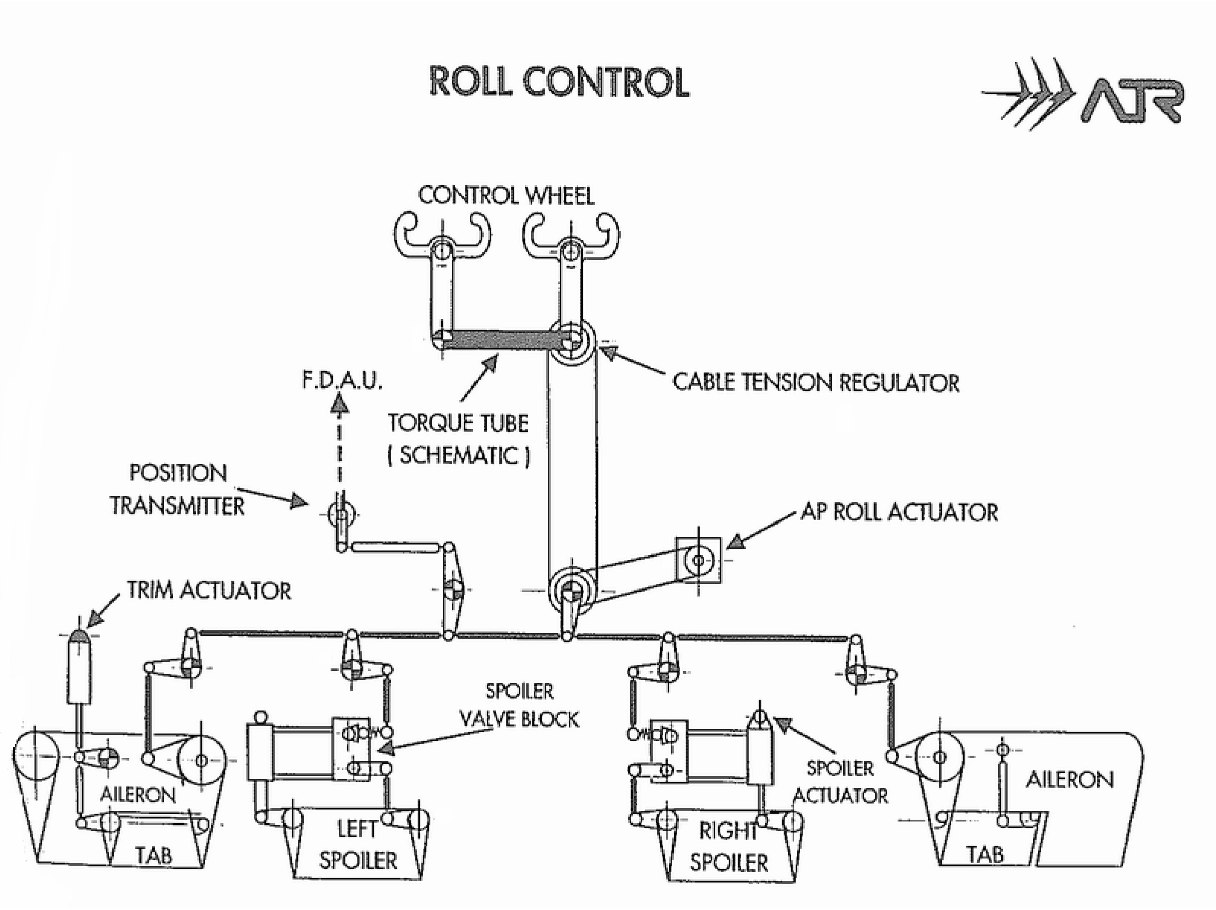

Figure 1.6-6 Roll control system diagram

The ailerons are driven by the cockpit control wheels through cables, bell cranks and push pull rods. The cable tension compensator maintains specific cable tension. An electric trim actuator motor is connected to the left aileron balance tab. The ranges of deflection for the ailerons, control wheels and the balance tabs are about +/- 14 degrees, +/- 65 degrees and +/- 4 degrees, respectively. The hydraulic actuated spoiler for each wing enlarges the lateral control system. The aileron control linkages control spoilers' deployment mechanically. The spoiler actuator for each side activates at the aileron deflection of 2.5 degrees trailing edge up, and the spoiler deflection is about to 57 degrees for 14 degrees of aileron deflection. The required input force to control wheel is related to the moment of balance tab hinge and the air pressure cover the tab.

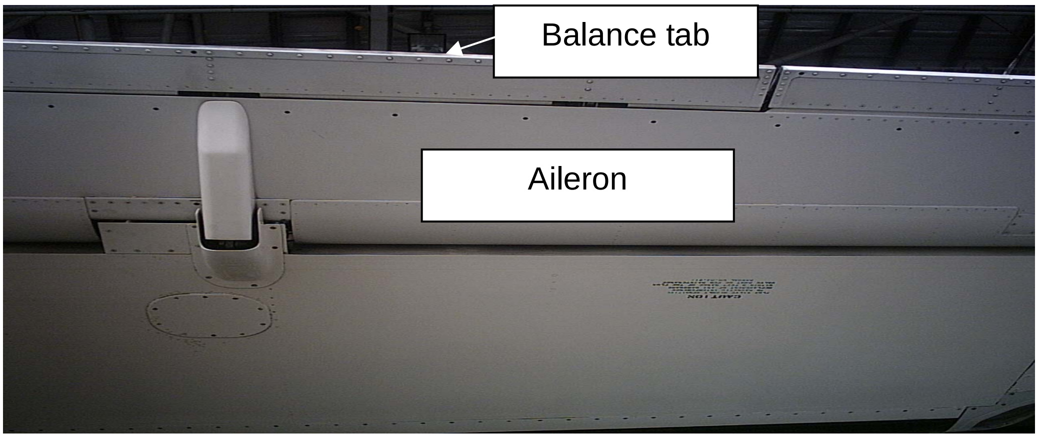

Figure 1.6-7 ATR72 aileron and balance tab

Figure 1.6-8 ATR72 horn

1.6.7 ATR72 Stall Protection System

The ATR72 stall protection system (SPS) provides crew different stages warning devices before the aircraft reaching AOAs consistent with “clean” and ice-contaminated flow separation characteristics. The devices are:

- An aural warning and a stick shaker, both activate simultaneously when the angle of attack reaches a predetermined value that affords a margin prior to the onset of adverse aerodynamic characteristics;
- A stick pusher activates and pushes down the aircraft in a strong movement when the AOA reaches a preset higher value nearer to the onset of stall.

Two MFCs control the stall protection system and are operated by the following sources:

- AOA probes;
- Flap position;
- Engine Torque;

- On-ground/in flight indicator;
- Horn anti-ice status;
- Airplane altitude above or below 500 ft; and
- The presence / absence of optional deicer leading edges

The AOA probe information is used to reduce the triggering threshold when the AOA is quickly moving toward positive values. In accordance with the aircraft maintenance manual (AMM), the phase lead of the triggering threshold has a maximum value of plus 3 degree AOA and does not intervene with the anti-icing system in use.

Even though a single failure of any component in the system does not result in the loss of the stick pusher function, improper activation of the stick pusher, the loss of aural warning alert, or the loss of both stick shakers.

The ATR72 has icing and non-icing AOA triggering thresholds to actuate stick shaker for flap at 0^0 and 15 ^{0} configurations as following table1.6-7.

Table 1.6-7 Icing and non-icing AOA triggering thresholds to actuate stick shaker

Aircraft Configuration	Flight Condition		
	Normal	Icy Condition	
		Take-off (10 mn)	Cruise or Take-off more than 10 mn
Flaps 0	15.9	/	11.2
Flaps 15	16.3	12.5	12.5

The AOA triggering thresholds to actuate stick pusher for flap at 00 and 15 configurations are as following table 1.6-8

Table 1.6-8 Icing and non-icing AOA triggering thresholds to actuate stick pusher

Aircraft Configuration	Flight Condition		
	Normal	Icy Condition	
		Take-off (10 mn)	Cruise or Take-off more than 10 mn
Flaps 0	20	/	15.3
Flaps 15	20	16.4	16.4

When flying in icing conditions defined in 14 CFR Part 25, Appendix C, the SPS activates at lower AOAs when the anti-icing system is on to cope with the aerodynamic changes. The SPS does not cover more adverse icing weather beyond that defined by 14 CFR Part 25, Appendix C, for instance, in a freezing rain condition.

1.6.8 Automatic Flight Control System

A Honeywell SPZ-6000 Digital Automatic Flight Control System (DAFCS) is equipped on the ATR72 including following subsystems:

- Attitude and Heading Reference System (AHRS);
- Air Data System (ADS);
- Electronic Flight Instrument System (EFIS);
- Flight Guidance System (FGS) and
- PRIMUS 800 Color Weather Radar System

The DAFCS is an automatic flight control system that offers fail-passive flight director guidance; autopilot, yaw damper and pitch trim functions. The autopilot computers continuously monitor the system and alert the flight crew to any fault that has been detected. The autopilot system uses two in-flight bank angle selections: “HIGH” bank angle (default 27 degrees) and “LOW” bank angles (default 15 degrees). The flight crew can manually select the limits and the selection applies the maximum amount of bank angle executed by autopilot.

The autopilot will trip automatically if the computer senses any of the following system faults or malfunctions:

- One of the engagement conditions of the AP and/ or YD is no longer met, includes the exceeding travel rate of the ailerons (3.6 degrees per second), or
- A disagreement between the two AHRS or between the two ADCs (air data computers), or
- A mismatch between the two pitch trims, or
- Stall warning indicator threshold is reached.

If the aileron rate monitor is tripped, power will be removed from autopilot servo- motor and servo clutch. The crew will receive an aural and visual warning alert.

1.6.9 ATR 72 Anti/De-icing System Maintenance Record

According to TNA Aircraft Maintenance Program, the wing de-icing boot was scheduled to be inspected at each C check. The latest 7C check was completed on June 21, 2001.

1.6.9.1 The AD of Anti/De-Icing System

The contents and performance of the AD in Anti/De-icing system of this aircraft were described as following：

1. CAA AD 83-ATR-108G (French DGAC AD 1996-207-031(B) R1) /USA FAA AD 96-09-28) was issued to improve the severe icing condition. This AD changed the operation procedures and the system design. It required the operator to revise the “Operation Limitations” and ”Operation procedures” of Aircraft Flight Manual before July 10, 1996.also required to complete the following works before December 11, 1996:

   (1) Change the logic circuit of flap extension (SB ATR72-27-1039),

   (2) Install the wider de-icing boots at both outer wing leading edges (SB ATR72-30-1023 & 57-1015 & 57-1016).

   Reviewed the AD records of TNA and verified:

   (1) This aircraft completed the SB ATR72-27-1039 on March 17, 1996,

   (2) This aircraft completed the SB ATR72-30-1023, ATR72-57-1015 and ATR72-57-1016 on December 2, 1996,

   (3) The TNA Engineering Department requested the Flight Operations Division to revise the Aircraft Flight Manual on May 23, 1996. The Flight Operations Division responded and confirmed the revision of AFM completed on May 31, 1996.

2. CAA AD 88-ATR-146B (French DGAC AD 1999-015-040(B) R1/ USA FAA AD 99-09-19) Requested to revise ATR72 AFM regarding the description of severe icing condition:

   (1) The AFM of ATR 72 had to be revised before May 4, 1999 regarding the ”Operation Limitation”, ”Normal Procedures” and ”Emergency Procedures”,

   (2) The revised contents in AFM should be incorporated in FCOM before May 16, 1999.

   The performance of this AD in UK and Taiwan were verified as below:

   (1) Gill Airways, UK completed this AD on April 22,1999,

   (2) TNA purchased from ATR the 14th edition (published in September 2000) AFM to comply with the requirement of AD.

   Reviewed the revised procedures including the ”Operating limitations”, ”Normal procedures” and ”Emergency procedures” in AFM and found the revised procedures were complied with the AD requirement. The page 9 and 10 of chapter 2.04.05 of FCOM concerning the De/Anti-icing procedures were all revised in July 2000.

3. CAA AD 88-ATR-147A (French DGAC AD 1999-166-041(B) R1)

This AD concerning the aircraft design change in severe icing condition required to complete the following works before September 30, 2001:

(1) Change the logic circuit of flashing ”Icing” light (SB ATR72-30-1034),

(2) Install the wider mid wing leading edge de-icing boots (SB ATR72-30-1032R1 & 30-1033R1or 30-1037).

Gill Airways, UK completed the SB ATR72-30-1032, 30-1033 & 30-1034 on November 15, 1999. SB ATR72-30-1037 was not applied to this aircraft.

4. CAA AD 90-ATR-153 (French DGAC AD 2001-045-054(B))

This AD was issued for revising the description of anti/de-icing system in AFM. It was required to revise the content of the ”Normal procedures” by issuing the 14th edition revision of AFM before February 18, 2001.

Reviewed this AD record and found:

(1) Gill Airways, UK revised the AFM on January 31, 2001,

(2) TNA purchased the 14th edition of AFM（Published in September 2000）during receiving this -returning aircraft from Gill Airways to comply with this AD requirement.

1.6.9.2 The SB Concerning the De/Anti Icing System

The SB concerning the De/Anti-icing system were described as below:

1. SB ATR72-30-1032 (Installed the extended de-icing boots), ATR72-30-1033 (Installed the wider de-icing boots) and ATR72-30-1034(Change the logic circuit of ice detection light)were the contents of CAA AD 88-ATR-147A (DGAC AD 1999-166-041(B)) .According to the airworthiness records of CAA,UK and the work order number 000029 of Gill Airways on November 15, 1999, those SB were all completed in accordance with the AD requirement.
2. The SB ATR72-30-1014 (Change the ice detection function) SB ATR72-30-1026 (Change number 1 and 2 wing leading edge de-icing boots), and SB ATR72-30-1030 (Change the pressure regulator and shut off valve of de-icing system) were optional SB and not applied to this aircraft after evaluated by TNA Engineering Department.
3. The SB ATR72-30-1027 (Avoiding the over heat to the painting of elevators and rudder horns) and ATR72-30-1028 (Avoiding the over heat to the painting of aileron horn) were the kind of recommended SB and not applied after the evaluation of the TNA Engineering Department.
4. The SB ATR72-30-1020 (Anti-icing valve seat heating) and

ATR72-30-1039 (Avoiding the electricity leaking from propeller to damage the 15th bearing) were the kind of optional SB and not applied to this aircraft. The engineering evaluation records of these two SB were not provided by TNA.

1.6.9.3 Aircraft Logbook entries for De/Anti Icing System

The Aircraft Logbook entries from December 21, 2001 to December 21, 2002were reviewed. The following Logbook entries identify the discrepancy and the work accomplished regarding to de/anti Icing System:

- Aircraft Log dated January 02, 2002, indicated that propeller de-icing system block out for #1 engine. The propeller brush block assembly was replaced and function checked normal.
- Aircraft Log dated January 02, 2002, reported that propeller de-icing system block out for #2 engine. The propeller brush block assembly was replaced and function checked normal.
- Aircraft Log dated January 02, 2002, the dual airframe de-icing distribution valve was replaced for work order requires and function checked normal.
- Aircraft Log dated January 02, 2002, the de-icing regulator/shutoff valve was replaced for re-certification purpose. The function checked was normal.
- Aircraft Log dated January 09, 2002, indicated that propeller de-icing system block out for #1 engine. The propeller brush block assembly was replaced and function checked normal.
- Aircraft Log dated April 04, 2002, indicated that IEP light was out. The light bulb was replaced and illumination checked normal.
- Aircraft Log dated May 11, 2002, write-up that anti-icing propeller 2 fault was occurred. The item was deferred and MEL 30-61-1 was applied.
- Aircraft Log dated May 13, 2002, that anti-icing propeller 2 fault was closed due to replacement of the propellers.
- Aircraft Log dated May 18, 2002, indicated that anti-icing propeller 1 fault was occurred. The item was deferred and MEL 30-61-1 was applied.
- Aircraft Log dated May 19, 2002, that anti-icing propeller 1 fault was fixed due to replacement of the propellers.
- Aircraft Log dated July 08, 2002, found L/H air intake duct clamp was installed wrong direction. It was reinstalled and the item was cleared.
- Aircraft Log dated August 24, 2002, indicated that L/H wing outboard

side boot was sustained impact damage during engine run-up in Macau. The whole leading edge boot was replaced and operation checked normal.

- Aircraft Log dated October 27, 2002, found #1 engine air intake broken at 6 o'clock position. The intake was replaced and function check normal.
- Aircraft Log dated November 18, 2002, indicated that #2 engine propeller de-icing system block brushes length less than 9 ㎜. The propeller brush block assembly was replaced and operation checked normal.

1.6.10 The TNA AD and SB Records Keeping

During reviewing the records of the AD and SB applied to B-22708, investigators found that TNA maintained the records by following the procedures described in item 2-7,section 10, in Chapter 3 of Aircraft Maintenance Control Manual (AMCM published on April 10,1996). The TNA Maintenance Manager expressed that the cover page of the work order sheet of AD and SB were kept on file but not the working procedures and parts replacement records before August 1997.

The Aircraft Maintenance Control Manual, AMCM published on August 13,1997 stated the processes of SB, SIL (Service Information Letter), AD and Engineering Order, EO but without stating the keeping time required. Before the year of 1997,TNA completed the AD and SB by following the procedures of ”The handling of AD and SB” that stated at item 2-7, section 10, in Chapter 3 of the AMCM approved by CAA. The AMCM stated:

1. *The engineer printed out the Work Order Sheet with the AD and SB attached and passed it to Principal Production Control, PPC. The PPC issued the work order to the Maintenance Shop and Quality Control Center, QCC.*
2. *After the work completed by the Maintenance Shop and QCC , the PPC made the record in Aircraft Logbook and returned the work order sheet to the Engineering Section.*
3. *When all the work applied to the aircraft completed, Engineering Section made two Engineering Authorization/ Modification sheet, one for CAA and one for his own copy.*

1.6.11 The CAA Regulation to Record Keeping

According to the Civil Aircraft Maintenance and Release Procedures revised on October 24,1995, it stated: the record keeping time unless described at other place, should be kept as a basic record, such as the Aircraft Logbook, for two more years after the termination of usage, phase out on the damaged aircraft, engine and propeller.

To alteration, configuration change or fabrication, the procedures of Civil Aircraft Maintenance and Release stated:

> *After completing the alteration, configuration change and fabrication works, not only the working records and references, but the major contents including work card number, file number, issued work sheet number, part number, serial number, type, component, description and alteration should be kept for two years in the Aircraft Logbook and Engine /Propeller Logbook for reference.*

There was an order in the Airworthiness Inspector's Manual published on March 25,1996 describing the record keeping:

> *The Job Function 1& 2*
>
> *- The inspection procedures at main and secondary base:*
>
> *"B. Inspect the database of the operator: Verify that all the technical data are updated and can be retrieved. If the data is stored in microfilm, an available device of reading should be provided. If applicable, the technical data should contain: Procedures,*
>
> *Operator's General Maintenance Manual, Manufacturer's Aircraft Maintenance Manual, Original Manufacturer's Propeller, Engine, Applied equipments and Emergency Equipments Manual, Original Manufacturer's Service Bulletin/Letter, Applicable CAA Regulation, Applicable AD, Applicable type certificate information and supplemental type certification, Approved Aircraft Flight Manual, Operator's Maintenance Record."*
>
> *C. Review the aircraft maintenance record keeping mechanism to verify the following:*
>
> *(1) All maintenance work were completed by following the maintenance manual*
>
> *(2) Systematically provide the methods to retrieve the records for a reasonable long time*

The JOB FUNCTION 5, Spot Inspection in Airworthiness Inspector's Handbook stated the items to be inspected as the following:

> *Maintenance Records*
>
> *During performing the Spot Inspection, the inspector should notice the following records of AD including the dissemination control and procedures.*
>
> *Procedures C. Prepare to inspect the following items:*
>
> *The new regulation or AD that applied to the aircraft for inspection.*

1.6.12 The CAA Airworthiness (Maintenance and Avionics) Inspection

1.6.12.1 The Organization of CAA Airworthiness Inspection

There are five inspecting groups in CAA to inspect the domestic airlines and repair stations. They are China Airlines Inspecting Group, EVA Airways Inspecting Group, General Aviation Inspecting Group, Repair Station Inspecting Group and Regional Airlines Inspecting Group. The Regional Airlines Inspecting Group inspects TNA. The Regional Airlines Inspecting Group is organized by a Chief Inspector, three airworthiness inspectors (including two Principal Maintenance Inspectors and one Assistant Maintenance Inspector) and two Avionic inspectors (including one Principal Avionic Inspector and an Assistant Avionics Inspector). The Regional Airlines Inspection Group will inspect the airworthiness of TNA, Far Eastern Air Transport, CAA Official aircraft fleet.

1.6.12.2 The Duty of Maintenance/Avionic Inspector

Inspectors are the media of airworthiness inspection between CAA and TNA. The inspector has the accountabilities to ensure the maintenance, preventive maintenance and major alteration programs of TNA are all complied with CAA regulations.

1.6.12.3 The CAA Airworthiness Inspection

The CAA inspectors inspect the continuous airworthiness maintenance program and monitor the different phases of the maintenance work including the maintenance, engineering, quality control, training and program of reliability of the airlines by following the Inspector’s Handbook. It is required to assure the aircraft maintenance work including the maintenance manual, airworthiness, aircraft release, periodic maintenance, qualified human resources, tool and equipments are meeting the airworthiness standard and complied with the CAA regulations, the CAA approved manuals, programs and procedures.

1.6.12.4 Airworthiness Directives （AD）Inspection of CAA

There is an Aircraft Design , Manufacturing and Certification Institute （ACI） established under the Civil Aviation Act by CAA. ACI will publish the AD in accordance with the CAA regulation. According to the 5.2.2 ,Chapter 4 of the Operating Manual of ACI, it describes：

> *5.2.2 The AD issued by the Civil Aviation Authority of the original aircraft manufacturer: After ACI received the AD from the foreign countries, ACI will examine the AD. The contents examined by ACI are the effective date, compliance time or period and the necessary to send a feed back report to CAA. The examined conclusion will be recorded in the content of the AD. CAA will issue the AD. When the AD is directly adopted from the foreign authority, there is no necessary to be approved by CAA for the ACI to issue the AD.*」

The job function 12 in Airworthiness Inspector Hand Book has established the procedures for CAA to perform the continuous airworthiness inspection to AD.

1.6.13 Weight and Balance

The total takeoff weight of this aircraft was 21,217 kg as the cargo 6,455kg in weight. The center gravity of takeoff was 27.9% and the location of center gravity was within the limited range between 23% and 29%. The Stabilization Setting was 1.0. See Table 1.6-9 for loading and trimming data. Figure 1.6-9 shows the schematic of ATR72 cargo compartments locations. For the loading and trimming table, see Appendix 2.

Table 1.6-9 Weight and Balance Data

Zero fuel weight	11,803 kg
Limit of payload	6,738 kg
Total payload of cargo	6,455 kg
Details of cargo weight for each of compartments	
Bay #11	566 kg
Bay #12	1,069 kg
Bay #13	1,035 kg
Bay #21	1,103 kg
Bay #22	1,136 kg
Bay #23	1,164 kg
Bulk Cargo	382 kg
Takeoff fuel weight	3,000 kg
Consumed fuel when taxing	41 kg
Total takeoff weight	21,217 kg
Location of takeoff center gravity	27.9% M.A.C.
Stabilization setting	1.0

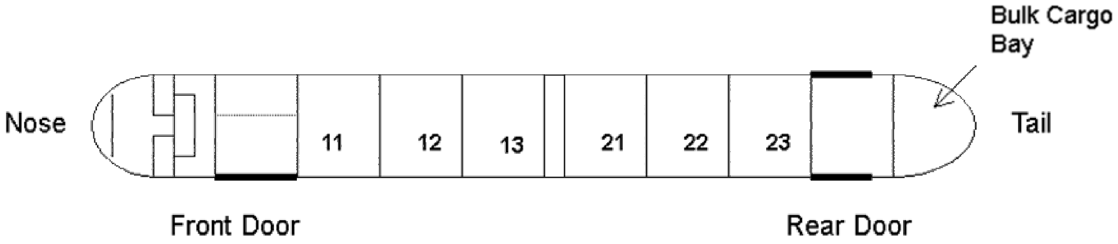

Figure 1.6-9 Schematics of ATR72 Cargo Bays

1.7 Meteorological Information

1.7.1 Weather Synopsis

The surface weather and upper air conditions for eastern Asia were summarized from the Central Weather Bureau (CWB) Weather Depiction Charts at 2000, December 20 and 0200, December 21. The charts revealed a low pressure center moving easterly in the sea area near Kyushu Island, Japan. A stationary front extended in a southwesterly direction from the low pressure center to central Taiwan. Broken to overcast cloud with rain or temporary light rain were occurring to Taiwan. The surface temperature of plus 20℃ was being reported near the site of the accident.

The CWB's 850 hPa analysis charts (recorded about 5,000 feet MSL) at 2000, December 20 and 0800, December 21 indicated an area of low pressure with the center located in the sea area near Kyushu Island, extended in a southwesterly direction to southern China. A trough of temperature located near 110° E. The temperature were plus 11℃ to plus 13℃ in the area of Taiwan Strait with moisture evident from southern China to Taiwan and Ryukyu Islands.

The CWB's 700 hPa analysis charts (recorded about 10,000 feet MSL) at 2000, December 20 and 0800, December 21 indicated a trough of low pressure located in the western China. A southwesterly flow located over central and southern China with gusty winds in the coast area of southern China. The temperature were plus 2℃ to plus 4℃ in the area of Taiwan Strait with moisture evident from southern China to Taiwan and Ryukyu Islands.

The CWB's 500 hPa analysis charts (recorded about 18,000 feet MSL) at 2000, December 20 and 0800, December 21 indicated a trough of low pressure located in the western China. A strong southwesterly flow located over southern China. The temperature were minus 9℃ to minus 10℃ with moisture evident in the area of Taiwan Strait.

The CWB's 400, 300 and 200 hPa analysis charts (recorded about 24,000, 30,000 and 40,000 feet MSL respectively) at 2000, December 20 and 0800, December 21 indicated a jet stream located in the southern China. The temperature were minus 21℃, minus 37℃ and minus 55℃ respectively with moisture evident decreased with time in the area of Taiwan Strait.

Lightnings were detected in the sea area east and northeast of Taiwan and there was no lightning reported in Taiwan and Taiwan Strait from 0120 to 0220, December 21.

Total Air Temperatures (TAT) and derived Static Air Temperatures (SAT) from FDR are as followers:

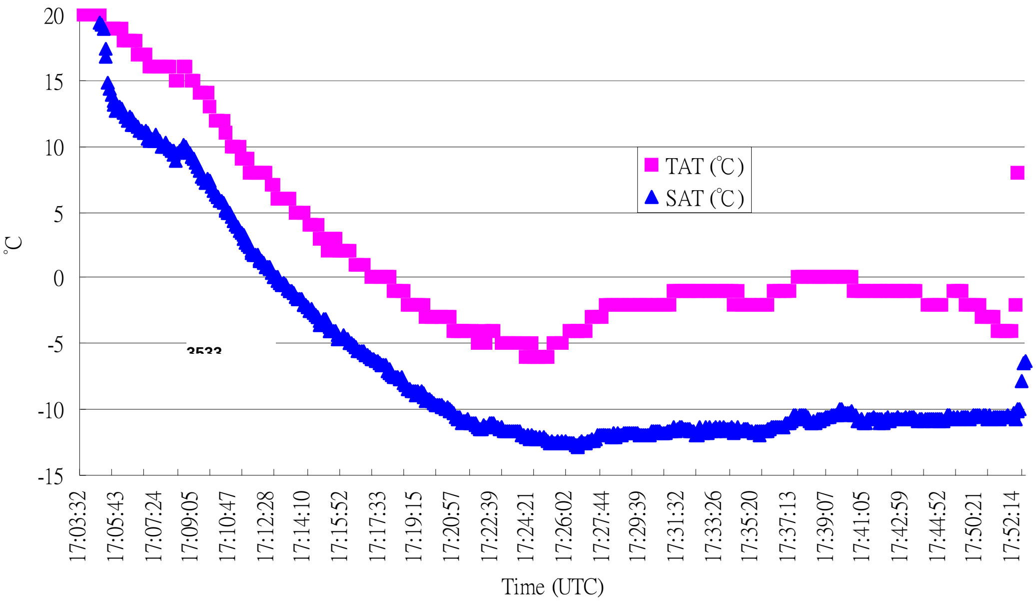

Figure 1.7-1 TAT and SAT along the track of FDR.

The GMS-5 infrared imager data (image at 0131, December 21 is in Appendix 3) and the Doppler weather radar data indicated some convective movement developed from the coast area of southern China and moved to Taiwan with the flow. Convective clouds were found in Eastern Chinese Sea, central and northern Taiwan and Taiwan Strait. From departure to way point “CHALI” along the track of GE791, tops of the highest cloud layer were mainly about 35,000 feet MSL with temperature about minus 49℃. The tops became lower to 24,000-26,000 feet MSL with temperature about minus19-minus 25℃ from way point “CHALI” to “SIKOU”. It became further lower to about 20,000 feet MSL with some gaps of the cloud layers from way point “SIKOU” to “MAKUNG”. From way point “MAKUNG” to the accident site, it became higher to about 29,000 feet.

There was no any AIREP received around the time of the accident.

1.7.2 Surface Weather Observations

Surface weather observations surrounding the accident site and takeoff airport were as follows:

CKS International Airport (RCTP) [located 253 kilometers northeast of the accident site]: Time— 1700 UTC, December 20; Wind— 040 degrees at 11 knots; Visibility— greater than 10 kilometers; Clouds— scattered 800 feet, broken 1200 feet, overcast 4000 feet; Temperature— 20 degrees Celsius; Dew Point—20 degrees Celsius; QNH—1014 hPa; Trend Forecast-TEMPO Visibility-3000 meters; Present Weather-moderate rain; Clouds-broken 800 feet overcast 3000 feet=

Time— 1800 UTC, December 20; Wind— 040 degrees at 8 knots; Visibility— 7000 meters; Present Weather— light rain; Clouds— scattered 800 feet, broken 1200 feet, overcast 4000 feet; Temperature— 19 degrees Celsius; Dew Point— 19 degrees Celsius; QNH— 1014 hPa; Trend Forecast-TEMPO Visibility-3000 meters; Present Weather-moderate rain; Clouds-broken 800 feet overcast 3000 feet; Remark rain amount 0.50 millimeters =

Makung Airport (RCQC) [located 21 kilometers northeast of the accident site]: Time— 1700 UTC, December 20; Wind— 020 degrees at 16 knots gusting 28 knots; Visibility— 6000 meters; Present Weather— light rain; Clouds— scattered 600 feet, broken 1000 feet, overcast 4000 feet; Temperature— 20 degrees Celsius; Dew Point— 19 degrees Celsius; QNH— 1013 hPa; Trend Forecast-no significant change; Remark rain amount 1.30 millimeters =

Time— 1800 UTC, December 20; Wind— 040 degrees at 15 knots gusting 27 knots; Visibility— 7000 meters; Present Weather— light rain; Clouds— scattered 600 feet, broken 1000 feet, overcast 4000 feet; Temperature— 20 degrees Celsius; Dew Point— 19 degrees Celsius; QNH— 1012 hPa; Trend Forecast- no significant change; Remark rain amount 0.30 millimeters =

Kaohsiung International Airport (RCKH) [located 137 kilometers southeast of the accident site]: Time— 1700 UTC, December 20; Wind— 360 degrees at 5 knots; Visibility— 6000 meters; Present Weather— light rain; Clouds— scattered 800 feet, broken 1500 feet, overcast 4500 feet; Temperature— 20 degrees Celsius; Dew Point— 19 degrees Celsius; QNH— 1012 hPa; Trend Forecast-no significant change; Remark rain amount 0.75 millimeters =

Time— 1800 UTC, December 20; Wind— 340 degrees at 6 knots; Visibility— 6000 meters; Present Weather— light rain; Clouds— scattered 800 feet, broken 1500 feet, overcast 4500 feet; Temperature— 20 degrees Celsius; Dew Point— 19 degrees Celsius; QNH— 1011 hPa; Trend Forecast- no significant change; Remark rain amount 0.50 millimeters =

Chiayi Airport (RCKU) [located 96 kilometers east of the accident site]: Time— 1800 UTC, December 20; Wind— 090 degrees at 6 knots; Visibility— 3200 meters; Present Weather— light rain and mist; Clouds— scattered 1000 feet, broken 2500 feet, overcast 5000 feet; Temperature— 19 degrees Celsius; Dew Point— 19 degrees Celsius; QNH— 1013 hPa; Trend Forecast-no significant change; Remark rain 1.8 millimeters =

Chinmen Airport (RCBS) [located 151 kilometers northwest of the accident site]: Time—1800 UTC, December 20; Wind—030 degrees at 4 knots; Visibility—4500 meters; Present Weather—light rain; Clouds—few 800 feet broken 2200 feet broken 5000 feet; Temperature—17 degrees Celsius; Dew Point—15 degrees Celsius; QNH—1016 hPa; Trend Forecast-no significant change; Remark rain amount 2.00 millimeters =

Rain amount records of CWB surrounding the accident site were as follows:

STATION [location from the accident site]	**TIME (UTC)**				
	15~16	**16~17**	**17~18**	**18~19**	**19~20**
TAICHUNG [146 km northeast]	0	0	1.1(mm)	0.3(mm)	0.6(mm)
CHIAYI [100 km east]	T	0.5(mm)	2(mm)	T	2(mm)
TAINAN [94 km southeast]	0.5(mm)	0.5(mm)	0.5(mm)	0	1(mm)
PENGHU [15 km northeast]	T	0.8(mm)	0	0.5(mm)	2.5(mm)
TUNGCHITAO [33 km southeast]	T	1(mm)	0	1(mm)	1.5(mm)
T: trace					

1.7.3 Weather Advisories

The Taipei Aeronautical Meteorological Center (TAMC) had responsibility for issuing Significant Meteorological Information (SIGMETs) for the Taipei Flight Information Region (FIR) and low-level (SFC to FL100)/ medium-level (FL100 to FL250) Significant Weather Prognostic Charts (SIGWX Charts). The following SIGMETs were valid before and after the time of the accident:

> RCTP SIGMET 2 VALID 200600/201000 RCTP-
> TAIPEI FIR EMBD TS OBS AND FCST S OF N27 CB TOP FL 450 MOV ENE 10 KT NC=
>
> *[SIGMET 2 Valid at 0600 UTC to 1000 UTC, December 20 for Taipei FIR; Embedded thunderstorm observed and forecasted south of N27; Cumulonimbus top— FL 450; Moving east-northeasterly at 10 knots; Intensity— no change.]*
>
> RCTP SIGMET 3 VALID 202030/210030 RCTP-
> TAIPEI FIR EMBD TS OBS AND FCST N OF N23 AND E OF E118 CB TOP FL 400 MOV ENE 10 KT WKN=
>
> *[SIGMET 3 Valid at 2030 UTC to 0030 UTC, December 21 for Taipei FIR; Embedded thunderstorm observed and forecasted north of N23 and east of E118; Cumulonimbus top— FL 400; Moving east-northeasterly at 10 knots; Intensity— weaken.]*

According to the low-level (SFC to FL100) and medium-level (FL100 to FL250) SIGWX charts issued from TAMC, valid at 0200, December 21 and 0800, December 21 (medium-level SIGWX charts are in Appendix 4), the forecasted weathers of Taipei to Penghu Islands were as follows:

Precipitation in the form of rain with broken to overcast cloud. Cloud ceilings were 1,500 to 3,000 feet and cloud tops were equal to or greater than 25,000 feet. Stratus (St) and stratocumulus (Sc) overlaid by altostratus (As) and altocumulus (Ac). Isotherm of 0℃ was at about FL120. No icing or turbulence (moderate or severe) indicated.

The following SIGMETs were issued from Hong Kong Observatory (HKO) and valid in Hong Kong Control Area (CTA) around the time of the accident:

> VHHK SIGMET 4 VALID 201340/201740 VHHH-
> HONG KONG CTA EMBD TS FCST IN AREA W OF E114 BTN N18 AND N20 CB TOP FL350 MOV NE 20 KT NC=
>
> *[SIGMET 4 Valid at 1340 UTC to 1740 UTC, December 20 for HONG KONG CTA; Embedded thunderstorm forecasted in area west of E114 and between N18 and N20; Cumulonimbus top— FL 350; Moving northeasterly at 20 knots; Intensity— no change.]*
>
> VHHK SIGMET 5 VALID 201635/202035 VHHH-
> HONG KONG CTA EMBD TS FCST IN AREA (1) N OF N21 E OF E115 CB TOP FL350 MOV E 15 KT WKN AND IN AREA (2) E OF E113 BTN N18 AND N20 CB TOP FL400 MOV E 20 KT INTSF=
>
> *[SIGMET 5 Valid at 1635 UTC to 2035 UTC, December 20 for HONG KONG CTA; Embedded thunderstorm forecasted in area (1) north of N21 and east of E115; Cumulonimbus top— FL 350; Moving easterly at 15 knots; Intensity—weaken. (2) east of E113 and between N18 and N20; Cumulonimbus top— FL 400; Moving easterly at 20 knots; Intensity— intensify.]*
>
> VHHK SIGMET 6 VALID 202035/210035 VHHH-
> HONG KONG CTA EMBD TS FCST E OF E115 BTN N18 AND N20 CB TOP FL400 MOV E 20 KT NC=
>
> *[SIGMET 6 Valid at 2035 UTC, December 20 to 0035 UTC, December 21 for HONG KONG CTA; Embedded thunderstorm forecasted in area east of E115 and between N18 and N20; Cumulonimbus top— FL 400; Moving easterly at 20 knots; Intensity— no change.]*

According to the medium-level SIGWX chart of eastern Asia issued from HKO, valid at 0200, December 21 (Appendix 5), the forecasted weathers of Taipei to Penghu Islands were as follows:

Isotherm of 0℃ was at about FL120. Moderate icing was at FL120 and higher. Moderate turbulence was at FL220 and lower.

The following SIGMETs were issued from Tokyo Aviation Weather Service Center (TAWSC) and valid in Naha FIR around the time of the accident:

> RORG SIGMET 3 VALID 201220/201620 RJAA-
> NAHA FIR FRQ TS FCST IN AREA BOUNDED BY N27E126 N27E127 N29E130 N30E130 N30E127 N29E126 AND N27E126 MOV NE 20 KT NC=
>
> *[SIGMET 3 Valid at 1220 UTC to 1620 UTC, December 20 for Naha FIR; Frequent thunderstorm forecasted in area bounded by*

N27E126 N27E127 N29E130 N30E130 N30E127 N29E126 AND N27E126; Moving northeasterly at 20 knots; Intensity— no change.]

RORG SIGMET 4 VALID 202110/210110 RJAA-
NAHA FIR MOD TO SEV TURB FCST IN AREA BOUNDED BY N24E124 N24E127 N27E130 N30E130 N30E127 N28E126 N26E124 AND N24E124 FL350/390 MOV ENE 20 KT INTSF=

[SIGMET 4 Valid at 2110 UTC, December 20 to 0110 UTC, December 21 for Naha FIR; Moderate to severe turbulence forecasted in area bounded by N24E124 N24E127 N27E130 N30E130 N30E127 N28E126 N26E124 AND N24E124 at FL350/390; Moving east-northeasterly at 20 knots; Intensity— intensify.]

According to the SIGWX charts issued from TAWSC for surface to 14,000 meters height (Appendix 6), southwest Taiwan and Penghu area were not included. The forecasted weathers of were as follows:

For SIGWX chart valid at 0200 on December 21, moderate icing was at FL120 to FL240 and moderate turbulence was at FL20 to FL380 in north Taiwan Strait, central and north Taiwan and the sea area of northeast Taiwan.

For SIGWX chart valid at 0800 UTC on December 21, moderate icing was at FL80 to FL220 and moderate turbulence was at FL20 to FL320 in east Taiwan and it’s sea area.

1.7.4 Weather Information Provided To the Pilots

From the interview with the dispatcher for the accident flight, the flight release contained Meteorological Reports (METARs) and Terminal Aerodrome Forecasts (TAFs) of RCTP, VMMC and VHHH at 1800 on December 20, infrared satellite image at 1800 on December 20 and wind/temperature forecast of FL020, FL050, FL100, FL150 and FL200 eastern Asia at 0100, December 21.

The flight information station (FIS) in CKS International Airport provided TAFs of Southeast Asia valid from 2000 on December 20, GMS-5 infrared satellite image at 2130 on December 20, ICAO Area G (Asia/Europe, FL 250-630) SIGWX Chart valid until 0200 on December 21, wind/temperature chart of FL180 for Asia/Europe and FL300, FL340 and FL390 for East Asia valid until 0800, December 21. The SIGWX chart was issued from London World Area Forecast Center and the upper level wind and temperature forecast were issued from Washington World Area Forecast Center. In wind/temperature chart at FL 180 air temperature forecast was minus 10℃ around Taiwan Strait.

There is no evidence whether the crew displayed or not any other updated weather information available for the flight on FIS computer.

1.7.5 Doppler Weather Radar Information

Weather radar data were collected from the WSR-88D Doppler weather radar sites located in Mt. Wufan, Taipei County (RCWF, located 295 kilometers northeast of the accident site and 55 kilometers east of RCTP), and the METEOR 1500S Doppler weather radar sites located in Chiku, Tainan County (RCCG, located 74 kilometers southeast of the accident site and 244 kilometers south-southwest of RCTP). The radars are operated by the CWB.

Weather radar images from RCWF and RCCG for 0100 to 0200 on December 21, at the elevation angles of 0.5, 1.4(1.45), 2.4, 3.4 and 4.3 degrees were reviewed. The heights of the radar beam center in the waypoints along the GE791 track are as follows:

	Elevation Angles						Beam width
	0.5°	1.4	1.45°	2.4°	3.4°	4.3°	
RCWF							
CHALI	9700[8]	-	17000	24200	-	-	7200
CANDY	12500	-	21500	30500	-	-	9000
SIKOU	17200	-	28700	40200	-	-	11500
MAKUNG	24300	-	38900	53500	-	-	14600
RCCG							
CHALI	11500	20800	-	31000	41300	50500	9800
CANDY	8400 ft	15900	-	24200	32600	40100	7900
SIKOU	5000 ft	10200	-	15900	21700	26900	5500
MAKUNG	2900 ft	6400 ft	-	10200	14000	17500	3600

---

[8] Unit: ft

The computed echo intensities along the GE791 track are as follows:

Time	Aircraft Altitude （ft）	Echo Intensity (dBZ)	Note
0113	10200	17.7	
0114	11000	18.3	
0115	11900	18.8	
0116	12700	25.3	
0117	13400	22.1	
0118	14200	14.3	
0119	14900	13.3	
0120	15600	14.7	
0121	16200	17.0	
0122	16700	20.3	
0123	17300	20.5	
0124	17700	20.2	
0125	18000	19.9	Waypoint “CHALI”
0126	18000	19.2	
0127	18000	18.9	
0128	18000	19.6	
0129	18000	19.4	
0130	18000	18.8	
0131	18000	18.5	Waypoint “CANDY”
0132	18000	15.8	CVR: Looks like it’s iced up…. look at my side your side is also iced up right
0133	18000	22.0	CVR: There’s not enough moisture outside minus twelve degrees
0134	18000	15.3	CVR: Oh it’s icing up FDR：Airframe De-Icing on
0135	18000	15.0	
0136	18000	10.1	
0137	18000	11.8	FDR：Airframe De-Icing off
0138	18000	10.5	Waypoint “SIKOU”
0139	18000	7.4	
0140	18000	3.7	
0141	18000	4.5	FDR：Airframe De-Icing on
0142	18000	<MDS[9]	
0143	18000	<MDS	
0144	18000	<MDS	CVR: It’s iced up quite a huge chunk
0145	18000	<MDS	
0146	18000	<MDS	
0147	18000	3.8	
0148	18000	8.9	Waypoint “MAKUNG”

---

[9] The smallest incoming signal that will be detected, and produce a discernable target, is referred to as the minimum discernable signal (MDS)

0149	18000	2.3	
0150	18000	2.0	CVR: Wow it’s a huge chunk CVR: What an ice
0151	18000	<MDS	CVR: Just as long as no more moisture because we have moisture now CVR: So do you want to move up or ah severe icing up
0152	18000	<MDS	CVR: It’s severe icing up

The Plan Position Indicator (PPI) of radar images with the ground track of GE791 superimposed are contained in Appendix 7. The cross section charts of radar images with the track of GE791 superimposed are contained in Appendix 8.

Weather radar data indicated an area of higher echo intensity about 25-45dBz, moving east-northeasterly with the clouds in the northern part of Taiwan Strait. The length of about 200 kilometers and width about 100 kilometers and located from FL60 to FL120. Tops of the highest cloud layer overlaid the area were about 35,000 feet MSL. The GE791 flew above the area from before waypoint “CHALI” to waypoint “CANDY”.

1.7.6 Weather information from aircraft near the accident site

The Safety Council collected the flight data of the aircraft around the accident site to get the better understandings of the weather conditions. According to the TACC radar recordings, two aircraft with the assigned beacon codes of 3533 and 3563 flew over the accident site. After the flight data were synchronized, both flight tracks were superposed with the track of GE791. Figure 1.7-2 displays the results. The blocked area in figure 1.7-2 is the area where GE791 disengaged the airframe De-Icing device until it disappeared from the radarscope. The flight track of the beacon code 3563 aircraft was similar to the GE791’s, also via airway A1 to over fly the accident site from 0141:24 to 0145:26 on December 21. As the beacon code 3563 aircraft descent from FL350 to FL240, the average wind was 260 degrees at 88 knots and the Total air temperature (TAT) increased from minus 16.5℃ to plus 3.3℃. Detail winds and TAT are shown in Figure 1.7-3.

The beacon code 3533 aircraft (A300-600R) over flew the accident site from 0207:55 to 0215:18 on December 21. The CI611 flight track labeled as “c” was on the right hand side about 22 km of airway A1 and “d” in Figure 1.7-2. As the beacon code 3533 aircraft descent from FL300 to FL240, the average wind was 260 degrees at 66 knots and the TAT increased from minus 10.5℃ to plus 2.5℃. Detail winds and TAT are shown in Figure 1.7-4. The witness statements of the pilots are address in section 1.18.3.10.

The variation of winds and TAT with altitude information of both aircraft is shown in Figure1.7-5.

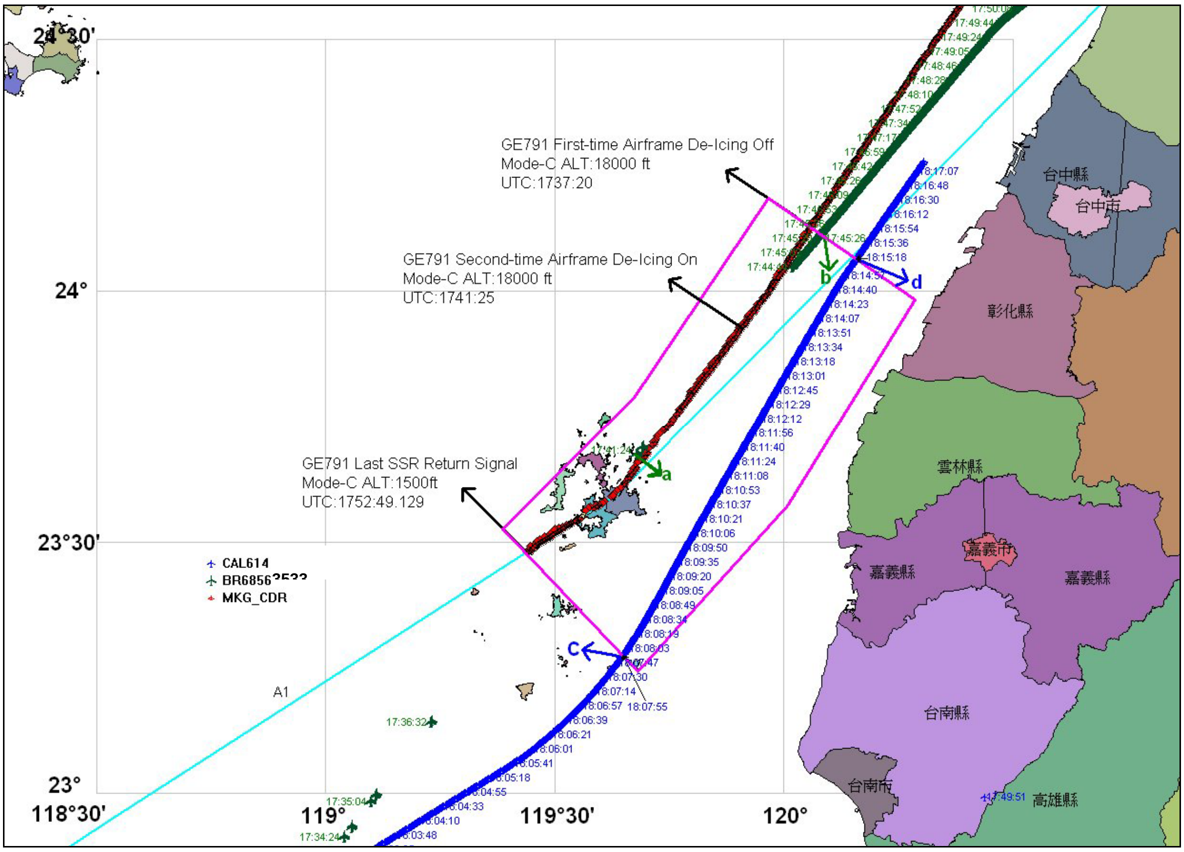

Figure 1.7-2 Superposition of the flight tracks of beacon code 3533 and 3563 aircraft near the accident site of GE791.

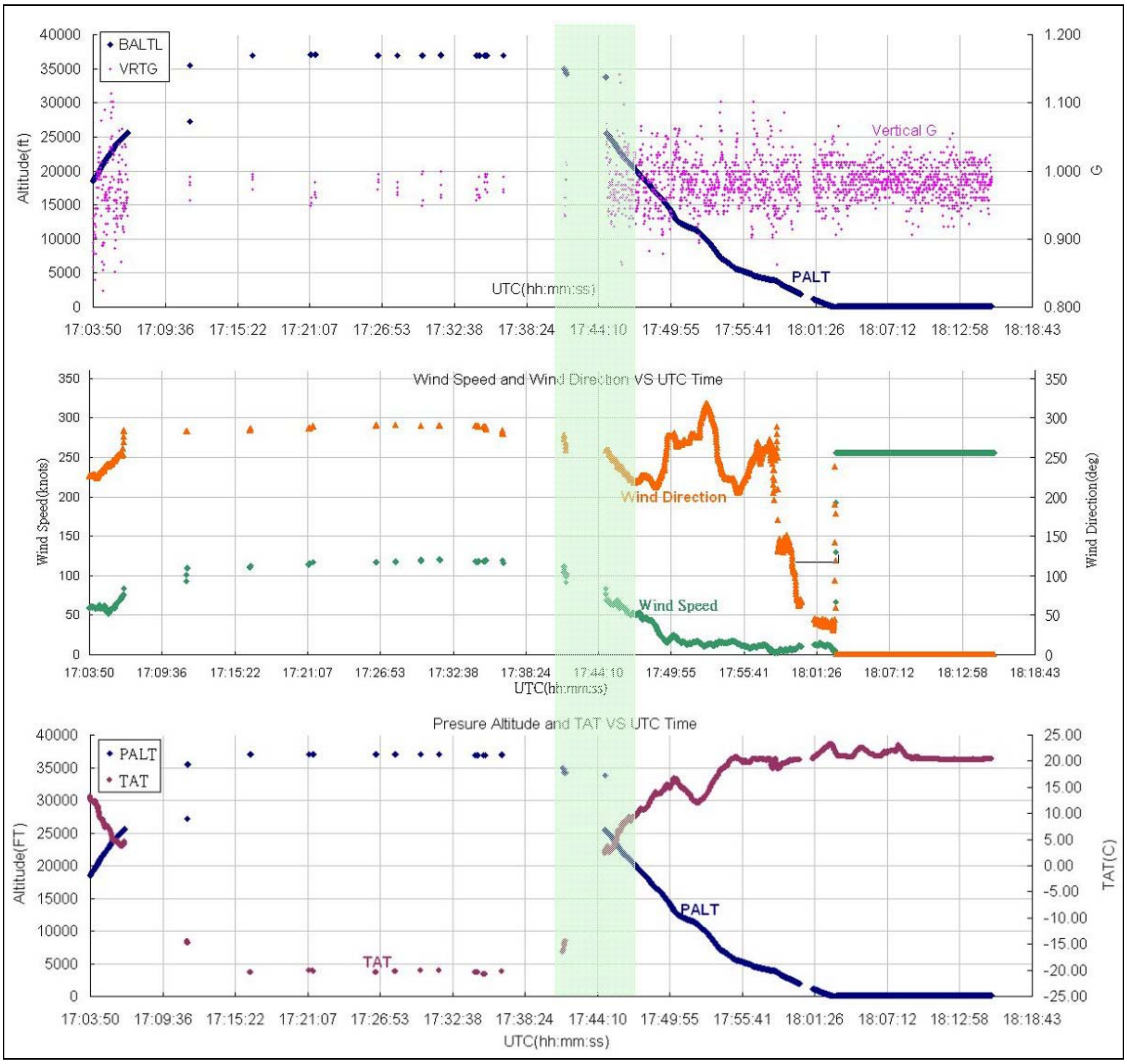

Figure 1.7-3 The wind condition and TAT of the beacon code 3563 aircraft

（The green area was flown pass by the accident site.）

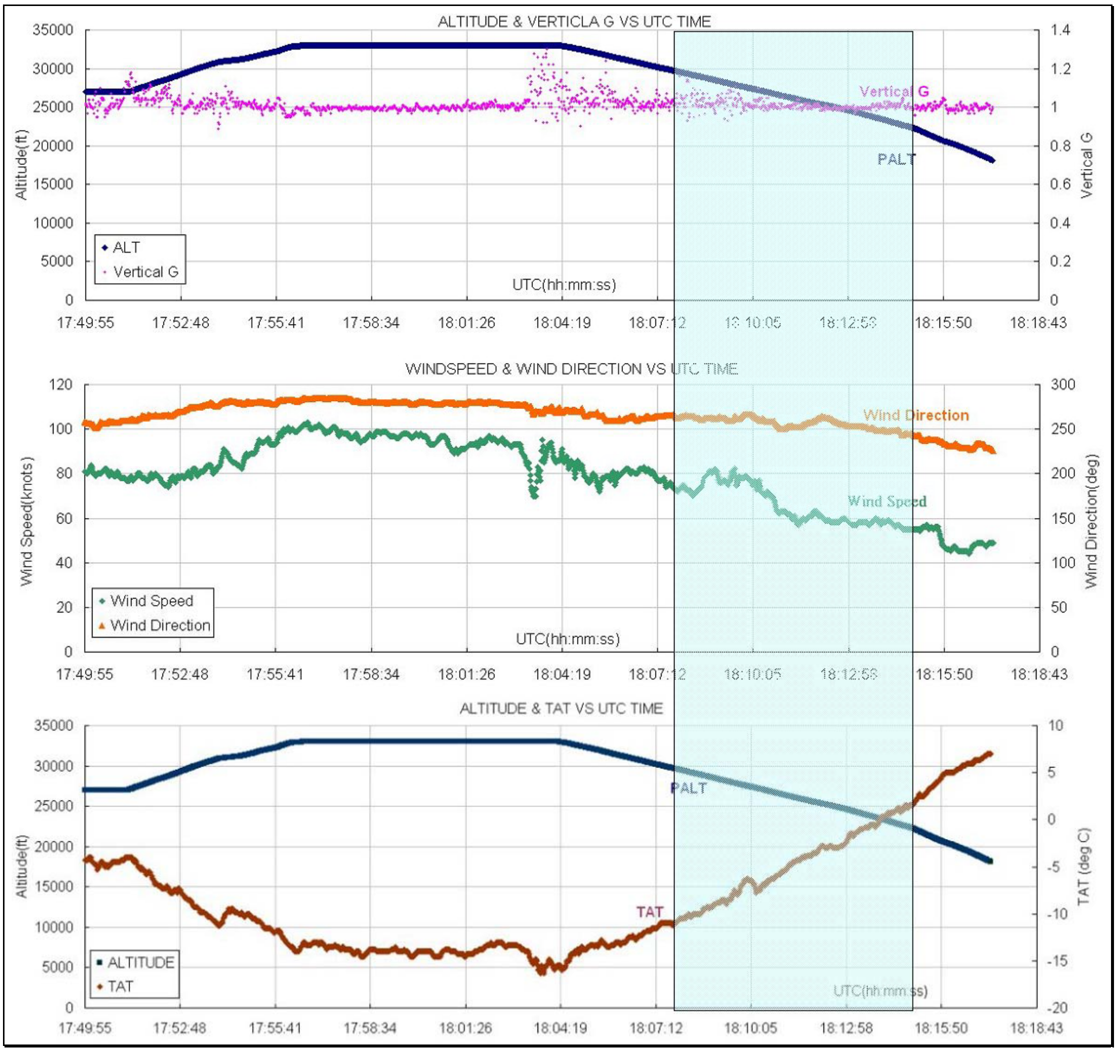

Figure 1.7-4 The wind condition and TAT of the beacon code 3563 aircraft
（The blue area was flown pass by the accident site.）

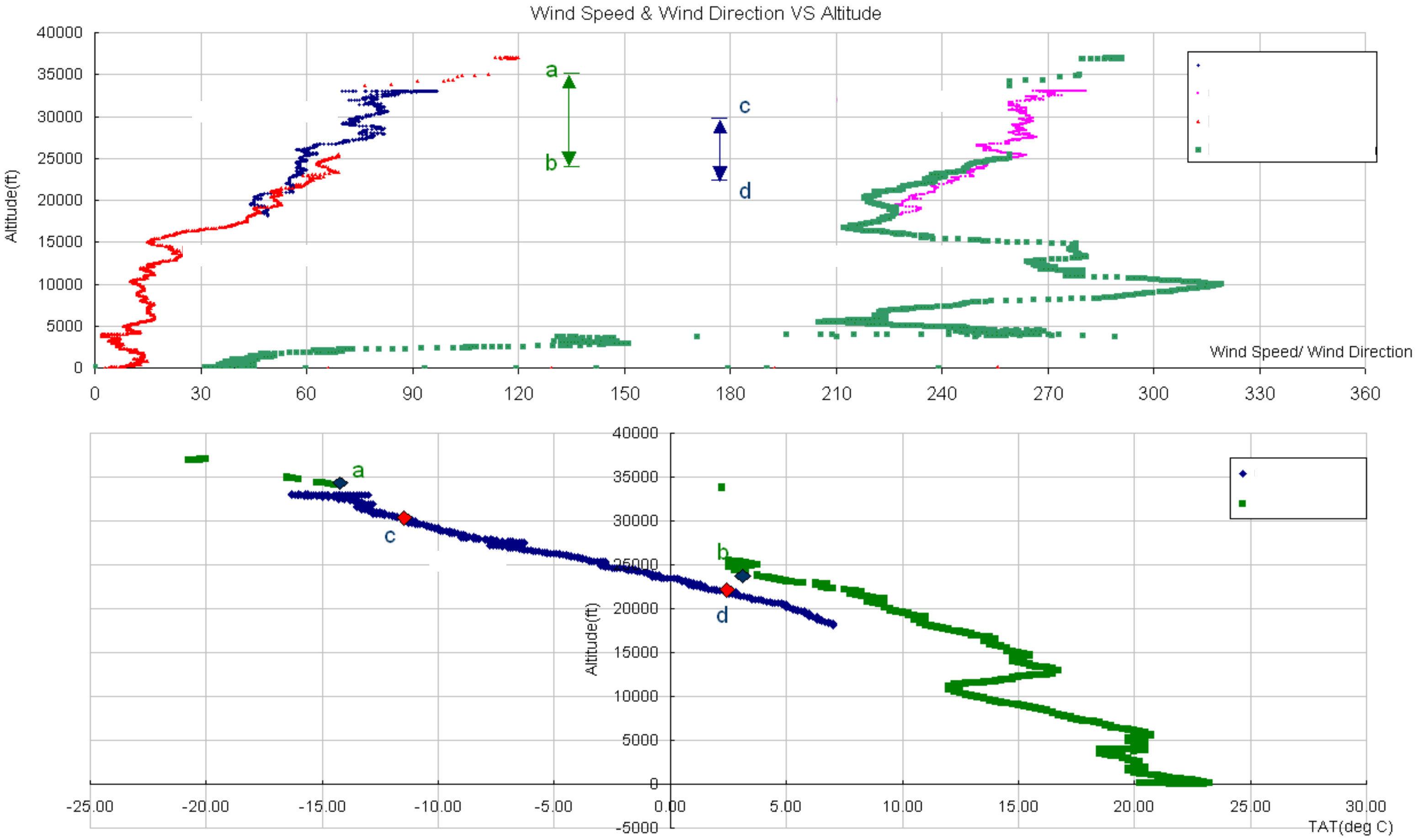

Figure 1.7-5 The variation of wind condition and TAT with altitude of the beacon code 3533 and 3563 aircraft.

1.8 Aids to Navigation

There were no known malfunctions with the aids to navigation involved in this accident.

1.9 Communications

There were no known difficulties with internal or external communications except the following radio garbles.

Time	ATC Transcript	CVR Transcript
01:25:34	(Radio communications between ATC and the other aircraft)	(Radio garble for 2.3 seconds)
01:25:38	(Radio communications between ATC and the other aircraft)	(Radio garble for 1.7 seconds)
01:25:40	(Radio communications between ATC and the other aircraft)	(Radio garble for 6.1 seconds)
01:25:47	(Radio communications between ATC and the other aircraft)	(Radio garble for 4.7 seconds)
01:27:27	transasia seven niner one request elato estimated	transasia ... (Intermittent radio garble for 14.9 seconds)
01:27:44	transasia seven niner one request elato estimated	transasia seven ... (Radio garble for 4.1 seconds)
01:28:00	transasia seven niner one affirmative request elato estimated	transasia seven niner one ... (Intermittent radio garble for 2.2 seconds)
01:30:25	(Radio communications between ATC and the other aircraft)	(Radio garble for 12 seconds)
01:31:03	transasia seven niner one please contact Taipei control one two niner point one transasia seven niner one	(Radio garble for 5.6 seconds)

1.10 Airport Information

Not applicable.

1.11 Flight Recorders

The accident aircraft was equipped with a Fairchild model A100 Cockpit Voice Recorder (CVR) and a Loral model F800 Digital Flight Data Recorder (FDR). The FDR was recovered 22 days after the accident occurred and one day after FDR recovered the CVR was recovered. Both recorders were delivered to the ASC Investigation Laboratory for disassembling and readout.

1.11.1 Cockpit Voice Recorder（CVR）

1.11.1.1 Examination and Readout

The exterior of the CVR unit was seriously damaged when it was found. The protective dust cover was separated from the unit. The front panel, without the underwater locator beacon (ULB) and nameplate, was seriously distorted but still attached to the chassis. It arrived ASC lab in a container filled with fresh water. There were several dents and scratches on the interior crash enclosure. The recording assembly appeared to be in good condition except several damages on the plastic reel. The magnetic tape was wet and remained in its original positions without damage. Discoloration and dirt were found on the tape.(refer to figure 1.11-1)

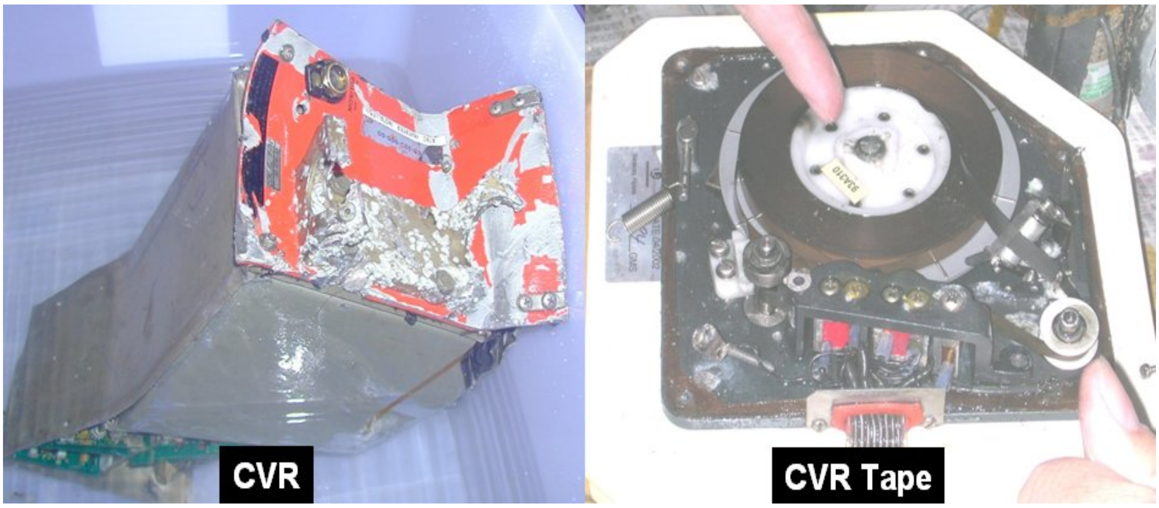

Figure 1.11-1 CVR physical damage and the CVR tape

The recording contained four channels of audio information including the information of captain, first officer, cockpit area microphone (CAM), and the passenger address system. The time correlation between the CVR recording and the air to ground radio communication was done according to the last radio transmission with ATC at 0151:59. Total 30 minutes and 53 seconds of good quality recording was transcribed as in Appendix 9.

The recording started at 0121:58 when the controller asked the aircraft to climb and maintain flight level one eight zero. No significant event is recorded until the first single chime (SC) was heard at 0134:29. It's the first time the pilots confirmed encountering icing condition. At 0134:32 and 0141:21, another two SC cautions were recorded. The captain said the icing was big at 0144:47 and mentioned it again at 0150:29. During the discussing to each other about their situation, the first officer requested to descend and maintain flight level one six zero from Taipei Area Control Center (TACC) at 0151:51 and received the decent clearance at 0151:55. After a short conversation, a series of warnings recorded from 0152:10 until the end of recording at 0152:51.

1.11.1.2 Aural Alerts

According to ATR72 Flight Crew Operating Manual 1.02.10, three types of aural alerts were defined for ATR72 to alert the crew:

- A continuous repetitive chime (CRC) is used for all warnings directly identified by a specific CAP light
- A single chime (SC) is used for all cautions directly identified by a CAP system light
- Specific aurals for alerts not directly identified by a specific CAP light and which are of a particular operational significance:

(warnings)

stall (cricket)

overspeed: VMO, VFE, VLE (clacker)

- AP disconnect (cavalry charge)
- Trim in motion (whooler)

(cautions)

Altitude alert ("c chord")

Calls (door bell)

AP capability downgrading (3 click)

All the aural alerts identified in the recording were listing as table1.11-1:

Table 1.11-1 Aural Warnings in the CVR Recording

Start Makung radar (hh:mm:ss)	Start (CVR time) (mm:ss)	Duration（second）	Sound	Alert
01:23:04.03	01:31.03	1.92	C chord	altitude alert
01:34:28.98	12:55.98		SC	amber caution
01:34:33.13	13:00.13		SC	amber caution
01:41:21.72	19:48.72		SC	amber caution
01:52:10.45	30:37.58	00.19	similar to stick shaker	stall warning
01:52:11.05	30:38.18	pulse	similar to stick shaker	stall warning
01:52:11.55	30:38.68	01.02	similar to stick shaker	stall warning
01:52:11.67	30:38.80	01.10	cricket	stall warning
01:52:12.91	30:40.04	00.62	cavalry charge	autopilot disengage
01:52:13.97	30:41.10	00.55	similar to stick shaker	stall warning
01:52:14.98	30:42.11	01.35	cricket	stall warning
01:52:15.02	30:42.15	01.52	similar to stick shaker	stall warning
01:52:16.64	30:43.78		SC	amber caution
01:52:17.46	30:44.59	01.69	similar to stick shaker	stall warning
01:52:17.63	30:44.76	01.96	CRC	red warning
01:52:19.71	30:46.84	00.65	similar to stick shaker	stall warning
01:52:19.76	30:46.89	00.86	cricket	stall warning
01:52:20.93	30:48.06	01.36	C chord	altitude alert
01:52:22.45	30:49.58	00.46	cricket	stall warning
01:52:23.18	30:50.31	00.15	cricket	stall warning
01:52:23.48	30:50.62		SC	amber caution
01:52:23.63	30:50.76		similar to stick shaker pulse	stall warning
01:52:25.14	30:52.27	00.36	CRC	red warning
01:52:26.02	30:53.15	01.65	C chord	altitude alert
01:52:27.99	30:55.12		SC	amber caution
01:52:29.11	30:56.24	00.22	cricket	stall warning
01:52:29.46	30:56.59	01.12	clacker	overspeed
01:52:30.88	30:58.01	00.23	cricket	stall warning
01:52:31.17	30:58.30	19.93	clacker	overspeed

Unlike those specific aurals of particular operation significance, SC cautions and CRC warnings could not be identified without further evidences.

1.11.2 Flight Data Recorder

1.11.2.1 Examination of Recorder

The damaged Loral model F800 FDR, part number 17M800-261, serial number 3490, was brought to the lab in a container filled with water. The protective dust cover and circuit board assemblies were lost while the front panel with the ULB and nameplate was still attached to the unit. The magnetic tape was stained and wet with the inside half squeezed out of the reel. There was a cutting break on the tape between the corner guide roller and the write heads. After it was cleaned and re-reeled, a detail examination showed some discoloration and wrinkle on it, especially the portions exposed to the outside or contacting with the mechanism. Several serious wrinkles were found near the cutting end.（refer to figure 1.11-2）

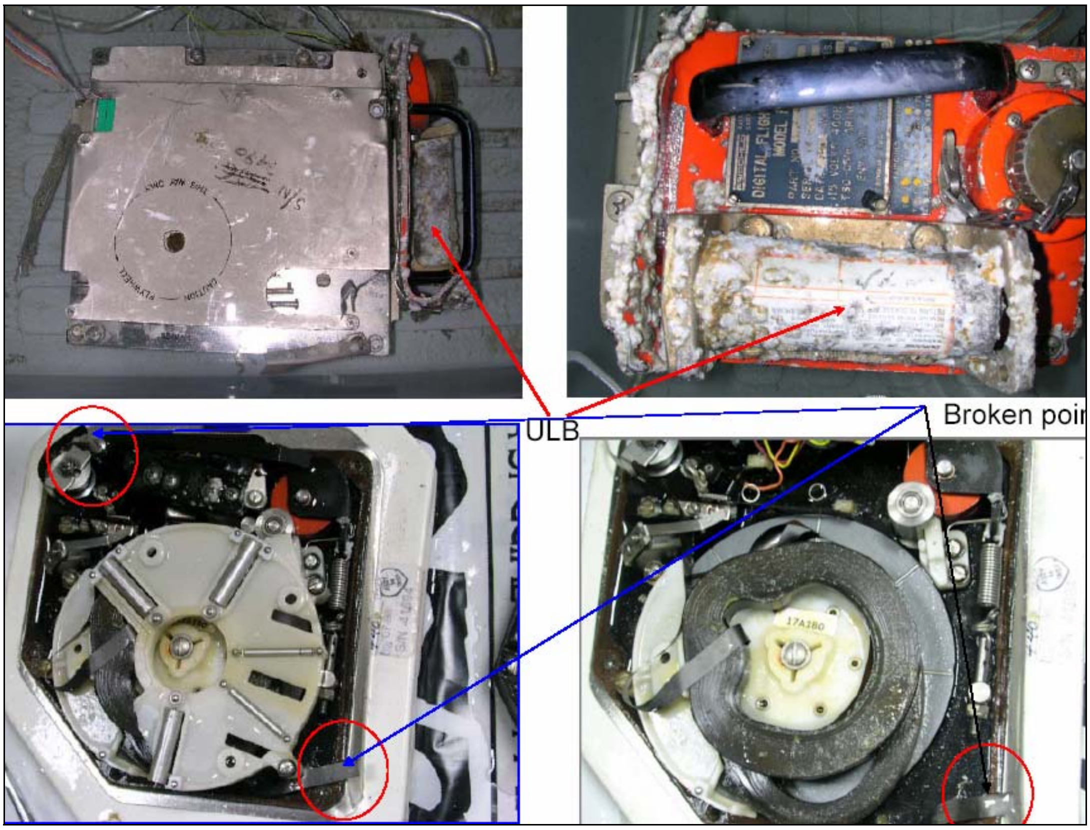

Figure 1.11-2 FDR physical damage and FDR tape

1.11.2.2 Readout of the FDR

The modified NAGRA-T recorder was used to playback the FDR tape and then the Recovery Analysis and Presentation System (RAPS) was used to transcribe the original wave signal into engineering data. According to the converting algorithms provided by BEA, a total of 136 parameters were recorded in the FDR. All the recorded parameters were listed in Appendix 10. The signals of the last 7-second recordings were too weak to be recognized by the RAPS. The damaged tape was brought to the BEA and the last 7-second recordings were successfully read out with their specialized readout system and machine.

1.11.2.3 Time correlation

The time correlation among the ATC communication transcript, radar data, CVR and FDR was based on the common events in different recording systems. The time correlation between CVR and ATC communication was based on the same communication contents. The time correlation between FDR and CVR was based the VHF keying data recorded on FDR. The time correlation between FDR and radar was based on the altitude recorded on both FDR and radar system. This CVR also recorded the Frequency Shift Key Modulation (FSK) signal. The FSK signal recorded on CVR every 4 seconds. The BEA provided the FSK decoder to decode the FSK signal, which could relate to FDR data. From the stable recorded FSK signals close to both ends were17:28:47 and 17:59:23. These two timings correlated to ATC, Makung radar and CVR time systems are as follows,

FSK timing	ATC UTCtime	Makung radarUTCtime	CVR relative time
17:28:47	17:22:02	17:22:03	00:00:32.5
17:59:23	17:52:38	17:52:39	00:31:06.1

The timings could be correlated as following equations,

1. Makung radar UTC= FSK - 0:06:44,
2. Makung radar UTC= ATC UTC + 00:00:01
3. Makung radar UTC=SRN[10] + 59621 second
4. Makung radar local time＝Makung radar UTC＋08:00:00

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[10] Signal Reference Number (SRN), which was based on the FDR readout system and count by synchronization words.

1.11.2.4 Summary of the FDR Readout

1. The accident flight data was recorded on track no.4 and the signals of the recording nearby the breakup of the tape was weak.
2. The recording started at 0053:15 without interruption until FDR stopped recording at 0152:50
3. Six un-mandatory parameters without correct signal input to FDR. Anti-ice propeller no. 1 and no.2, icing AOA, icing detector status and fuel quality 1 and 2.
4. GE791 climb to reach its assigned altitude FL180 at time 0124:56, “Altitude capture” activated and ”IAS mode” deactivated.
5. The “Airframe de-icing” parameter indicates activated within two periods during the flight, from 0134:29 to 0137:20 and from 0141:25 to the end respectively.
6. Between 0151:56 and 0152:12, ”vertical speed” activated. Indicated airspeed (IAS) was about 158 knots.
7. At 0152:09, the altitude was 17,881 feet; IAS was 158 knots; pitch attitude was 3.3 degrees; and left bank was 7.4 degrees; and the left and right angle of attack (AOA) were 8 and 9 degrees, torque ratio of two engines was 69%.
8. Autopilot was disengaged at 0152:11 with altitude 17,853 feet, IAS 158 knots, pitch attitude 2 degrees, left bank 48.9 degrees, left and right AOA were 12 and 9 degrees, torque ratio of two engines was 68.5%.
9. Master warning activated twice during the rapid descent maneuver. The first activation was between 0152:16 and 0152:18 from altitude 17,428 feet, IAS 164 knots, pitch attitude 22.9 degrees, right bank 58.7 degrees; the second activation was between 0152:44 and 0152:47 with altitude 4,303 feet, IAS 406 knots, pitch attitude 69.2 degrees, left bank 1.4 degrees.
10. At 0152:14, altitude was 17,703 feet; IAS was 161 knots; pitch attitude was 3.5 degrees; left bank was 68.6 degrees; left and right AOA were 16 and 22 degrees and torque ratio of two engines was 69.5%.
11. At 0152:29, altitude was 14,085 feet; IAS was 262 knots; pitch attitude was 70.1 degrees; left bank was 171.9 degrees; left and right AOA were 6 and 10 degrees and torque ratio of two engines were 88.5% and 89.1%, respectively.
12. Vertical acceleration fluctuated from +1.3G to +4.0G during the rapid descent.
13. FDR was stopped recording at 01:52:50 with altitude 484 feet, IAS 436.4 knots, pitch attitude 62.5 degrees, right bank 34.8 degrees and left and right AOA -0.4 and +0.4 degrees.

Selected parameters plots referred to Appendix 11. The reference time of these pilots are in Makung radar UTC time.

1.11.2.5 Calculation and Calibration of the Flight Data

The descent rate was calculated by the time differential of the pressure altitude or the Mode-C altitude of the Makung radar recording.

The FDR of ATR72 did not record the angles of control column deflection (CCD) and control wheel deflection (CWD). But these two parameters were calculated from the recorded angles of the elevator and aileron with the formulation below[11]:

CWD = 4.643 * Aileron Deflection (degrees), (aerodynamics force neglected)

CCD = 0.5 * Elevator Deflection (degrees), (aerodynamics force neglected)

The left and right AOA (α_{Local}) recorded were not the true AOA (α_{True}) but could be modified to true AOA with the formulation below:

α_{True} =0.6262 * α_{Local} +0.98 (degree), with flap =0

The functions of CCD and CWD are a linear model which does not take into account the elasticity of the control cable and the aerodynamic force effects. After the calculation and calibration, we found:

1. Maximum true AOA were 10.8 of the left and 15.0 of the right at 0152:14 with 3 seconds after AP disengaged, altitude 17,703 feet, IAS 161.2 knots, pitch attitude 3.5 degrees, left bank 68.6 degrees and descent rate 42 feet per second (ft/s);
2. Minimum true AOA were -4.6 of the left and -5.2 of the right at0152:16 with altitude 17,428 feet, IAS 164.2 knots, pitch attitude 22.9 degrees, right bank 58.7 degrees, descent rate 204 ft/s;
3. Between 0152:33 and 0152:52 the descent rate was over 500 ft/s and the vertical acceleration fluctuated from +3.08G to +4.02G; and
4. Between 0152:43 and 0152:45.5, the descent rate was from 729 ft/s to 1,273 ft/s when the vertical acceleration increased from +3.36G to +4.02G.

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[11] The formulations were provided by ATR company with Document No 420.182/90

1.11.2.6 The Anomaly of the Non-Recorded Tracks

Both track 1 and 2 of the accident FDR tape were found abnormal, regardless using the readout equipment in the Safety Council or in BEA. Most of these two tracks recorded non-signal or strange signals which like a continuous recordings of constant value of 14934 and 3622 (with 15-word coding). The total unreadable signal portion of track 1 is 78% (about 3.25 hours) and 86% of track 2 (about 3.58 hours). That means there were 6.83 hours data lost out of the 25 hours recording.

Aircraft Accident Investigation Board (AAIB, British) investigated an accident occurred on October 10, 2000. They found that the tape of the accident model F800 FDR installed on the aircraft did not record any good signal on track 1 and 2. That caused the lost of 8 hours flight data from the 25 hours recording.

Appendix 12 and 13 are the manufacturer’s comments to the unrecorded tapes of model F800 FDR. It indicated that the manufacturer has not produce model F800 since 1996. And the tapes used by those recorders such as model F800, A100, A100A were no longer provided since July 2002.

At regular flight recorders survey in 2002, there were six civil aircraft installed with model F800 FDR and approximately forty civil aircraft still installed with model A100 or A100A tape based CVR in Taiwan.

1.12 Damage to aircraft

The aircraft was broken into small pieces and totally damaged.

After inspecting totally 199 pieces of wreckages, the honeycomb structure was seriously broken into very small pieces. There was no sharp impact marks on honeycomb surface. The fracture edges were irregular. The surface fiber layers were separated from honeycomb wafer. The Group also did not find any burn phenomenon marks on surface. The metal wreckage was seriously bended and wrinkled. The fracture edges were very irregular. The surface painting was clean and also no fire phenomenon found. The details of damage description as follows,

1. Fuselage structure

The recovered fuselage structure included skin, window frame, door, and tail cone. This wreckage covered the fuselage from nose to tail.

- Fuselage skin: They were seriously wrinkled. The fracture edges were irregular. The painting surface has no any fire phenomenon. The fracture surfaces have no fatigue and corrosion phenomenon(refer to figure1.12-1).

Figure 1.12-1 Fuselage skin

- Window frame were separated from skin. The fracture surface was particular to longitudinal (refer to Figure 1.12-2).

Figure 1.12-2 Window frame

- Right after door：The door handle was at close position. The front was seriously compressed and perpendicular to longitudinal（refer to figure1.12-3）.

Figure 1.12-3 Right after door

- Tail cone was seriously broken. The fracture edge was irregular. The lines of front wrinkle were perpendicular to longitudinal (refer to figure1.12-4).

Figure 1.12-4 Tail cone

Cabin partition was seriously broken. Metal bar was bent and perpendicular to the longitudinal axis.（Figure1.12-5）。

Figure 1.12-5 Cargo compartment partition

2. Wing structure

- Front spar： It's seriously broken and bended. The fracture edge was irregular. Wing root were bent downward and perpendicular to the longitudinal axis. Wing tip bent downward and 45 degree perpendicular to the longitudinal axis. Trailing edge structure broken and bent afterward.（Figure 1.12-6~8）。

Figure 1.12-6 Wing root skin（bottom of fuel tank）

Figure 1.12-7 Wing tip structure（top of fuel tank）

Figure 1.12-8 Wing trailing edge structure

- Flap structure：Driven mechanism was broken. Honeycomb structure was seriously broken. The surface layer was separated from core structure. There was no impact marks found on surface. The leading edge was broken. The skin at front part was broken. The fracture surface was perpendicular to longitudinal (refer to figure1.12-9~11).

Figure 1.12-9 Flap driven mechanism

Figure 1.12-10 Flap honeycomb structure

Figure 1.12-11 Flap leading edge structure

- Tail structure：The honeycomb structure of vertical stabilizer , rudder and elevator was seriously broken and delaminated. Fracture surface was irregular. The paint was peel off. Some dents and scratch found on surface. Separated window frame protruded into the honeycomb structure of rudder (refer to figure 1.12-12~16)

Figure 1.12-12 Vertical stabilizer honeycomb structure

Figure 1.12-13 Vertical stabilizer skin

Figure 1.12-14 Rudder leading edge

Figure 1.12-15 Window frame stuck into rudder

Figure 1.12-16 Elevator

3. Body landing gear: The damage around the body landing gear including supporting structure broken, vicinity skin wrinkled, landing gear strut bended, wheel separated and broken, and tire broken (figure 1.12-17~21).

Figure 1.12-17 Landing gear structure and vicinity skin

Figure 1.12-18 Landing gear shock strut

Figure 1.12-19 Wheel, axel and brake assy.

Figure 1.12-20 Broken wheel hub

Figure 1.12-21 A piece of broken tire

4. Systems

- Power plant: The damage found on recovered power plant included exhaust pipe squeezed, tail cone separated but not broken, propellers broken, bended and separated (refer to figure 1.12-22~24)

Figure 1.12-22 Exhaust pipe

Figure 1.12-23 Power plant tail cone

Figure 1.12-24 Propeller blade

- ADF antenna: The antenna was separated form body. The shape is still conserved. The front skin was delaminated (refer to figure 1.12-25).

Figure 1.12-25 ADF antenna

- Pipes: The recovered pipes were small segments and flat (refer to figure 1.12-26).

Figure 1.12-26 Pipes

- Wing de-icing regulator valve: The adjacent pipes were broken, but shape is still conserved (refer to figure1.12-27).

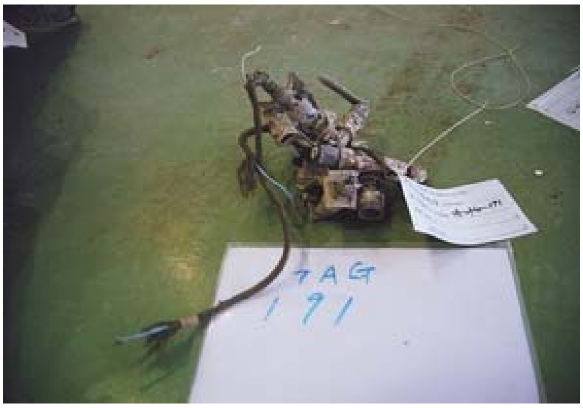

Figure 1.12-27 Wing de-icing regulator

- Wing de-icing boot: It was broken into small pieces (refer to figure 1.12-28).

Figure 1.12-28 Wing de-icing boot

- Remote Control Audio Unit（RCAU）metal case: The case was separated from the unit. The leading edge of the case was bended and wrinkled (refer to figure 1.12-29).

Figure 1.12-29 RCAU case

- Cargo (cloth)：There is no fire phenomenon on the cloth. One roll of cloth was protruded by floor structure (refer to figure 1.12-30~31).

Figure 1.12-30 Cargo (cloth)

Figure 1.12-31　One roll of cloth was protruded by floor structure

- Pilot seat structure was seriously broken and bent (refer to figure 1.12-32).

Figure 1.12-32　Pilot seat structure

- Flight operation manual: The cover of flight crew operation manual was recovered (refer to figure 1.12-33).

Figure 1.12-33　Flight crew operation manual

1.13 Medical and pathological information

No abnormal remarks found in the pilots’ CAA medical examination records.

1.14 Fire

There was no fire in this accident.

1.15 Survival aspects

There was no person survived in this accident.

1.16 Tests and Research

1.16.1 ATR 42 and 72 Incidents /Accidents

The ATR 42 and ATR 72 service history aircraft were examined by the Safety Council, with an emphasis on incidents / accidents involving severe icing conditions. Eight occurrences involved the ATR 42 and 72 were reported since 1994. Two of them are accidents, one is American Eagle Flight 4184 at Roselawn, and another is Trans Asia Airways Flight GE791 at Penghu Island, Taiwan.

Table 1.16-1 summarizes the 8 occurrences with significant conditions, i.e. autopilot status, de-icing, altitude, airspeed, angle of attack (AOA), flap position and outside air temperatures.

The eight occurrences involving severe icing conditions are:

1. American Eagle Flight 4184, Roselawn, Indiana, USA, October 31, 1994.（Accident, ATR 72-212,NTSB）
2. Near Cottbus, Germany, December 14, 1998. （Incident, ATR 42-300, BFU）
3. Trans States Airlines approach to Lambert-ST-Louis International Airport, Missouri, USA, January 7, 1999.（Incident, ATR 42-300, NTSB）
4. Jet Airways over the Indian, June 12, 2000.（Incident, ATR 72-212A, ATR）
5. Near Berlin-Tegel, Germany, January 28, 2000. （Incident, ATR 42-300, BFU）
6. Air New Zealand over the New Zealand, May 2, 2002. （Incident, ATR 72-212A, ATR）
7. Czech Airlines, December 12, 2002. （Incident, ATR 42-400, ATR）
8. TransAsia Airways at Penghu Island, Taiwan, December 21, 2002.（Accident, ATR 72-202, ASC）

Figure 1.16-1 through Figure 1.16-3 plots the previous flight data of ATR42/72 incident or accidents.

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icing speed corresponding to A/Ct flight conditioned	167(*)	158(*)	128(*)	158	165	16
Event AOA (deg)	5.2	11	-1.2	7	5	8
AOA / SP icing alarm threshold	11.2 / 15.3	11. / 21.55	11. / 21.55	11. / 21.55	11.2 / 15.3	11.2 /
Visual cues reported	N/A	Side window cue	Side window cue	Side window cue	Side window cue	N/
Flight phase	initial descend after holding	climb	Approach	climb	cruise	capture FL
Ice effects on aerodynamics	aileron hinge moment reversal	asymmetric stall	Elevator pitch down	No event	asymmetric stall	asymm stall moder
Ice protection system	Level III	Level III	Level III	Level III	Level II	Leve
Airframe Deicing Activated	25 min	12 min	22 min	8 min	OFF	17 r
A/C model hardware status	BASIC	CONF=1	CONF=1	CONF=1	CONF=1+2	CONF
A/C model procedure status	BASIC	PROC.=1	PROC.=1	PROC.=1+2	PROC.=1+2	PROC.= 3
△Drag Count due to icing cond.	40	500	500	400	150	52
Probable Cause	A/C loss of control, attributed to a sudden and unexpected aileron hinge moment reversal that occurred while in holding at flap 15 deg after a ridge of ice accreted beyond the deice boots.	The crew lost the control after the A/C entered and continued operation in severe icing conditions for which the A/C is not certified. The crew had failed to associate icing of the forward side windows with the severe icing phenomenon.	During approach phase the crew noticed ice shapes on the side windows and A/C deceleration. The A/C was flying in identified severe ice conditions (visual cues). A moderate pitch down and roll occurred when flap extended to 30°.	The A/C had entered atmospheric conditions of severe icing for which it is not certificated. Application of the AFM procedures implemented for such encounter, allowed the flight crew to exit these severe icing conditions and to continue a safe flight and landing.	After prolonged exposure to icing conditions with the airframe de-icing OFF, the A/C lost 25 Knots of speed followed by a mild roll of 15°.	A/ encour the ic condi during The c notice shapes side wi an decrea rate of The applica AFM s icir emerg proce (increas speed Knots diseng autopil the A/

	+ AAS new flashing logic
PROC 1 =	Side window cue + Hold prohibited in icing with flap extended + exit and
PROC 2 =	Minimum icing +10knots when severe icing + new severe icing cues : Dec
PROC 3 =	De-icing ON at first visual indication of ice accretion and as long as icing
(*) for reference only : introduced by DGAC AD 1999-015-040(B) R1 (referenc	

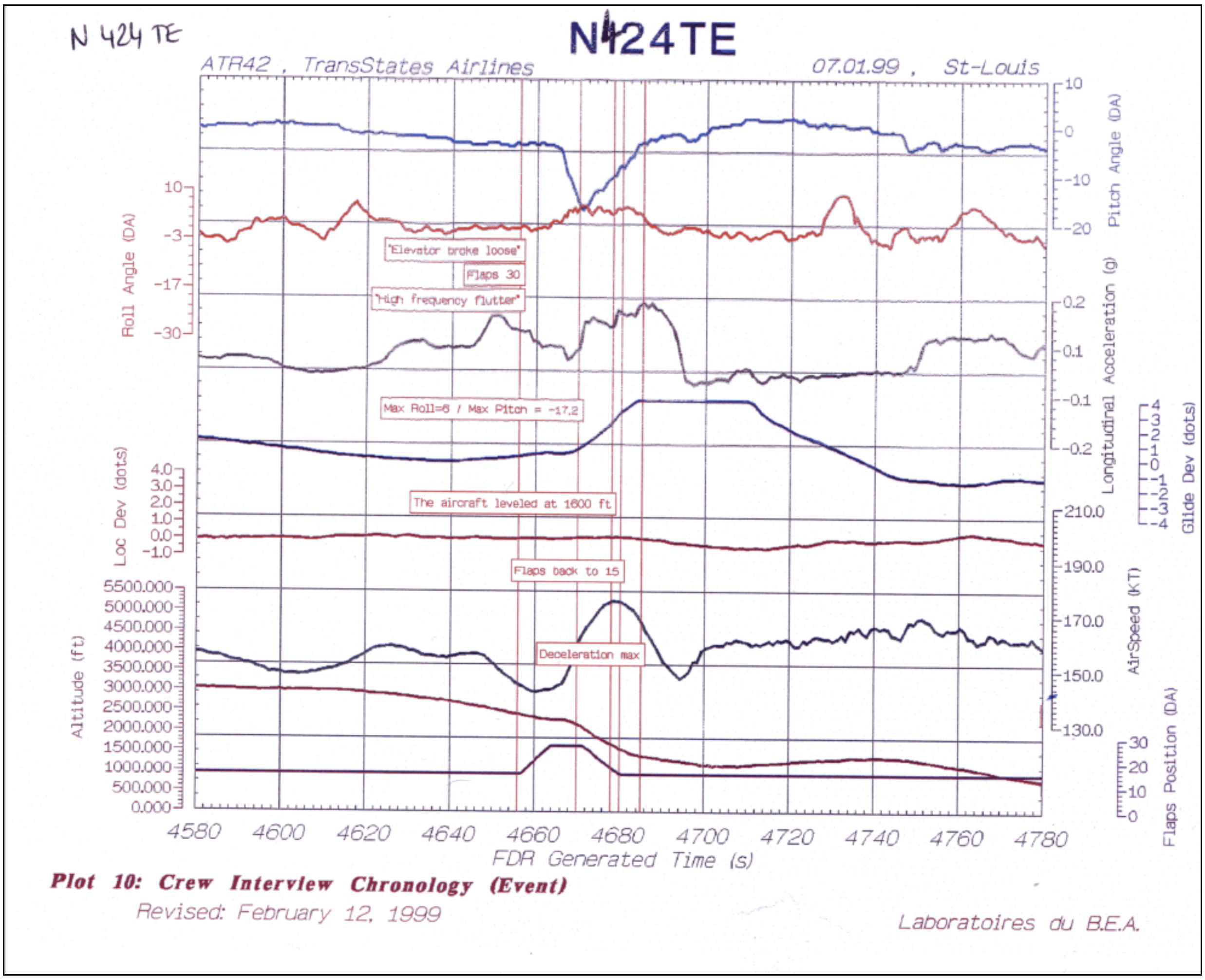

Figure 1.16-1 Trans States Airlines ATR42FDR Data (BEA)

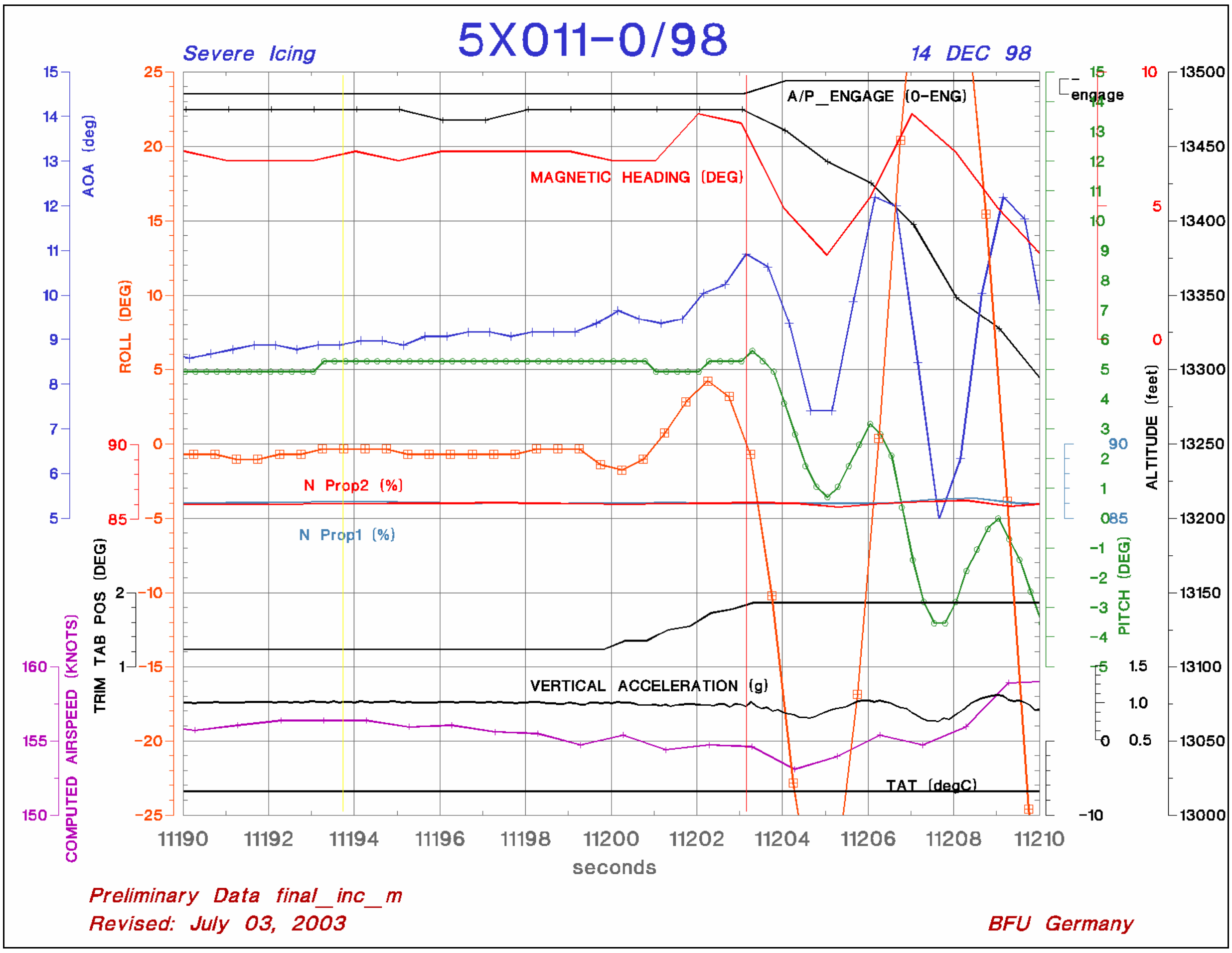

Figure 1.16-2 Cottbus, Germany, ATR42 FDR Data (BFU, Report No.:5x011-0/98)

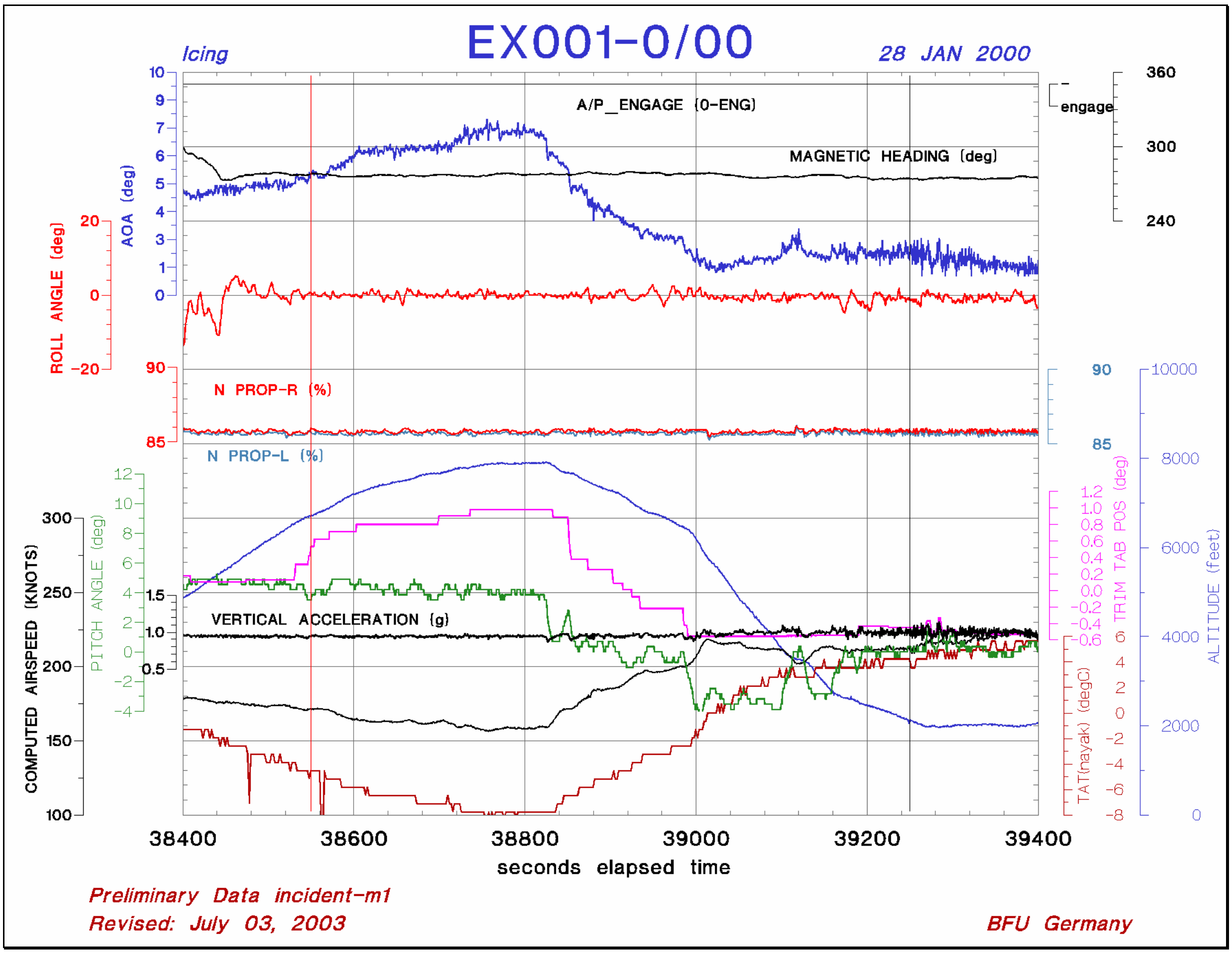

Figure 1.16-3 Near Berlin-Tegel, Germany, ATR42 FDR Data (BFU, Report No.: EX001-0/00)

1.16.2 ATR72 Flight Simulator Test

Tests and research were conducted to assess aircraft performance and stability. Details of these tests are contained in the Performance Section of this report, Section 2.4, relevant report as follows:

A Full Flight Simulator (FFS) test and engineering flight simulation were organized by ATR in aid of ASC and BEA to evaluate the flight dynamics and recovery of GE791 accident. This activity took place from March 27 to 28, 2003 at Toulouse, France.

- ATR 72-200: Trans Asia Airways MSN 322 – Accident Analysis. (October, 2003)
- ATR72 full flight simulator test report. SUBJECT : Report of simulation session with ASC and BEA. (May, 2003)
- Simulation analysis performed by ATR in 2004. (July, 2004)
- Performance and Stability Analysis of Flight GE791 Accident (March,

2004)

- Comments on the Report to ASC on Performance and Stability Analysis of Flight GE791 Accident. (July, 2004)

1.16.3 The Suspected Fatigue Examination

One window frame with fracture surface (refer to figure1.16-4) was sent to CSIST for fatigue examination.（Refer to Appendix 14）

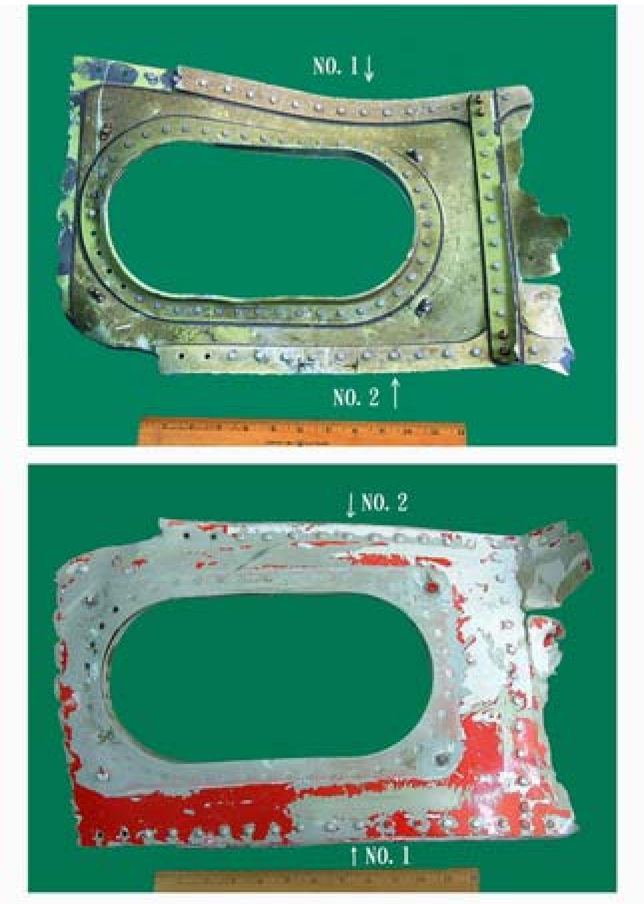

Figure 1.16-4 Wreckage with suspected fatigue crack

The examination result as follows,

1. Visual inspection

The window frame was inspected from every view. The fracture edge appears irregular. The fracture surface at right side shows torsion damage.

2. SEM examination

The surface of this sample was covered a layer of oxide which is adverse for SEM examination. This examination found dimple structure on fracture surface which due to overload damage (refer to figure 1.16-5).

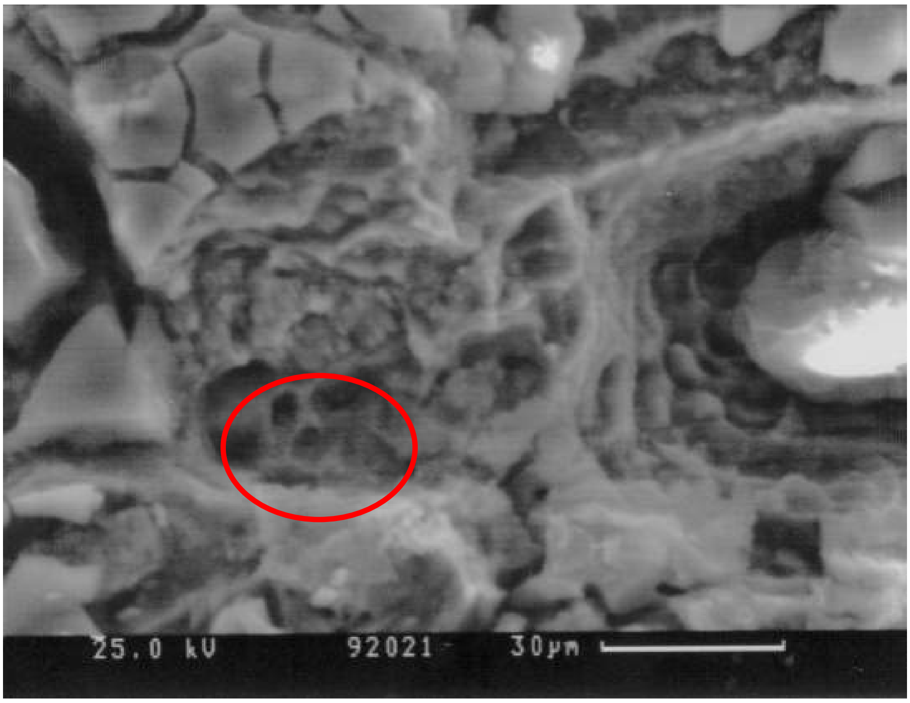

Figure 1.16-5 SEM examination showing the dimple structure (790X)。

1.17 Organizational and Management Information

The depictions stated in this Section are based on the status as of the time when the accident took place.

1.17.1 Organization and Management pertaining to TNA

TNA is composed of Security & Safety Office, System Operation Center, and Flight Operations Department among other units. See Figure 1.17-1 for details.

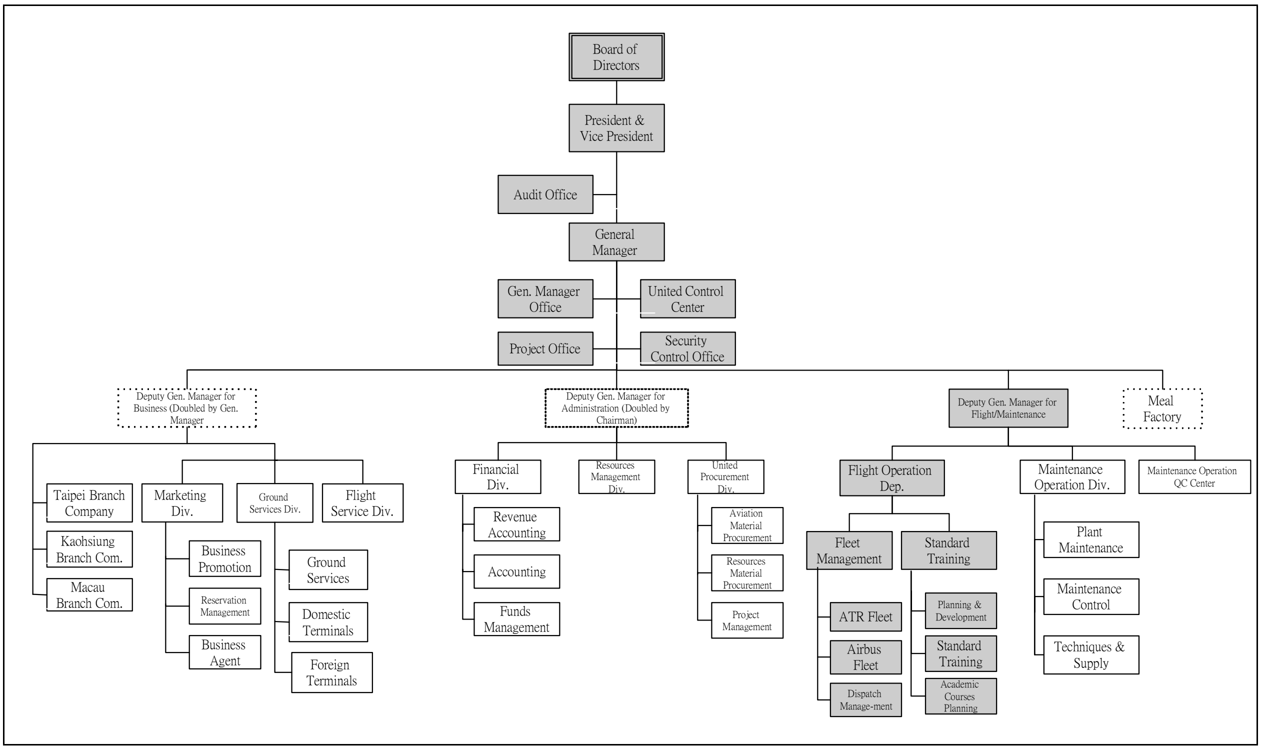

Figure 1.17-1 TNA Organizational Chart

1.17.1.1 System Operation Center

The System Operation Center (SOC) is subordinated to General Manager Office. According to "Operations Manual of TNA System Operation Center":

1. The purposes of establishing SOC are *"to strengthen the functions of TNA airport business coordination and aircraft fleet dispatching operation under the premise of assuring flight safety in order to implement an effective management of air traffic, and serve as a means of rapid response measure to meet the demands of ever-increasing air transportation."*

2. The functions of SOC include: *"…6. Giving a briefing on Flight crew mission." The functions of SOC dispatchers include "assuring that crew members are to report for duty in time" and "presenting relevant operational information regarding the flight which include…and signing the Flight Plan and the Takeoff Clearance together with captain after the captain confirms that the Flight Plan contains no doubts about flight safety…."*

3. The operational procedures of SOC include that *"members of domestic flight crew shall check in to SOC 40 minutes prior to their first departure time and members of international flight crew who fly from CKS International Airport shall check in to SOC 20 minutes prior to transport to CKS International Airport."*

The SOC is staffed with a Vice Manager, a deputy director and 12 dispatchers. All staff under deputy director (inclusive) has licenses for dispatching, and dispatchers in shifts perform the dispatching tasks. Since the introduction of nighttime flights, deputy director has joined in the shifts sometimes.

1.17.1.2 Security & Safety Office

The Flight Safety Office under TNA Flight Operations Department was separated and transferred to under General Manager Office in May 1995. The functions of security protection and labors safety were incorporated into the Safety Control Office to become Security & Safety Office (SCO) on January 1, 2002, which are manned with 6 persons: 1 director, 3 assistants and 2 senior officers.

The interview records indicated: The functions of Safety Control Office involve units of flight operation, engineering and maintenance operation, QC, ground services. Its main tasks include:

1. Assisting flight operation department in analyzing Line Operations Monitor System (LOMS) and dealing with general business regarding flight safety;

2. The LOMS operation is divided into two parts: the SCO is responsible for operation management and analysis of overall trend, and the Flight Operations Department designating pilots to provide assistance in confirming incidents and handling the follow-on work;

3. Participating daily maintenance meeting to have an awareness of operating conditions;

4. Coordinating Ground Services Division and heads of each station to conduct selective inspections of flight safety procedures and report the results to SCO via fax machine;

5. Implementing hazardous material education to all employees of TNA;

6. Organizing a mobile education team to instill the concept of "all-employees flight safety" in which each unit is responsible for flight safety of its own; and
7. Flight Operations Department is responsible for handling "flight crew reports" while units involving flight safety are providing assistances together with SCO.

1.17.1.2.1 Flight Safety Education & Training

TNA flight safety education & training include flight safety education for new employees and annual flight safety recurrent training. The flight safety education for new flight crewmembers includes:

1. Professional flight safety education, 2 to 4 hours;
2. Resources management training for air services crew members, 4 to 8 hours;
3. First aid and other trainings (including emergency escape, hijacking, anti-hijacking, explosive objects, hazardous material and CPR); 16 hours.

The annual flight safety recurrent training for flight crew is conducted once per year (adopting an alternative approach of classroom review and discussion and simulation practices for every other year). Training courses takes 2 to 6 hours including land escape, water escape, use of various first aid and survival equipment, flight crew's duty and work in emergent situations and evacuation, measures for taking care of disabled and handicapped, and the physiological effects under circumstance of oxygen less over altitude 10,000 ft and in condition of failed pressure cabin.

1.17.1.2.2 All-employees Flight Safety Reporting System

All-employees flight safety report can be divided into four categories: flight crew report, passenger cabin crew report, flight safety abnormal incident report, and compulsory reporting incidents.

The flight crew report (limited to flight crew use only) must be filed when accident, serious incident, incident occurred and shortcoming are found in maintenance operations, ground handling operations, dispatching operations, passenger services, and equipment/facilities that may impose danger to flight safety and violate aviation regulations. Flight Operations Department is the responsible unit for handling these reports.

The flight safety abnormal incident report is used (by all employees) when individual operation has imposed danger to flight safety or other individuals and/or objects that are found to have impact on flight safety. SCO is the responsible unit for handling these reports.

1.17.1.3 Flight Operations Department (FOD)

The FOD is subordinated to Deputy General Manager for Flight/Maintenance. According to Operations Manual of TNA FOD, its functions include:

1. Pushing for Flight Operation policy;
2. Assuring flight safety;
3. Developing and implementing relevant operating manuals and procedures;
4. Implementing manpower planning, training, employment, evaluation and management of flight pilots; and
5. Assigning and implementing flight missions.

The establishment of FOD includes two departments: Aircraft Fleet Management (AFM) and Standard Training (ST). The AFM is composed of AIRBUS fleet, ATR fleet and Scheduling Management Office, with the chief pilot of AIRBUS fleet doubled as manager. Under the ST department, there are three sections: Academic Courses Planning, Standard Training, and Planning & Development, with the director of Standard Training doubled as acting manager.

The (deputy) assistant vice president of FOD acts as the leader of FOD whose responsibilities include:

1. Overseeing internal affairs and communicating with other units;
2. Supervising and developing policies and procedures of TNA flight operations;
3. Supervising the implementation of flight operations;
4. Supervising training of flight crew members;
5. Supervising and planning policies to ensure flight safety; and
6. Supervising, evaluating and managing subordinates.

Followings are the summary of interviews with relevant personnel of flight operation: Currently, the FOD has two positions remained vacant: the flight training manager for about one year and deputy director in charge of personnel records. TNA often used technical personnel to form mobile teams that result in excess workload due to manpower overlapping. FOD has no full-time on ground school instructor. In selection of manager of flight training department, the modus operandi of recommending candidates by unit chiefs had been adopted in the past. And now, the candidates are selected first by Human Resources Division, who will then be inquired by personnel unit of personal willingness, and elected by the vote of fleet pilots. The hopefuls emerged out of voting result then will be compared and assessed by general manager, deputy general manager and chiefs of flight operation units before reporting to president for a final decision.

There are two fleets in FOD, but the pilots of these two fleets receive different pay as the pilots of AIRBUS fleet receive higher pay than those of ATR fleet do. Pilots of ATR fleet staged a strike in 1999. Pilots of this fleet are lacking motivations to attend trainings courses and flight safety meetings due to lower pay and manpower shortage. Nevertheless, TNA has requested the ATR fleet pilots to maintain a substantial level in hope of achieving a better management of flight operations. However, the management can only do what it can in light of a shortage of manpower and resources.

The test questions of annual training were not difficult, the instructor pilots and check pilots often gave briefing before tests. TNA has decided to drop this practice of giving briefing before tests. Generally, the evaluation records were not written in full details. The instructor pilots and check pilots have eliminated no one in the recurrent checkride that the interviewee attributes to the checkride standards adopted. TNA has considered inviting instructors from outside for the job, but it was not realized due to high costs. As to the problems of pilot competence and professionalism, they can be identified through two ways: one is from the remarks on regular tests sheet and the other from the individual performance during route check. The chief pilot will coordinate with Flight Training Office to work out a training plan for reinforcement. A monthly aircraft fleet instructor pilots meeting are chaired by the chief pilot of the two fleets alternatively.

Parts of the pilots are lacking aggressive motivations that could not be improved by training alone; a stricter evaluation system by the instructor pilots is needed. It’s not easy for all flight crewmembers to attend the meetings; therefore the Fleet Circular is used as a substitute for the meetings. What the Fleet Circular publicized are mostly the things already known and repeated, but there were still some who were mindless of this. One of the answers to this problem lies in cultural aspect to beef up selective checking to foster the senses of seriousness and honesty of the pilots. The other way is to increase the manpower of instructor pilots and pilots.

When receiving the Notices and technical documents from outside, Flight Operations Department makes an abstract and publicizes them after chief pilot and deputy assistant vice manager put their signatures. Each pilot will get a copy. These Notices may fall within the ambits of test in the recurrent training. A member of flight operation management indicated that he didn’t hear anything about the Winter Operation Reminder issued by ATR manufacturer on December 5, 2002.

TNA headquarters pointed out in the weekly Wednesday meeting one month ago that using Hong Kong as the alternate airport is not appropriate for ATR Freighter in light of the close distance to Macau when the weather changes abruptly and it would run a high risk when situation of single engine flight takes place. But, at last, the only thing could be done to respond was to persuade chief pilot to assign the pilots with better quality.

When concurrently undertaking management or administrative work, pilots have to spend much of extra time on office work besides their duty flight time, therefore most of pilots not willing to take concurrent job. But when someone did choose to pick up the job, sidelong remarks from others follow. There has been no specifically established system in written form to govern the selection of flight operation leaders. The president and general manager of TNA have been changed frequently. Each change would bring new operation style and ideas when the tacit mutual understanding runs in short supply.

TNA operation team was reshaped in March 2002. The management level has been fluctuated in the past. When it changed, the units under it changed correspondingly.

Making profits has been the policy of TNA as it has to be responsible for its shareholders. All of TNA units are endeavoring after this goal. The flight operation units are TNA's executive units and have to cooperate with company's projects. In budget, the policy of broadening sources of income and reducing expenditure to cut costs has been executed thoroughly. Employees and hardware are all managed in a most economical way. Promotion of personnel has been frozen for two years unless it is deemed a necessity. The thrift measures taken in management of personnel and administration include reducing the space of offices, merging units, consolidating the posts of leaders with that of deputy leaders, and other streamlining measures. Education and training courses are reduced substantially while those regarding flight operations are maintained only at standard level required by civil aviation regulations. The company's participation in activities such as international annual conference and ATR annual conference has been reduced.

The number of ATR and AIRBUS fleets were planned to reduce to 8 aircraft for each fleet in the Project 2002 drawn up in the end of 2001. However, the surplus aircraft were unable to sell out due to shrinking aircraft market and by contraries, one more Freighter, B-22708, was joined in due to some reasons. This aircraft arrived at CKS International Airport in December 2001 and was converted into a freighter after inspection and repair. It started to fly between Taipei and Macau from February 26, 2002. Since the release of Project 2002, the manpower streamlining policy has been implemented under a preferential payment program. The civil aviation regulations have imposed restrictions on maximum flight time of pilots, but as in the case of manager of Standard Training Department, doubled by director of Standard Training Division who has to fly for 40 hours per month and handle staff work in non-flight duty hours. According to the monthly flight schedule, each pilot's flight time sum up to 80 to 85 hours, but their actual monthly flight time were 65 to 70 hours due to incidental cancellation of flights. This has caused perplexity in mission assignment and diminished the willingness of pilots to attend training courses and flight safety meetings.

In the past, Flight Crew Report has been rarely filed in TNA. Now, it is a mandate that any problem be reflected in "Flight Crew Report " which will be sent to relevant unit for an answer. Then the chief pilot will hand it over to captains for confirmation. After signed by deputy general manager of

Flight/Engineering and Maintenance Divisions, the case is officially closed. Pilots will be punished if they have not written a “Flight Crew Report ” when it should be done.

1.17.1.3.1 Fleet Management Department

Aircraft Fleet

ATR fleet has 10 ATR72 passenger aircraft and 1 ATR72 freighter with 33 captains (of which 3 are CAA designated examiners, 2 are check pilots and 2 are instructor pilots) and 27 first officers, 60 in total. AIRBUS fleet contains 9 AIRBUS 320/321 aircraft with 28 captains (of which 2 are CAA designated examiners, 3 are check pilots and 3 are instructor pilots) and 26 first officers, 54 in total.

According to Operations Manual of TNA Flight Operations Department, the responsibilities of chief pilot include:

1. Implementing test and evaluation of pilots;
2. Conducting selection review of new pilots, pilots for advanced training and pilots for transfer training, and manpower planning;
3. Attending and supervising required study classes;
4. Management of fleet personnel including pilot flight skills, disciplines and habits in daily life;
5. Conducting checks on various skills and evaluation of annual individual pilot performance; and
6. Handling “Flight Crew Member Report”

Crew Scheduling Section

The Assignment Management Section (AMB) is staffed with 8 persons including director.

According to Operations Manual of TNA Flight Operations Department, the functions of AMB include:

1. Receiving, issuing and distributing Flight Crew Member Report;
2. Developing flight crew flight schedule and day-to-day flight crew mission schedule;
3. Supervising mission assignment and handling occasional or unusual conditions of pilots;
4. Handling preplanning, statistics and adjustment of pilot flight time;
5. Producing, translating, and receiving/issuing official papers;

6. Producing, translating and publicizing Flight Operations Circular and Fleet Circular; and
7. Maintaining and updating the manuals on aircraft.

1.17.1.3.2 Standard Training Department

Standard Training Section (STS)

STS is staffed with director, one staff member, and a task-based team composed of check pilots and instructor pilots.

According to Operations Manual of TNA Flight Operations Department, the functions of STS include:

1. Revising and enlarging various standard flight operation doctrines such as Standard Operations Procedures, Flight Operations Manual, Flight Training Management Manual, Flight Training Manual and Route Manual;
2. Collecting and compiling teaching material and questions pool regarding ground academic training, simulator training and flight training of each type of aircraft;
3. Supervising the instructor pilots in conducting training, qualifying techniques and skills, evaluating training results and tracking shortcomings, as well as conducting checks on lag of training progress and events of poor grade examination and raising suggestions;
4. Taking part in the process of selecting and evaluating new pilots and pilots for advanced and transferring training, and attending the fleet manpower appraisal meeting; and
5. Holding meetings to check pilots’ flight competence and skills.

According to Operations Manual of TNA Flight Operations Department, the responsibilities of Check pilots and Instructor Pilots of the task-based team include:

1. Conducting checks and tests on various pilot techniques and skills;
2. Implementing various flight trainings (including flight-related ground academic subjects and civil aviation regulations and laws);
3. Reflecting training problems and improving training or operational procedures;
4. Appraising and checking the qualifications of pilots; and
5. Participating regular instructor pilot meetings as well as personnel techniques and skills appraisal meetings.

The Operations Manual of TNA Flight Operations Department states:

1. *Section 2-9, "ATR and A320/321 Regular Recurrent Training," of Chapter 2, "Training Procedures and Regulations," has set forth the disciplines and hours of ground academic training that are conducted twice a year, and the cold weather operation procedures class shall be scheduled in the second half year for 1 hour.*
2. *Section 3-4-5, "Emergency Procedures," of Chapter 3, "Standards of Training and Completing Checks," requires of pilots to make a correct explanation of emergency procedures to judge their expertise which include "icing: 1. airframe; 2. engines."*

Programming & Training Section

Programming & Training Section (PTS) is staffed with director, deputy director and one staff member.

According to Operations Manual of TNA Flight Operations Department, the functions of PTS include:

1. Developing training programs and tracking the implementation of them.
2. Coordinating with Dispatch Center to arrange the recurrent training of pilots;
3. Safekeeping, sorting out and replenishing training material, books and training equipment;
4. In charge of various flight and ground academic trainings, and collecting and assessing the opinions from instructors and trainees.
5. Arranging trainees for simulator recurrent training and handling information; and
6. Tracking trainees' stage trainings and their examination records.

Planning & Development Section

Planning & Development Section (PDS) is composed of a director and one engineer.

According to Operating Manual of TNA Flight Operations Department, the functions of PDS include:

1. Developing flight operation policy, regulations pertaining to aircraft functions, fuel policy, flight programs and related operational procedures;
2. Providing relevant performance information related to establishing new route and charter flight operation;
3. Designing manual-loading and -trimming table for each type of aircraft;

4. Providing engineering database for computer-loading and -trimming table; and
5. Conducting analysis and statistics of flight time and fuel consumption of each type of aircraft in each route.

Remarks on interview records: A line pilot concurrently holds the post of Standard Training Section (STS) director. The post of Standard Training Department (STD) manager has not been formally filled and is doubled by STS director. The acting STS manager is parallel to director of Academic Courses Planning Section in rank, and they maintain a communication and coordination relations in operations. STD has no full-time manager.

ATR simulator training is conducted in foreign country, 2 hours for training and a checkride in every half a year. The training is aimed at the requirements and shortcomings while the checkride focused on critical subjects required by civil aviation regulations. The training time is quite tight and it is difficult to complete all courses at one training session. If additional simulator training is required when pilots have failed to pass the test, the coordination for an extra training is difficult.

The simulator technical trainings are based on the teaching material provided by manufacturer that are dispensed in a circle of three years including all normal/abnormal subjects. Also, there are some training that will be added into the courses according to different seasons, environments, and the requirements of different aircraft fleets. In addition, some critical check items and compulsory subjects, such as the approach procedures for the changed runway 28 in Sungshan Airport, for instance, required by CAA will be included in the courses as well. The training results of each pilot will be recorded and reported backs to CAA every 3 months and will be used as an appraisal item in rating his annual performance. Such subjects include wind shear operation, thunderstorm weather operations, traffic alert and collision avoidance system, and controlled flight into terrain. The basic operations include step turn, stall, etc. All of these subjects are essential in annual tests. The simulator training accounts for only 12 hours in a circle of three years, it is difficult to complete all subjects training within this short period.

Due to a shortage of manpower, there have been flaws on the part of Flight Operations Department in follow-on tracking minor shortcomings found in the school courses tests. Instructor pilots and examiners decide the simulator training subjects. The key training subjects and the essential subjects that must be completed in each half a year are mentioned in instructor pilots meeting and all of them know the key points and standards of each subject. The simulator tests have seen none failing to pass in recent year as there were 3 pilots (not including CM-1) and 1 or 2 first officers narrowly passed the basic school courses tests. They needed to exert more efforts.

The total flight time of ATR fleet pilots in 2000 and before the end of 2001 nearly reached the flight limit of 1,000 hours. The shortage of manpower is apparent. The situation has been improved recently, however, if pilots get ill or take leave, the training will be affected. This has been the part that CAA particularly concerned during in-depth inspections. CAA has demanded TNA to improve in this regard. ATR fleet has recruited a number of new pilots in recent years, but they are uneven in quality. ATR fleet has launched five echelons of recruitment in 2001, in one of which only one of six candidates is qualified, hence the manpower requirements are unable to be satisfied.

“Icing” is not an individual subject, it varies depending on environmental conditions that needs pilots alertness to cope with. In the ground school course and simulator tests, questions about icing subject have rarely appeared. Nor the severe icing subject have been included in simulator training and test because Taiwan is located in subtropical zone with low possibility of severe icing, and a severe icing happened in 2002 and was not attached importance. Training for handling severe icing is not emphasized in particular in school courses and technical trainings. A severe icing cannot be reproduced on a simulator, only the methods to handle icing condition are instructed. Therefore, it is not sure that all pilots are aware of the definition and phenomenon of severe icing. Director of Programming Courses Planning Section is responsible for the examination questions of ground school courses that are diversified in category. The examination questions provided by original ATR manufacturer are written in English but some Chinese questions are added into by TNA. The examination questions of school subjects are written in English and, when necessary, other questions will be used to replace the original English questions. School Courses Planning Section is responsible for this task.

The format of Load and Trim Sheet is designed by Planning & Development Section, which is determined and implemented after the dispatchers of System Operation Center gives consent in reply.

1.17.2 The Organization of Maintenance & Engineering Division

The organization and human resources of the Maintenance & Engineering Division is shown on the chart 1.17-2. There are 91 CAA A/E and 6 FAA A/P license holders in TNA.

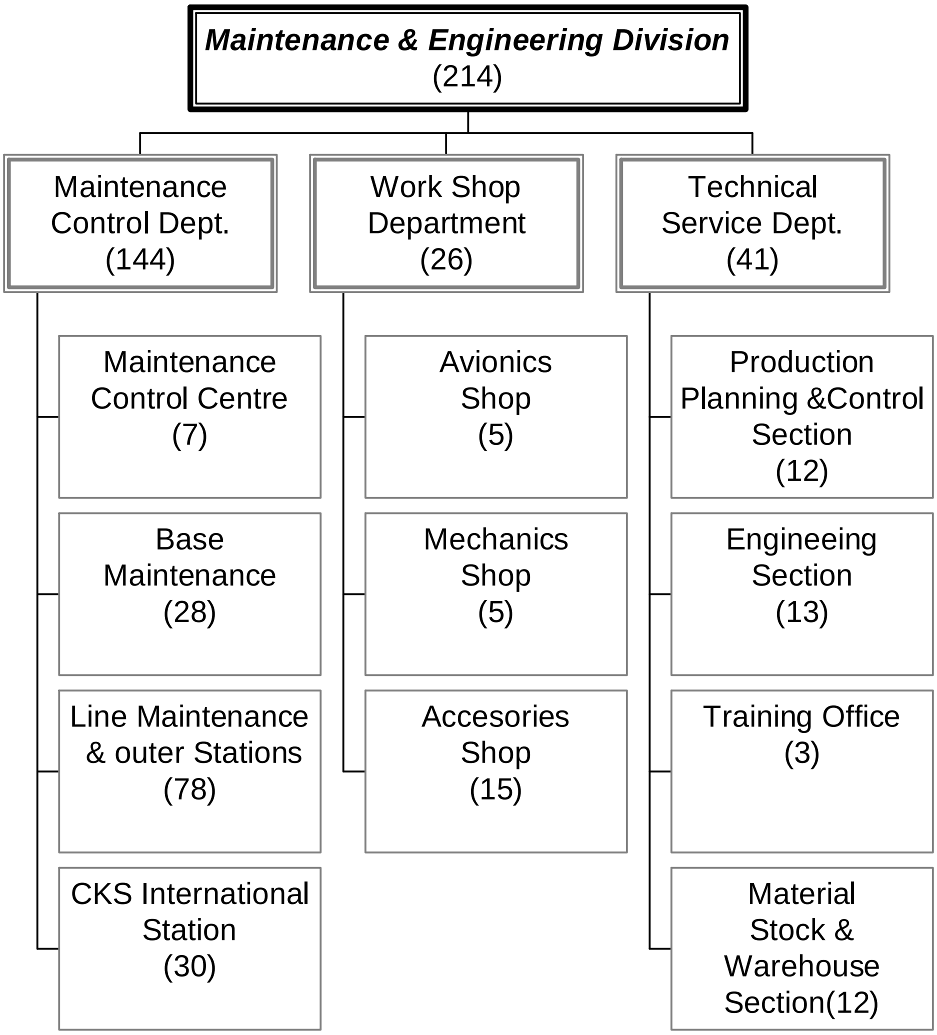

Figure 1.17-2 The Organization Chart of TNA Maintenance and Engineering Division

1.18 Additional Information

1.18.1 Air Traffic Control

The operations of CKS Approach Control Tower and Taipei Area Control Center were normal. The control operations of GE791 were transferred to Taipei Area Control Center from CKS Approach Control at 0121:30, December 21.

1.18.2 Radar

1.18.2.1 General

Airport Surveillance Radar (ASR) data were acquired from the Taipei Air Control Center (TACC) of CAA and Xiamen of China. There were five radar that detected the accident flight track including: CCC(CKS Radar), KSR（Kaohsiung Radar）, MKR（Makung Radar）, DHS, and Xiamen. Both Secondary Radar Returns and Primary Radar Returns were recorded in the various radar data sets. The MKR that close by the GE791 accident site only recorded the primary data.

After accident occurred, TACC provided all relevant radar data. Both primary and secondary radar data were extracted as Continuous Data Recording (CDR) or National Track Analysis Program (NTAP) text format. NTAP data format includes: time, beacon code of the airplane, altitude, longitude and latitude position. The data contents of CDR include: time, slant range, azimuth / ACP[12]s. The flight track, track angle and ground speed were calculated according to the location of radar site and PSR data.

Xiamen radar is a secondary radar system that only records the secondary signals. The system can only playback the recording with video format. Viewer transcribed the time, ground speed and Mode C altitude manually.

1.18.2.2 Secondary Radar Signals

These five radar’s Secondary Radar covered the accident flight track from taking off until signal disappeared on the radar screen. The timing system of

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[12] ACP（Azimuth Change Pulses），Digitalize azimuth angle（0° to 360°）to 0 to 4095.Therefore,1 ACP=360°/4096 = 0.08789°。

radars are different, Makung radar timing system is selected as reference time to synchronize the others. Table 1.18-1 lists time correlation, scan rate, time duration of each radars data for the GE791, and relevant Mode-C altitude.

Figure 1.18-1 shows the GE791 radar track recording from 01:03:31 (100ft) until 01:52:49.129. According to TACC radar recordings, the last transponder signal received from Makung radar was at 01:52:49, and the altitude was 1,500ft. Figure 1.18-2 shows that GE791 started to descent at 01:52:04.780. The last transponder signal received from Xiamen radar was at 01:52:38, the altitude was 2,740 m (8,989 ft). Fig. 1.18-3 shows the superposition of the GE791 radar tracks, which were detected by the MKR, CCC, and KSR.

Table 1.18-1 Time correlation of each radar sites between MKR

Radar Site	Scan Rate	Starting Time	Ending Time	Time difference between MKR Radar Site (sec)
		Mode-C Altitude（Ft）	Mode-C Altitude（Ft）	
TACC-NTAP	12 sec/times	0147:11	01:52:10	0
		18000	17900	
DAHAN –NTAP	12 sec/times	0151:38	01:52:46	-0.2
		18000	3600	
CCC-CDR	4.6 sec/times	0103:31.777	01:52:22.129	0
		100	16600	
MKR-CDR	5 sec/times	0109:58.78	01:52:49.129	0
		6800	1500	
KHR-CDR	4.6 sec/times	0150:04.130	01:52:34.582	-0.56
		18000	11200	
Xiamen-Radar Image Record	4 sec/times	0150:11	01:52:38	-4
		18011.59	2740m(8989ft)	

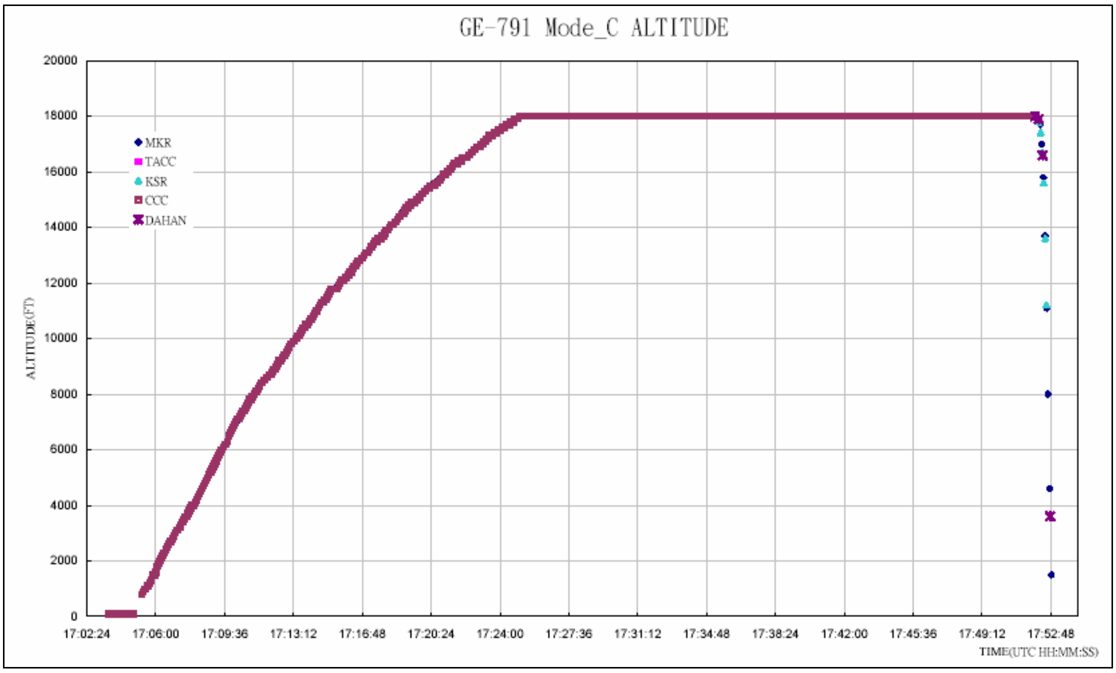

Figure 1.18-1 Mode-C altitude of GE791 (01:03: 31~01:52:56)

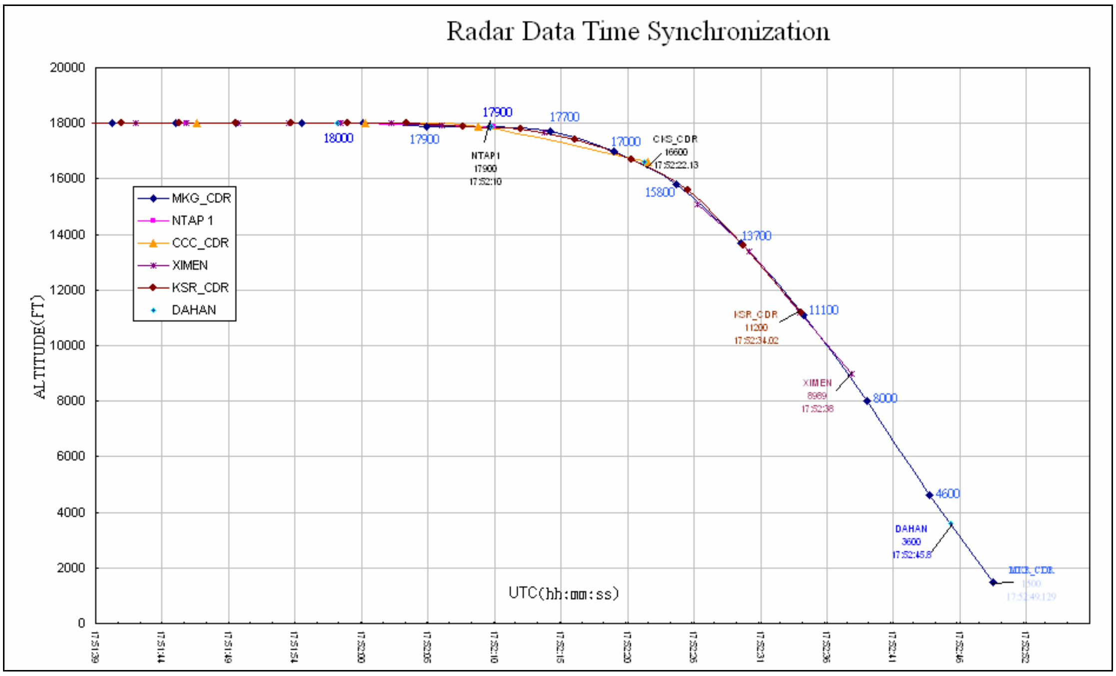

Figure 1.18-2 Mode-C altitude of GE791 (01:51:38~01:52:48)

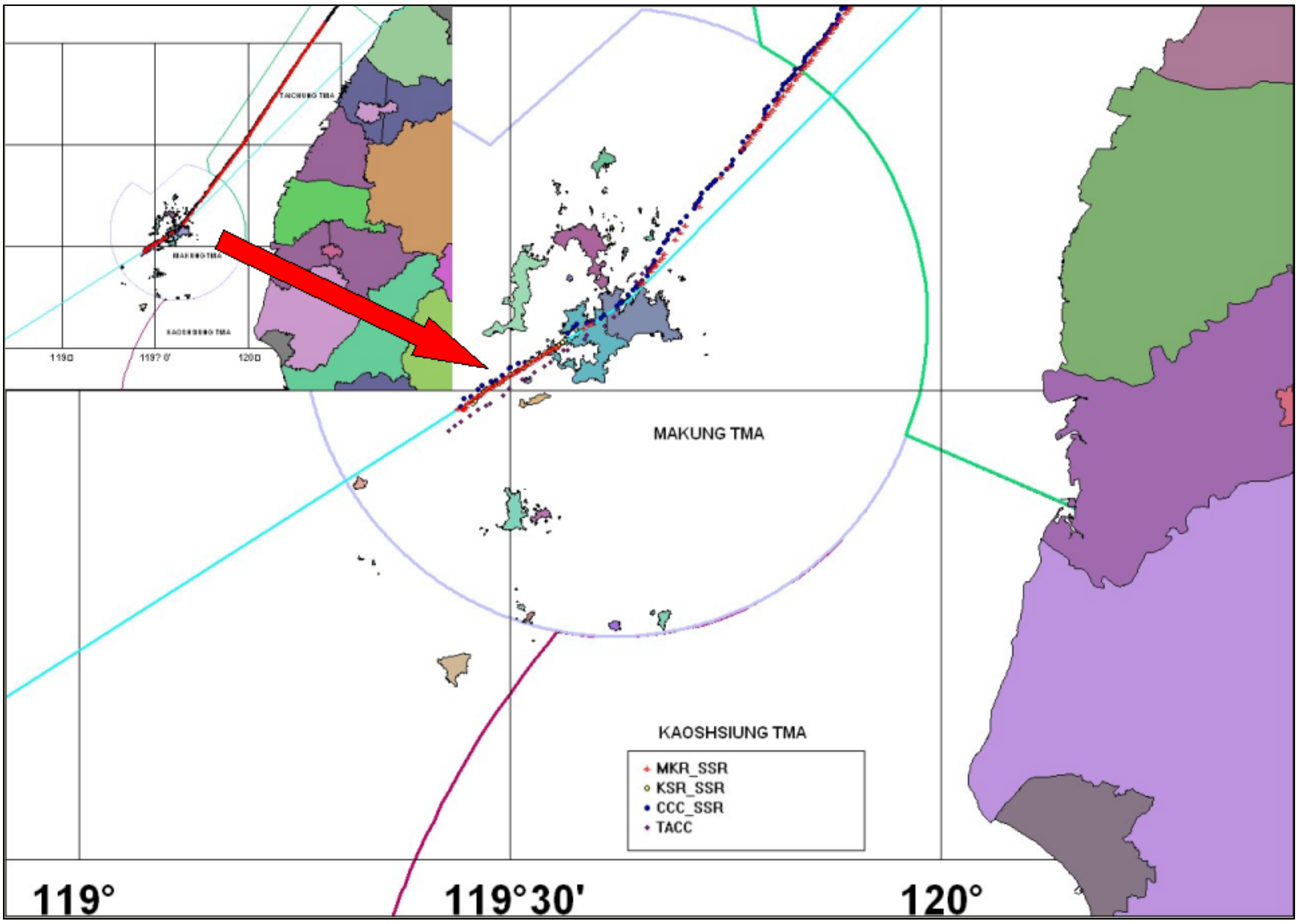

Figure 1.18-3 Superposition of the GE791 radar track, which were detected by the MKR, CCC, and KSR.

1.18.2.3 Primary Radar Return

Primary radar returns extracted from the MKR were calculated, and correlated with the secondary radar returns. Figure 1.18-4 shows the results of superposed sonar targets. Figure 1.18-4 indicates the relative distance between the last transponder position (N23°28’47.89”, E119°26’23.04”, altitude 1,500 ft) and major sonar targets is 186 meters. This figure also shows six primary radar returns were found near the accident site since 01:52:49 until 0200:00. Table 1.18-2 lists the primary radar returns with time, position, and the relative distance.

Table 1.18-2 Primary radar return in the GE791 accident site

	SSR last return time	Latitude	Longitude	Distance (m)
	01:52:49.129	119°26’23.04”	23°28’47.89”	
No	PSR return time	Latitude	Longitude	Distance (m)
1	01:52:49.129	119°26’21.33”	23°28’54.53”	206
2	01:52:54.130	119°26’37.32”	23°28’53.84”	442
3	01:52:59.000	119°26’39.29”	23°28’49.86”	463
4	01:53:04.000	119°26’30.67”	23°28’49.86”	225
5	01:53:13.776	119°26’37.32”	23°28’53.84”	442
6	01:53:58.453	119°26’27.72”	23°28’55.92”	281

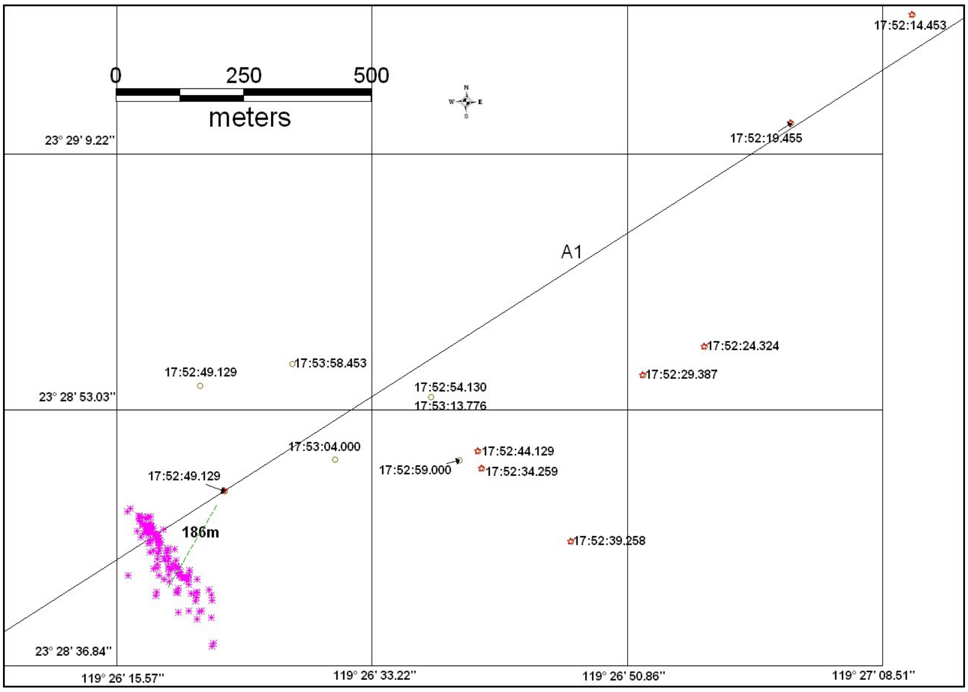

Figure 1.18-4 Primary and Secondary radar return of MKR and sonar targets

1.18.2.4 Radar Video Recording System of TACC/CAA

There are two radar data playback systems at TACC. One is the ATC Automation System (ATAS), which only records the secondary radar returns. The other is the Micro-ARTS, which can playback both primary and secondary returns. These radar video recordings were exported into the digital video recorder（DV） t, and post-processing the DV to specific frames. Figure 1.18-5 indicates the GE791radar track at 01:51:54.970, its Mode-C altitude is 18,000 ft. The last transponder signal received from MKR at 01:52:49, and then primary radar returns continuously appeared until 01:53:12.

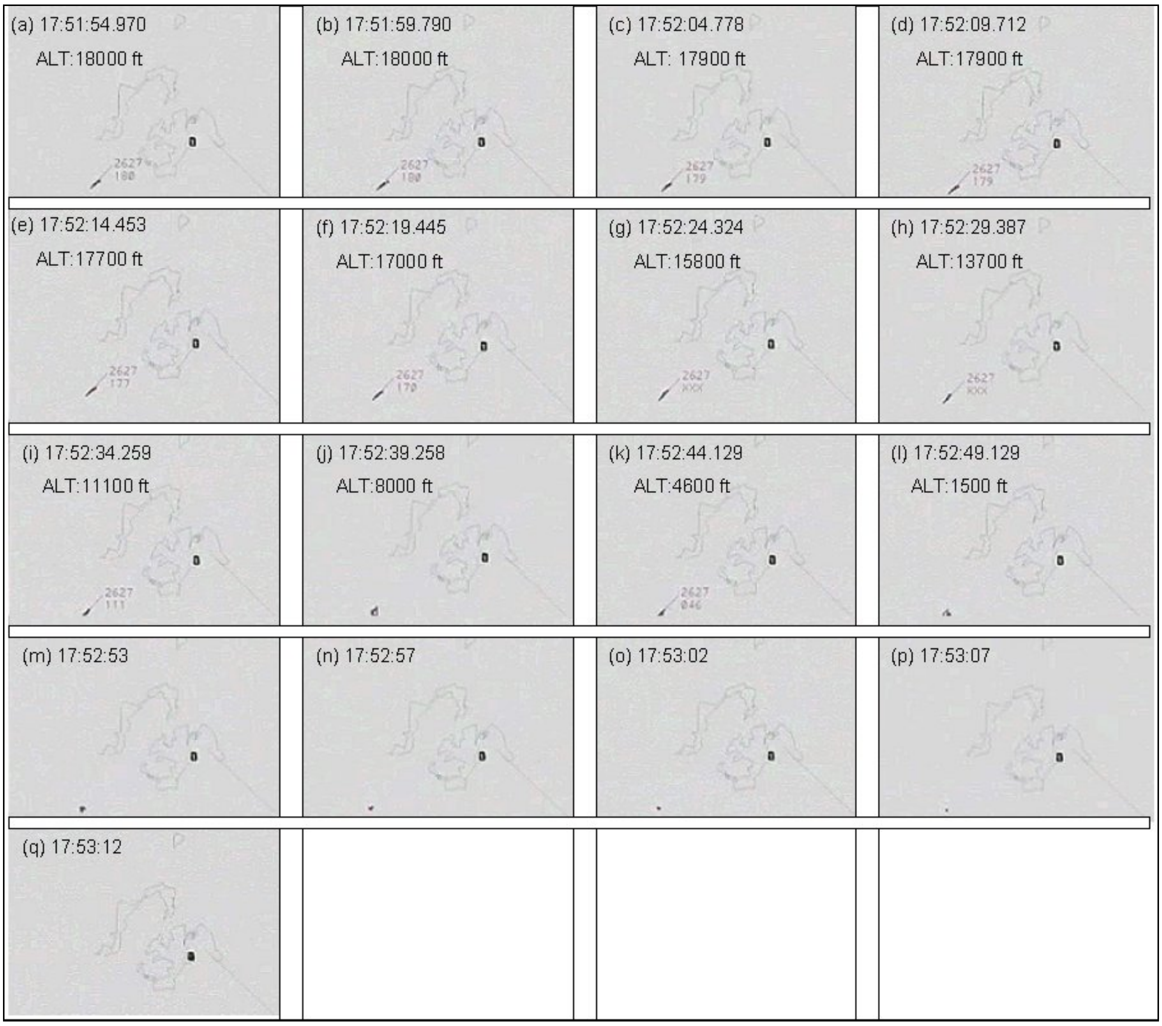

Figure 1.18-5 Secondary and primary radar returns recorded by the ATAS（from TACC）

1.18.3 Summary of Interviews

1.18.3.1 A Summary of interview with Dispatcher

The interviewee was in night shift on December 20, 2002, who was responsible for GE791 flight plan and mission reminder. Around 1900 that evening, he heard a colleague in front of him answered a phone call from CM-2, saying that he was not sure if CM-1, residing in Taoyuan, would report to Sungshan Airport. Then he made a phone call to CM-1 at 1918 for an inquiry and learned that CM-1 would directly report to CKS International Airport AT 2310 and meanwhile, he made the flight crew briefing on the phone.

He then called CM-2, telling him that CM-1 would arrive at CKS International Airport and that a briefing has been made for CM-1. CM-2 arrived at System

Operation Center (SOC) at 2140 to receive a briefing and represented CM-1 to sign on Flight Crew Briefing sheet, then took a vehicle at 2200 heading for CKS International Airport.

The SOC operating manual stipulates that all pilots have to report to SOC, Sungshan Airport regardless of performing domestic or international flight, and that after receiving the flight crew briefing, the captain and the dispatcher have to jointly sign the flight plan to suggest that a consensus is reached.

The interviewee revealed that he learned from one of his colleagues that CM-2 contacted SOC at 0200 December 21 via cockpit radio saying the aircraft was just passing through Makung when it was at FL 180, everything is normal.

The interviewee indicated: The contents of the briefing included weather conditions and the visibility at CKS and Macau airports, a 6-hour weather forecast at 1800, and a description of possible rain in both airports with the forecast of minimum visibility 3,000m and BR[13]; no special condition was noted in NOTAM, and CM-1 was suggested to take a look at it by himself when available. Attached to the flight crew briefing were weather satellite IR image and upper layer wind information ranged from 2,000ft, 5,000ft, 10,000ft, 15,000ft, to 20,000ft which were printed out from Multidimensional Display System (MDS) of CKS Flight Information Station, in which the temperature data of those altitudes were marked as 20 degrees Celsius at the ground of CKS International Airport, 0 degree Celsius at altitude of 10,000ft and minus16 degrees Celsius at 18,000ft. He told CM-1 to fill with a little more fuel as strong headwind was expected. CM-1 said he got it and ended the phone briefing.

1.18.3.2 A Summary of Interview with Pilots who Operated B-22708 One Day before the Accident

Two crewmembers who performed flight GE793 and GE794 (CKS International Airport to/from Macau International Airport) on December 20, 2002, expressed during the interview:

GE794 took off around 2100 carrying over 3,200kg cargo. The planned flight altitude was FL 190, and then requested to climb to FL 230 because of clouds influence, where the static air temperature (SAT) was about minus 18 to 19 degrees Celsius. After passing through Makung, the aircraft flied into clouds but the density of moisture was not thick during the course of descending. Icing condition was encountered along the route but no evident signal of moisture shown in radar screen.

The interviewees indicated that the methods of dealing icing has been instructed in simulator training in the past year, but the ground school training

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[13] BR is a code representing light fog.

is insufficient and the professionalism of instructors were considered substandard. It is appropriate to employ professional instructors from outside or step up training to develop in-company instructors. It is suggested that the severe icing in Quick Reference Hand Book (QRH) be regulated as a Memory Item.[14]

Two crewmembers who performed flight GE791 and GE792 (CKS International Airport to/from Macau International Airport) on December 20, 2002, expressed during interview:

It was heard before the accident that when flying in bad weather, B-22078 still encountered a severe icing even the de-icing system and “-20℃ Switch” had been activated. During which, the aircraft’s angle of elevation augmented and airspeed decreased. The pilots requested clearance to descend from FL 180 to FL 140 and the conditions restored to normal after descending. Normally, when B-22708 flying and maintaining at FL 180 and using autopilot and cruise power, the indicated airspeed is around 200 knots. TNA Flight Operations Department did not issue special notice in 2002 to remind ATR aircraft pilots of potential icing problem and handling procedures, but AIRBUS fleet did issue a special notice due to the fleet prepare for the first time flight to a cold weather area.

1.18.3.3 A Summary of Interview with Crew Member who had Flied with the Crew Pilots before the Accident

The pilot who flied with CM-1 on the last flight before the accident indicated:

They performed Sungshan→Makung→Kaohsiung→Makung→Kaohsiung passenger flight missions in the afternoon, December 17, 2002. It was about 2000 when they arrived at Kaohsiung and stayed overnight at Kaohsiung. About 0810 the next day, 18, they performed Kaohsiung→Makung→Kaohsiung→Makung→Sung Shan passenger flight missions and were off duty around 1200. The flights during the two days were normal without any special condition, and CM-1’s sentiments and operation were all sound and normal.

The pilot who flied with CM-1 on the last second flight before the accident indicated:

In the afternoon, December 14, 2002, they performed 4 two-way passenger flights between Sungshan and Hualian and those operations were all normal. The interviewee considered CM-1’s performance prudent and no abnormal condition had been noted in previous co-working.

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[14] It refers to the items of emergency processing procedures that have to be memorized and recited by pilots.

The pilot who flied with CM-1 on CKS—Macau two-way freighter flight before the accident indicated:

The weather was fine and the flight operation normal on December 10, 2002. The anti-icing and de-icing equipment were not activated. Another pilot who flied with CM-1 on the CKS—Macau two-way freighter mission before the accident indicated: He reported to Sungshan Airport on November 21 and 22, 2002, and SOC told him that CM-1 would directly report to CKS International Airport, hence the dispatcher made a briefing to him who in turn made the briefing to CM-1 after his arrival at CKS International Airport. He also handed the whole package of flight plan over to CM-1. CM-1 read it in guest room. When a staff member told him that cargo was all loaded, CM-1 asked to fill with additional fuel to upper limit, i.e. about 2,800kg. The two-way flights were normal.

The pilot who flied with CM-2 on the last flight before the accident indicated:

At 2000, December 17, 2002, they performed passenger flight mission from Sungshan to Hualian and stayed overnight there. They performed passenger flight mission from Hualian back to Sungshan. CM-2 was the pilot flying (PF) on both missions, and his performance both in the air and in landing met with requirements. His mentality and sentiments were nothing abnormal. He was off duty after landing at Sungshan Airport. The interviewee conceived CM-2 brilliant, prudent and stable in flight performance.

The pilot who flied with CM-2 on the last second flight before the accident indicated:

They performed four two-way flights on passenger flight between Sungshan and Hualian, 8 flights in total. CM-2 was the pilot flying in 6 of them and his performance was normal.

The pilot who flied with CM-2 in CKS—Macau two-way freighter before the accident indicated:

The weather conditions were stable on November 22 and 23, 2002, the interviewee especially reminded CM-2 of cargo payloads and fueling condition, and asked him to keep informed of information about high altitude wind, unstable airflow area and altitude of icing during the flight crew briefing. CM-2 was well prepared and had solid expertise in these regards. He had a clearer awareness about the flight route than other first officers and was able to fully identify the checkpoints in or near the route. He frequently checked with the flight plan and flight chart throughout the flight. He had no problem in jotting down and responding to ATC clearances. And he demonstrated a good capability in staying alert to conditions and in controlling aircraft throughout the flight mission. The interviewee conceived that CM-2's professionalism met with the standards and he was modest in getting along with people.

1.18.3.4 A Summary of Interview with Simulator Examiner and Check Pilot on Route Check

The CAA designated examiner who conducted the latest simulator rating to CM-1 and was the same examiner who conducted the latest rating to CM-2 indicated:

He conducted the simulator rating to CM-1 and CM-2 on June 23 and July 25, 2002, respectively. The performance of both pilots was not excellent but was falling within qualifying standards. They passed the rating.

CM-1 was a little slow in reacting to emergency conditions in simulator recurrent training and not so good on such subjects as basic operation flight, single engine go-around, and instruments cross check and scanning.

CM-2 was not so familiar with “system knowledge” and “standard call out”. For example, for the item of low oil pressure, he could not tell and test whether the signals were false.

In reference to the training records, the interviewee recalled to mind something about CM-1’s simulator training and subjects: 1. No question about autopilot approach; 2. An evident deviation from flight track occurred during basic operation flight. The performance was not good, but it was gradually improved after reminded by pilot monitor (PM); 3. Crosscheck and scanning were slow; 4. When single engine approach, the same event during basic operation flight happened; and 5. Same event happened during single engine go-around. As for CM-2, he was apt to omit procedural call out and system (procedures), but it was not a problem after he finally got it. The appraisal ratings of CM-1’s and CM-2’s reactions were slow and normal respectively. Though there were shortcomings in CM-1’s training, they all fell within the norms after reminded by PM.

The check pilot who conducted the latest route check to CM-1 indicated:

A route check to CM-1 was conducted on June 11, 2002. He passed the check and he demonstrated a good control capability in a thundershower condition. He held a same test to CM-1 on February 19, 2001, and a Shortcoming Notice was issued to him. The interviewee also recalled to mind that CM-1’s performance was unstable on basic operation flight and single engine flight under low visibility condition during simulator training. CM-1’s performance had become steady after he and the interviewee reviewed the operation guidelines together and special simulator flight training was conducted for CM-1.

The check pilot who conducted the latest route check to CM-2 indicated:

A route check to CM-2 was conducted on June 3, 2002. He passed the check.

1.18.3.5 A Summary of Interview with an ATR72 Pilot who has Encountered Severe Icing

The interviewee described the course of the event:

In late November 2002, he performed GE793 (Taipei to Macau) freighter. His aircraft climbed to FL 180 around 1100 and encountered a severe icing before reaching ELATO[15]. He immediately requested descend to FL 140. The aircraft carried a full payload and was climbing at indicated airspeed 170 knots after takeoff from CKS International Airport. Icing occurred when it flied through FL 140. The climbing rate was 500ft/min between FL 150 and 160. When the climbing rate was lower than 500ft/min, the Engine Power Management System was adjusted to Maximum Continuous (MTC) position.

The aircraft was passing through cloud intermittently, which was thick before the aircraft reached ELATO. During level flight, everything was fine while he continued watching the functioning status of de-icing boots. After a while, the nose was found elevated and the airspeed slowed down. The cruise airspeed reduced from indicated airspeed 200 knots to close to but not lower than red bug. When the airspeed was lower than 190 knots, a request for descending altitude was already made to ATC and then the autopilot was disengaged and the manual operation was performed in stead to descend. At this point, the Engine Power Management System was moved to MCT position. The descending rate was 1,400ft/min. When descending to FL 160 and the indicated airspeed was 220knots, the control wheel was normal. The airspeed could be maintained though the aircraft was still within the clouds. Therefore, clearance was obtained from ATC to maintain at FL 160.

The interviewee noted as he recalled: It happened around 15 to 20 seconds from nose elevation, gradually reduced airspeed to requesting permission to descend. This was the first severe icing he encountered. He regarded it as a valuable experience worth sharing. He told every colleague he met about this event and mentioned it in crew standby room, but didn’t write a report.

1.18.3.6 Summary of Interview with CAA Principal Operations Inspector

In early 2001, CAA designated a principal operation inspector (POI) in TNA. The POI conducted a random cockpit en-route check on CM-1, in which CM-1’s flight skills and performance met the requirements of Standard Operation Procedures (SOP) and TNA. The interviewee recalled that during a TNA’s instructor pilot meeting, the improvement on CM-1’s simulator ratings with his past shortcomings was brought up and discussed.

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[15] In route A-1, the significant point on the border of Taipei and Hong Kong Flight Information Region is located at 140 nautical miles southwest of Makung VOR/DME.

There are two designated examiner simulator checking a year to foreign countries by CAA. The monthly instructor pilot meeting also serves the purpose of examining the results of simulator rating carried out in the previous month. The inspection focuses on pilot's performance including operation procedures and skills to see if the SOP is complied with. The pilot's annual route check includes oral test.

A recurrent training for pilots who have had finished their trainings is conducted once in half a year, the ground courses includes laws and regulations, flight information, JEPPESEN charts. The recurrent training can't cover all academic subjects at one session; instead these subjects shall be allocated in coordination with the simulator skill courses so that they can be all covered in a period of two years. The inspection on pilot's academic courses focuses on whether they attend classes as required, whether the contents of the courses meet the requirements, whether a test is given and whether they have passed the test.

1.18.3.7 A Summary of Interview with Flight Crew who were Flying in Nearby Area when the Accident Took Place

The two interviewees were captain and first officer of a certain airline who indicated:

They lifted from Honk Kong International Airport at 0119, December 21, 2002, and climbed to FL 270 via A-1 heading for their destination CKS International Airport. About 20 nautical miles before ELATO, they requested for permission to climb to FL 330 due to weather conditions and in the meantime entered M-750 local flight route. The wind direction was 260 degrees and wind speed 90 knots at FL 330. They heard SOS signals before flying through TONGA[16], and immediately told Taipei Area Control Center. After that, they began descending and approaching. The altitude of clouds ceiling was about 30,000 ft. They encountered turbulence, into cloud and rain when descending, but no lightening. The weather radar screen showed green, and no purple, red or yellow colors were noted. When descended to about 800 ft, the aircraft flied out of cloud.

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[16] M-750 local flight route is a key point on the border of Flight Information Region, which is located at Makung azimuth 187 degree, 25.3 nautical miles.

1.18.4 Certification of Ice Protection System

1.18.4.1 Approval of Modified Deicing Boots

According to the NTSB Accident Report National Transportation Safety Board, Safety Report, NTSB-AAR-96/01, at Roselawn, Indiana on October 31, 1994. states:

> *Aerospatiale developed a modification that consists of an increase in coverage of the active portion of the upper surface of the outer wing deicing boots form 7 percent chord to 12.5 percent chord for ATR72. The enlarged wing deicing boots were certificated by extensive dry air and icing wind tunnel tests, and by dry air and natural icing flight tests conducted by Aerospatiale and FAA flight test pilots. In addition, an ATR72 fitted with the modified boots was flown behind the icing tanker at Edwards AFB. The results of all these tests revealed that the modified boots perform their intended function within the icing requirements contained in Appendix C of Part 25 of the Federal Aviation Regulations. All U.S. – registered Model ATR72 series airplanes were modified with the new boots prior to June 1, 1995.*
>
> *Aerospatiale developed the deicing boot modification to provide an increased margin of safety in the event of an inadvertent encounter with freezing rain or freezing drizzle (SLD). With the ability to recognize that an inadvertent encounter had occurred, flight crews would be afforded an increased opportunity to safely exit those conditions. However, even with improved boots installed, Model ATR72 airplane along with all other airplanes, are not certificated for flight into known freezing drizzle or freezing rain conditions.*

1.18.4.2 Operational Considerations that May Require Changes

The NTSB Accident Report No AAR-96/01 also states that:

> *Several recommendations regarding operational considerations for the turboprop transport fleet were made. These recommendations include changes to flight crew and dispatcher training, expanded pilot reports, Air Traffic Control and pilot cooperation regarding reporting of adverse weather conditions, flight crew training in unusual attitude recovery techniques, aircraft systems design and human factors, and Master Minimal Equipment List (MMEL) relief.*

1.18.4.3 Changes to the Certification Requirements

In addition, the NTSB Accident Report No AAR-96/01 states：.

> *The FAA recognizes that the icing conditions experienced by the accident airplane, as well as other airplanes involved in earlier accidents and incidents may not be addressed adequately in the certification requirements. Therefore, the FAA has initiated the process to create a rulemaking project under the auspices of the Aviation Rulemaking Advisory Committee (ARAC). The ARAC will form a working group, made up of interested persons from the U.S. aviation industry, industry advocacy groups, and foreign manufacturers and authorities. The ARAC working group will formulate policy and suggested wording for any proposed rulemaking in the area of icing certification.*
>
> *According to the SCR report, the team concluded, based on their review and evaluation of the data, that:*
>
> *1. The ATR72 series airplanes were certificated properly in accordance with the FAA and DGAC certification basis, as defined in 14 CFR parts 21 and 25 and JAR 25, including the icing requirements contained in Appendix C of FAR/JAR 25, under the provisions of the BAA between the United States and France.*
>
> *2. The Roselawn accident conditions included SCDD outside the requirements of 14 CFR Part 25 and JAR 25. Investigations prompted by this accident suggest that these conditions may not be as infrequent as commonly believed and that accurate forecasts of SCDD conditions do not have as high a level of certitude as other precipitation. Further, there are limited means for the pilot to*

determine when the airplane has entered conditions more severe than those specified in the present certification requirements.

The SCR team also made the following recommendations:

**The current fleet of transport airplanes with unboosted flight control surfaces should be examined to ascertain that inadvertent encounters with SLD will not result in a catastrophic loss of control due to uncommanded control surface movement. The following two options should be considered:*

1. The airplane must be shown to be free from any hazard due to an encounter of any duration with the SLD environment, or

2. The following must be verified for each airplane, and procedures or restrictions must be contained in the AFM:

a. The airplane must be shown to operate safely in the SLD environment long enough to identify and safey exit the condition.

b. The flight crew must have a positive means to identify when the airplane has entered the SLD environment.

c. Safe exit procedures, including any operational restrictions or limitations, must be provided to the flight crew.

d. Means must be provided to the flight crew to indicate when all icing due to the SLD environment has been shed/melted/sublimated from critical areas of the airplane.

**FAR 25.1419, Appendix C, should be reviewed to determine if weather phenomena which are known to exist where commuter aircraft operate most often should be included*

**Rulemaking and associated advisory material should be developed for airplanes with unpowered flight control systems to address uncommanded control surface movement characteristics that are potentially catastrophic during inadvertent encounters with the SLD environment. Discussions about these new criteria should consider the criteria already contained in the certification requirements ;*

**Existing criteria used for evaluation of autopilot failures [should] be used to evaluate the acceptability of the dynamic response of the airplane to an uncommanded aileron deflection. Moreover, since* *both of these events (failure/hardover aileron deflection) can occur without pilots being directly in the loop, the three-second recognition criteria used for cruise conditions also should be adopted;*

· Policy should be developed to assure that on-board computers do not inhibit a flightcrew from using any and all systems deemed necessary to remove an airplane from danger;

· Airplane Flight Manuals (AFM) should be revised to clearly describe applicable icing limitations;

· The FAA/JAA harmonization process for consideration of handling qualities and performance of airplanes while flying in icing conditions should be accelerated ;

· Evaluate state-of-the-art ice detector technology to determine whether the certification regulations should be changed to require these devices on newly developed airplanes;

· Flightcrew and dispatcher training related to operations in adverse weather should be reevaluated for content and adequacy;

· Flightcrew should be exposed to training related to extreme unusual attitude recognition and recovery;

· Pilots should be encouraged to provide timely, precise, and realistic reports of adverse flight conditions to ATC. The tendency to minimize or understate hazardous conditions should be discouraged;

· An informational article should be placed in the Winter Operations Guidance for Air Carriers, or airline equivalent, which explains the phenomenon of uncommanded control surface movement and the hazard associated with flight into SLD conditions;

· MMEL relief for all aircraft, particularly items in Chapter 30(Ice and Rain Protection),should be reviewed for excessive repair intervals; and

·Methods to accurately forecast SLD conditions and mechanisms to disseminate that information to flightcrews in a timely manner should be improved.

1.18.5 Wreckage Recovery

1.18.5.1 Wreckage distribution

After the accident occurred, the Coast Guard launched the search and rescue operation and several fishing boats joined the operation as well. The Coast Guard found floating wreckages around 119.26E, 23.25N, 119.35E, 24.55N and 119.26E, 23.25N. The Navy searching vessels used the side scan sonar and acoustic receiver to detect the wreckage and one of the flight recorders. The area of suspected targets detected by Navy shows in Figure 1.18-7 with blue circle. The suspected targets detected by Ocean Research II (OR-II) side scan sonar shows in 1.18-6 with green circle. With these targets, the Ocean Hercules double checked the targets with its video camera that was mounted on remote operating vehicle (ROV). Those wreckage found in area of latitudes from 119°26'16"E to 119°26'23"E , longitudes from 23°28'38"N to 23°28'47"N about 60 meters of water depth shows in Figure 1.18-6 red circle. The debris field distributed in an area of about 170 meters x 280 meters (see Figure 1.18-7). The Figure also shows the most dense area of wreckage in red circle. Wreckage such as power plants, landing gears and wing tanks were found in this area. Both flight recorders were found in this area as well. The densest distribution of wreckage shows in Figure 1.18-8. Figure 1.18-7 shows the less dense area was between red line and orange line. Small debris and less dense area were between orange line and blue lines.

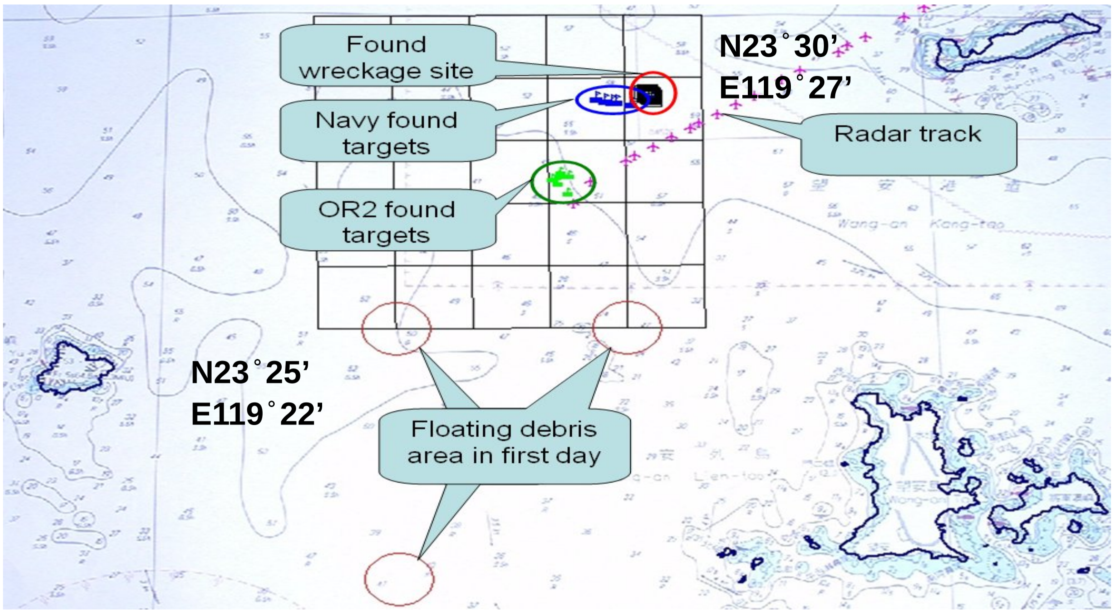

Figure 1.18-6 Shows the floating wreckage distribution, suspected targets areas and radar track.

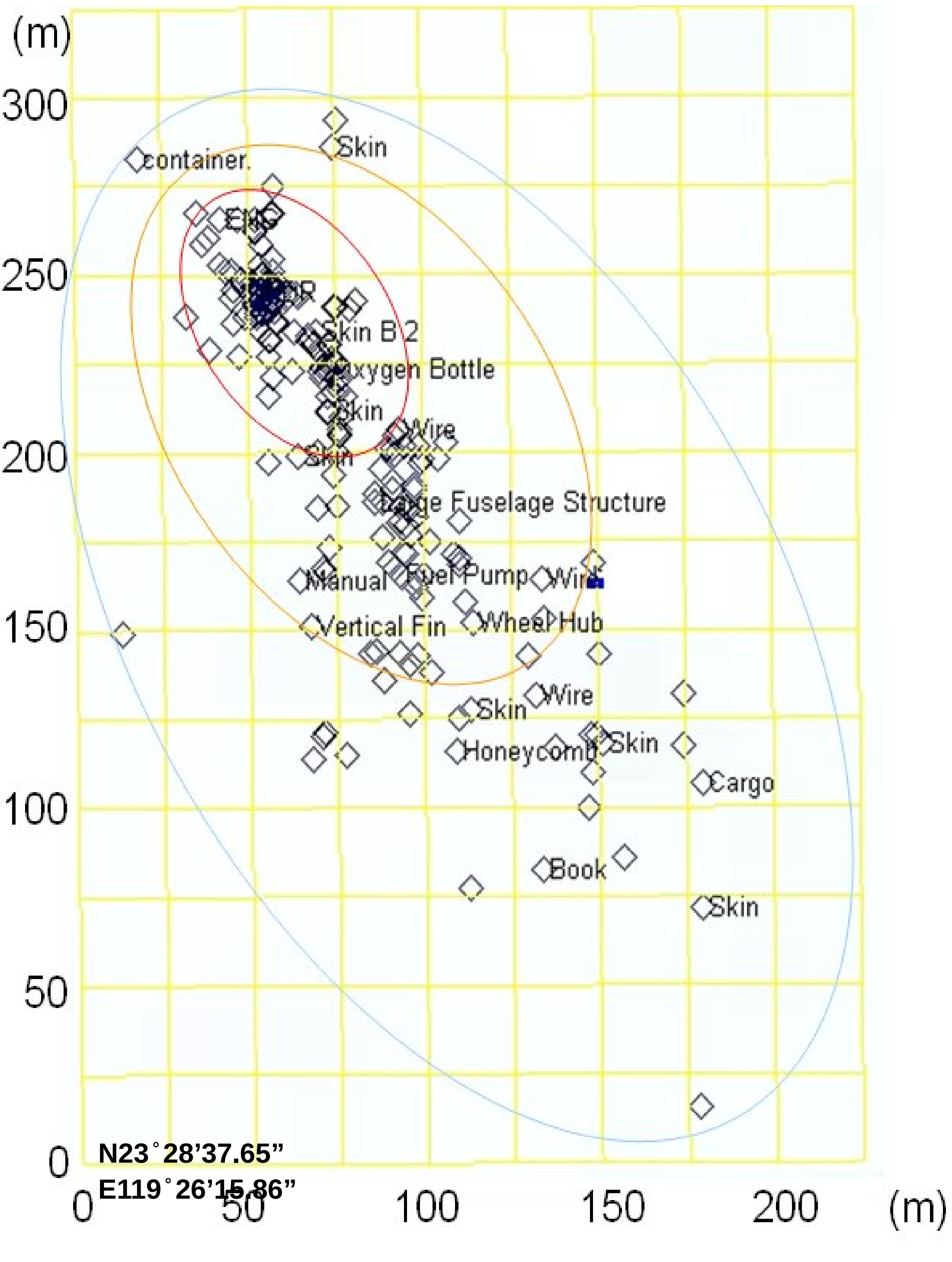

Figure 1.18-7 Wreckage distribution pattern

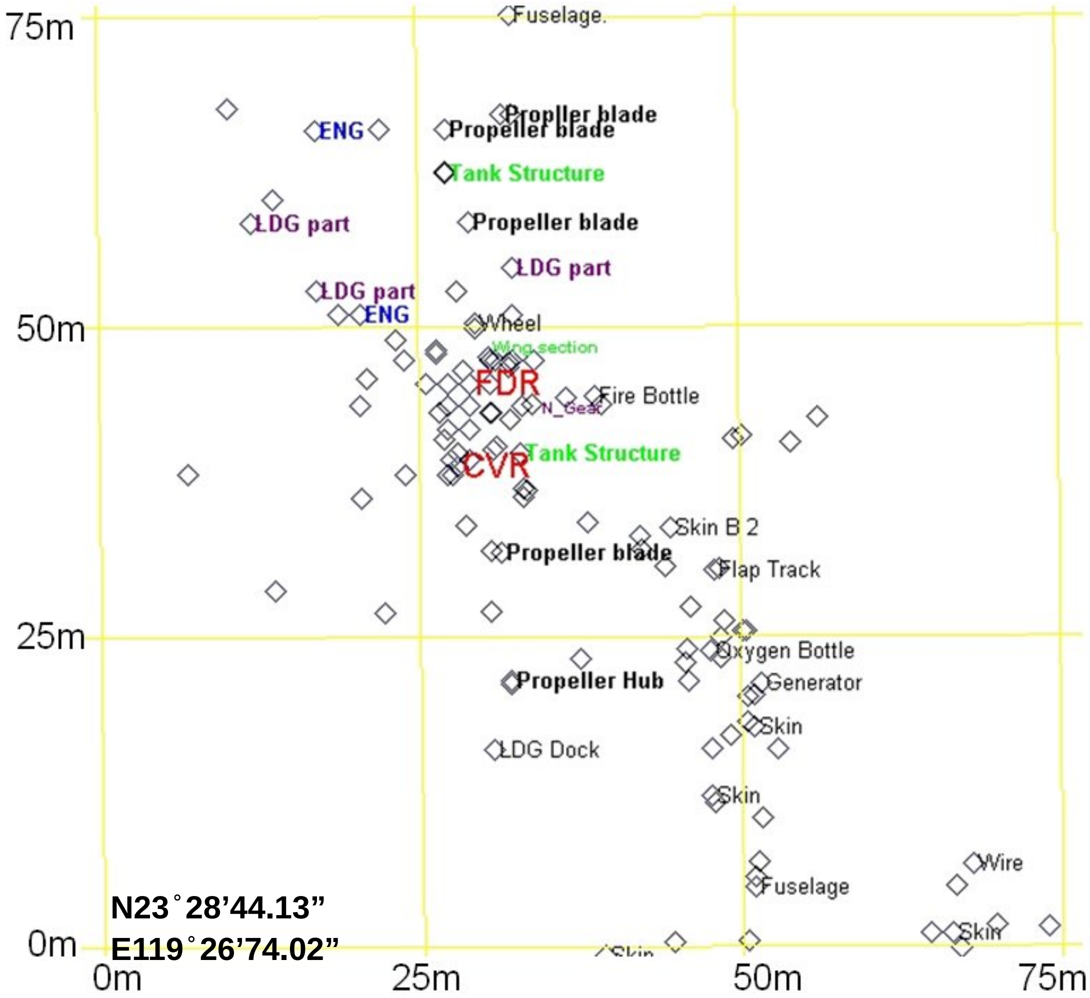

Figure 1.18-8 Wreckage distribution in dense area

1.18.5.2 Site Survey and Radar Tack

After finding the main wreckage site, Recovery Group measured the distance between the last transponder data position at the first calculated radar track and other found targets（see the purple track in Figure1.18-6）which was the reference point for site survey planning. For more precise calculation of the track, Recovery Group considered the local oval globe effect and re-calculated the track (see red track in Figure1.18-9). The distance between the last radar position and main wreckage site was about 186 meters.

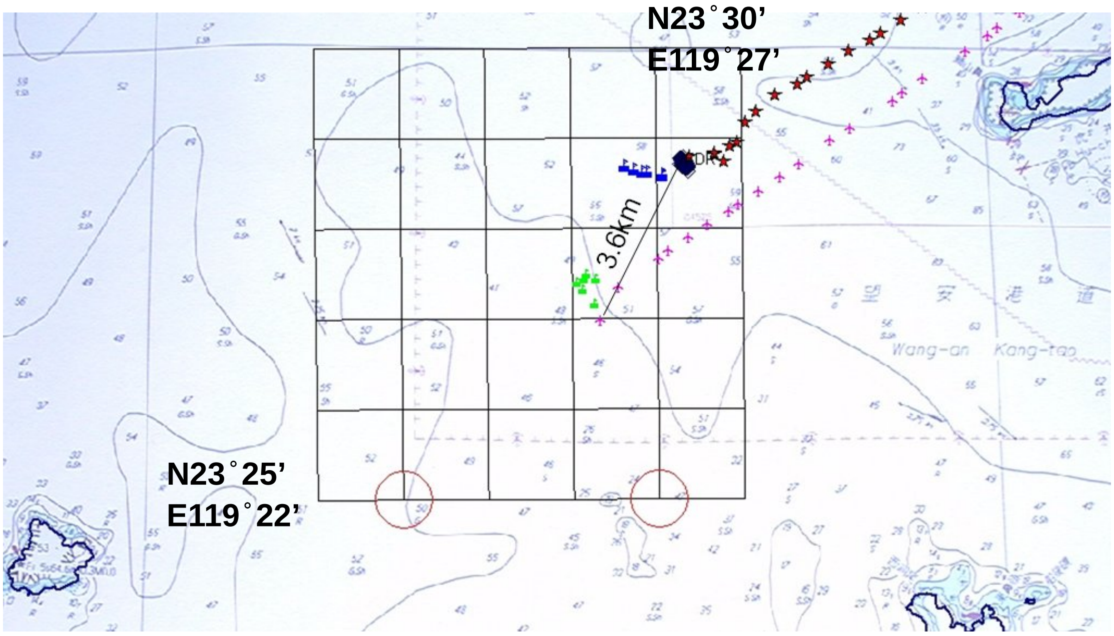

Figure 1.18-9 Comparison between radar tracks and main wreckage site

Floating wreckage: The floating wreckages found by Navy and Coast Guard was 87 pieces. Most of them are honeycomb of wing trailing edge, flaps, rudder, and elevators engine cowling and so on (refer to Figure 1.18-10). Some of them are clothing. The biggest one was number 55, which was a roll of clothing (210 cm X 17 cm). The smallest one is a taco meter of engine rpm (10cmX1cm)

Figure 1.18-10 Floating wreckages

Underwater wreckage：The Ocean Hercules recovered 10 pieces of wreckage and trawling operation recovered 102 pieces. Most of them are from of wing structure, fuselage skin, landing gears, wheel, stringer and frame (refer to Figure 1.18-11). The biggest piece is a cargo floor (no.198 with size of 205cmX135cmX6cm). The smallest one was fuselage skin (no.152 with size 24cmX8cmX0.2cm).

Figure 1.18-11 Underwater wreckage recovered by trawling operation

1.18.5.3 Search Operation

On the second day of the GE791 accident, ASC began the wreckage search operation.

Search team included the Navy, Coast Guards, Chung-Shan Institute of Science and Technology (CSIST), National Science Council (NSC) and Ocean Hercules of SMIT Salvage Company (see Figure 1.18-12~15). The search team would gauge weather condition, then hold coordination meetings to work out a search and salvage plan.

Figure 1.18-12 Underwater search and survey team- Navy

Figure 1.18-13 Underwater search and survey team- Coast Guard

Figure 1.18-14 Underwater search and survey team- OR- II

Figure 1.18-15 Salvage vessel- Ocean Hercules ROV

Search Plan

The search plan maps out search areas with reference to the location where GE791's radar target disappeared from radarscope. The plan also covers areas where the Coast Guards found floating wreckages and the aerial search team found oil patches. Then the course of current, seabed terrain, possible flight path and speed as the aircraft hit water, wind direction and speed were considered. Lastly, capabilities of the vessels and their search / salvage devices were taken into account to designate their search areas (Figure 1.18-16). A preliminary area of 25 km^2 was planned.

At the beginning of search operation, the Navy called regular meetings for reporting search results of the day, weather forecast and plans for the next operation. Representatives from the ASC, Defense Command, Navy, Tran Asia Airways, Coast Guard and Makung Airport were invited by Navy. The Safety Council provided radar data and sketch of the salvage operation region for Navy's reference, the Navy then deployed the vessels to conduct surface and underwater search operation accordingly.

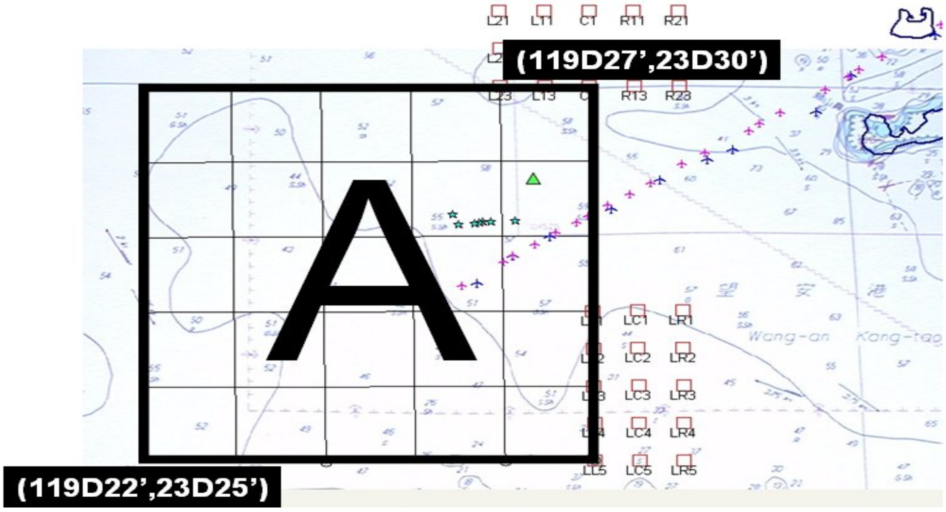

Figure 1.18-16 Initial search and survey area

Search Operation Units

The navel ship has sonar search and sound perceiving device, and began operation soon after the negotiation meeting. The Coast Guard on the other hand, teamed with ASC and CSIST in the operation (Figure 1.18-17~18). The NSC vessel Ocean Research II mainly used sonar side scan to conduct wide range search operation, while SMIT Ocean Hercules conducted underwater filming to confirm target objects. Details of operation units as follows: mode

Operation Units	Period	Form
Navel Ship Unit I	2002/12/21~2003/01/09	Underwater sound perceiving
Navel Ship Unit II	2002/12/21~2003/01/09	Sonar scan
ASC & Coast Guard	2002/12/21~2003/01/09	Underwater sound perceiving
CSIST & Coast Guard	2003/01/05~2003/01/11	Underwater sound perceiving
NSC Ocean Research II	2003/01/05~2003/01/13	Sonar side scan
SMIT Ocean Hercules	2003/01/10~2003/01/22	Sonar side scan, ROV filming

Figure 1.18-17 Search flight recorders with pinger receiver

Figure 1.18-18 CSIST engineers searched flight recorders at Coast Guard boat.

Search Result

During operation period, the Navy perceived signals at two sites suspected to be the flight recorders underwater pinger, and also found target objects at eight sites seemed to be wreckages. ASC, CSIST and the Coast Guard confirmed the pinger signal at one site, but could not confirm the signal at the second site (Figure 1.18-19~21). The Navy also assisted ASC in using triangle-positioning method to lock position of the source of recorders signal.

Suspected wreckage position and recorders underwater pinger positions as follows:

Figure 1.18-19 Flight recorders searching- BEA safety investigator

Figure 1.18-20 Flight recorders searching- ASC investigator(1)

Figure 1.18-21 Flight recorders searching- ASC investigator(2)

Table 1.18-3 Targets found by Navy

Item	Description	Dim.(mxm)	Lattitude	Longtifude
NP-1	Many wreckage scattered	8x5	23D28.716’	119D26.352
NP-2	Big metal reflection	9x5	23D28.582	119D26.07
NP-3	3 segments	10x4	23D28.644	119D25.733
NP-4	Protruded into seabed 15 degree	7x2	23D28.683	119D25.626
NP-5	Impact position on seabed	8x6	23D28.592	119D26.067
NP-6	Marks caused by undertwater spot impacted	15.9x10.3	23D28.617	119D25.883
NP-7	Unknow	7.5x6	23D28.624	119D25.826
BB-1	Suspected targets 1 flight recorders	-	23D28.298	119D25.449
BB-2	suspected target 2	-	23D28.77	119D26.33

Table 1.18-4 Targets found by Ocean Research II

Target	Priority	Dem.(m x m)	Latitude	Longtitude
A	2	5x2 4x3, 4x3, 4x2, + F	23D28.757	119D26.299
B	2	6x2, 3x1	23D28.743	119D26.325
C1	2	5x2, 6x1, + F + 5x3 (50m to N)	23D28.417	119D26.203
C	2	5x1, 3x3 + F	23D28.764	119D26.292
D	1	4x3	23D28.466	119D26.202
E	1	5x2, 4x1	27.997	119D26.113
F	1	4x1, 3x2	23D28.459	119D26.202

G	2	10x4, 10x1, 7x2, 5x2, 5x1	23D28.455	119D26.007
H	2	4x2, 3x3	23D28.570	119D26.006
I	1	5x4, 5x3	23D28.467	119D26.007
J	2	11x3 + F	23D28.307	119D25.848
K	2	6x3, 5x1	23D28.453	119D25.957
L	2	4x2 +F	23D28.328	119D25.915
M	1	8x3	23D28.600	119D25.823
N	2	9x5	23D28.457	119D25.820
O	2	5x1, 3x2	23D28.404	119D25.748
P	2	6x1	23D28.261	119D25.682

1.18.5.4 Salvage Operation

On January 9, 2003 SMIT Ocean Hercules arrived at Kaoshiung harbor for customs clearance and supply, then sailed for the accident site at Penghu waters. In early morning on January 10, 2003 the vessel was on stand by at Makung out port, and at 0900 ASC and TNA staff were ferried by the Coast Guard to the Ocean Hercules, to begin operation (Figure 1.18-22).

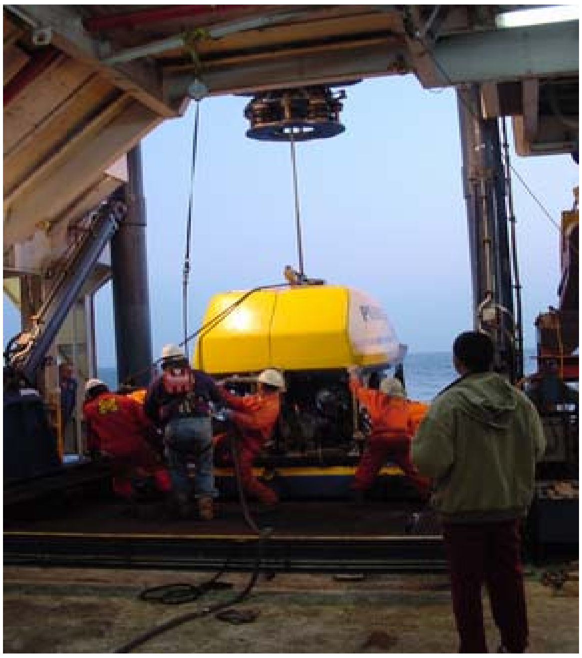

Figure 1.18-22 ROV operation on Ocean Hercules

On January 10, 2003, marine weather at wind 7 knots, gust 9 knots, wave 4 m, underwater current 5knots to 6 knots. Although the condition was over operation criterion, but nonetheless Ocean Hercules sailed to the accident site, and attempted dynamic positioning to release the ROV for underwater search. However, due to rough seas, the dynamic positioning system suffered power cut several times, thus the attempt had to be aborted, and the ROV also could not operate in such strong current. The wind slowed down at 1600, and ROV began search operation. Areas of ROV search operation are NP-1, NP-2, NP-3, NP-5, NP-6 (Figure 1.18-23), only at NP-1 were small pieces of wreckages found.

Figure 1.18-23 ROV operation_launching

In early morning of January 11, 2003, tidal current slowed down, ROV began filming operation at the eight sites provided by the Navy. Tiny pieces of wreckage were found at NP1, nothing other than coral reef was found at other sites. At 0900 the sea became rough, and ROV could not continue operation. After some discussion, decided to use underwater sonar side scan operation. The sonar side scan has a pinger installed, which could transmit precise scanned points onto the coordinates system.

Later, the underwater coordinates provided by Ocean Research II were used to plan sonar side scan range. Several target objects were found after twelve hours, their spread range were similar to the Ocean Research II data. When the current slowed down, an area of $350m^2$ with 25m grids was mapped, and ROV was sent down to scan at 50m in diameters (Figure 1.18-24).

Figure 1.18-24 Visual check with ROV video camera and forward sonar scanning

At 0626 on January 12, 2003, ROV discovered the FDR fore part and pinger, its orange casing came off. At 0800, ROV mechanical arm salvaged the FDR (Figure 1.18-25,26), and subsequently discovered wreckages such as: Brake disk, Engine mounting, Engine casing, Landing gear#2, Large engine part, Generator, etc. Work continued until 1630 when current became strong. The FDR was ferried to shore by Coast Guard vessel, and taken to ASC Lab by IIC.

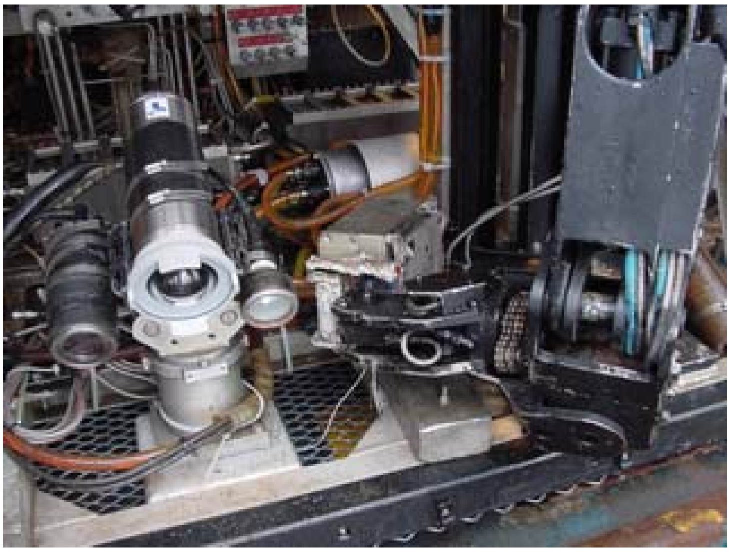

Figure 1.18-25 FDR recovered by ROV

Figure 1.18-26 FDR close view while recovered

At 0140 on January 14, 2003, ROV discovered CVR fore part（Crash Survivable Unit, CSU）, its pinger being lost, and without the orange casing. At 1900 ROV mechanical arm salvaged CVR (Figure 1.18-27,28), and subsequently discovered wreckages.

Figure 1.18-27 CVR recovered by ROV

Figure 1.18-28 CVR closed view while recovered

From January 14 to 24, 203, Ocean Hercules used scanned coordinates provided by Ocean Research II, to sweep and search the seabed, no further discoveries.

From January 21 to 24, Ocean Hercules continued salvaging operation (Figure 1.18-29), and salvaged several pieces of wreckage, including landing gear and engine propeller.

Figure 1.18-29 Diving operation

At 1200 on January 24, 2003, Ocean Hercules ceased salvage operation. Wreckages on the deck were ferried to shore by Coast Guard vessel, then land transferred to and stored at the Air Force Base in Makung (Figure 1.18-30).

Figure 1.18-30 Wreckage storage at Air Force base

During the Ocean Hercules salvage operation, ASC also planned trawler operation. After Ocean Hercules ceased salvaging, ASC coordinating with TNA. In the domestic the CSIST had skills and experiences for CI611 recovery through trawlers. Therefore, It was hired by to provide technical supports, including trawling plan, equipment support and operation. Before getting underway, the CSIST had installed an Integrated Navigation System in each trawler and the control center. Its functions included GPS, track recording, trawling line management and real time position reporting to the control center. It helped trawlers to navigate at sea and allowed people to monitor the present positions and tracks of all trawlers at the control center。 During trawler operation from February 18 to March 24, 2003, 102 wreckage pieces were salvaged, wreckage list as Appendix 15. Including the pieces salvaged by Ocean Hercules, there are a total of 199 wreckage pieces.

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2 Analysis

2.1 General

The GE791 flight crews were properly certificated and qualified in accordance with applicable Civil Aviation Regulations. The flight crew's duty and rest periods were normal within the 72 hours prior to the accident. There was no evidence indicating the crew had any physical or psychological problems, nor any use of alcohol or drugs. The aircraft was and was within allowable weight and balance limitations.

During the course of the investigation, the Safety Council concluded that this accident was unrelated to air traffic services. According to the CVR transcript, the radio garbles between ATC and GE791 from 0127:27 to 0131:03 happened before the following conditions:

0132:35: CM-2 said, "Looks like it's iced up….look at my side your side is also iced up right"

0134, 0140: The flight crew activated de-icing system.

0144:47: CM-1 said, "it's iced up there and quite a huge chunk"

0150:29: CM-1 yelled, "wow such a huge chunk"

The Safety Council also concluded that this accident was unrelated to communications.

Based on the evidence collected during the accident investigation, the analysis in weather information, flight operations, performance and flight dynamic of the flight in Ice accretion, icing detection system and stall warning system, aircraft damage, technical document control and maintenance records keeping, the anomaly of the non-recorded tracks is presented as follows:

2.2 Weather Information

2.2.1 Icing severity

2.2.1.1 Definitions

The following are the current and proposed icing severity definitions[17]:

1. Based on icing conditions encountered and/or actions required by pilots

In ICAO DOC 4444 APP. 1, there are 3 levels of icing intensity designed for reporting icing conditions in flight:

- *Light: Conditions less than moderate icing.*
- *Moderate: Conditions in which change of Heading and/or altitude may be considered desirable.*
- *Severe: Conditions in which immediate change of Heading and/or altitude may be considered essential.*

Currently accepted icing intensity definitions are those which appear in the Aeronautical Information Manual (AIM). These definitions date from the 1960s were designed for reporting icing conditions in flight:

- *Trace: Ice becomes perceptible. The rate of accumulation is slightly greater than the rate of sublimation. It is not hazardous even though deicing/anti-icing equipment is not utilized, unless encountered for an extended period of time – over 1 hour.*
- *Light: The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if the deicing/anti-icing equipment is used.*
- *Moderate: The rate of accumulation is such that even short encounters become potentially hazardous and the use of deicing/anti-icing equipment or flight diversion is necessary.*
- *Severe: The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary.*

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[17] A History and Interpretation of Aircraft Icing Intensity Definitions and FAA Rules for Operating in Icing Conditions. DOT/FAA/AR-01/91, Final Report, Nov. 2001

In response to the former in-flight icing accidents and incidents that had occurred to different models of turboprop aircraft, the FAA In-flight Aircraft Icing Plan of USA and DGAC (Direction Générale de l'Aviation Civile) Icing Committee of France undertook actions separately to perform associated researches. Such included redefining icing terminology and updating guidance on "icing reporting" for in-flight operations. The following are the proposed changes in terminology by the FAA[18]:

- *Light: The rate of ice accumulation requires occasional cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is ¼ inch to one inch (0.6 to 2.5 cm) per hour on the outer wing. The pilot should consider exiting the condition.*
- *Moderate: The rate of ice accumulation requires frequent cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is 1 to 3 inches (2.5 to 7.5 cm) per hour on the outer wing. The pilot should consider exiting the condition as soon as possible.*
- *Heavy: The rate of ice accumulation requires maximum use of the ice protection systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is more than 3 inches (7.5) per hour on the outer wing. Immediate exit from the conditions should be considered.*
- *Severe: The rate of ice accumulation is such that ice protection systems fail to remove the accumulation of ice and ice accumulates in locations not normally prone to icing, such as areas aft of protected surfaces and areas identified by the manufacturer.*

2. Based on liquid water content (LWC)

In 1950s, Meteorologists defined 4 levels of LWC as trace, light, moderate and severe. By 1956 the U.S. Air Force defined 5 levels of LWC and ice collection rates on 0.5-inch probe as trace, light, moderate, heavy and severe. The severity scale is shown in table 2.2-1.

3. Based on rate of ice accretion

This method defined icing severity in terms of the time required for 0.25 inch depth of ice to accumulate on an individual airfoil during exposure to icing conditions. It was proposed that trace, light, moderate and severe icing could correspond to conditions where 60 minutes or more, 15-60 minutes, 5-15 minutes and less than 5 minutes, respectively, are required to accumulate 0.25 inch depth of ice.

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[18] Introduction of New Terminology for The Reporting and Forecasting of In-Flight Icing. Meteorological Information Data Link Study Group Seventh Meeting, Montreal, 26 to 29 August 2003.

4. Based on the effects on the aircraft

By 1997 FAA in-flight aircraft icing plan proposed that the pilot report format be modified to include an item called a level-of-effect, based on the effects the reportable icing encounter had on the reporting aircraft. This four-level characterization of aircraft icing conditions[19] is shown in table 2.2-2.

Table 2.2-1 Based on liquid water content (LWC)

Icing Intensity Scale for forecasters		Icing Severity Scale used by the U.S. Air Force in 1956			
Icing Intensity	LWC (g/m3)	Icing Intensity	LWC (g/m3)	Ice collection rates	Aircraft Performance Criteria
				Inches per 10 miles	
Trace	0.0 - 0.1	Trace	0.0 – 0.125	0.0 – 0.09	Barely perceptible ice formations on unheated aircraft components
Light	0.1 – 0.6				
		Light	0.125 – 0.25	0.09 – 0.18	Evasive action unnecessary. (No perceptible effects on performance)
		Moderate	0.25 – 0.60	0.18 – 0.36	Evasive action desirable. (Noticeable effects on performance)
Moderate	0.6 – 1.2	Heavy	0.6 – 1.0	0.36 -0.72	Eventual, evasive action necessary. (Aircraft is unable to cope with icing situation and extended operation is not possible)
		Severe	> 1.0	> 0.72	Immediate evasive action is required. (Aircraft uses climb power to hold altitude, and continued operation is limited to a few minutes.)
Severe	> 1.2				

Table 2.2-2 Based on the effects on the aircraft

Aircraft Effect	Speed Loss (See note 1)	Power Required (See note 2)	Loss of Climb rate (See note 3)	Control (See note 4)	Vibration (See note 5)
Level 1	< 10 knots	< 10 %	< 10 %	No effect	No effect

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[19] Characterizations of Aircraft Icing Conditions. SAE Report No. AIR5396, issued March, 2001.

Level 2	10 ~ 19 knots	10 ~ 19 %	10 ~ 19 %	No effect	No effect
Level 3	20 ~39 knots	20 ~ 39%	> 20%	Unusually slow or sensitive response from control input	Controls may have slight vibration
Level 4	> 40 knots	Not able to maintain speed	Not able to climb	Little or no response to control input	May have intense buffet and / or vibration

Notes:

Speed: loss of speed due to icing. It is based on the indicated airspeed, which was being maintained prior to encountering ice on aircraft and before applying additional power to maintain original speed.

Power: additional power required to maintain aircraft speed / performance that was being maintained before encountering icing on aircraft. Refer to primary power setting, i.e., torque, rpm, or manifold pressure.

Climb: Estimated decay in rate of climb due to aircraft icing, example 10% loss in rate of climb.

Control: Effect of icing to aircraft control inputs.

Vibration/Buffet: May be felt as a general airframe buffet or sensed through the flight controls. It us not intended to refer to unusual propeller vibration in icing conditions.

2.2.1.2 Estimations of LWC, droplet size and icing severity

According to 1.16.4.1, LWC encountered by GE791 above freezing level is as follows.

TIME	LWC (g / m^3)	
	Mean	Max
01:15 - 01:25	0.35	-
01:25 - 01:31	0.40	0.70
01:31 - 01:35	0.30	0.45
01:35 - 01:38	0.25	-
01:38 - 01:48	0.25	0.30
01:48 - 01:50	0.10	1.00
01:50 - 01:52	0.10	1.00

Droplets sizes estimated by Penn State University diagram （See Appendix 16）and formula, the computed radar echo intensities and LWC are as follows.

TIME	Droplets size
01:15 - 01:40	Maximum 500μm
01:40 - 01:48	Maximum 200μm
01:48 - 01:52	Maximum 150μm, but most of droplets smaller than 50μm

From "Lucas Aerospace diagram"（See Appendix 17）, assuming that the total collection efficiency (ρ) is 0.6, ice accretion speed can be determined:

TIME	IAS (knots)	TAS (knots)	Ice Accretion Speed (mm/min)	
			Mean	Max
01:15 - 01:25	160	215	0.81	-
01:25 - 01:31	180	240	1.02	1.89
01:31 - 01:35	195	260	0.84	1.32
01:35 - 01:38	195	260	0.75	-
01:38 - 01:48	190	250	0.70	0.81
01:48 - 01:50	186	250	0.27	2.7
01:50 - 01:52	170	225	0.24	2.55

By 1998, FAA Wm. J. Hughes Technical Center developed an equation to calculate ice accretion[20]. From LEWICE[21] ice accretion model, the rate of ice buildup of any aircraft to 0.25 inch is linear in time and proportional to the product of LWC, β and V_{TAS}, where β is the maximum value of the local collection efficient, V_{TAS} is the true air speed. In equation form this is

$$dD/dT=A*LWC*\beta*V_{TAS} \quad \text{or} \quad LWC=dD/(dT*A*\beta*V_{TAS})$$

where A is an empirical constant of proportionality.

For an ATR-72 situates 10000 to 15000 feet above sea level at an OAT of -10 ℃, droplet size assumed to be uniform with a MVD (median volume diameter) of 15-20μm, β and A will be 0.3-0.4 and 0.0011 respectively.

For the last 4 minutes of the GE791, the severe icing threshold (based on the proposed condition from No. 3, 2.2.1.1) of LWC was about 0.45-0.67 g / m3, but the maximum possible LWC encountered by the GE791 was 1.00 g / m3.

From the estimations above, icing severities encountered by the GE791 were moderate to severe. Based on the effects on the aircraft, the GE791 encountered icing severity of level 4 by air speed loss from 200 knots to 158 knots.

The Safety Council consider that the icing severity encountered by GE791 was moderate to severe after the second time of the deicing system activation. The liquid water content and maximum droplet size estimations were outside the icing envelope of FAR/JAR 25 appendix C.

2.2.2 Weather Advisories

2.2.2.1 SIGMET

According to the AIP, the meteorological services for civil aviation in the Taipei FIR are provided by the Taipei Aeronautical Meteorological Center (TAMC) of the Air Navigation and Weather Services, Civil Aeronautics Administration, Ministry of Transportation and Communications. The service

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[20] A workable, Aircraft Specific Icing Severity Scheme. AIAA-98-0094, 1998. (R. Jeck,, FAA William J. Hughes Technical Center)

[21] The NASA Icing Branch has developed a computer program, called LEWICE (LEWis ICE accretion program), to provide information about the ice accumulation and extend of ice coverage (impingement limit) that might have accreted on the airplane. It’s a software used by literally hundreds of users in the aeronautics community for predicting ice shapes, collections efficiencies, and anti-icing heat requirements. The atmospheric parameters of temperature, pressure, and velocity, and the meteorological parameters of liquid water content (LWC), droplet diameter, and relative humidity are specified and used to determine the shape of the ice accretion.

is provided in accordance with the provisions contained in the following ICAO documents:

1. ICAO ANNEX 3, Meteorological Service for International Air Navigation.
2. ICAO DOC 7030, Part 4 Regional Supplementary Procedures (MET Procedures).
3. ICAO DOC 8896, Manual of Aeronautical Meteorological Practices.

From Section 3.5-Meteorological watch offices, Chapter 3-World Area Forecast System and Meteorological Offices, ICAO ANNEX 3, TAMC shall prepare, supply and disseminate SIGMET information within the Taipei FIR.

From Chapter 7- SIGMET and AIRMET Information, Aerodrome Warnings and Wind Shear Warnings, ICAO ANNEX 3, TAMC shall prepare, supply and disseminate SIGMET information within the Taipei FIR, SIGMET information shall be issued by a meteorological watch office concerning the occurrence and/or expected occurrence of specified en-route weather phenomena, which may affect the safety of aircraft operations, and of the development of those phenomena in time and space. Specified en-route weather phenomena include thunderstorm, tropical cyclone, cumulonimbus, hail, moderate to severe turbulence, severe icing, severe mountain wave, heavy duststorm, heavy sandstorm and volcanic ash. The sequence number of SIGMET messages shall be issued for the flight information region since 00:01 UTC on the day concerned. The period of validity of a SIGMET message should be not more than 6 hours, and preferably not more than 4 hours.

Clouds of the stationary front extended in a southwesterly direction from Japan to Taiwan and Hong Kong. The GMS-5 infrared imager data and the Doppler weather radar data indicated some convective movement developed from the coastal area of southern China and moved to Taiwan with the flow. Convective clouds were found in Eastern Chinese Sea, central and northern Taiwan and Taiwan Strait. SIGMETs concerning cumulonimbi were issued by the authorities of Naha FIR, Taipei FIR and Hong Kong CTA. Since there were no any AIREP or forecast of severe icing, SIGMETs concerning severe icing were not issued.

2.2.2.2 SIGWX Chart

From Section 9.6- Flight documentation — significant weather charts, Chapter 9- Service For Operators And Flight Crew Members, ICAO ANNEX 3, where information on significant en-route weather phenomena is supplied in chart form to flight crewmembers before departure, the charts shall be significant weather charts valid for a specified fixed time. Such charts shall show, as appropriate to the flight:

a Thunderstorms;

b Tropical cyclone;

c Severe squall lines;

d Moderate or severe turbulence (in cloud or clear air);

e Moderate or severe icing;

f Widespread sandstorm/duststorm;

g For flight level 100 to flight level 250, clouds associated with a to f;

h Above flight level 250, cumulonimbus cloud associated with a to f;

i Surface position of well-defined convergence zones;

j Surface positions, speed and direction of movement of frontal systems when associated with significant en-route weather phenomena;

k Tropopause heights;

l Jetstreams;

m Information on the location of volcanic eruptions...

n Information on the location of an accidental release of radioactive materials into the atmosphere.

From Section 3.3- Regional area forecast center — significant weather charts, Chapter 3- World Area Forecast System and Meteorological Offices, ICAO ANNEX 3, significant weather charts should be issued four times a day for fixed valid times of 0800, 1400, 2000 and 0200. The transmission of each forecast should be completed at least 9 hours before its validity time. The significant weather charts should include the phenomena between flight levels 250 and 630 and flight levels 100 and 250 for limited geographical areas. Significant weather charts between flight levels 250 and 630 are provided by the World Area Forecast Centers in Washington and London.

With regard to the clouds above freezing level which supercooled liquid water is possible to be existed, Hong Kong Observatory and Tokyo Aviation Weather Service Center would mark symbols for moderate icing on the significant weather charts. This is to emphasize the situation awareness of icing en-route to dispatchers and pilots. Icing severities of the aircraft are affected by the meteorological parameters of temperature, LWC and droplet size, and size and shape of airfoil, speed, angel of attack, flap position and anti-ice/de-ice equipment. The icing condition which is overlooked by large passenger aircraft may be a critical problem for turboprop aircraft.

2.2.3 Flight Documentation

The issues regarding TAMC medium-level (FL100-250) SIGWX chart provided to flight crew by TNA/SOC are as follows:

1. The interview notes and the documents gave by dispatcher showed that

he didn’t provide that chart to CM-2. It had been confirmed in Factual Information Confirmation Meeting held on October 20-24, 2003. All parties including TNA had attended the meeting.

2. On November 9, 2004, TNA provided a statement（See Appendix 18） signed by the dispatcher on October 14, 2004, explaining that the chart was included in flight documentation of GE791.

3. According to the TNA’s System Operation Control Operations Manual, flight plan controller shall complete the following flight preparation documents for daily international flights:

    a. Schedule and Crew List (Flight Clearance)

    b. Operational Flight Plan

    c. SIGWX (FL250-450)

    d. TAF and METAR

    e. Upper Wind (300Hpa, 250Hpa, 200Hpa)

    f. NOTAM

    g. Satellite Picture

    h. Flight Plan (ATC)

The Manual mentions SIGWX and upper wind charts at higher levels, above FL 250. It’s not applicable for turboprop aircraft such as GE791.

2.3 Flight Operation

2.3.1 Weather Information given to the Flight Crew

The flight crew received the weather information (see Paragraph 1.7.4) was effective until 0800 local time on December 21. The Wind and Temperature Aloft indicated the temperature at FL 180 was -10 degree Celsius in the vicinity of A-1.

Paragraph 2.02.08, Icing, ATR72 Flight Crew Operating Manual, states:

> *Atmospheric icing conditions exist when OAT on ground and for take-off is at or below 5 ℃ or when TAT in flight is at or below 7 ° C and visible moisture in the air in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow sleet and ice crystals).*

The weather information provided to the flight crew indicated the forecast temperature at cruise altitude (FL 180), was -10°C in the Taiwan Strait area. There is no evidence to prove that the flight crew was aware they might encounter icing conditions at the cruise altitude. However, the Safety Council believes that with the forecast temperatures, the flight crew should have been aware of the possibility of encountering icing conditions.

2.3.2 Severe Icing

2.3.2.1 Conditions of Potential Severe Icing

Paragraph 4.05.05, Severe Icing, ATR72 Airplane Flight Manual, states:

> *The following weather conditions may be conducive to severe in-flight icing: - Visible rain at temperatures close to 0 degrees Celsius ambient air temperature. – Droplets that splash or splatter on impact at temperatures close to 0 degrees Celsius ambient air temperature.*

The FDR had no Static Air Temperature (SAT) parameter record. The crews had the opportunity to know the SAT by manually pushing the TAT button. During the period from when the airframe de-icing system was first activated until the aircraft stalled, the TAT was between -1 and -4 degrees Celsius. The temperature outside the aircraft at the time of the accident confirms conditions of potential severe icing existed.

2.3.2.2 Indications of Icing

Paragraph 2.06.01 Icing Conditions – Severe Icing, ATR72 Airplane Flight Manual, states (Paragraph 2.02.08 and Paragraph 2.04.05 of ATR72 Flight Crew Operating Manual have the same descriptions):

> [22]*During flight, severe icing conditions that exceed those for which the airplane is certificated shall be determined by the following:*
>
> *Visual cues identified with severe icing is characterized by ice covering all or a substantial part of the unheated portion of either forward side window, possibly associated with water splashing and streaming on the windshield.*
>
> *And/or*
>
> *Unexpected decrease In speed or rate of climb.*
>
> *And/or*
>
> *The following secondary indications:*
>
> - *Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.*
> - *Accumulation of ice on the lower surface of the wing aft of the protected area.*
> - *Accumulation of ice on the propeller spinner farther aft than normally observed.*

Additional descriptions can be found in Paragraph 2.06.01 Icing, ATR72 Airplane Flight Manual, which states:

> *Note: This cue is visible after a very short exposure (about 30 seconds). At night, this pattern is put forward by the pilot's reading lights oriented towards the side window.*

The CVR recording indicates, at 0144, CM-1 said, "it's iced up there and quite a huge chunk" At 0150, CM-1 yelled, "wow such a huge chunk" At 0150, CM-1 exclaimed, "the speed is getting slower and slower. It was one hundred two hundred then one hundred and ninety but now it is one hundred and seventy" The nature of these comments speaks "*an unexpected decrease in speed or rate of climb*" which meets a phenomenon of severe icing.

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[22] AFM 4.01.01 states: The framed items correspond to actions performed by memory by the crew within a minimum period of time. FCOM 2.04.01 states: Memory items are BOXED for identification.

The Safety Council believes that the "*unexpected decrease in speed*" indicated by the airspeed indicator is a solid indication of severe icing.

2.3.2.3 Flight Crew's Situational Awareness

At 0132, the aircraft reached FL 180 and began to level off. About seven minutes later, CM-2 informed CM-1 of ice build-up.

Paragraph 3.04.01 Icing Condition, ATR72 Airplane Flight Manual, states:

> *Note : Be alert to severe icing detection.*

Paragraph 3.05 "Entering icing conditions" and "At first visual indication of ice accretion and as long as icing conditions exist", ATR72 Quick Reference Handbook states:

> ***BE ALERT TO SEVERE ICING DETECTION.***
> *In case of severe icing, refer to 1.09*

Paragraph 2.06.01 Icing Condition – Severe Icing, ATR72 Airplane Flight Manual, warning:

> ***WARNING:***
> *Severe icing may result from environmental conditions outside of those for which the airplane is certificated. Flight in freezing rain, freezing drizzle, or mixed icing conditions (super cooled liquid water and ice crystals) may result in ice build-up on protected surfaces. This ice may not be shed using the ice protecting system, and may seriously degrade the performance and controllability of the airplane.*

Paragraph 2.02.08 Severe Icing – Detection, ATR72 Flight Crew Operating Manual, describes:

> *Note: This cue is visible after a very short exposure (about 30 seconds). At night, this pattern is put forward by the pilot's reading lights oriented towards the side window.*

The CVR and FDR of the aircraft revealed:

1. The first time of the flight crew detected icing condition at 0132:35, and the airframe de-icing system was activated twice at 0134 and 0141, after each of that, the flight crew did not read the procedures of paragraph 3.05 of the Quick Reference Handbook, all the time, which included the procedures of "Entering icing conditions" and "At first visual indication of ice accretion and as long as icing conditions exist", thereby the procedure was not able to inform the flight crew and to remind them of "***BE ALERT TO SEVERE ICING DETECTION***".

2. The flight crew detected "…quite a huge chunk" and "…such a huge chunk" between 0144:47 and 0150:29, after that, no further discussion or mention regarding severe icing was noted.

3. During the period of time when the airframe de-icing system was activated twice and until the indicated airspeed dropped to 157 knots (at 0152:12), the TAT was between -1 and -4 degrees Celsius. The dialogue between the flight crew had nothing to do with this flight and none of their conversation had shown them being alert, aware or examining the above mentioned conditions regarding severe icing. There was no evidence showing they were alert to severe icing detection.”

4. From 0148:34 to 0150:50, the variation of indicated airspeed and pitch angle were recorded as follows:

   At 0131:43 (FL 180) – The indicated airspeed reached cruising airspeed 200 knots and the pitch angle of the airframe was about 1 degree.

   At 0148:34–The indicated airspeed reduced to below 190 knots.

   At 0149:04–The pitch angle of the airframe increased to 2 degrees.

   At 0149:35–The indicated airspeed decreased to below 185 knots.

   At 0150.04–The pitch angle of the airframe increased to 2.5 degrees.

   At 0150:17– The indicated airspeed decreased to below 180 knots.

   At 0150:19–The pitch angle of the airframe increased to 3 degrees.

   At 0150:28–The indicated airspeed decreased to below 175 knots.

   At 0150:32–The pitch angle of the airframe increased to 3.5 degrees.

   At 0150:48– The pitch angle of the airframe increased to 4 degrees.

   At 0150:50–The indicated airspeed decreased to below 170 knots.

   At 0150:55–When CM-1 found the airspeed was getting slower and slower, the flight crew did not take actions in accordance with Emergency Procedures while they were still discussing conditions on the pitot tube and autopilot or go higher or lower.

5. At 0151:38 when CM-1 found “…severe icing up”, he did not remind CM-2 to take actions in accordance with Emergency Procedures.

The Safety Council believes that the flight crew did not respond to the severe icing conditions with the appropriate alert situation awareness and that the aircraft might have encountered and flight through severe icing that was “*outside that for which the aircraft was certificated and might seriously degrade the performance and controllability of the aircraft*”. After the flight crew detected icing condition and the airframe de-icing system was activated twice, the flight crew did not read the procedures of the Quick Reference Handbook, thereby the procedure was not able to inform the flight crew and to remind them of “***BE ALERT TO SEVERE ICING DETECTION***”.

2.3.2.4 Handling and Recovery Procedures

2.3.2.4.1 Handling

Paragraph 2.04.05 Severe Icing, ATR72 Flight Crew Operating Manual, describes the Emergency Procedures as follows:

SEVERE ICING

- ***If severe icing as determined above is encountered accomplish the following:***
  - *Immediately increase and bug the minimum maneuver/operating icing speeds by 10 knots. Increase power, up to MAX CONT if needed.*
  - *Request priority handling from Air Traffic Control to facilitate a route or an altitude change to exit the severe icing conditions.*
  - *Avoid abrupt and excessive maneuvering that may exacerbate control difficulties.*
  - *Do not engage the autopilot.*
- ***If the autopilot is engaged,*** *hold the control wheel firmly and disengage the autopilot.*
- ***If the flaps are extended,*** *do not retract them until the airframe is clear of ice.*
- ***If an unusual roll response or uncommanded roll control movement is observed,*** *maintain the roll controls at the desired position and reduce the angle of attack by:*
  - *Pushing on the wheel as needed,*
  - *Extending flaps to 15,*
  - *Increasing power, up to MAX CONT if needed.*
- ***If the aircraft is not clear of ice:***
  - *Maintain flaps 15, for approach and landing, with ”reduced flaps APP/LDG icing speed” + 5 knots.*
  - *Multiply landing distance flaps 30 by 1.91*
  - *Report these weather conditions to Air Traffic Control.*

COMMENTS

- *Since the autopilot may mask tactile cues that indicate adverse changes in handling characteristics, use of the autopilot is prohibited when the severe icing defined above exists, or when unusual lateral trim requirements or autopilot trim warnings are encountered while the airplane is in icing conditions.*
- *Due to the limited volume of atmosphere where icing conditions unusually exists, it is possible to exit those conditions either:*
- *by climbing 2,000 or 3,000 ft, or*
- *if terrain clearance allow, by descending into a layer of air temperature above freezing, or*
- *by changing course based on information provided by ATC.*

The CVR and FDR revealed:

1. At 0150:50, CM-1 said, “The airspeed is getting slower and slower, it was a hundred two hundred then one hundred and ninety but now it is one hundred seventy” (By this time, the angle of attack of the aircraft had increased to about 4 degrees and the pitch angle to about 4 degrees. There was no evidence showing that the flight crew had taken relevant steps concerning the “severe icing”.)
2. At 0150:47, i.e., 52 seconds after the indicated airspeed decreased to 170 knots, the CVR recorded: “down down! down down down notify them quickly”. This was the first time that the crew had expressed their determination to descend to a lower level. At that time, the indicated airspeed was 162 knots, the angle of attack about 5.5 degrees and pitch angle about 4.4 degrees. Despite the fact of a rapid decrease of indicated airspeed and rapid increase of both pitch angle and angle of attack, the crew did not take relevant actions in accordance with Severe Icing Emergency Procedures. At 0151:55, when the crew requested Air Traffic Control for descending clearance to FL 160, the aircraft began to descend when its indicated airspeed was 159 knots, its angle of attack 6.5 degrees and its pitch angle 4.7 degrees.

   At 0152:10, CVR recorded sounds emitted likely from the stick-shaker. At 0152:11, the CVR recorded stall-warning sounds. The flaps remained at the “up” position and the power levers were at the same position.

The Severe Icing Emergency Procedures of ATR72 states: *If a severe icing is confirmed, immediately increase and bug the minimum maneuver/operating icing speeds by 10 knots.* Paragraph 2.0201 Minimum Maneuver/Operating Speeds – Conservative Maneuvering Speeds states: *When performance consideration does not dictate use of minimum maneuver/operating speeds, the following conservative maneuvering speeds are recommended. They cover all weights, normal operational maneuvers and flight conditions（normal* *and icing conditions）: Flaps 0: 180kt.*

According to CVR recording, there was no discussion between the crew on calculating or resetting the “minimum maneuver/operating icing speed” after the airframe de-icing system was activated. If it was set according to take-off weight, the “minimum maneuver/operating icing speed” should be around 169 knots. If it was calculated on the weights at level flight, the “minimum maneuver/operating icing speed” should be around 165 knots. There was no evidence showing the exact minimum maneuver/operating icing speed was set when the accident occurred. It was likely set according to take-off weight at 169 knots, as is a common practice.

The speed of this type aircraft, when flying in icing conditions, must not be lower than “minimum maneuver/operating icing speed”. When it’s indicated airspeed is below that speed, an effective action to increase airspeed shall be taken immediately. When a severe icing is confirmed, the crew should immediately increase and bug the minimum maneuver/operating icing speeds by 10 knots according to the Emergency Procedures above-mentioned. The crew did not apply any procedure to the aircraft except changing the altitude.

The Safety Council believes that the flight crew was too late in detecting the severe icing conditions. After detection, they did not change altitude immediately, nor apply any other Severe Icing Emergency Procedures.

2.3.2.4.2 Unusual Attitudes Recovery

The FDR and CVR revealed: During the 3.5 second period from 0152:08, the attitude of the aircraft increased from left roll 1.4 degrees to 72 degrees, and the angle of attack increased from 8 degrees to 11 degrees while the control surfaces of aileron and rudder remained unchanged. At 0152:10 and on, CVR recorded sounds emitted likely from the stick-shaker and from stall-warning signals. At 0152:08, the aircraft was in an “*unusual or non-steered rolling and pitching*” state, then a stall occurred.

From 0152:12 till the stop of FDR recording, the attitude of the aircraft continued rolling and pitching unstably, rolling repeatedly between left and right, with rapid continual rolling (up to 720 degrees at most).

The variations of positions of each control surface, pitch angles, indicated airspeeds and vertical accelerations are listed (see Table 2.3-1) as follows:

- The positions of aileron: From 0152:12 to 0152:14, approximately 12 to 14 degrees of left banking angle was developed, and from 0152:16 to 0152:19, the angle was switched to the opposite direction for about 6 to 9.5 degrees. Such angular changes to reverse direction took place again later.
- The positions of rudder: At 0152:12, the nose of the aircraft was directed 5.8 degrees to the left and up to 23.6 degrees one second

later. Within 5 seconds from 0152:15, the angle was switched to reverse direction about 2 to 8 degrees. Such angular changes to reverse direction took place again later.

- The position of elevators: During the 20 seconds from 0152:12, there were irregular variations with 1 to 3 second periods, and most of the time thereafter, the aircraft remained nose down during which there were three times when the nose down had reached approximately 5 degrees at 0152:15, 0152:19, and 0152:22 respectively.
- The positions of pitch angle: Within 4 seconds between 0152:16 and 0152:20, the nose down pitch angles varied between 15 to 26 degrees and continued to increase. From 0152:24 until stop of recording, the nose down pitch angles were more than 50 degrees with a maximum of 86 degrees at 0152:41.
- Indicated airspeed: The lowest was 157 knots at 0152:12, and it began to continue to accelerate. At 0152:28, it had exceeded the maximum maneuvering/operating speed (250 knots), reaching 255 knots and continuing to accelerate. The utmost speed was 436 knots at 0152:50 (the last second before the recording stopped).
- Vertical acceleration: At 0152:16, the value of vertical acceleration recorded was -0.27G while all other values recorded were positive. From 0152:27 until the stop of recording, it remained over 2Gs, with the largest value being 3.819Gs.
- The positions of flaps and power levers: From 0131:43 when the aircraft reached cruising altitude (FL 180) and cruising airspeed (indicated airspeed 200 knots) until the FDR stopped recording (at 0152:50), the flaps were maintained at the up position and the power levers at the same angle.

Table 2.3-1 FDR recorded data before and after the stall warning

Time (HHMM:SS)	Left Aileron Position (Deg＞0 Turn Right)	Rudder Position (Deg＞0 Turn Left)	Left Elevator Position (Deg＞0 Nose Down)	Pitch Angle (Deg＞0 Nose Up)	IAS (knots)	Vertical Accel. (G＞0 ＝ Up)
0152:09	-4.4	0.2	-3.68	3.3	158	0.912
0152:10	-2.3	0.7	-2.362	3.6	158	0.9
0152:11	-1.6	2.3	-1.835	2	158	0.974
0152:12	-12.3	-5.8	-2.275	-4.9	157	0.827
0152:13	-13.7	-23.6	-0.342	-10.4	158	0.864
0152:14	-13.7	-0.6	1.932	-3.5	161	1.294
0152:15	-3.2	4.4	4.831	-6.5	163	1.187
0152:16	8.4	3.6	-2.362	-23	164	-0.27
0152:17	4.5	1.3	-2.801	-25.6	171	0.227
0152:18	9.5	2.3	-1.923	-20.9	178	1.322
0152:19	6.1	8.3	4.392	-15.1	182	1.425
0152:20	-2.3	3.7	-2.011	-21.5	185	1.065
0152:21	1.9	-0.6	-0.782	-34.9	190	1.518
0152:22	-5.9	-7	5.534	-47.2	195	1.548
0152:23	-5.1	-0.9	-0.869	-48.6	201	0.818
0152:24	2.4	0.3	-0.957	-52.9	211	1.164
0152:25	1.8	-1	-1.133	-59.1	221	1.665
0152:26	6.3	5.2	1.054	-65.1	235	1.992
0152:27	3.5	3.2	0.264	-59	245	2.109
0152:28	4.4	6.4	-0.079	-55.8	255	2.567
0152:29	4.3	2.3	0.351	-70.1	262	2.516
0152:30	4.4	0.9	-0.782	-64.8	273	3.034
0152:31	3.7	0.8	0.527	-59.9	279	2.94
0152:32	5.3	-0.8	-1.396	-71.6	288	2.848
0152:33	4.8	-1	0.264	-71.8	299	3.011
0152:34	4.3	-1.2	-0.167	-65.6	310	3.052
0152:35	1.4	0.2	-0.167	-64.4	320	3.068
0152:36	-0.6	-1.1	-1.484	-6.87	330	3.08
0152:37	5.7	1.6	-1.396	-72.3	341	3.199
0152:38	3.2	2.7	-0.869	-76.1	356	3.123
0152:39	5.1	1.3	-1.045	-79.4	368	3.029
0152:40	0.8	1.6	-1.045	-83	377	3.386
0152:41	1.2	2.7	-0.869	-86	384	3.503
0152:42	-1.3	1.2	0.088	-84	393	3.324
0152:43	-3.5	3.3	-0.167	-76.7	402	3.382
0152:44	0.6	2.9	-2.187	-69.2	406	3.405
0152:45	-11.4	20.6	0.791	-60.7	411	3.819
0152:46	0.5	4	-5.26	-55.7	415	2.78
0152:47	0.9	1.5	-5.875	0	421	2.475
0152:48	-0.1	2.7	-1.309	-67.1	426	2.997
0152:49	-9.3	2.6	-0.694	-69.6	126	2.944
0152:50	1.1	1.7	-1.484	-62.5	436	3.35

The rudder design functions:

1. In normal operations, for directional control：During the takeoff/landing roll when on ground, or during the landing flare with crosswind for the crab maneuver, and or for turn co-ordination to prevent excessive sideslip;
2. To counteracting thrust asymmetry; and
3. In some other abnormal situations, such as runaway rudder trim, aileron jam, landing with unsafe indications, or landing gear not locked down.

The unusual attitudes recovery procedures, when steep nose down, high/no bank angle, and speed increasing rapidly, are as follows:

1. Pull back the power levers to flight idle and level wings simultaneously;
2. Pull the control column back smoothly; and
3. Maneuver the aircraft, stabilize and adjust power with nose on horizon.

When a dive angle is generated and out-of-stall, the appropriate actions that shall be taken are; pulling back the power levers, maintaining level wings and simultaneously pulling back the control column smoothly. The angles of the aircraft’s elevator control surface had varied irregularly between diving and pitching. There were three times in which the angles of elevator control surface caused the aircraft’s dive angles to augment up to approximately 5 degrees. These would not be correct pitching operations in terms of recovery of unusual attitudes. Under a normal situation, when a dive angle is generated after encountering a stall, the pilot in flight shall maintain level wings, pulling up the nose to level off, and meanwhile, adjust the angle of the power levers in concert with airspeed.

This accident occurred at midnight. According to the CVR recording, there were no signs of mental shakiness during their dialogue. The colors on the Electronic Attitude Director Indicator (EADI) of the aircraft were blue for Sky Zone, brown for Earth Zone, and a red arrow would appear on it when the diving angle was above 30 degrees. The aircraft was flying in instrument meteorological conditions, and 6 seconds after stall, the diving angle was 23 degrees, another 6 seconds later, it was up to 47 degrees, and after that, it was all above 50 degrees with 86 degrees as the maximum. The facts above-mentioned, explained that after 0152:22, no blue appeared on the EADI, but brown for Earth Zone — an EADI display that most pilots would have hardly experienced. Assumedly, the continuing augmentation of diving angle variation after stall, confused the pilots of the aircraft attitude.

After the aircraft had developed a stall and abnormal attitudes, the rudder positions and aileron control surfaces recorded by FDR, indicated some abrupt and excessive maneuvering. The recovery maneuvering did not comply with the operating procedures and techniques of Recovery of Unusual Attitudes. The performance and controllability of the aircraft may have been seriously degraded by then. However, it cannot be confirmed whether the unusual attitudes of the aircraft could have been recovered if the crew had complied with the relevant operational procedures and techniques.

2.3.2.5 Severe Icing Detection Equipment

The Ice and Rain Protection System of the ATR72 includes:

1. The Ice Detection System which includes the Ice Detector connected with warning light system; and
2. Icing Evidence Probe.

Upon detecting icing conditions, Ice Detector will activate the warning light and sounds. Icing Evidence Probe, which has a luminary, provides icing conditions that can be visualized by the flight crew. There was not any detection or warning equipment designed for detecting when severe icing developed on any type of turboprop aircraft. It totally relied on the flight crew to visually determine according to the instructions set forth in Paragraph 2.3.2.2.

Regarding the visual evidence of severe icing, the "*unexpected decrease in speed or rate of climb*" is quite definite. However, for other indications such as "*water splashing and streaming on the windshield*" could happen also during flight in sleet, which may not be determined as an indication of severe icing. As for the observation of three "secondary indications", even the crew observing closely with night luminary, it would be difficult for them to clearly observe the icing conditions on wings and propeller due to the relative positions and distances between cockpit and wings or engines. It would be difficult also to visualize the propeller spinner from ART72's cockpit; therefore the instruction "*Accumulation of ice on the propeller spinner farther aft than normally observed*" could be performed difficult. In addition, it would require flight crew to pay close and heavy attention to observe the development of icing conditions by "*pilot's reading lights oriented towards the side window at night*".

Though the severe icing exceeded the envelope for which the ATR aircraft was certificated, the possibility of development from icing conditions within the certificated range to severe icing exists. The Safety Council believes that though there are descriptions about observing indications of severe icing in Airplane Flight Manual and/or Flight Crew Operation Manual, it could be performed difficult to closely observe the indications of severe icing above-mentioned in an adverse weather environment at night.

2.3.3 Training and Rating of Flight Crew

TNA conducts ground recurrent training for its pilots on a twice-per-year basis. The contents and rating information are provided in Section 1.5 and Paragraph 1.17.1.3.2. Two hours are allocated for abnormal aircraft system operations in each ground recurrent training conducted twice a year. This class is aligned with the flight recurrent training which every three years, provides a total of 12 hours for the ground recurrent training. A 12-hour time span for abnormal aircraft system operations is assumedly not sufficient to cover all abnormal-operation-related training such as indications and detections of severe icing, and Emergency Procedures. There is a quiz questions pool available for reference before a ground recurrent training test. The questions for each test are selected from the questions pool or self-designed by instructor. These limited quiz questions are not able to fully cover the abnormal operations.

Aircraft operators shall establish ground academic and flight training programs to "*ensure that all flight crewmembers are adequately trained to perform their assigned duties*[23]." The training programs shall include flight crew resource management and emergency procedures under situations of airframe or system malfunctions, fire and other abnormalities. The pilot-in-command shall *ensure that the checklists are complied with in detail*[24].

The analysis in Paragraph 2.3.2 indicates that the crew:

- Did not adhere to "*Be alert to the severe icing detection*" requirement stated in Airplane Flight Manual when flying in a potential severe icing weather environment;
- Did not apply the instructions of flight crew resource management to remind and designate tasks of keeping alert to severe icing conditions and observe the indications of severe icing;
- Did not detect the indications of severe icing in a timely manner;
- Did not take timely actions according to Emergency Procedures and many of the procedures were not performed; and
- Did not apply the maneuvering/operating guidelines to recover unusual attitude.

In summary, the flight crew was not as conversant as they should be with the indications, observations, situational awareness, flight crew resource management and recovery of unusual attitudes in respect to severe icing. The Safety Council believes that TNA's training and rating of aircraft severe icing for this crewmembers have not been effective and that the crewmembers have not developed a familiarity with the Note[25], CAUTION[26] and WARNING[27] set forth in Flight Crew Operating Manual and Airplane

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[23] Article 148 of Aircraft Flight Operation Regulations.

[24] Item 2, Article 140 of Aircraft Flight Operation Regulations.

[25] An operating procedure, technique etc… considered essential to emphasize.

[26] An operating procedure, technique etc… which may result in damage to equipment if not carefully followed.

Flight Manual to adequately perform their duties.

2.3.4 Flight Operation Management

2.3.4.1 Abnormal Incident Report

A certain crewmember of the ATR fleet who carried out the same mission about one month before the accident, encountered severe icing indications (see Paragraph 1.18.3.5 for details). He only told his colleagues around him about the severe icing indications after he had experienced it, but did not write a Flight Crew Report.

Despite an established flight safety report system in TNA, as described in Paragraph 1.17.1.3, the crewmember did not write the Flight Crew Report with respect to the conditions of the severe icing indications he encountered and the actions he took.

The Safety Council believes that if the crewmember who had experienced the severe icing indications, did write a “Flight Crew Report” and TNA had properly circulated it for crew information, the fleet pilots’ situational awareness of severe icing should have been enhanced.

2.3.4.2 Flight Crew Reporting Procedures

CM-1 headed for CKS airport directly to report before the flight mission. The dispatcher at Sungshan airport only made an on-the-phone briefing (see Paragraph 1.18.3.1).

The Operations Manual of TNA System Operation Center, stipulates that for international flights departing from CKS airport or domestic flights departing from Sungshan airport, crewmembers have to report to TNA System Operation Center at Sungshan airport to complete their briefing procedures. Then, the pilot-in-command and dispatcher will sign on the flight plan together. CM-1’s violation of reporting procedures. However, there is no evidence showing that such flaw had anything to do with the accident.

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[27] An operating procedure, technique etc… which may result in injury or loss of life if not carefully followed.

2.3.5 Compilation of Relevant Flight Manuals

2.3.5.1 Enhancing Warning and Memory Items about Severe Icing

In this accident, the crew "*attached deficient alertness to the development from icing to severe icing conditions*", "detected severe icing when it was too late", and "*handled the severe icing conditions improperly*". They were not able to detect the severe icing conditions in a timely manner and the development of severe icing advanced due to weather conditions existing at that time. To prevent accidents resulting from detecting severe icing too late, all chapters/sections concerning "*severe icing*" in ATR Airplane Flight Manual, Flight Crew Operating Manual and Quick Reference Handbook shall have "WARNING" remarks to inform pilots.

The Safety Council believes that in order to win time efficiency, it shall consider to turn selected critical items from the severe icing Emergency Procedures to memory items. Therefore pilots would have no need to check the manuals in case severe icing is not detected in a timely manner.

2.3.5.2 Compilation of Special Remarks

The "WARNING" remarks in Paragraph 2.06.01 Severe Icing of ATR72 Airplane Flight Manual, and the "NOTE" remarks in Paragraph 2.02.08 Awareness of Severe Icing of ATR72 Flight Crew Operating Manual, appear in relevant manuals（See Appendix 19） as follows:

- The above-mentioned NOTE remarks are not appearing in Paragraph 2.06.01 Limits of Severe Icing, Airplane Flight Manual;
- The above-mentioned WARNING and NOTE remarks are not appearing in Paragraph 4.05.05 Severe Icing Emergency Procedures, Airplane Flight Manual;
- The abovementioned WARNING remarks are not appearing on p.13, Paragraph 2.02.08 Awareness of Severe Icing in Adverse Weather, Flight Crew Operating Manual;
- The above-mentioned WARNING and NOTE remarks are not appearing on p.9, Paragraph 2.04.05 Severe Icing Emergency Procedures, Flight Crew Operating Manual; and
- The above-mentioned WARNING and NOTE remarks are not appearing in QRH 1.09 Severe Icing Emergency Procedures.

The important WARNING and NOTE information are not adequately appearing in all of the relevant Chapter/Section of ATR's Airplane Flight Manual and Flight Crew Operating Manual.

2.4 Performance and Flight Dynamic of the Flight in Ice Accretion

According to CVR and FDR data, GE791 encountered icing condition while cruising 18,000 ft. This section analyzes the aerodynamic performance and dynamic of the flight during ice accretion based on GE791 configuration and flight data.

ATR Performance Analysis of the GE791 (refer to Appendix 20) indicates a drag increase of 100 counts (equivalent to +35 % of aircraft drag in normal flight condition). This drag increase induced airspeed decay by 10 knots in the first 25 minutes. The drag continued to increase and four minutes prior to autopilot disengaged was 500 counts (equivalent to +170 % of drag in normal flight condition) and airspeed decayed down to 158 knots.

2.4.1 Analysis of Previous ATR 42/72 Incidents/Accidents

To gather as much as information, on the ATR severe ice encounters, an analysis of the seven previous severe ice events have been collected and analyzed. (See table 1.16-1)

1. American Eagle Flight 4184, Roselawn, Indiana, USA, October 31, 1994. （Accident, ATR 72-212,NTSB）

De-Icing Equipment: Standard de-icing boots.

During holding and beginning of descent phase, from 10,000 feet, the aircraft was flying at flaps extended 15 degrees in severe icing conditions, airframe de-icing equipment activated for 25 minutes. Because of flaps extended, with a low AOA, airframe icing only caused a drag increase of about 40 counts. When they began to descent the flight crew retracted the flaps to 0 degrees. An airflow separation due to a ridge of ice, which accreted behind the boots while the aircraft was flying at flaps 15, induced an aileron hinge moment reversal”.

Probable Cause: Aircraft loss of control, attributed to a sudden and unexpected aileron hinge moment reversal that occurred after a ridge of ice accreted beyond the deicing boots.

The Roselawn accident is largely discussed and studied by NTSB and results are given in the final report including result of petition for reconsideration.

After Roselawn accident, the manufacturer decided:

- To extend the outer de-icing boots, to prevent the formation of any ridge of ice in front of the aileron.
- To provide the flight crew with the means, discovered during such tests, to

recognize the entry into severe icing conditions.(side window; ice evidence probe, speed decay)

- To provide updated procedure for flight in severe ice conditions such as autopilot disengage and start the escape maneuver maximum of thrust available to the engines.
- To provide the crew with the adequate procedures for aircraft recovery in case of upset.

The whole ATR fleet, including the TNA ATR 72-210 flight GE791, had the modified boots, ice evidence probe, procedures in the flight manual updated, including the indication of the means to detect the severe ice conditions and the flight procedures.

2. Near Cottbus, Germany, December 14, 1998. （Incident, ATR 42-300, BFU）

De-Icing Equipment: External wing boots extended + Flap extension allowed above VFE. Procedure: no autopilot in severe ice condition, Visual cues to recognize severe ice, Minimum airspeed in ice condition, upset recovery procedure.

During climbing at 13,500ft the aircraft encountered icing, flight crew activated airframe-deicing for about 12 minutes. Airframe icing caused drag increase of about 500 counts, and caused an asymmetric wing stall, followed by autopilot disengaged.

Probable Cause: The crew lost control after aircraft entered and continued operation in severe icing conditions outside appendix C. The crew had failed to associate icing of the forward side windows with severe icing phenomenon.

3. Trans States Airlines approach to Lambert-ST-Louis International Airport, Missouri, USA, January 7, 1999.（Incident, ATR 42-300, NTSB）

De-Icing Equipment: External wing boots extended + Flap extension allowed above VFE. Procedure: no autopilot in severe ice condition, Visual cues to recognize severe ice, Minimum airspeed in ice condition, upset recovery procedure

The aircraft was flying in severe icing condition during an approach at flap 15, when the flap were lowered to 30 degrees and a moderate pitch down and roll occurred. The crew retracted the flap, when the aircraft was outside the severe ice zone the flap were lowered again completing the flight with an eventful landing.

Probable Cause: The flight crew noticed during approach (altitude 3,000 ft) ice shapes on the side windows and aircraft deceleration. The aircraft was flying in identified severe ice conditions (visual cues). AFM procedure was updated to prohibit the approach in severe ice condition with flap 30.

4. Near Berlin-Tegel, Germany, January 28, 2000. （Incident, ATR 42-300, BFU）

De-Icing Equipment: External wing boots extended + Flap extension allowed above VFE. Procedure: no autopilot in severe ice condition, Visual cues to recognize severe ice, Minimum airspeed in ice condition, upset recovery procedure.

During final approach (from altitude 6,000 ft to 3,000 ft) the aircraft encountered icing; flight crew activated airframe-deicing equipment about 8 minutes. Airframe icing caused drag increases of about 400 counts. Flight crew performed manual flight and the AFM procedures to exist the icing conditions.

Probable Cause: The aircraft had entered atmospheric conditions of severe icing for which it is not certificated. Application of the AFM procedures implemented for such encounter allowed the flight crew to exit these severe icing conditions and to continue a safe flight and landing.

5. Jet Airways over the Indian, June 12, 2000.（Incident, ATR 72-212A, ATR）

De-Icing Equipment: External wing boots extended + Flap extension allowed above VFE. Median wing boots extended + AAS[28] new flashing logic.

During cruising at 17,000 ft the aircraft encountered icing, after prolonged exposure to icing conditions with the airframe de-icing switch off. Airframe icing caused drag increase about 150 counts caused the wings asymmetric stall, and then caused autopilot disengaged.

Probable Cause: After prolonged exposure to icing conditions with the airframe de-icing OFF, the aircraft lost 25 Knots of speed followed by a mild roll of 15°.

6. Air New Zealand over the New Zealand, May 2, 2002.（Incident, ATR 72-212A, ATR）

De-Icing Equipment: External wing boots extended + Flap extension allowed above VFE. Median wing boots extended + AAS new flashing logic.

During cruising at 16,000 ft the aircraft encountered icing, flight crew activated airframe deicing about 17 minutes. Airframe icing caused drag increase about 520 counts, caused the wings asymmetric stall and roll upset and then caused autopilot disengaged.

Probable Cause: Aircraft encountered the icing conditions during climb. The crew noticed ice shapes on the side windows and decreasing rate of climb. The non-application of AFM severe icing emergency procedure (icing speed increase by 10 Knotsand autopilot disengage) led the aircraft to angle of attack where aerodynamics anomalies appeared. The subsequent crew action of quickly reducing the angle of attack recovered a normal situation.

7. Czech Airlines, December 12, 2002. （Incident, ATR 42-400, ATR）

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[28] Amber caution light & Icing AOA light

De-Icing Equipment: External wing boots extended + Flap extension allowed above VFE. Median wing boots extended + AAS new flashing logic.

During climbing (16,600 ft) the aircraft encountered icing, flight crew activated airframe deicing about 12 minutes. Airframe icing caused drag increase about 480 counts caused the asymmetric wings stall, and then caused autopilot disengaged.

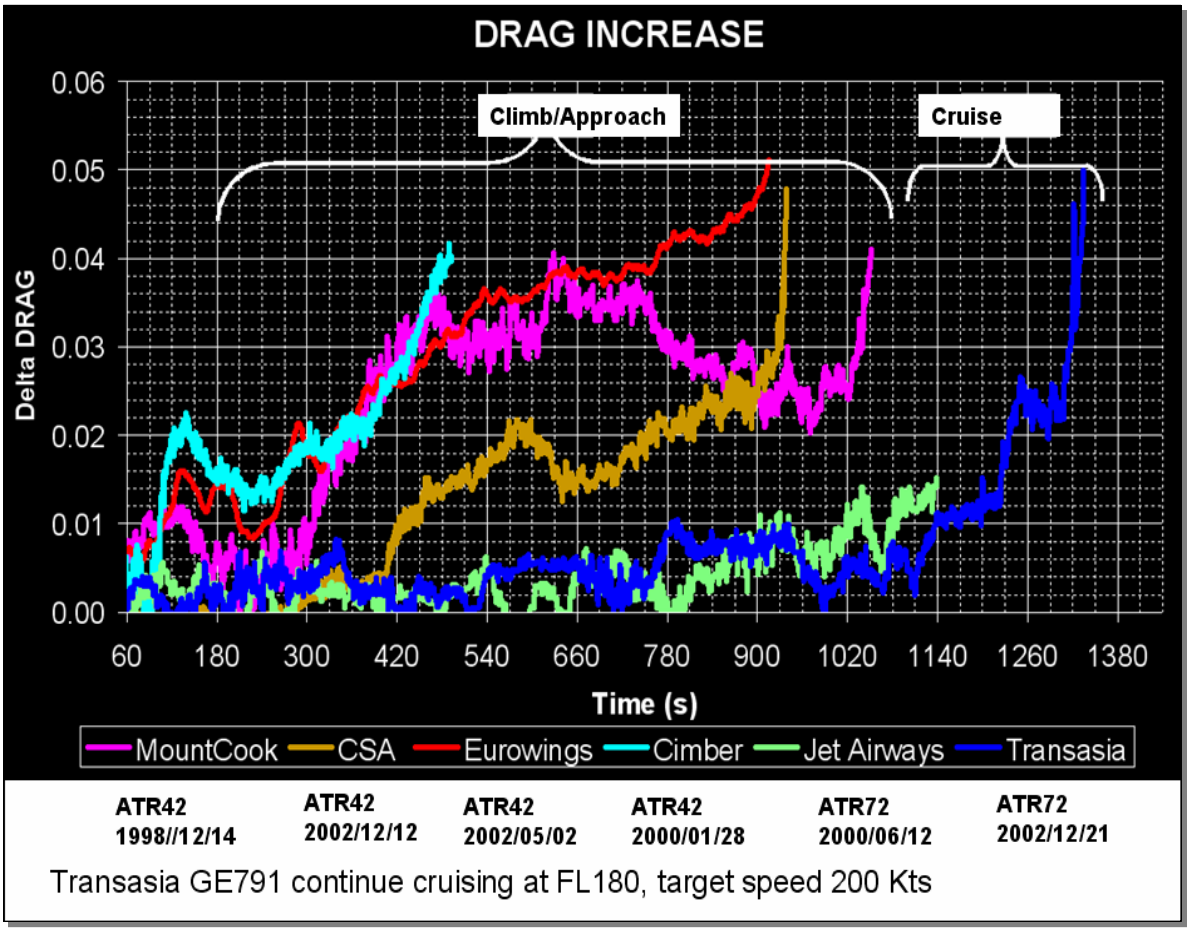
Probable Cause: The crew noticed ice shapes on the side windows and decreasing rate of climb, they continued operation in severe icing conditions and stalled with un-commanded roll excursion.

Seven severe icing related incidents / accidents involving ATR 42 / 72 occurred from 1994 to 2002. The analysis of these events gives the following significant details:

- In case no. (1/2/3/4/6/7), the flightcrews have recognized the severe ice conditions through side window cues for all incidents except the no. 5. For which the report is not available but the flight analysis and the increase of drag level clearly indicate that the aircraft flow through severe ice conditions.
- All events occurred while the aircraft was flying into severe ice conditions with autopilot engaged which is not in agreement with procedures reported into aircraft AFM.
- In all events except no.1 (Roselawn: because of small drag) and no.3 (severe ice encounter in approach: no rate of climb or speed reduction) the aircraft experienced rate of climb or speed decay which are one of the means to recognize severe ice conditions.
- The ice protection system was on level III, which means: AOA, engine, and airframe protection on except for no.5 were airframe anti ice system was off and the flight was most probably in severe ice.
- All aircraft were equipped with the extended boots (in front of ailerons) which prevent the formation of ridge of ice in front of aileron, which were the causes of Roselawn accident.

The drag variation versus time of above mentioned ATR42/72 accidents/incidents related to icing condition is plotted in Figure 2.4-1.

The Roselawn accident is not included into Figure 2.4-1, because of the very small amount of drag created by severe ice, in fact the ice accumulated was only in front of aileron and the roll upset was created by the influence of this ridge on the aileron hinge moment variation. All the other events presented a very high drag increase with large speed penalties.



Transasia GE791 continue cruising at FL180, target speed 200 Kts

Figure 2.4-1 Aircraft extra drag due to ice versus time after Roselawn (1998~2002)

The Safety Council believes that ATR 42 /72 after prolonged exposure to severe icing conditions and continuously activated the airframe de-icing, icing accretion may caused drag increased to 500 counts, and caused the aircraft upset or stall.

8. TransAsia Airways over Penghu Islands, Taiwan, December 21, 2002.（Accident, ATR 72-202, ASC）

De-Icing Equipment: External wing boots extended + Flap extension allowed above VFE. Median wing boots extended + AAS new flashing logic.

During cruising (18,000 ft) the aircraft encountered icing, flight crew activated airframe deicing about 18.5 minutes. Airframe icing caused drag increases of about 500 counts, and caused the asymmetric wings stall, left roll upset and autopilot disengaged.

Probable Cause: to be determined

2.4.2 GE791 Performance Analysis of Ice Accretion

The calculation of lift and drag during cruising phase was based upon the FDR parameters, weight and balance information of GE791. There are two methods to balance the aircraft’s lift and weight during cruising. One is to increase airspeed by increasing engine power the other is to increase lift (CL) by increasing angle of attack (AOA). Therefore, the increase of lift will also increase the drag. Following equation (1) describes the relationship of lift and weight.

$$W = L = 0.5\rho V_{tas}^{2} C_L \quad \text{--} \quad (1a)$$

$$C_L = C_{L,0} + C_{L\alpha}\alpha$$

$$C_D = C_{D,0} + {C_L^2}\big/{\pi e AR}; AR = {b^2}\big/{S} \quad \text{--} \quad (1b)$$

Figure 2.4-2 plots the GE791’s extra drag due to ice versus time, from cruising at 18,000 ft until autopilot disengaged. Three lines are plotted: clean configuration (blue line), failure ice shape[29] (green line) and GE 791 icing encounter (red circle). According to the aircraft drag calculation from FDR data, the result is consistent with that derived by the ATR, respectively plotted by symbols ”+” and ”o”.

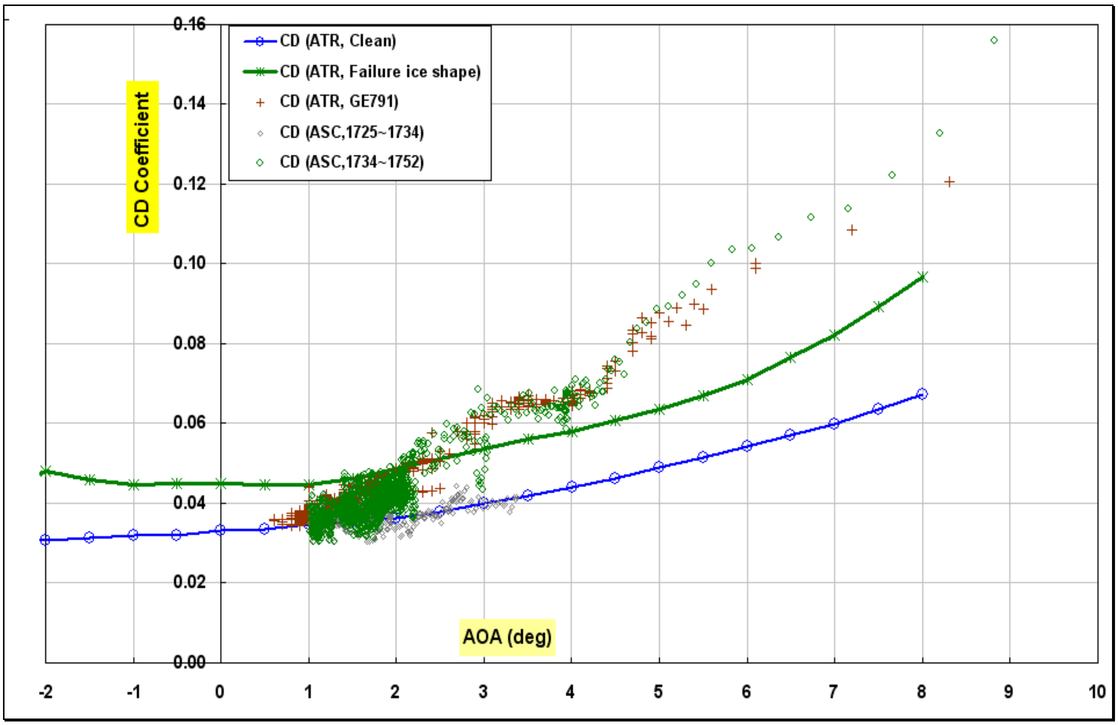


Figure 2.4-2 The extra drag of GE791 due to ice versus time (blue: clean configuration; green: de-icing boots inoperative; red: GE791 ice accretion)

During cruising at 18,000 ft (0125:00 ~0152:12), the GE791 airframe de-icing conditions, airspeed, altitude, outside air temperature, drag, angle of attack versus

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[29] Failure Ice shape: aircraft polluted with ice shapes due to boots not operating as per certification requirements FAR/JAR 25 Appendix C.

time is plotted in Figure 2.4-3 (a) ~ (c). Figure 2.4-4 illustrates the lift-drag ratio versus true angle of attack.

Due to the effect of icing accretion, the lift and drag variation of GE791 was discussed in following stages:

Time 0125:00 ~ 0134:28

According to the ATR Performance Analysis Report (Appendix 20), the indicated airspeed with autopilot engaged was 202 knots, and with an estimated weight of 20,800 Kg.

At 0124:56, the aircraft climbed to cruising altitude of 18,000 ft. At 0132:34, airspeed was 201 knots. Prior to the first activation of airframe de-icing, airspeed decayed to 197 knots, outside air temperature was about minus 12 º C, vertical acceleration variation of 0.12G. Figure 2.4-3 shows that at 0131, the drag due to ice accretion become appreciable. From 0132:30 to 0134:28, the aircraft probably flew into clouds and encountered light to moderate turbulence. During this period the airspeed was 199 ± 2 knots, lift-drag ratio was 11.4, AOA was 1.0º and pitch attitude was 1.5º.

The Safety Council believes that GE791 encountered icing at 0131 and remained in cloud conditions; the variation of 0.12G in vertical acceleration was caused by light to moderate turbulence.

Time 0134:29 ~ 0141:24

According to CVR, at 0134:29, a sound of single chime was recorded. FDR data indicated that flight crew immediately activated the airframe de-icing system. Thirty seconds later the aircraft decelerated to 194 knots (0135:03), lift-drag ratio was 14.3, and true AOA was 1.4 º and pitch attitude was 1.9 º. At 0136:19, the indicated airspeed speed back to 199 knots, which shows the airframe de-icing system was effective.

At 0138:08, the indicated airspeed resumed to 200 knots, and maintained that speed until 0138:22. From 0138:22 to 0141:24, the airframe de-icing system was switched off, outside air temperature was minus 11º C. Vertical acceleration indicated the variation of 0.1G, the aircraft was probably in clouds again and encountered moderate turbulence. FDR data indicated the airspeed decayed from 200 knots to 195±2 knots, lift-drag ratio was 11.6, true AOA was 1.3º and pitch attitude 1.2º. During this stage the icing accretion caused about 5% decrease in lift-drag ratio.

Figure 2.4-3 shows after the airframe de-icing system switched off, the extra drag due to icing accretion increased about 20 counts higher than clean configuration. At time 0140, drag counts raised to 50 counts.

After airframe de-icing system switched off, it is highly probable that the residual ice covered on the wings caused the drag higher than clean configuration about 50 counts, lift-drag ratio lost about 5%.

Time 0141:25 ~ 0152:12

(a) 0141:25 ~ 0145:20

According to CVR, at 0141:21.7, a single sound chime was recorded. At 0142:25 (3 second after the single chime) flight crew activated the airframe de-icing system. Outside air temperature was minus 10ºC. Four minutes after the second activation of de-icing system, the indicated airspeed decelerated from 196 knots to 186 knots, lift-drag ratio was 11.3, true AOA was 1.8º and pitch attitude was 2.1º. During this stage, icing accretion caused about 20% decreased in lift-drag ratio.

(b) 0145:20 ~ 0150:30

At 0144:47 (3 min 25 sec after the single chime), the indicated airspeed was 188 knots. At this moment, CM1 mentioned “It’s iced up quite a huge chunk.” During the next 4 minutes, no discussion in cockpit on icing was recorded.

From 0145:20 to 0147:30, airframe de-icing system continued “ON”, the indicated airspeed resumed from 188 knots to 192 knots. Moreover, indicated airspeed maintained at 190±2 knots until 0148:26. From 0148:27 (7 minutes after the single chime) until 0150:30, the indicated airspeed decayed from 191 knots to 174 knots. At this moment, CM1 mentioned “Wow it’s a huge chunk.” Figure 2.4-3 indicates at 0149 the extra drag due to ice accretion increased about 100 counts, and a rapid increase tendency appeared until autopilot disengaged.

When the true AOA was greater than 2.2º (after 0150:17), Figure 2.4-4 shows that the lift-drag ratio was less than the condition of failure ice shape. At 0150:30 (9 min after the single chime), the indicated airspeed decelerated to 174 knots, the extra drag due to ice accretion increased about 200 counts, lift-drag ratio was 10, true AOA was 3º and pitch attitude was 3.5º. During this stage, the ice accretion caused about 39% decrease in lift-drag ratio.

ATR Performance Analysis Report (Appendix 20) also indicates that the true AOA was between 3º and 4.5º (0150:33 ~ 01:51:51), the lift gradient corresponding to an aircraft contaminated with ice due to de-icing boots inoperative. At the same time, the extra drag due to ice accretion was about double as much the de-icing boots inoperative conditions. The difference was a sign that GE791 encountered a severe icing condition worse than icing certification requirements of FAR/JAR 25 Appendix C.

(c) 0150:30 ~ 0152:11

At 0151:21, the indicated airspeed decelerated to 166 knots, the extra drag due to ice accretion increased about 210 counts, lift-drag ratio was 10, true AOA was 3.9º and pitch attitude was 4.0º. During this stage, the ice accretion caused about 42% loss in lift-drag ratio.

At 0151:49, CM1 mentioned “Sixteen thousand.” Two seconds later, CM2 contacted the Taipei Area Control Center: “taipei control trans asia seven nine one request descend maintain flight level one six zero.”

Beginning of the descent (Refer to Figure 2.4-5)

At: 0151:56 according to FDR the crew initiated the descent. The aircraft began to lose altitude (about 6 Ft/s), and the speed decayed to 159 kKnots. The extra drag due to ice accretion increased about 360 counts, lift-drag ratio was 8, the true AOA was 5.0º and pitch attitude was 4.8º. During this stage, ice accretion caused about 50% loss in lift-drag ratio.

At: 0151:56 to 0152:07

Despite an increase of descent rate (to about 720 Ft/min) at 0152:05 the indicated airspeed was 158Kt. The selected vertical speed (VS) stopped the speed decay but was insufficient to increase airspeed.

At 0152:07 the FDR data indicated:

Local AOA =8°

Pitch attitude = 3°

Elevator deflection = -2° (negative value: elevator trailing edge up)

Elevators trim = -0.5°

Vertical load factor =0.9 g

Left Aileron deflection = 1.55° (positive value: aileron trailing edge down).

From 0152:07 up to AP disconnection (0152:10.5), the aircraft begins to bank to the left (with 5.6°/s roll rate) despite an autopilot aileron order (up to 4.4°, then reduced to 2.5°) to counter this roll to the left.

At 0152:10.5 Indicated airspeed was 158 knots, At 0152:11 was recorded the lowest airspeed value of 157 knots. The extra drag due to ice accretion increased about 500 counts, lift-drag ratio was 5.5, true AOA was 8.3º and pitch attitude was 2.0º. During this stage, the ice accretion caused about 64% loss in lift-drag ratio.

The effect of ice accretion increased the drag of about 500 counts, lift-drag ratio loss was about 64% and the indicated airspeed decayed in about 1 min and 50 sec. from176 knots (Minimum severe icing speed) to 158 knots.

The Safety Council, after analysis of FDR and CVR data, believes that the GE791 probably encountered a severe icing condition, which was worse than icing certification requirements of FAR/JAR 25 Appendix C.

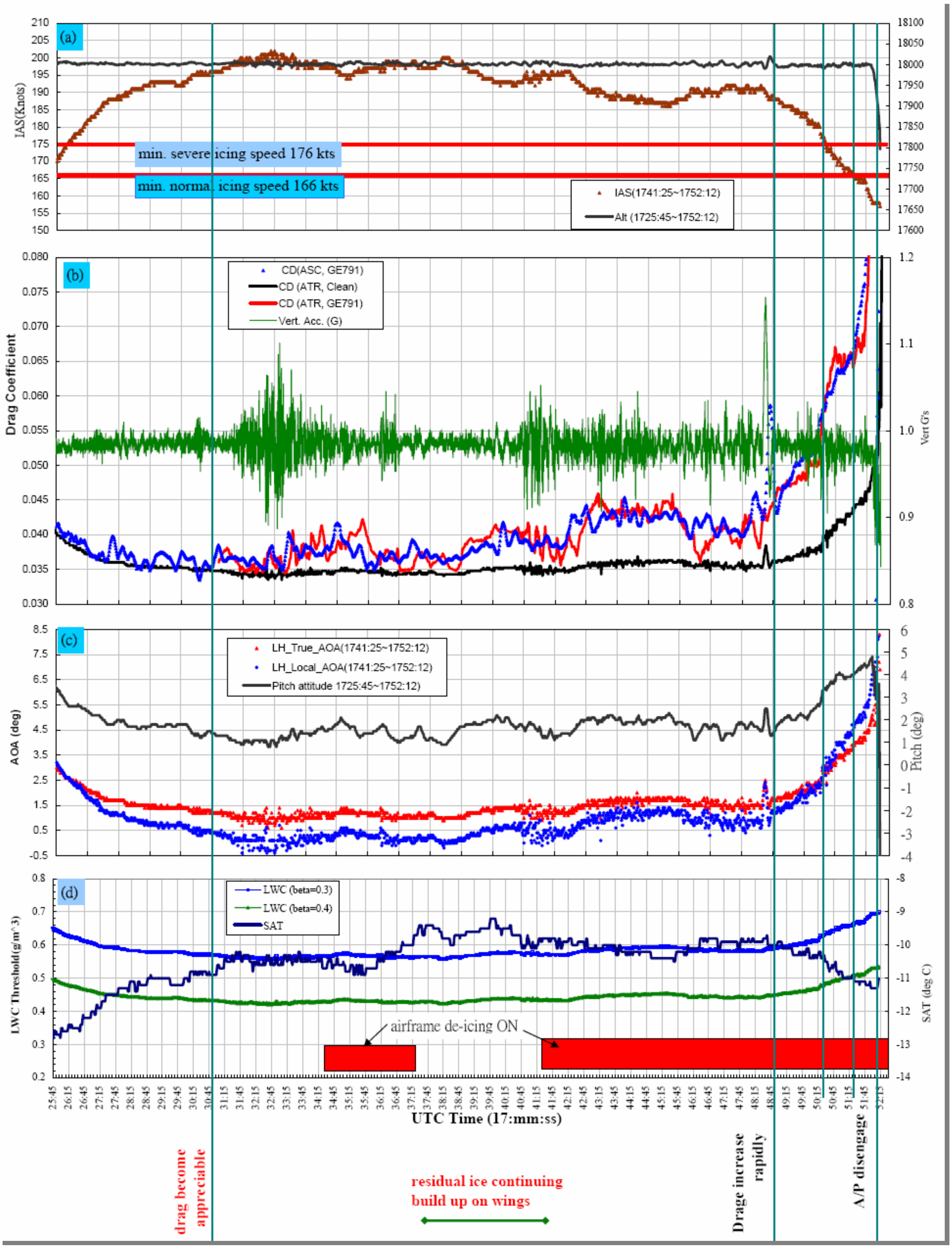

Figure 2.4-3 GE791 performance data plot due to ice accretion versus time (airspeed, altitude, OAT, drag, and severe icing threshold value of LWC)

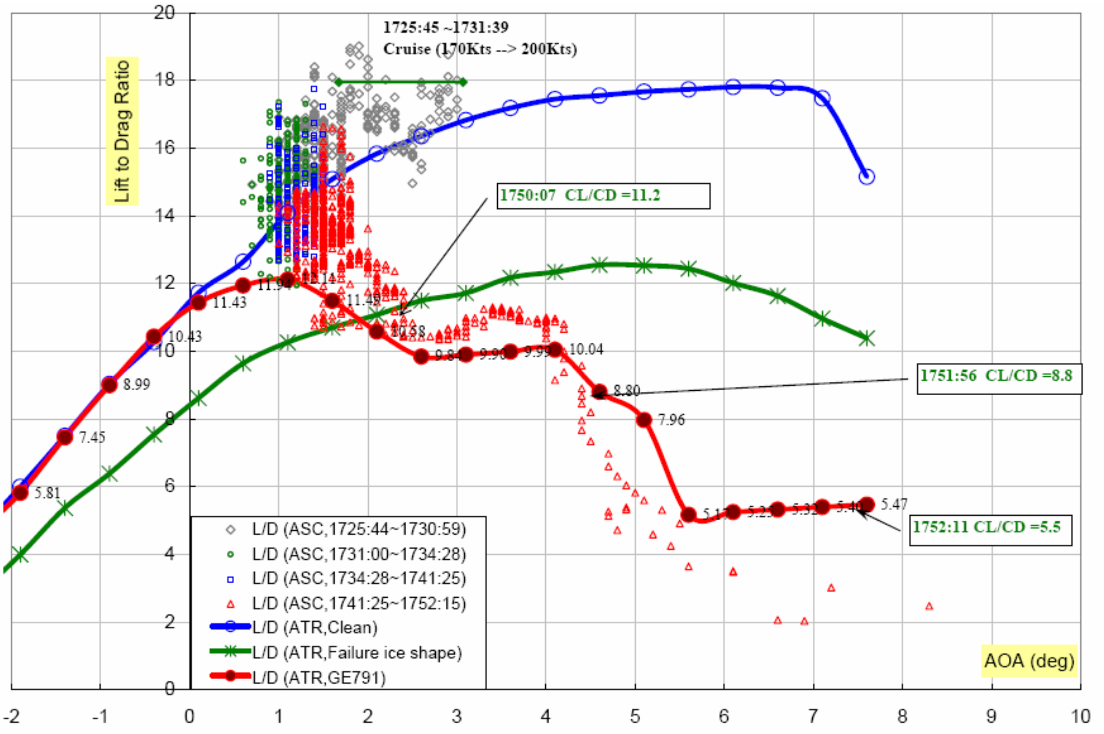

Figure 2.4-4 The lift-drag ratio of the GE791 due to ice accretion versus true AOA

Performances during roll excursion

After the autopilot disengaged, the GE791 entered the maneuver of roll excursion and rapid descent, refer to Figure 2.4-5. The performance analysis is obtained through a comparison between FDR recorded parameters, and simulation parameters computed with the clean aerodynamic model adding the drag and lift degradation up to match FDR data.

The Figure 2.4-6 shows the drag and lift versus true AOA computed during the speed decay and the roll excursion. It can be observed that at about 4.5° of true AOA, the severity of the ice produced a flow separation on the wing, which induced a loss of lift and a drag increase.

At about 5.5° of true AOA and few seconds before the autopilot disconnection, the loss of lift and the increase of drag clearly indicate that the left wing of the GE791 is entering the stall. After the autopilot disconnection the drag and the loss of lift continued to increase up to the maximum AOA (at 0152:14, 22.5° vane; 15.07° true AOA). Since the activation of stick pusher (at 0152:13.75, 12.83° true AOA) until maximum AOA, then the AOA decreased rapidly the due to time delay to recover from lift the flow remained separated on the wing inducing a further additive drag of 600 counts.

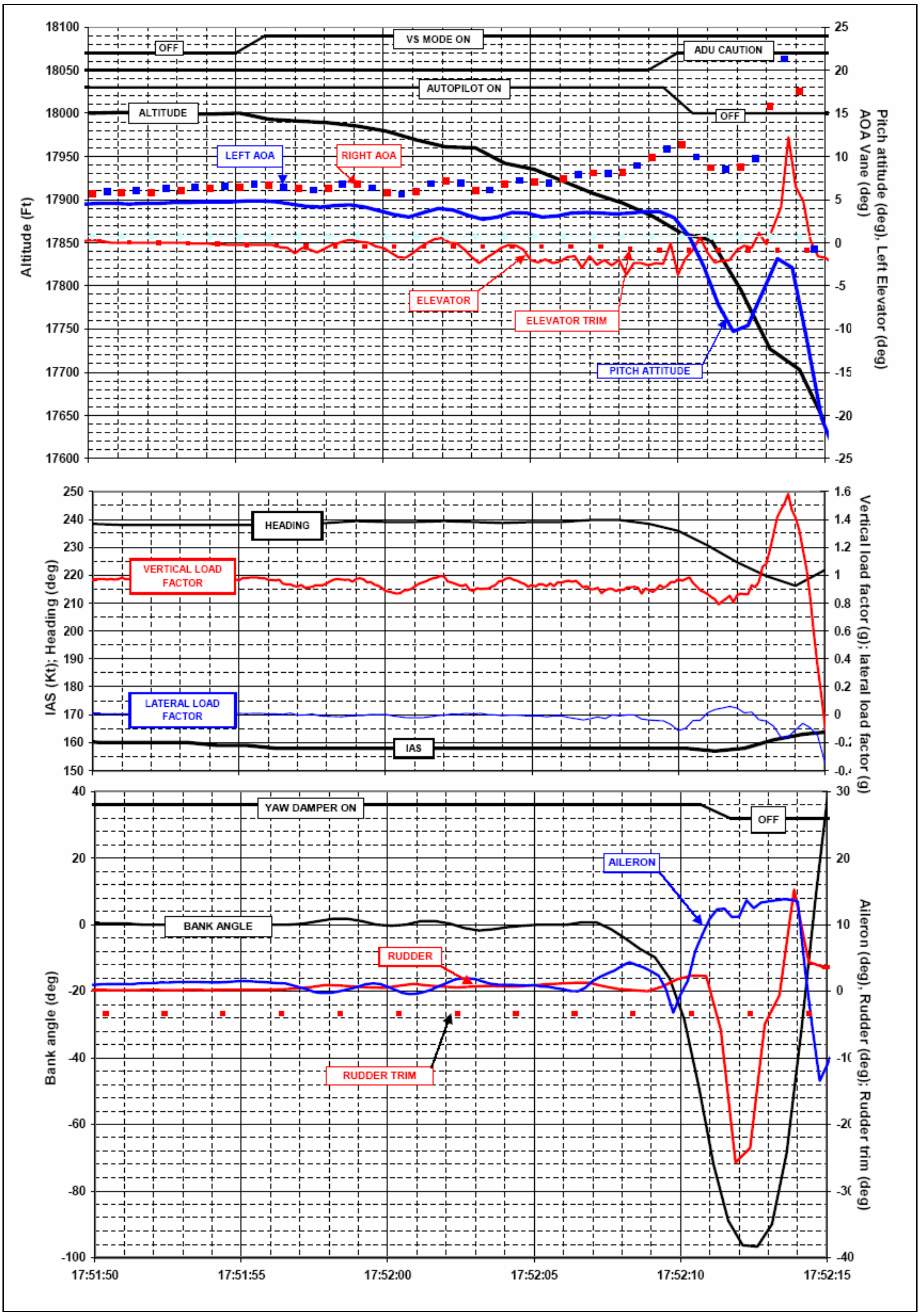

Figure 2.4-5 GE791 FDR data plot during the roll upset

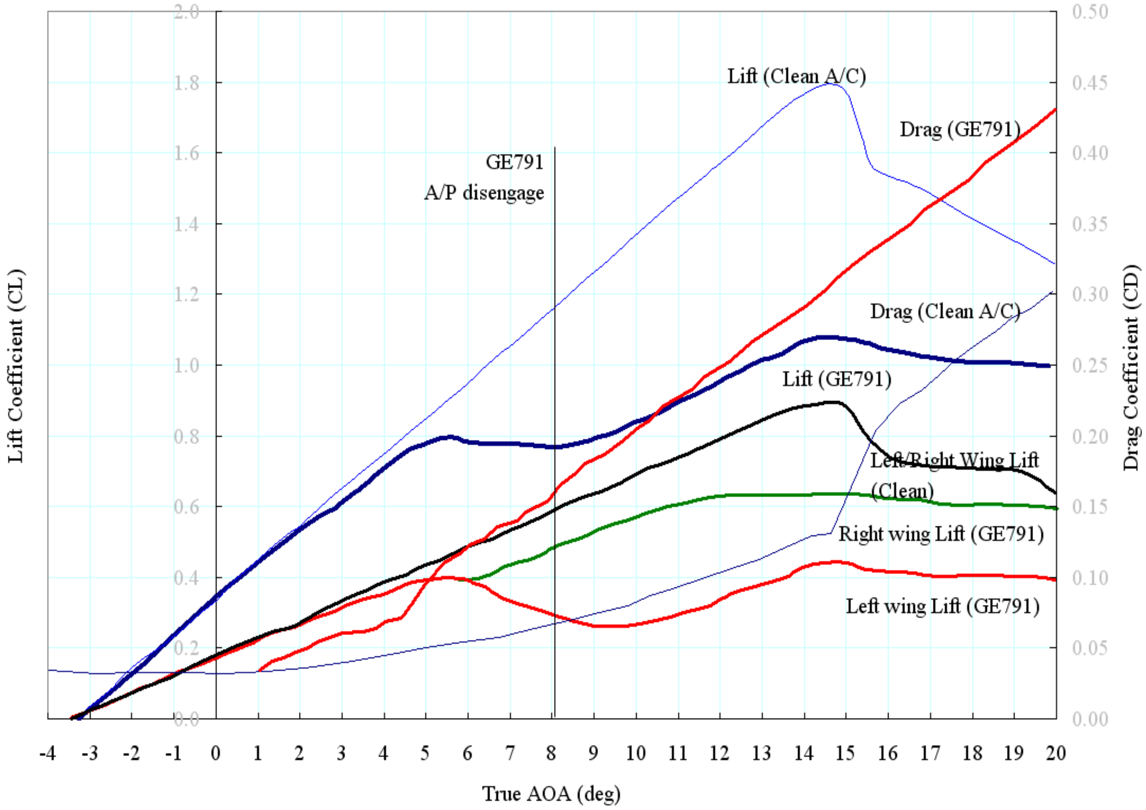

Figure 2.4-6 The lift and drag coefficients versus true AOA (ATR72 clean and GE791 ice polluted)

2.4.3 Results of Full Flight Simulator Test

Four different scenarios were demonstrated from the same initial conditions (refer to table 2.4-1). Detail full flight simulator test refers to Appendix 21.

Table 2.4-1 Initial conditions of full flight simulation test

Weight (W)	20,500 kg
Center Gravity (CG)	28% Mac
Indicated Airspeed (IAS)	200 Knots
Cruise Altitude	18,000 ft
Icing Condition	Before stall, 7 minute Severe icing condition[30]
Autopilot	Engage
Power setting (NP)	86%
Wind Conditions	0 deg/0 knots

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[30] Severe icing condition: ATR 72 Full Flight Simulator Test Default Setting.

For each scenario, the pilot first let the aircraft follow its natural behavior before initiating any maneuver, i.e. Stick-shaker and AP disconnection, roll motion until about 45° of bank angle.

Scenario 1 : Pilot off the loop

It was intended to demonstrate the natural behavior of the aircraft without any action by pilot.

As expected, the rolling motions were increasing, and so did the negative pitch angle.

Scenario 2 : Recovery attempt with roll control only

GE791 accident flight data showed that the stick was kept around pitch neutral position, except during a very short instant at the activation of the stick pusher, and the pilot only made roll inputs trying to bring back the wings level.

The pilot flew the simulator by reproducing the same flying techniques, applying only roll inputs and keeping the stick in pitch neutral position.

The result was that the aircraft maintained in stall conditions by fighting on the roll axis, the bank angle was kept in reasonable margins, but still with erratic roll motions, and the full control never regained.

Scenario 3 : Recovery by pushing the stick.

This recovery technique was the most natural one, the loss of control was due to a high angle of attack (AOA), and the pushing of stick immediately decreases the AOA and allows the speed to increase.

Two demonstrations were made and showed the efficiency of this technique.

ASC and BEA representatives jointly performed this maneuver.

Scenario 4 : Recovery by flaps extension.

The extension of flaps 15 was another procedure recommended by ATR : as soon as the flaps begin to extend, the AOA immediately decreases for the same stick position and speed.

Two demonstrations showed that the recovery was immediate, with the advantage that the loss of altitude was minimized compared to the preceding technique.

Highlights of flight simulator test allowed demonstrating the main follows:

- Severe icing conditions induce speed decay;
- If the pilot does not observe the minimum speed recommended by the procedure, a stall may occur with uncommanded roll motions;

- The stalling conditions are maintained if the pilot only counteracts the roll motions and keeps the stick around the neutral position;
- The control of the aircraft was immediately regained when applying the recovery techniques recommended by ATR

Further simulation analysis performed by ATR in 2004 (refer to Appendix 22). The simulation study reproduced the FDR parameters and provides adequate elements for a better understanding of the roll excursion and the loss of control of the aircraft.

The figures (refer to Appendix 22, figures 1 ~ figures 4) show that the simultaneous application of AFM procedure in the same accident flight conditions leads to the recovery of the correct flight attitude. Two lines are plotted in these figures- GE791 (solid line) and recovery with AFM procedure (dash line).

(1) Recovery without Flap Extension

The longitudinal recovery shows the elevator pitch down command and the effect on the pitch angle. The AOA is reduced and the recovery is easily attained.

The lateral recovery shows the aileron command and the effect on the bank. The actions on the aileron combined with the AOA reduction obtained with elevator push down leads to complete recovery.

(2) Recovery with Flap Extension

The longitudinal recovery shows the effect of flap extension on the recovery. The effect on the pitch angle is immediate.

The lateral recovery shows the aileron command combined with flap maneuver and the effect on the bank.

The actions on the aileron combined with the AOA reduction generated by flap extension leads to complete recovery.

Among full flight simulator test and flight recorders analyze show that the after second activation of airframe de-icing system, the aircraft engaged the autopilot and continued fly in icing environment about 11 minutes. The loss of control of the GE791 has been initiated by an asymmetrical lift between right- and left- wing due to a long exposure to severe icing conditions. This asymmetrical lift induced a consequential left roll when the autopilot disconnected. Large rudder input during the roll induced a further increase of angle of attack, which produced stick pusher activation.

2.4.4 GE791 Stability Analysis

The Investigation Team conducted a research based on the analysis report provided by the Aerospace Department, Kansas University, (refer to Appendix 23). Further stability analysis also performed by ATR in 2004 (refer to Appendix 24), the nominal aerodynamic and stability derivates are describing in manufacturer’s report. The aerodynamic and stability derivatives in the last four minutes prior to autopilot disengaged were discussed as follows.

Longitudinal stability

As general aerodynamic rule: the tail plane works at lower AOA than the wing (-3 to -5°). In severe icing conditions and at positive AOA the flow separation appears on the wing. On the other hand, at large negative AOA the flow separation occurs on tail plane.

(1) 0147:57 ~ 0150:51 for GE791 (refer to fig. 2.4-7& 2.4-8).

The aerodynamic center of the GE791 is situated at 50.6% MAC (Mean Aerodynamic Chord). Flight test conducted31 on ATR 72 200 shows that the aerodynamic center with the same configuration is situated at 49% MAC. Longitudinal stability of GE791 flight is nominal in this period. Due to the ice accretion on the wings, the lift curve slope ($CL\alpha$) decay from the nominal value 5.95 rd-1 decreased to 4.7 rd-1.

(2) 0150:51 ~ 0151:57 for GE791 (refer to fig. 2.4-11& 2.4-12).

During this period the aerodynamic center of the GE791 is situated at 73.5% MAC. This period confirms that the tail plane is nominal because the aerodynamic center moves back (generally a loss of efficiency of tail plane moves forward the aerodynamic center and reduces the longitudinal stability). In fact, the flow separation on the wing due to severe ice produces a loss of lift. So that, the lift curve slope further decayed to 2.86 rd-1.

(3) 0151:57 ~0152:10 for GE791 (refer to fig. 2.4-11& 2.4-12).

When the autopilot initiated the descent a flow separation occurred simultaneously on both wings (no roll) up to AOA=6°, and an asymmetrical left roll appeared.

During this period it is difficult to check correctly the longitudinal stability due to the time delay to recover from the lift change (the lift curve slope shift to -2.86 rd-1). Then, after the roll departure (0152:07) the lift curve slope decayed to 2.86 rd-1.

The last four minutes prior to autopilot disengaged, the severe ice accretion caused the aerodynamic center of the GE791 shifted from 50.6% to 73.5% (which means at 73.5% MAC further aft the center of gravity.) In addition, the lift curve slope degraded about 50% (5.95 rd-1 decayed to 2.86 rd-1).

Lateral Stability

The roll damping derivative (Clp) for an ATR 72-200 in clean aircraft is -34.9 rd-1.

(1) 0147:57 ~ 0150:51 for GE791

During this period the roll damping derivative in nominal value (-34 rd-1).

(2) 0150:51 ~ 0151:57 for GE791

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[31] ATR 72-200 develop flight test records- longitudinal stability clean A/C flap 0 powered. (Flight 268 A/C98)

During this period the roll damping derivative is lower than nominal but it is effective (- 20.7 rd-1)

(3) 0151:57 ~ 0152:07 for GE791

During this period the flow separation occurs on the wings, inducing a loss of lift (negative lift curve slope -2.8 rd-1) without roll motion. The roll damping derivative is 20.7 rd-1.

(4) 0152:07 to 0152:10

During the left roll upset, the roll damping derivative changed to -20.7rd-1.

Before the roll excursion, the roll damping derivative degraded about 40% (-34.9 rd-1 decayed to -20.7 rd-1).

The aileron control effectiveness (Clδa) of the GE791 is -2rd-1 and corresponds to the nominal values before the roll excursion.

The rolling stability derivative (Clbeta) is - 1.45rd-1 (which is the nominal). This value is not changed on the GE791 flight and its contribution to the loss of control is negligible because the beta (sideslip angle) is zero or negligible respect to the other attitude angles.

During the 10s before the roll excursion (0151:57 to 0152:07) the longitudinal and lateral stability has been modified by the ice accumulated on the wings producing the flow separation. In particular the application of recovery procedures using a significant reduction of aircraft AOA (3°) by a pitch down elevator input or flaps extension (15) lead the aircraft in a situation where all aerodynamic parameters are nominal.

All performance analysis report reveals that a significant icing occurred after 01:31:05. The Safety Council believes that GE791 probably encountered icing condition at 0131. Ninety seconds later, flight crews perceived icing condition. Three minutes later, flight crews activated airframe de-icing system. At 0132:35, CVR recorded the CM2 mentioned “Looks like it’s iced up….look at my side your side is also iced up right.” At 0133:32, CM1 responded, “There’s not enough moisture outside minus twelve degrees.”

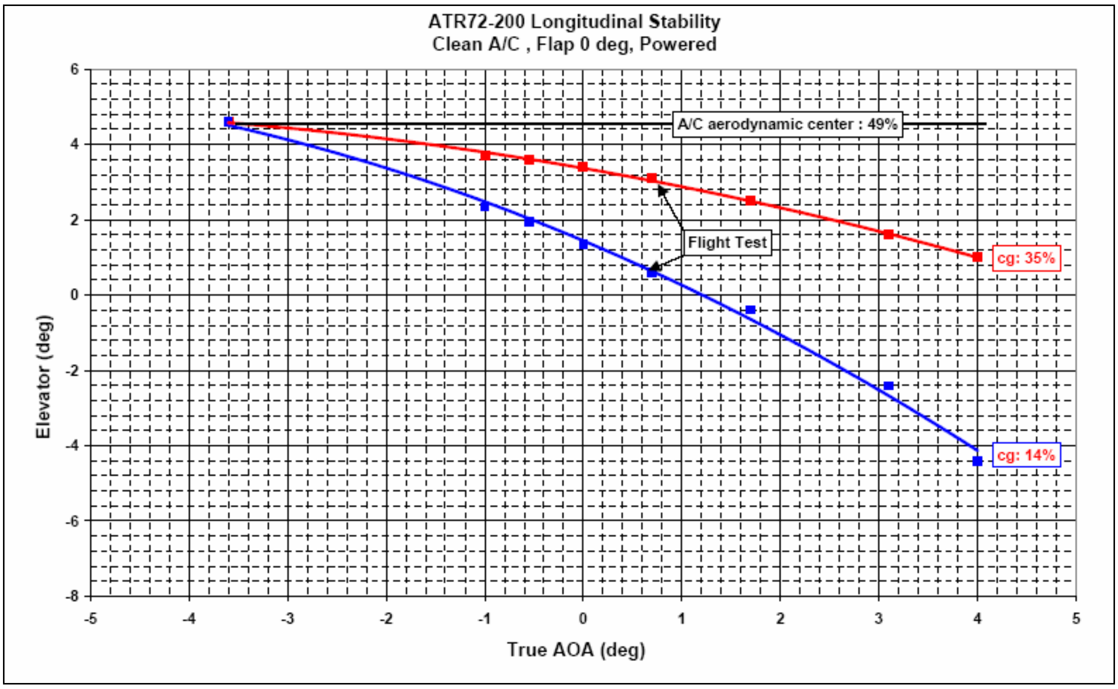

Figure 2.4-7 ATR 72-200 longitudinal stability

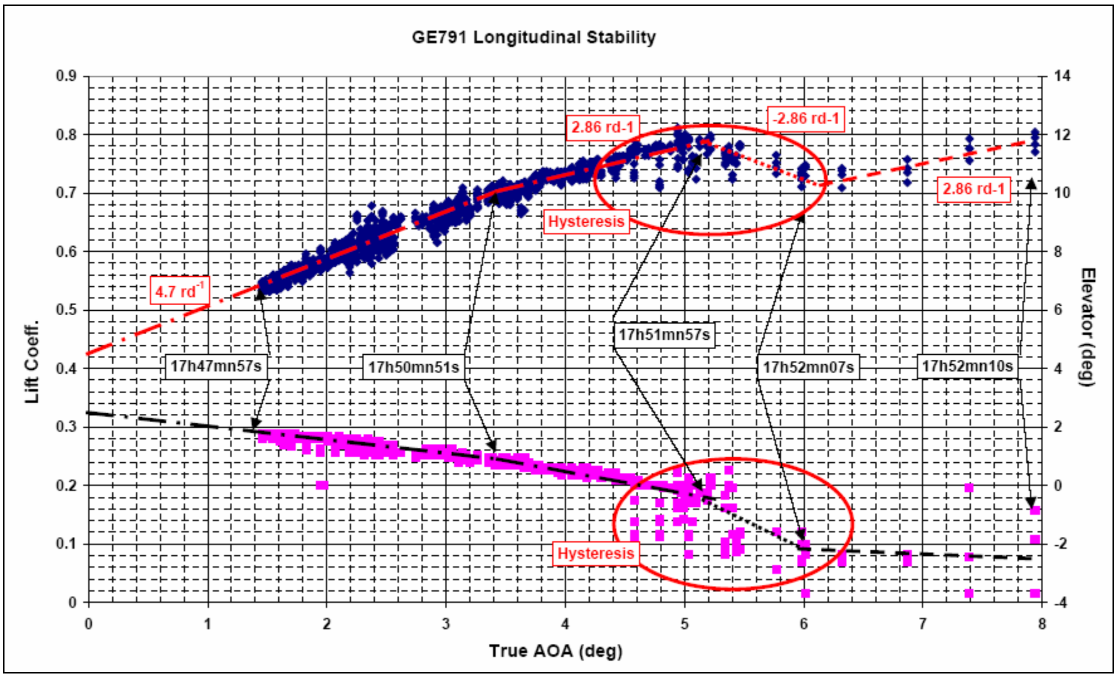

Figure 2.4-8 GE791 longitudinal stability (derived from FDR data)

2.5 Icing Detection System and Stall Warning System

2.5.1 Icing Detection System

The ATR-72 Maintenance Manual Section 30.80 states, “*The purpose of the ice detection system is to help the crew to detect icing conditions. The primary mode of detection remains visual detection of ice formation by the crew.”*

The CVR recording indicates that the single chime triggered at time 01:34:29 and 01:34:32. The single chime alert might stand for one of many cautions. Without associated light, it may not directly link to the specific caution. However from the CVR recording at time 01:34:29, CM1 mentioned, “*oh it’s icing up*”, the Safety Council believes two single chimes at time 01:34:29 and 01:34:32 were triggered by the icing detection system.

The FDR recording indicates the airframe de-icing system was first activated at time 01:34:29 during this flight. Based on this data and the conversation between flight crews at time 01:32:35 and 01:34:32 in CVR, the Safety Council concludes the icing detection system had detected icing and alerted the flight crews, they had noticed this alert and activated the airframe de-icing system.

The airframe de-icing system was activated for 2 minutes and 52 seconds then was turned off at time 01:37:21. Because of the primary mode of detection remains visual detection of ice formation by the flight crews**,** when the flight crews judged no more ice the pilots will take further action such as turning off the airframe de-icing system. The CVR recording at 01:37:24, CM1 mentioned, “*it’s gone again*”. The Safety Council believed the flight crews perceived that icing condition no longer existed at time 01:37:21 then the airframe de-icing system was switched off. When the airframe de-icing system was switched off no single chime was recorded in CVR. At this moment there might be no icing existed or there might be ice accreted that icing detection system was not able to detect. The Section 2.4.2, performance analysis, concludes that there was residual ice on the wings after the airframe de-icing system switched off at time 01:37:21. Four minutes later, at time 01:41:21, the single chime sounded again. The airframe de-icing system was activated again at time 01:41:25. The Safety Council believes the single chime at 01:41:21 was triggered by the icing detection system. From 01:37:21,when the airframe de-icing system switched off until 01:41:21 when the icing detection system generated aural alert, within four minutes there was no icing alert however residual ice remained on wings.

Even the primary mode of detection remains visual detection of ice formation still by the flight crews. From the flight operation's viewpoint on severe icing detection system, Section 2.1.2 concludes, " in adverse weather conditions and night time, it's very difficult to judge the icing condition according to the Flight Operation Manual. The Safety Council concludes that the existing icing detection system and the visual detection of ice formation neither do not provide sufficient information related to ice accretion to the flight crews nor provide a capability of the icing severity. However similar issues have been discovered after the investigations of the American Eagle Flight 4184 accident in 1994 and the Comair Flight 3272 accident in 1997.

To solve icing condition related issues, beginning of 1998 the ARAC (Aviation Rulemaking Advisory Committee) have assigned the IPHWG (Ice Protection Harmonization Working Group) to work on various tasks related to icing. This group is constituted with representatives of Airworthiness Authorities (FAA, Transport Canada and JAA), Aircraft manufacturers (Boeing, Bombardier, Embraer, Cessna, Saab, BAe, Airbus and ATR) and Research centers (NASA, National Research Council of Canada) and meets regularly to conduct the assigned tasks. The Task 1 is related to icing detection system - "As a short-term project, consider the need for a regulation that requires installation of ice detectors, aerodynamic performance monitors, or another acceptable means to warn flight crews of ice accumulation on critical surfaces requiring crew action (regardless of whether the icing conditions are inside or outside of Appendix C of 14 CFR Part 25). Also consider the need for a Technical Standard Order for design and/or minimum performance specifications for an ice detector and aerodynamic performance monitors. Develop the appropriate regulation and applicable standards and advisory material if a consensus on the need for such devices is reached." The task 1 and task 2 which are related to icing detection and protection are being finalized. The regulatory materials will be distributed for comments during next year (2005)[32.] A draft rule will be released in the 2006 time frame by the airworthiness authorities (FAA, JAA, Transport Canada)[33]. The Safety council understands the mature

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[32] Information provided by one of the IPHWG members, the aircraft manufacturer, ATR.

[33] Update on SLD Engineering Tools Development by Dean R. Miller, Mark G. Potapczuk, and Thomas H. Bond. Glenn Research Center, Cleveland, Ohio. Presented at FAA In-Flight Icing/Ground De-Icing International Conference sponsored by the Society of Automotive Engineers Chicago, Illinois, June 16–20, 2003

definition, technology and regulation for severe icing detection are not ready to be installed on aircraft today. Continuous development of sophisticated icing detection system is still highly needed to enhance the flight crews' understanding and awareness of ice accretion and associated effects.

2.5.2 Stall Warning System and Low-Speed Alert

The purpose of stall warning system is to warn pilot by aural warning, stick shaker and stick pusher when aircraft is about to stall. The warning should warn pilot prior to stall to allow pilot responds timely.

The CVR recording indicates the first stall aural warning activated at 01:52:10.45. The AOA was 11.7 degrees recorded on FDR at 01:52:11. According to the ATR72 Maintenance Manual Chapter 27.36 under icy condition the primary stall warning activates when the AOA reaches 11.2°. The Safety Council concluded the stall warning system worked as designed. There was a minor difference (0.5°) between stall warning activation threshold and the recorded AOA on FDR which is acceptable because the FDR data-sampling rate of AOA was 2 Hz. The recorded data may be close to the activation threshold but not just the exact trigger value.

However, at 01:52:08, GE791 began to roll to the left and the stall warning activation time was 01:52:10.45. When the stall warning activated, the roll angle reached 48.9°.At this moment the aircraft was difficult to control. In other words, the stall warning system was not activated when the aircraft initially rolled to the left. There was no other alerting/warning systems to warn flight crews while aircraft in roll upset[34] situation. The Safety Council believes under severe icing condition and aircraft performance degradation seriously the stall warning system was not enough to provide adequate warning.

When aircraft in icing environment, the ice may accrete on both wings asymmetrically. The ice will cause asymmetric lift and drag on both wings. If autopilot still engages, the aircraft would eventually enter roll upset situation. If the system could provide additional and timely warning to flight crews, they would avoid such situation. During cruise phase, when aircraft in icing environment with autopilot system engaged in Altitude-hold mode, the obvious change was the airspeed decreasing due to the drag increasing. When autopilot system engaged, the flight crew does not control the wheel/column directly. Therefore the flight crew could not easily feel the aircraft performance degradation caused by ice accretion. The Flight Operation Manual Section 2.02.01 prescribes the minimum normal icing speed and the minimum severe icing speed. The pilots need to monitor airspeed continuously. Under autopilot system engaged, if the aircraft could provide the "Low-speed" warning, it might provide additional and timely

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[34] Refer to chapter 2.4.4 stability analysis

warning to the pilot when the pilots fail to monitor the airspeed. The minimum normal icing speed of GE791 was 166 knots at 01:51:21. The minimum severe icing speed of GE791 was 176 knots at 01:50:23. Both occurred earlier than the time（01:52:10） of stall warning activation which were 49 seconds and 107 seconds respectively. According to CVR transcripts, at 01:50:55 CM1 mentioned "*This speed is getting slower it was a hundred two hundred one hundred and ninety now one hundred seventy*". The time of GE791 flight crew found the airspeed getting slower was late than the time of minimum normal icing speed about 32 seconds. The Safety Council believes in icing environment the low-speed alert would reduce the accident caused by the pilot's failure of monitoring and maintaining airspeed.

2.5.3 Stall Warning System Enhancement and Icing management System Research

The primary trigger data of stall warning system are based on AOA. When the AOA reaches the preset threshold the associated warning activated. The aircraft performance will change if ice accreted on the wings. The stall AOA varies by the different severity of icing contamination. The trigger AOA of stall warning system of GE791 was 16.5° when flap set to 0. Under icing condition and flap set to 0, the trigger AOA of GE791 is 11.2°. However the threshold was changed according to the aircraft configuration and anti-icing system on/off other than the actual performance degradation. As Section 2.4.4 stability analysis describes, at time 01:51:56 the accreted ice on both wings may result in the local airflow separation and induce the pre-stall buffeting. The time of stall warning activation (01:52:10) was late of the time of stall most likely occurred.

Since the computation technology had improved significantly in the last decade, the real time calculation of the aerodynamics becomes feasible. When the wings were contaminated the aerodynamics would change accordingly. Comparing the aerodynamics of contaminated wings and clear wings would provide the degradation of aircraft performance and adequate warning. The NASA has launched the "Smart Icing System[35]" project since 1998. The system provides icing effects on aircraft performance, stability and controllability. It also incorporates the icing protection system and pilot automation system. The system improves the safety of aircraft operating in icing condition. The Safety Council believes a continuous support and research of similar activity from the aircraft manufactures, aviation authority and national research agency would benefit to improve aircraft operating in icing condition.

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[35] Smart Icing Systems (SIS) project is a joint venture between the University of Illinois, the University of Ohio, and the NASA Glenn Research Center. This system is intended to measure environmental and performance parameters to determine if ice accretion is occurring before warning the pilot or independently taking action to prevent the aircraft from entering a potentially critical situation.

2.6 Aircraft Damage

The general currents were southeasterly at the time of accident. The heavier wreckage such as engines and landing gear that sank to the bottom of sea were close to where they impacted the water. The rest of them were drifted along from near to far by the currents depending on the size and weight.

The wreckage that were recovered from the sea bed include: pilot seat, handbook in the cockpit, fuselage structure, tail cone, rudder, elevator control surface, wing structure, leading edge and trailing edge.

Observation made by remote operating vehicle indicates that the wreckage including structure and components of accident aircraft are distributed within an area of 200 by 300 meter（Figure 2.6-1）.

Two engines were observed during the ROV underwater survey, but the recovery was not successful due to adverse weather and rough sea state. The structure wreckage scattered on seabed were in small pieces that are difficult to identify. The distribution of wreckage can be observed from the images transferred by ROV camera as well as the GPS diagrams.

The fuselage skin was serious wrinkled, both sides of right aft entry door were compressed, window frame broken etc, all above damages were exhibit that the aircraft impacted with the object along the longitudinal axis, i.e., the aircraft fuselage was about perpendicular to the water surface during the impact.

The wing root and wing tip was bent downward. Trailing edge wing structure broken and bent afterward, exhibit that the aircraft pitch down angle over 90° during the wing impact.

The pilot sear strut, wheel and tire of the landing gear, all above strong structures were burst apart, exhibit that the diving speed of the aircraft was very high during the water impact.

Total 199 pieces of wreckage were examined. There were no evidence of slow growth damage, i.e., no structure fatigue damage was found. All the structure failure was cause by over load damage and occurred during water impact.

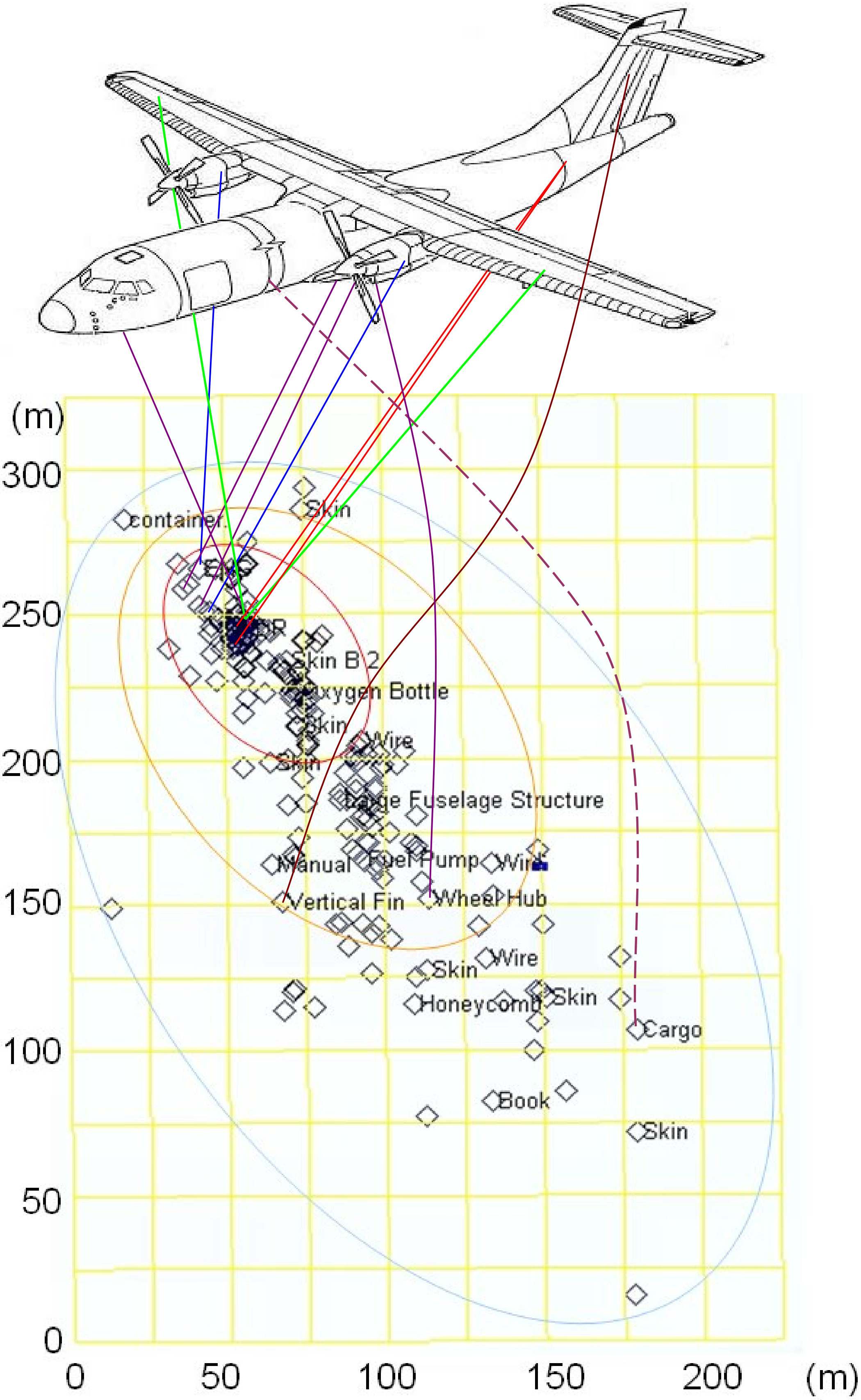

Figure 2.6-1 Wreckage scattering observed from ROV

2.7 Technical Document Control and Maintenance Records Keeping

2.7.1 Technical Document Evaluation Processes

During investigation it was found that two of the ATR72 Service Bulletins had no evaluation records. Before August 1997, TNA evaluated the technical documentation in accordance with the CAA approved Aircraft Maintenance Control Handbook (1996 edition). TNA evaluated those two SBs and chose not to apply to it's ATR fleet. The SBs were nevertheless kept on file but no record of evaluation was found.

The Service Bulletin（SB）, Service Information Letter (SIL) and Service Letter (SL) are closely related to airworthiness and safety of flight operation. A well-established evaluation system would eliminate the omission of installation of safety related SBs. The Safety Council believes that the evaluation system of technical document at that time was imprecisely established.

At present time, TNA performs maintenance work in accordance with the Aircraft Maintenance Control Manual that was approved by CAA on August 13, 2001. After receiving Airworthiness Directives (ADs) or Alert Service Bulletins (ASBs), TNA will evaluate them immediately and complete the evaluation of SB, Technical Information Letter or Technical Letter within six months. The evaluation records will be kept on file with related technical documentation.

2.7.2 Maintenance Records Keeping

According to the CAA's Aircraft Certification Regulation in 1976:

> *"2), of Article 19： Aircraft, aircraft engine or propeller historic logbooks should be kept for 2 years after they are destroyed or withdrawn from service."*

According to the CAA's Aircraft Flight Operation Procedures in 1976:

> *"Article 46：In addition the regulations specify, all the records shall be kept for a minimum period of 90 days after the unit to which they refer has been permanently withdrawn from service."*

After reviewing the TNA's ATR 72 maintenance records, the Safety Council finds that TNA kept the cover page but working procedures and parts replacement records of ADs and SBs that were applied before August 1997 were not included.

The CAA established the Inspection System in August 1997 and required operators to establish maintenance programs compliant with the requirements of CAA's five phases of air carrier certification. After establishing the maintenance program, TNA evaluated all SBs and kept the evaluation records accordingly. TNA established a due date to the applicable SB and transferred the SB to be an EO. The EO provided working procedures with diagrams and signature columns for the working unit. The implemented EO would be reviewed by the relevant units and sent to the Quality Control Center for stipulating Required Inspection Items (RII) and then passed to the working units. After SB implemented, the EO and worksheet would be returned to the related department for filing. The Safety Council believes that TNA established a maintenance records keeping system in accordance with CAA requirements after August 1997.

2.8 The Anomaly of the Non-Recorded Tracks

According to the factual data in section 1.11.2.6, some of the FDR magnetic tape signals were unable to convert into raw stream data. The total unrecoverable signal of track 1 is 78% (about 3.25 hours) and 86% of track 2 (about 3.58 hours). That means there were data lost 6.83 hours out of the 25 hours recording. However with the same signal process to retrieve track 5 and 6, about 99% of flight data are readable, the Safety Council believes the problem is not on the readout equipment. Aircraft Accident Investigation Branch (AAIB, British) investigated an accident occurred on October 10, 2000. AAIB also found that two tracks were unrecoverable with F800 FDR tape. Because of the samilar difficulty of tape based FDR is commonly found in accident investigations. The new type of FDR, solid state recorder, has better recoverability than tape based recorder. The manufacturer had discontinued production of F800 FDR since 1996.The Safety Council believes phasing out the tape based recorder and retrofit of solid state recorder will be beneficial to accident investigation.

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3 Conclusion

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

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

The findings related to risk identify elements of risk that have the potential to degrade aviation safety. Some of the findings in this category identify unsafe acts, unsafe conditions, and safety deficiencies that made this accident more likely; however, they cannot be clearly shown to have operated in the accident. They also identify risks that increase the possibility of property damage and personnel injury and death. Further, some of the findings in this category identify risks that are unrelated to the accident, but nonetheless were safety deficiencies that may warrant future safety actions.

Other findings identify elements that have the potential to enhance aviation safety, resolve an issue of controversy, or clarify an issue of unresolved ambiguity. Some of these findings are of general interest and are not necessarily analytical, but they are often included in ICAO format accident reports for informational, and safety awareness, education, and improvement purposes.

3.1 Findings Related to Probable Causes

1. The accident flight encountered severe icing conditions. The liquid water content and maximum droplet size were beyond the icing certification envelope of FAR/JAR 25 appendix C.（2.2.1, 2.3.2.1, 2.4.2 and 2.4.4）
2. TNA’s training and rating of aircraft severe icing for this pilots has not been

effective and the pilots have not developed a familiarity with the Note, CAUTION and WARNING set forth in Flight Crew Operating Manual and Airplane Flight Manual to adequately perform their duties.（2.3.3）

3. After the flight crew detected icing condition and the airframe de-icing system was activated twice, the flight crew did not read the relative Handbook, thereby the procedure was not able to inform the flight crew and to remind them of “be alert to severe icing detection”. （2.3.2.3）
4. The “unexpected decrease in speed” indicated by the airspeed indicator is an indication of severe icing.（2.3.2.2）
5. The flight crew did not respond to the severe icing conditions with pertinent alertness and situation awareness that the aircraft might have encountered conditions which was “outside that for which the aircraft was certificated and might seriously degrade the performance and controllability of the aircraft”.（2.3.2.3）
6. The flight crew was too late in detecting the severe icing conditions. After detection, they did not change altitude immediately, nor take other steps required in the Severe Icing Emergency Procedures.（2.3.2.4.1）
7. The aircraft was in an “unusual or uncontrolled rolling and pitching” state, and a stall occurred thereafter.（2.3.2.4.2）
8. After the aircraft had developed a stall and an abnormal attitude, the recovery maneuvering did not comply with the operating procedures and techniques for Recovery of Unusual Attitudes. The performance and controllability of the aircraft may have been seriously degraded by then. It cannot be confirmed whether the unusual attitudes of the aircraft could have been recovered if the crew’s operation had complied with the relevant procedures and techniques.（2.3.2.4.2）
9. During the first 25 minutes, the extra drag increased about 100 counts, inducing a speed diminishing about 10 knots. (2.4.1)
10. During the airframe de-icing system was intermittently switched off, it is highly probable that residual ice covered on the wings of the aircraft. (2.4.2)
11. Four minutes prior to autopilot disengaged, the extra drag increased about 500 counts, and airspeed decayed to 158 knots, and lift-drag ratio loss about 64% rapidly. (2.4.2)
12. During the 10s before the roll upset, the longitudinal and lateral stability has been modified by the severe ice accumulated on the wings producing the flow separation. Before autopilot disengaged, the aerodynamic of the aircraft (lift/drag) was degraded of about 40%. (2.4.4)

3.2 Findings Related to Risk

1. The TAMC medium-level SIGWX chart indicated around Taiwan Strait cloudy areas and air temperature of minus 9℃ at FL 180. The WAFC Washington wind/temperature chart provided to the crew by the FIS of CKS indicated that forecasted air temperature was minus 10℃ at FL 180 around Taiwan Strait.（1.7.3, 1.7.4）
2. At the SOC the flight plan controller is in charge to prepare flight documents for international flights. The SOC Operations Manual only mentions SIGWX and upper wind charts at higher levels, above FL 250. It’s not applicable for ATR flights. （2.2.3）
3. An ATR pilot who had experienced severe icing indications did not write “Fight Crew Report”.（2.3.4.1）
4. Important WARNING and NOTE information are not adequately appearing in all of the relevant Chapter/Section of ATR’s Airplane Flight Manual and Flight Crew Operating Manual.（2.3.5.2）
5. There was no detection or warning equipment designed for detecting severe icing conditions on any type of turboprop aircraft. It totally relied on the flight crew to visually determine.（2.3.2.5）
6. It could be performed difficult to closely observe the indications of severe icing in an adverse weather environment at night.（2.3.2.5）
7. Recent ATR 72 incidents indicated that after prolonged exposure to severe icing conditions and continued activating the airframe de-icing, icing caused drag increased about 500 counts, and caused the aircraft upset or stall.（2.4.1）
8. The aircraft probably encountered icing condition at 0131. Flight crews perceived icing condition at 1.5 minutes later. Three minutes later, flight crews activated airframe de-icing system.（2.4.4）
9. The icing detection system was operating normally during flight, the flight crews were aware of the ice accretion and activated the airframe de-icing system**.** However currently there is no any on board system which is able to identify the severe icing condition and provide proactively sufficient information related to ice accretion and associated effects to the flight crews.（2.5.1）
10. The stall warning system was operating as designed. The Safety Council believes under severe icing condition and aircraft performance seriously degradation, the stall warning system could not provide adequate warning.（2.5.2）

3.3 Other Finding

1. This accident bears no relationship with air traffic control services and communications.（2.1）
2. The pilots were properly certificated and qualified in accordance with applicable Civil Aviation Regulations.（2.1）
3. The flight crew’s duty and rest time was normal within the 72 hours prior to the accident. There was no evidence indicating the crew had any physical or psychological problems, nor the use of alcohol and drugs.（2.1）
4. According to the maintenance records, the aircraft was certified, equipped, and maintained in accordance with CAA regulations and approved procedures. There was no evidence of pre-existing mechanical malfunctions or other failures of aircraft structure, flight control systems, power plants or anti/de-icing systems that could have contributed to the occurrence. (1.6.9.1, 1.6.9.3)
5. The aircraft’s weight and balance were within the limitations.（2.1）
6. There is no evidence that the crew did not display on FIS computer any other updated weather information available for the flight.（1.7.4）
7. It would be difficult to visualize the propeller spinner from the ATR72’s cockpit, therefore the guidance “Accumulation of ice on the propeller spinner farther aft than normally observed” could not be performed difficult.（2.3.2.5）
8. The TAMC medium-level SIGWX charts stood on ICAO Annex 3, marking moderate or severe icing symbols in the non-CB clouds area when moderate or severe icing was forecasted. With regard to the clouds above freezing level which supercooled liquid water is possible to be existed, Hong Kong Observatory and Tokyo Aviation Weather Service Center would mark symbols for moderate icing on that charts. This is to emphasize the situation awareness of moderate icing en-route to dispatchers and pilots. (2.2)
9. CM-1did not follow reporting procedures manifested a flaw in flight operation management.（2.3.4.2）
10. The wings of the aircraft contaminated by severe ice caused asymmetric stall and left roll upset and stall warning which induced the disengagement of autopilot.（2.4.3）
11. Observation made by remote operating vehicle indicates that the wreckage including structure and components of accident aircraft are distributed within an area of 200 by 300 meter.（2.6）
12. The aircraft pitch down angle over 90° during the wing impact. （2.6）
13. The diving speed of the aircraft was very high during the water impact.

（2.6）

14. There is no structure fatigue damage was found.　All the structure failure was cause by over load damage and occurred during water impact.（2.6）
15. Before August 1997, TNA’s procedures to SB evaluation, to EO production and to maintenance record keeping system in General Maintenance Manual were not established very well. (1.6.9.2、1.6.10,、1.6.11、2.7.1、2.7.2)
16. Totally 6.8 hours data unrecoverable was found on the track 1 and track 2 of accident FDR which was a tape based recorder, model F800, but the unrecoverable data didn’t included the accident flight. (2.8)

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4 Safety Recommendation

4.1 Recommendation

4.1.1 Interim Flight Safety Bulletin

The Safety Council issued an Interim Flight Safety Bulletin (Issue No：ASC-IFSB- 03- 01- 001) on January 24, 2003. It is recommended that all operators with turboprop aircraft review their training programs to ensure the program contains the necessary training for pilots to recognize and effectively respond to all levels of "Icing Conditions." It is also recommended that operators emphasize additional training in pilot's situation awareness of icing conditions.

4.1.2 Safety Recommendations

To TransAsia Airways

1. Review the managing procedures for the SOC Operations Manual to revise that manual timely when related operation-factor variations existed. -ASC-ASR-05-04-001
2. Request to the flight crews to check the weather documentation they received from the dispatcher that it is applicable to the flight. -ASC-ASR-05-04-002
3. Review and improve the implementation and management of ground school courses, flight training and rating to ensure that all pilots are competent in performing their duties. -ASC-ASR-05-04-003
4. Require pilots to ensure that the adequacy of read and follow the checklist’s procedures in abnormal or emergency conditions.

-ASC-ASR-05-04-004

5. Enhance pilots of the ATR aircraft fleet with their training and rating on areas such as awareness, observing indications of severe icing, briefings and workload sharing, emergency procedures, and unusual attitude recovery. -ASC-ASR-05-04-005

6. Review the relevant rules and procedures of Flight Crew Reports. -ASC-ASR-05-04-006

7. Evaluate the retrofit of all company aircraft to use of solid flight data recorders. -ASC-ASR-05-04-007

To ATR Aircraft Manufacturer

1. Evaluate to include Severe Icing Emergency Procedures as memory items when encountering severe icing condition. -ASC-ASR-05-04-008

ATR Response:

Severe icing emergency procedures in the relative manuals were updated and memory items were included in September 2003.

2. Add WARNING remarks to all of the severe-icing-related Chapter/Section in ATR's relative Manuals to remind flight crew. -ASC-ASR-05-04-009

3. Proactively develop a more sophisticated icing detection system to enhance the flight crews' understanding and awareness of icing condition. Evaluate a new system to provide flight crew additional warning when aircraft operates in icing environment with autopilot engaged to reduce the potential risk of pilot's failure of monitoring and maintaining airspeed. Continuously support and engage a research activity similar to Smart Icing System to reduce the accident s caused by severe icing. -ASC-ASR-05-04-010

To DGAC, France

1. Proactively develop a more sophisticated icing detection system to enhance the flight crews' understanding and awareness of icing condition. Evaluate a new system to provide flight crew additional warning when aircraft operates in icing environment with autopilot engaged to reduce the potential risk of pilot's failure of monitoring and maintaining airspeed. Continuously support and engage a research activity similar to Smart Icing System to reduce the accident s caused by severe icing. -ASC-ASR-05-04-011

To Civil Aeronautics Administration

1. In addition to ICAO's regulations, refer to the practices made by HKO and TAWSC. To emphasize the situation awareness of icing en-route to

pilots by marking symbols for, at least, moderate icing on the SIGWX charts, where the non-CB clouds above freezing level with supercooled liquid water is possible to be existed. -ASC-ASR-05-04-012

2. Review the TNA's pilots training to perform their duties effectively. -ASC-ASR-05-04-013
3. Evaluate the retrofit of all civil aircraft to use of solid flight data recorders. -ASC-ASR-05-04-014
4. Continuously review and evaluate the icing detection related Advisory Circular and Airworthiness Directive. -ASC-ASR-05-04-015

4.2 Safety Actions Accomplished or Being Accomplished

Except the response to safety recommendations from each party described in 4.1.2, ATR and DGAC provided another documentation about their safety actions accomplished or being accomplished which is listed in Appendix 26.

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Attachment 1 Summary of Acceptance for Other Parties' Comments

LEGEND：

A-Accepted
R-Rejected
PA-Partially Accepted
AC-Acknowledged

No.	Section or Page	Response
	BEA	
1	Section 1.1	A
2	Section 1.9	R
3	Section 1.17.1.3.2	PA
4	Section 1.18.3.1	PA
5	Section 2.2	PA
6	Section 2.3.2.1	PA
7	Section 2.3.2.3	R
8	Section 2.3.2.4.2	PA
9	Section 2.3.2.5	A
10	Section 2.3.4.2	R
11	Section 2.3.5.1	PA
12	Section 2.3.5.2	PA
13	Section 2.4.1	A
14	Section 2.5.2	AC
15	Section 2.8	A
16	Section 3.1 finding 12	R
17	Section 3.1 finding 15	A
18	Section 3.2 finding 3	R
19	Section 3.2 finding 4	A
20	Section 3.2 finding 9	A
21	Section 3.3 finding 10	R
22	Section 4.1.2, To ATR, Recommendation 1	PA
23	Section 4.1.2, To ATR, Recommendation 2	PA
24	Section 4.1.2, To CAA	R
	TNA	
1	Section 3.1 finding 1	A
2	Section 3.1 finding 2	PA
3	Section 3.1 finding 4	PA
4	Section 3.1 finding 6	R
5	Section 3.1 finding 7	R
6	Section 3.2 finding 1	A
7	Section 3.2 finding 2	R
8	Section 3.3 finding 7	R
9	Page xiv	A
10	Page xv	A
11	Page 26	A
12	Page 30	A
13	Page 35	A
14	Page 50	A
15	Page 106	A

16	Page 171	A
17	Page 171	A
18	Page 171	A
19	Page 179	A
CAA		
1	Page 32	R
2	Page 32	R
3	Page 32	R
4	Page 32	R
5	Page 32	R
6	Page 32	PA
7	Page 33	PA
8	Page 33	PA
9	Page 34	PA
10	Page 34	PA
11	Page 34	PA
12	Page 34	PA
13	Page 34	PA
14	Page 34	PA
15	Page 35	A
16	Page 35	R
17	Page 35	PA
18	Page 35	A
19	Page 35-36	PA
20	Page 37	R
21	Page 38	PA
22	Page 38	PA
23	Page 38	A
24	Page 39	PA
25	Page 132	R
26	Page 133	PA
27	Page 174	A
28	Page 174-175	A
29	Page 175	A
30	Page 177	PA
31	Section 4.1.2, To CAA, Recommendation 1	A
32	Section 4.1.2, To CAA, Recommendation 2	A
33	Section 4.1.2, To CAA, Recommendation 4	A

Attachment 2 Comments on Final Draft from BEA

The BEA appreciates the invitation extended to it by the ASC, as required by Annex 13 to the Convention on International Civil Aviation, to comment on the Draft Final Report on the accident to Flight GE 791 on December 21, 2002. This will serve as the BEA's Comments on that Draft Final Report, along with the BEA Contribution dated July 21, 2004 ("Study of weather conditions with associated procedures in use and their interaction on the management of the flight as a contribution to the ASC Investigation"), which is also the basis of the attached comments. We understand that the Board, as required by Section 6.9 of Annex 13, will either amend the Draft Final Report to include the substance of these Comments, or append these comments to the Final Report.

First of all, the BEA wishes to express its thanks to the ASC for its total participation in the investigation, the factual data collection and elaboration of facts, as well as the analysis phase, findings determination and writing of recommendations. This has led to significant agreement between our two investigative Authorities on facts, analysis and accident causes, as well as the safety recommendations to be properly taken into account by all the parties in the aviation community.

I understand that the official language of the Final Report will be Chinese. Thus the BEA is aware that slight differences could be perceptible between the meaning of certain words in English and in Chinese. This is the reason why some of the BEA's comments or remarks could appear to the ASC as non relevant. However, in such cases and before considering these comments or remarks as non relevant, the BEA wishes to ask the ASC to verify as clearly as possible meaning of the English wording which was chosen in its Draft final report.

Our comments address mainly two points.

The first one concerns the efficiency of the crew who identified the ice accretion, did not react and did not apply the correct and complete procedure.

The second one concerns the meteorological aspect in regard the geographical position of the country. In this region, icing is not in fact considered as a daily concern or anxiety. But in the winter season, between FL100 and FL200, it is always present.

Thank you once more for your confidence and please accept my best regards,

Accredited representative

COMMENTS ON THE PART 1: FACTUAL INFORMATION

"1.1 History of Flight"

In quoted CVR excerpt use the wording of the Appendix 9 (CVR transcript).

"1.9 Communications"

As expressed –very briefly– during TRM 2, there were *"known difficulties with … external communications"*: Radio garble was long enough, from 17:25:30 to 17:31:21, to disturb the crew and to delay their radio contact with ATC.

That phase of flight including partial radio contacts between ATC and other flights, changes of frequency and conversation not related to the flight, could also be interesting to be analysed in part 2. The flow of crew conversation and the long periods of crew silence show that they were overloaded by the situation.

"1.17 Organizational and Management information"

"… 1.17.1.3.2 Standard Training Department"

In the last but one paragraph: *"… Taiwan is located in subtropical zone with low possibility of icing…"*. Indeed, even if Taiwan is located in a subtropical zone, to assume that there is a *"low possibility of icing"* is not true, in altitude because :

1- within one month of year 2002 there were two cases of severe icing conditions which were encountered by flight crews of the only ATR fleet;

2- within every subtropical area, in winter season, particularly in this zone characterised by a frequent struggle between cold and dry air masses from the Sino-Siberian continent and warm and wet air masses from the western Pacific Ocean: above flight level 100 and especially between FL 100 and FL 200, there is a high possibility and even occurrences of severe icing conditions.

"1.18 Additional Information"

"… 1.18.3.1 A Summary of interview with Dispatcher":

Second paragraph: *"The SOC operating manual stipulates that all pilots have to report to SOC."* . There are also quotations of the operations manual.

According to the meaning of that excerpts, the attendance of the captain on time at the SOC seems to be mandatory. Since he did not attend, this should appear in the findings.

Secondly, there is no analysis about that flaw. In order to inform flight crews and every Personnel involved in flight preparation to be present on time and aware of the importance of their task.

COMMENTS ON THE PART 2: ANALYSIS

"2.2 Weather Information"

Several "Definitions" are reported.

Since new proposal of definitions are under discussion and even adopted in daily operations:

- cf the BEA Contribution to the ASC Investigation (July 21, 2004): *"7.1 General procedures requirements and new JAA-FAA plans"*;

- cf Meteorological Information data Link Study group, 7th Meeting, Montreal August 26-29, 2003 (report 31/7/03).

It would be useful to quote this definition also.

In this chapter link between paragraph 2.2.2 and *“2.2.3, Weather information given to the crew “* does not exist.

"2.3 Flight Operation"

"… 2.3.2.1 Conditions of Potential Severe Icing"

Second paragraph: *"The FDR had no Static Air Temperature (SAT) parameter record"*. Right, only the TAT was recorded, (Please cancel this part :”*because TNA Company did not choose that option, which was also offered”).*

It should be added that the crew had the opportunity to know the SAT by manually switching the TAT button. At 17 h 33 min 32, just after the crew visualised the ice covering the side windows, the captain switched the TAT button and directly read the SAT: -12 °C (see Appendix 9, CVR transcript). That action should be reported and analysed, just as all the captain's remark (*"There's not enough moisture outside, minus twelve degrees"*), of which the meaning is interesting, considering the weather conditions in flight at that time.

"… 2.3.2.3 Flight Crew's Situational Awareness"

In this paragraph, it would have been interesting to point out that the crew was not aware of "normal procedures" as well as "emergency procedures" and that their attention was only drawn by aural warnings in the cockpit. Even visual information or warnings did not draw their attention (rapid growing of ice accretion on the IEP, amber, blue and green lights on the panel). An analysis about the information given by these devices is proposed in our contribution § "*6. ATR aircraft icing protection devices"* and *"Appendix 12"* and *"Appendix13"*).

"… 2.3.2.4.2 Unusual Attitudes Recovery"

The rudder is not designed to function properly outside of the flight envelope and it should be added that the recovery procedures do not include use of the rudder. The recovery procedures are detailed in :

- AFM 4.05.05 page6 (SEP 99), AFM 4.05.05 page 5 (SEP 03)

- FCOM 2.04.05 page9 (JUL 00), FCOM 2.04.05 page9 (SEP 03)

- QRH 1.09 (JUL 00), QRH 1.09 (SEP 03).

Those procedures should be given in the report.

"… 2.3.2.5 Severe Icing detection Equipment" *(Please cancel "turboprop")*

In the sentence :" *There was not any detection of warning……on this type of aircraft "*, change the end in : "on any type of *turboprop* aircraft". Note that ice detection devices are only advisory. The main cues to identify a severe icing are the ice accreting the unheated forward side windows and the ice rapidly growing on the IEP (lighted at night) up to a huge chunk. The crew observed both cues. Would you add also with the cues : the speed decay and the decrease of rate of climb

"… 2.3.4.2 Flight crew Reporting procedures"

As seen above, the captain did not join the SOC. So, the flight file was not studied by both pilots together. This may have contributed to the accident.

"… 2.3.5.1 Enhancing warning and Memory Items about severe Icing"

Any non appliance of an emergency procedure, *"can result in injury or loss of life".* It's true for any of aircraft (piston, turboprop, jet…).

"… 2.3.5.2 Compilation of Special Remarks"

Note that multiplication of notes and warning remarks, repeated all over the documentation, may decrease the clarity of this documentation all over by overloading the procedure. They should not replace basic airmanship.

To improve the understanding of the procedures, wished by the ASC, the DGAC and ATR emitted a new AD (No F-1999-015-040 R2,December 10, 2003) concerning the AFM and ATR updated emergency procedures of AFM, FCOM and QRH (see above § 2.3.2.4.2) approved by DGAC.

"2.4 Performance and Flight Dynamic of the flight in Ice accretion"

"… 2.4.1 Analysis of Previous ATR 42/72 Incidents/Accidents"

Regarding the first reported event (Roselawn), we suggest to rephrase the second sentence as follow : modify please the “low AOA”

“During holding and beginning of descent phase, from 10,000 feet, the aircraft was flying at flaps extended 15 degrees in severe icing conditions, airframe de-icing equipment activated for 25 minutes. Because of flaps extended, with a low AOA, airframe icing only caused a drag increase of about 40 counts. When they began to descent the flight crew retracted the flaps to 0 degrees. An air stream separation due to a ridge of ice, which accreted behind the boots while the aircraft was flying at flaps 15, induced an aileron hinge moment reversal”.

"2.5 Icing Detection System and Stall warning System"

"… 2.5.2 Stall Warning System and Low-Speed Alert"

§ 3 describes a situation which is out of the certification envelope. No warning system is implemented to be used outside of the certification envelope. An alert system is efficient when the aircraft is reaching a beginning of graded situation as designed . In this event, the procedures had not been applied neither before the degradation, nor after and the crew did not monitor the situation.

The aircraft was very largely ice polluted before reaching the critic AOA which activates the stick shaker. The warning reacted indeed when the AOA reached the critic value but the aircraft was already stalled.

"2.8 The Anomaly of Non-Recorded Tracks"

Change *"Aircraft Accident Investigation Board (AAIB British)"* into "Air Accident Investigation Branch".

COMMENTS ON THE PART 3: CONCLUSION

"Findings Related to Probable Causes"

In the chapter 2.3.2.4, it had been shown during the simulated checks within

ATR with participation of ASC and BEA investigators, that the recovery is always possible. The study of all others events show that the procedure has been always efficient. So, the finding 12 is not relevant.

On finding 15, The sentence should begin with :” *During the four minutes up to the auto pilot disengaged,….” In spite of “Four minutes prior…”.*

"Findings Related to Risk"

The finding 3 should be deleted. This is not addressed as such in the report and icing situation handling is basic airmanship.

In the finding 4, *“…on this type of aircraft..”* must be changed into : *“on any type of aircraft*”

In finding 9, the comment *:”However the icing detection… icing severity.”* The comment should be amended. The system of alert reacted as requested by the certification. According to the procedure, the crew role was to monitor the ice accretion of ice and evaluate continuously the situation and the aircraft speed. Presently, no system is able to identify severity of icing.

"Other Findings"

In finding 10, “*The aircraft pitch down angle over 90°…”*, the right angle is 86°.

COMMENTS ON THE PART 4: SAFETY RECOMMENDATIONS

"4.1 Recommendations"

"… 4.1.2 safety recommendations"

"… To ATR Aircraft manufacturer"

As seen above, §2.3.2.4.2, severe icing emergency procedures were updated and memory items were included in September 2003.The recommendation 1 should be deleted.

As explained above, § 2.3.5.1, any non compliance to normal and emergency procedures surely “*may result in injury or loss of life*”. The recommendation 2 is useless there and should be amended and included in recommendation to the operator in order to increase crews awareness on the risks due to icing.

"… To Civil Aeronautics administration"

Different optional FDR parameters were not, and are not still, included in the choice made by TNA to fit its ATR aircrafts, particularly parameters directly linked to the flight environment or attitude (Cancel please : Mach number, SAT an others) (all regarding the icing).

I suggest that the ASC may recommend or suggest to the CAA to discuss with TNA, as well as others Taiwanese companies, about selected parameters on

Attachment 3 Comments on Final Draft from TNA

一、與可能肇因有關之調查結果

項次	原紀錄內容	建議修改行動	事證及說明	附件
1	由駕駛員對積冰的觀察及調查的結果推斷出該機遭遇嚴重積冰。液態水含量及最大的小水滴尺寸超過美國聯邦/歐盟航空法規 FAR/JAR 25 附錄 C 的積冰適航範圍。(2.2.1, 2.3.2.1, 2.4.2, 2.4.4)	修改為： 從調查的結果推斷出該機可能遭遇嚴重積冰。液態水含量及最大的小水滴尺寸超過美國聯邦/歐盟航空法規 FAR/JAR 25 附錄 C 的積冰適航範圍。(2.2.1, 2.3.2.1, 2.4.2, 2.4.4)	刪除「由駕駛員對積冰的觀察」之原因： 從駕駛員之談話尚不足以推斷積冰大小。 易讓閱讀本報告者誤解駕駛員能從對積冰的觀察推斷出水滴尺寸。	無
2	台北航空氣象中心發布之中層航路顯著天氣預測圖顯示，台灣海峽於飛航空層 180 有雲層分佈，氣溫為負 9℃。位於松山機場的復興航空聯管中心，並未提供此圖予該機副駕駛員。（1.7.3, 2.2.3）	刪除	本公司中正-澳門貨機航線自 91 年 2 月奉核准營運至 91 年 12 月 21 日止，飛航計 915 航次，每航次本公司聯管中心於飛行前，簽派員均提供 SIGWX 中層 FL100-FL250 航路顯著天氣預測圖給駕駛員。曾飛航該貨機航線之本公司約 50 位 ATR 駕駛員皆可以佐證此項。 91 年 12 月 20 日聯合管制中心值勤人員，確實提供適當天氣資訊及 SIGWX FL100-FL250 資料給 GE 791 副駕駛。所提供之	GE 791 班次尚保留有部份飛航文件含 SIGWX 中層 FL100-FL250 有效期間 20/1200~21/0000UTC 資料如附件一。 另當日值班簽派員提供 FL100-FL250 SIGWX CHART 之確認文件，參閱如附件二。 提供本公司隨機查驗既有之 93 年 6 月 11 日 GE371/372 國際航班飛航文件均有提供 SIGWX 涵蓋 SFC-FL630 資料，參閱

			天氣資料足供飛航組員對可能遭遇積冰情況產生警覺，再加上衛星雲圖資料使飛航組員瞭解航路風向、風速、溫度及雲量分佈狀況，故機長才會考量天氣狀況後補油至 3000 公斤(原飛航計畫機坪油量為 2812 公斤)，以作必要之航路避讓天氣的準備。 當時聯管中心作業手冊雖然未及時修訂（僅要求提供高層 FL 250 以上的航路顯著危害天氣預測圖及高空風預測圖），但 GE 791 為 ATR 72 機型且當日飛航計劃之巡航高度為 FL180，故值班簽派員按實際狀況準備正確之飛航文件，亦確實提供 FL100-FL250 SIGWX CHART。 若駕駛員拿到不適用之天氣資料，也必定要求修正，不可能近 50 人均未發現所持天氣資料僅適用於 FL250 以上。	如附件三，飛安委員會可至本公司查證澄清。 該班次於中正機坪補充油量證明文件如附件三之一。
4	復興航空聯管中心的飛航計畫管制席負責國際線班機的飛航文件，聯管中心作業手冊僅要求提供高層（FL 250 以上）的航路顯著危害天	刪除	同項次 2 之事證及說明	

	氣預測圖及高空風預測圖，並不適用於 ATR 的班機。（2.2.3）			
6	復興對駕駛員有關航空器嚴重積冰之訓練及考驗等未能有效掌握。駕駛員對飛航手冊及/或操作手冊中之 Note、CAUTION 及 WARNING 等，未達能勝任其職務之熟習程度。（2.3.3）	刪除	重申：復興航空對駕駛員之訓練及考驗確實有所掌握，舉證如下： 84 年復興航空聘請 ATR 原廠檢定機師對全體 ATR 機師執行航路檢定，結果僅正駕駛乙員降為副駕駛。 93 年委聘國外訓練機構（Third Party）之檢定機師對全體機師執行模擬機學、術科檢定，全員及格。 以上委外鑑定之結果足以證明本公司任用之機師均符合標準。 對於 Page 171「綜上所述，該機飛航組員對 ATR 72 型機嚴重積冰情況之徵兆、觀察、狀況警覺、組員資源管理、緊急程序及不正常姿態改正等，未達應有之熟悉程度。」之說，可自潘員與劉員歷年訓練紀錄與統計資料，得知駕駛員接受之訓練及考驗次數應足以達到熟悉程度。 除以上重申內容外，另說明如下：	相關紀錄於本報告發佈前已函送 ASC

			僅以「個案」視為「通案」或以「結果論」來推斷本公司未能有效掌握駕駛員訓練及考驗狀況，並不適宜。 舉例來說，若要以「結果論」來推斷，則從91年11月底曾有駕駛員順利脫離嚴重積冰的案例而言，應表示本公司對駕駛員訓練確有掌握，與本項調查結果說法完全相反。 故不建議以上述「個案」做出結論。	
7	飛航組員曾發現該機結冰並兩度啟動機身除冰系統，但未使用快速查閱手冊進行處置程序，致飛航組員未獲該程序中對「*嚴重積冰偵測有所警惕*」之提示。（2.3.2.3）	修改為： 飛航組員曾發現該機結冰並兩度啟動機身除冰系統，但現有積冰偵測系統無法提供駕駛員對於全面的積冰情況及積冰嚴重程度之警告，以致飛航組員未使用快速查閱手冊進行處置程序，故未獲該程序中對「*嚴重積冰偵測有所警惕*」之提示。（2.3.2.3）	「結冰」狀況非屬緊急或不正常狀況，並不要求飛航組員使用快速查閱手冊進行處置程序。 依據「與風險有關之調查結果」第9項「現有積冰偵測系統無法提供駕駛員對於全面的積冰情況及積冰嚴重程度之警告」，以致組員無法從飛機警示系統獲知積冰狀況已達到需查閱QRH並執行緊急程序之程度。	無

二、與風險有關之調查結果

項次	原紀錄內容	建議修改行動	事證及說明	附件
1	復興未能為其機隊駕駛員營造良好無礙之溝通環境。（2.3.4.3）	刪除	事實報告（2.3.4.3）已不存在，本項調查結果應對應刪除。	
2	ATR 遭遇嚴重積冰徵兆之飛航組員，未填寫「飛航組員報告」。（2.3.4.1）	改列為「其他調查結果」或刪除	「其他調查結果」第7項：「台北航空氣象中心發佈之中層航路顯著天氣預測圖並未提供給該機駕駛員....相關做法」與本事故更直接且相關，卻被歸為「其他調查結果」，本項係其他班次駕駛員未填報告，反被歸為「與風險有關之調查結果」，相較之下，不甚合理。	無

三、其它調查結果

項次	原紀錄內容	建議修改行動	事證及說明	附件
7	雖然台北航空氣象中心發布之中層航路顯著天氣預測圖並未提供給該機駕駛員，但飛安會指出其缺少部份有益的資訊。香港天文台及東京航空氣象服務中心，對於位在結冰高度以上，有可能存在過冷水雲層，標示中度積冰之圖示，提供	1.”雖然台北航空氣象中心發布之中層航路顯著天氣預測圖並未提供給該機駕駛員，但飛安會指出其缺少部份有益的資訊”請刪除。 2. “香港天文台....並無相關做法”。此部份應改列為”可能肇因有	本公司聯合管制中心當日值勤人員，自民航局飛航服務總台台北航空氣象中心取得所需台北飛航情報區天氣資料，提供飛航組員作業，當日提供該機駕駛員之台北航空氣象中心發佈之中層航路顯著天氣預測圖 SIGWX 於計畫	如附件三之二

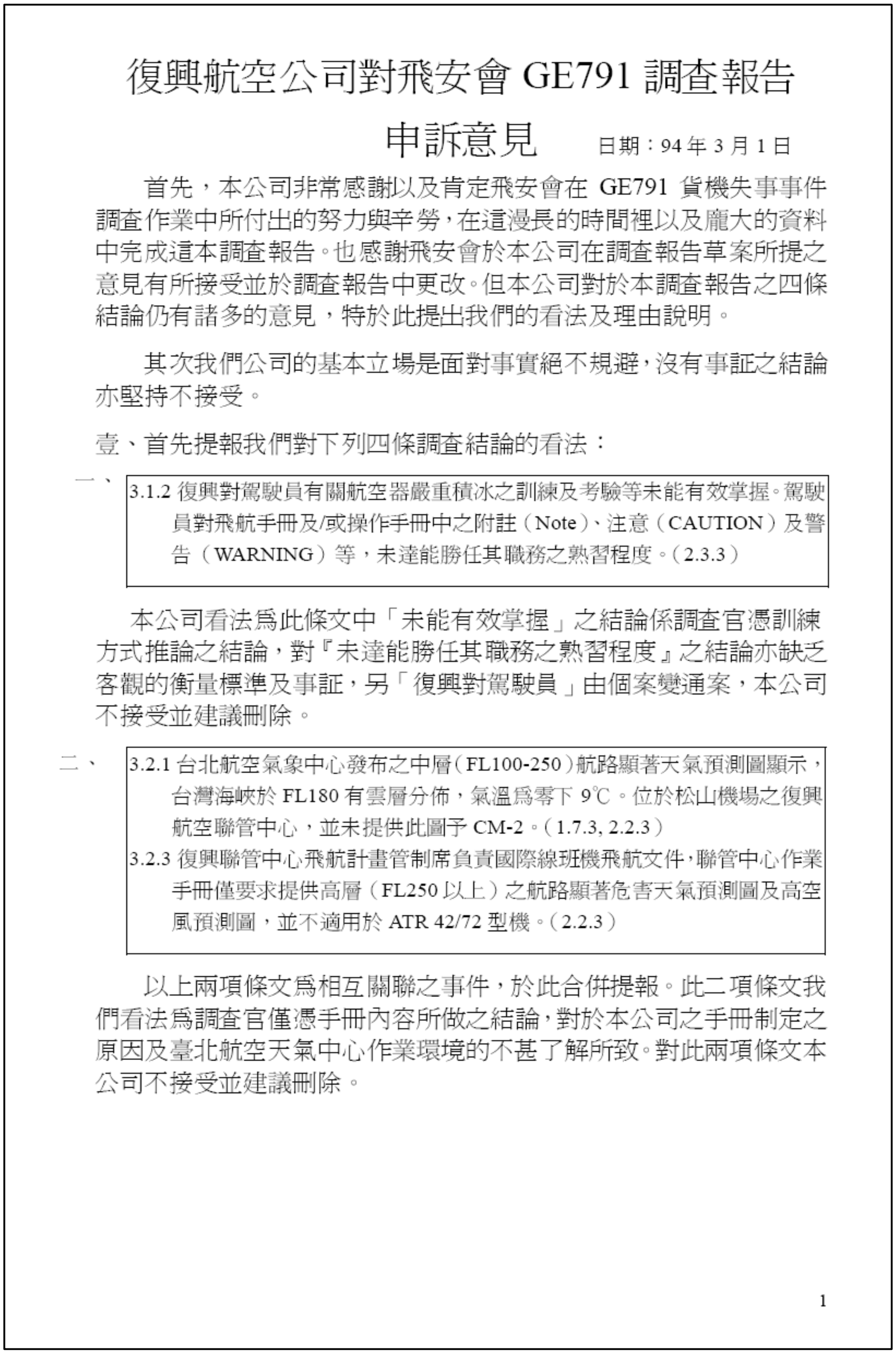
	簽派員及駕駛員對航路上，可能發生積冰警覺，台北航空氣象中心對於非積雨雲的雲區並無相關做法。(2.2)	關之調查結果”。	航路並無積冰或任何危害天氣圖示(請參閱『與可能肇因有關之調查結果』第 2 項之事證及說明)。另有關當日 SIGMET 資料部份，台北航空氣象中心其第 2 至第 3 報間之十個半小時 (如 1.7.3)，即 91 年 12 月 20 日 18 時至 21 日 04:30 時，民航局台北航空氣象中心未對「台北飛航情報區」空域發佈「SIGMET」故未提供予本公司簽派員及飛航組員相關警告訊息，但與台北飛航情報區相鄰的「那霸飛航情報區」及「香港管制區」，當時針對鄰接台北飛航情報區周邊的區域，於事故前後皆有發佈「SIGMET」，台北航空氣象中心直至 21 日凌晨 4 時 41 分，方發出第三報 SIGMET，其內容未有提到積冰狀況。 依調查報告顯示當時 GE 791 係遭遇嚴重積冰狀況, 台北航空氣象中心未按 AIP 程序(如附件三之二)發佈 SIGMET，且當時台北航空氣象中心定時發佈之 SIGWX CHART 中亦未標示任	

			何積冰圖示。 備註:以上時間為台北當地時間	

四、錯別字訂正

頁次	原紀錄內容	建議修改行動
xiv	EO 工程指令	刪除此行
xv	SIL 技術通報函	刪除此行
26	檢視民國 90 年 12 月 21 日至 91 年 12 月 21 日整年內航空器系經歷紀錄簿，下列為紀錄簿內有關防冰/除冰系統故障與施紀錄：	檢視民國 90 年 12 月 21 日至 91 年 12 月 21 日整年內航空器系經歷紀錄簿，下列為紀錄簿內有關防冰/除冰系統故障與改正措施紀錄：
30	民航局適航檢查員手冊工作項目 12 (Job Function 12)訂有適航指令檢查程序，以執行期後續適航監控作業。	民航局適航檢查員手冊工作項目 12 (Job Function 12)訂有適航指令檢查程序，以執行其後續適航監控作業。
35	2.5(mm)	2.5(mm)
50	紀錄器送抵實驗室時仍置於裝滿清水之水箱，紀錄器外表受傷嚴重；防塵外殼及所有電路板均遺失，資料牌及 ULB 則未脫落。防護盔殼完整，僅發現表面數道括痕。	紀錄器送抵實驗室時仍置於裝滿清水之水箱，紀錄器外表受傷嚴重；防塵外殼及所有電路板均遺失，資料牌及 ULB 則未脫落。防護盔殼完整，僅發現表面數道刮痕。
106	*主要最低裝備需求手冊其第 30 章內容中對於各項延遲缺點改正，其寬限週期應該需慎評估。*	*主要最低裝備需求手冊其第 30 章內容中對於各項延遲缺點改正，其寬限週期應該審慎評估。*
171	調查發現兩項 ATR 72 型機技術通告(Service Bulletin, SB)無評估紀錄。民國八十六年八月以前，復興係按民航局核備之航空器維護能力冊（民國八十五年版）執行。復興當時收到該兩項技術通告認為可不執行即予歸檔，而未留書面評估紀錄。 技術通告、技術資料信函(Service Information Letter, SIL)及技術信函(Service Letter, SL)等攸關航空器之適航與安全，嚴謹及完善之評估制度可避免執行之疏漏而影響飛航安全。本會認為，復興	調查發現兩項 ATR 72 型機技術通報(Service Bulletin, SB)無評估紀錄。民國八十六年八月以前，復興係按民航局核備之航空器維護能力冊（民國八十五年版）執行。復興當時收到該兩項技術通報認為可不執行即予歸檔，而未留書面評估紀錄。 技術通報、技術資料信函(Service Information Letter, SIL)及技術信函(Service Letter, SL)等攸關航空器之適航與安全，嚴謹及完善之評估制度可避免執行之疏漏而影響飛航安全。本會認

	當時之評估程序欠嚴謹。	為，復興當時之評估程序欠嚴謹。
171	目前，復興依據民國九十年三月一日民航局核備之航空器維護能力冊執行各項維護作業。復興收到後適航指令(Airworthiness Directives, AD)／警告技術通報(Alert Service Bulletin, ASB)後立即評估處理；對技術通告、技術資料信函與技術信函等，則於收到後六個月內完成評估作業，且評估單隨相關之技術文件併案歸檔。	目前，復興依據民國九十年八月十三日民航局核備之航空器維護能力冊執行各項維護作業。復興收到後適航指令(Airworthiness Directives, AD)／警告技術通報(Alert Service Bulletin, ASB)後立即評估處理；對技術通報、技術資料信函與技術信函等，則於收到後六個月內完成評估作業，且評估單隨相關之技術文件併案歸檔。
171	查閱復興 ATR 72 維修紀錄，發現民國八十六年八月前所完成之適航指令或技術通告，僅保存其完工簽證工單（Work Order Sheet）之首頁，並未保留其工作步驟與料件更換紀錄。	查閱復興 ATR 72 維修紀錄，發現民國八十六年八月前所完成之適航指令或技術通報，僅保存其完工簽證工單（Work Order Sheet）之首頁，並未保留其工作步驟與料件更換紀錄。
179	持續審視及評估有關結冰偵測系統之技術服務指南（Service Bulletin）、相關之民航通告（Advisory Circular）與適航指令	持續審視及評估有關結冰偵測系統之技術通報（Service Bulletin）、相關之民航通告（Advisory Circular）與適航指令



復興航空公司對飛安會 GE791 調查報告

申訴意見

日期：94 年 3 月 1 日

首先，本公司非常感謝以及肯定飛安會在 GE791 貨機失事事件調查作業中所付出的努力與辛勞，在這漫長的時間裡以及龐大的資料中完成這本調查報告。也感謝飛安會於本公司在調查報告草案所提之意見有所接受並於調查報告中更改。但本公司對於本調查報告之四條結論仍有諸多的意見，特於此提出我們的看法及理由說明。

其次我們公司的基本立場是面對事實絕不規避，沒有事証之結論亦堅持不接受。

壹、首先提報我們對下列四條調查結論的看法：

一、

> 3.1.2 復興對駕駛員有關航空器嚴重積冰之訓練及考驗等未能有效掌握。駕駛員對飛航手冊及/或操作手冊中之附註（Note）、注意（CAUTION）及警告（WARNING）等，未達能勝任其職務之熟習程度。（2.3.3）

本公司看法爲此條文中「未能有效掌握」之結論係調查官憑訓練方式推論之結論，對『未達能勝任其職務之熟習程度』之結論亦缺乏客觀的衡量標準及事証，另「復興對駕駛員」由個案變通案，本公司不接受並建議刪除。

二、

> 3.2.1 台北航空氣象中心發布之中層（FL100-250）航路顯著天氣預測圖顯示，台灣海峽於 FL180 有雲層分佈，氣溫爲零下 9℃。位於松山機場之復興航空聯管中心，並未提供此圖予 CM-2。（1.7.3, 2.2.3）
>
> 3.2.3 復興聯管中心飛航計畫管制席負責國際線班機飛航文件，聯管中心作業手冊僅要求提供高層（FL250 以上）之航路顯著危害天氣預測圖及高空風預測圖，並不適用於 ATR 42/72 型機。（2.2.3）

以上兩項條文爲相互關聯之事件，於此合併提報。此二項條文我們看法爲調查官僅憑手冊內容所做之結論，對於本公司之手冊制定之原因及臺北航空天氣中心作業環境的不甚了解所致。對此兩項條文本公司不接受並建議刪除。

1

三、

> 3.3.8 雖然臺北航空氣象中心發布之中層（FL100-250）航路顯著天氣預測圖，復興聯管中心並未提供給該機駕駛員，但此預測圖缺少部份有益資訊。香港天文台及東京航空氣象服務中心，對於位在結冰高度以上，有可能存在過冷水雲層，標示中度積冰之圖示，提供簽派員及駕駛員對航路上可能發生積冰之警覺。臺北航空氣象中心依據國際民航組織（ICAO）第三號附約之規定，對於非積雨雲的雲區預測有中度或以上積冰時才標示中度或以上積冰之圖示。（2.2）

此條文中所述『復興聯管中心並未提供給該機駕駛員』已在第 2 及 3 項條文之看法中所述，於此不再重複說明。因本條疑係闡述臺北航空氣象中心作業情況，不宜將本句併同列入，且本公司簽派員有提供該 SIGWX 圖予駕駛員。

飛航組員在飛航前若能獲得航路上的天氣資訊，本公司相信此天氣資訊能給組員一個先前的心理準備，且警覺心也相對的提高，故此項條文本公司認爲應刪除『復興聯管中心並未提供給該機駕駛員』之詞句，並把修訂之條文提列爲**與可能肇因有關之調查發現**之項目內。

貳、針對以上四項調查發現本公司提出以下理由請各位委員予以重新評定：

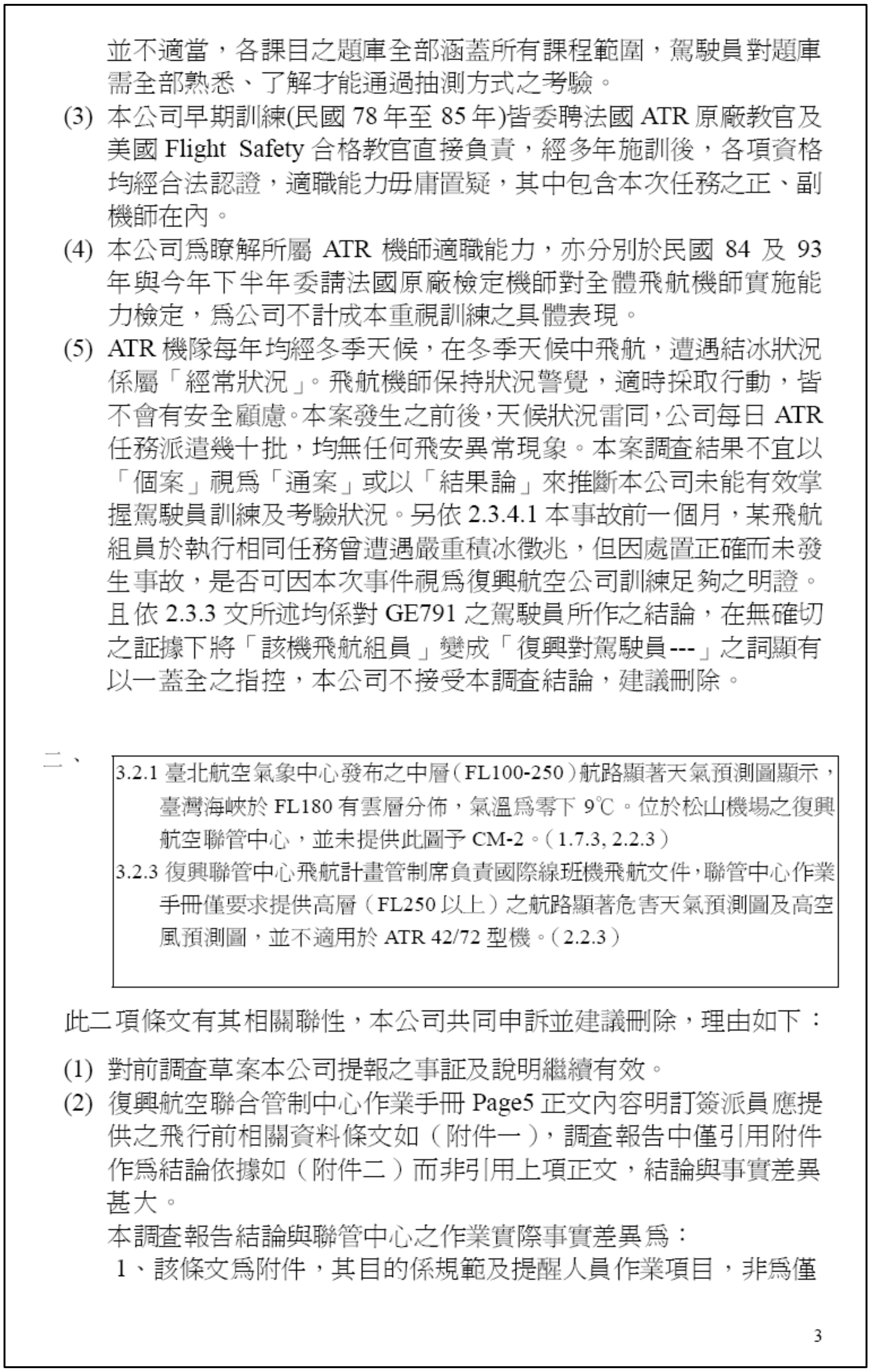
一、

> 3.1.2 復興對駕駛員有關航空器嚴重積冰之訓練及考驗等未能有效掌握。駕駛員對飛航手冊及/或操作手冊中之附註（Note）、注意（CAUTION）及警告（WARNING）等，未達能勝任其職務之熟習程度。（2.3.3）

本公司建議刪除此條文。理由如下：

(1) 對調查報告草案本公司先前所提報之事証及說明繼續有效。

(2) 『駕駛員對嚴重結冰訓練及考驗未能有效掌握及對飛航手冊及／或操作手冊中之 Note、Caution 及 WARNING 等，未達能勝任其職務之熟悉程度』之事係調查官依本公司訓練課目、時程、方式所作之結論，而本公司飛航人員訓練係依民航局規定訂立，人員訓練要求極爲嚴格，所有不正常課目操作必須達到熟悉且經過檢查員檢定及格而任用。僅依 2.3.3 所述『每三年以十二小時之時間循環一次實施「飛機系統不正常操作」複訓，難以完全涵蓋不正常操作相關課程』之推論並不適當。另於 2.3.3 分析一文中述及『地面學科定期複訓雖有題庫可供參考，每次測驗題目係由授課講師自題庫中選擇或自訂考題，難以涵蓋所有不正常操作』



並不適當，各課目之題庫全部涵蓋所有課程範圍，駕駛員對題庫需全部熟悉、了解才能通過抽測方式之考驗。

(3) 本公司早期訓練(民國 78 年至 85 年)皆委聘法國 ATR 原廠教官及美國 Flight Safety 合格教官直接負責，經多年施訓後，各項資格均經合法認證，適職能力毋庸置疑，其中包含本次任務之正、副機師在內。

(4) 本公司爲瞭解所屬 ATR 機師適職能力，亦分別於民國 84 及 93 年與今年下半年委請法國原廠檢定機師對全體飛航機師實施能力檢定，爲公司不計成本重視訓練之具體表現。

(5) ATR 機隊每年均經冬季天候，在冬季天候中飛航，遭遇結冰狀況係屬「經常狀況」。飛航機師保持狀況警覺，適時採取行動，皆不會有安全顧慮。本案發生之前後，天候狀況雷同，公司每日 ATR 任務派遣幾十批，均無任何飛安異常現象。本案調查結果不宜以「個案」視爲「通案」或以「結果論」來推斷本公司未能有效掌握駕駛員訓練及考驗狀況。另依 2.3.4.1 本事故前一個月，某飛航組員於執行相同任務曾遭遇嚴重積冰徵兆，但因處置正確而未發生事故，是否可因本次事件視爲復興航空公司訓練足夠之明證。且依 2.3.3 文所述均係對 GE791 之駕駛員所作之結論，在無確切之証據下將「該機飛航組員」變成「復興對駕駛員---」之詞顯有以一蓋全之指控，本公司不接受本調查結論，建議刪除。

二、

3.2.1 臺北航空氣象中心發布之中層（FL100-250）航路顯著天氣預測圖顯示，臺灣海峽於 FL180 有雲層分佈，氣溫爲零下 9℃。位於松山機場之復興航空聯管中心，並未提供此圖予 CM-2。（1.7.3, 2.2.3）

3.2.3 復興聯管中心飛航計畫管制席負責國際線班機飛航文件，聯管中心作業手冊僅要求提供高層（FL250 以上）之航路顯著危害天氣預測圖及高空風預測圖，並不適用於 ATR 42/72 型機。（2.2.3）

此二項條文有其相關聯性，本公司共同申訴並建議刪除，理由如下：

(1) 對前調查草案本公司提報之事証及說明繼續有效。

(2) 復興航空聯合管制中心作業手冊 Page5 正文內容明訂簽派員應提供之飛行前相關資料條文如（附件一），調查報告中僅引用附件作爲結論依據如（附件二）而非引用上項正文，結論與事實差異甚大。

本調查報告結論與聯管中心之作業實際事實差異爲：

1、該條文爲附件，其目的係規範及提醒人員作業項目，非爲僅

提供該空層天氣資料而訂立。

2、依調查報告 1.7.3 飛航天氣資訊所述『臺北航空氣象中心負責發布低（SFC-10,000 呎）、中（FL100-250）層航路顯著天氣預測圖（SIGWX Chart）及臺北飛航情報區（Taipei FIR）之顯著危害天氣預報（SIGMET）』。

聯管中心簽派員之實際作業情況爲：

聯合管制中心值勤人員每日均自臺北航空氣象中心取得其製作之 SIGWX CHART:SFC-FL100 及 FL100-FL250 資料，並於國際航線執行任務提示時複印提供飛航組員。原作業手冊中**飛航計劃管制席位任務執行要項**中特別註明 SIGWX (FL250-450)高度部份，係因臺北航空氣象中心僅製作臺北飛行情報區內低空層 SFC-FL100 及中空層 FL100-FL250 之 SIGWX CHART 之資料，爲考量松山機場僅提供國內航班飛航空層 FL250 以下之 SIGWX CHART，故國際航班所飛航有超過 FL250 空層之班機，特以括號加註 FL250 以上空層，提醒非由臺北航空氣象中心製作而須另行取自另一辦公室所轉發自倫敦區域預報中心 WAFC 製作之高層 FL250 以上 SIGWX CHART 之資料，與原提供之 SFC-FL250 資料銜接。

(3) 本公司規定簽派員應提供離場、目的地機場及航路天氣資料，所有飛航機師所獲得之天氣資料完全符合該批飛航任務所使用，且簽派員均遵此規定執行此一任務。

(4) 本公司聯管中心確依規定提供該圖予副駕駛員，該圖係由臺北航空氣象中心人工繪製提供飛航使用，每批飛行前聯管中心簽派員必須取回提供駕駛員飛行使用，當晚松山機場僅本公司有夜間飛航任務，如未前往拿取資料，如何會有備用資料存檔備查。

(5) 調查條文中僅依聯管中心手冊之註腳（FL250-450）所述高度已超越 ATR 之運作空層與『僅要求及並不適用於 ATR 的班機』之說詞(2.2.3)，未能查証括號之使用原因即予以判定『聯管中心未提供 FL180 高度天氣圖予該機副駕駛員』之說詞與事實不符，且機師於執行任務前，天氣提示爲固定及必要之程序，澳門貨機已執行將近十個月計飛航達 852 架次，如何判定固定飛航於 FL160 至 FL200 之間的機師僅獲得 FL250 至 FL450 之相關天氣資料。

三、

> 3.3.8 雖然臺北航空氣象中心發布之中層（FL100-250）航路顯著天氣預測圖，復興聯管中心並未提供給該機駕駛員，但此預測圖缺少部份有益資訊。香港天文台及東京航空氣象服務中心，對於位在結冰高度以上，有可能存在過冷水雲層，標示中度積冰之圖示，提供簽派員及駕駛員對航路上可能發生積冰之警覺。臺北航空氣象中心依據國際民航組織（ICAO）第三號附約之規定，對於非積雨雲的雲區預測有中度或以上積冰時才標示中度或以上積冰之圖示。（2.2）

本公司建議應刪除文中『復興聯管中心並未提供給該機駕駛員』之詞句，因本公司簽派員確有提供該 SIGWX 圖予該機副駕駛，且本條文所述之臺北航空氣象中心作業情況不應併入上項無關聯之詞句。並把修訂之條文提列爲**與可能肇因有關之調查發現**之項目內。理由如下：

(1) 本公司對前調查草案提供之事証及說明繼續有效。
(2) 臺北飛航情報區發布之 SIGWX（顯著航路天氣預測圖）僅提到高空溫度及雲頂高度，未有危害飛航之其他重要天氣資訊，依調查報告 2.2.2.2 所述『顯著天氣預測圖應包含----中度或嚴重積冰』，民航局發布之航空氣象規範 9.5 亦有此規定，本條調查結論飛安會亦指出『缺少部份有益資訊』，此爲重要之飛航資訊，且臺北航空氣象中心於該 GE791 班機之前後時段未發布 SIGMET 之顯著危害天氣資訊，致該班機駕駛員未能適時獲得該有益之天氣資料提醒及增加其警覺性，做好防範措施而避免事件發生。
(3) 依調查報告 2.2.2.2 最後一段指出『航空器嚴重結冰程度受到溫度、液態水含量及水滴直徑等三個重要氣象參數，以及翼剖面大小及形狀、速度、攻角、襟翼位置、防／除冰裝置等影響。對於大型客機，積冰情形可能輕微，但是該天氣情況對小型航空器，尤其是渦輪螺旋槳航空器，或許是嚴重問題』。依此段所述証明天氣因素確爲此事件之主要肇因之一，且 ATR 型機七次之嚴重結冰事件更証明天氣因素之直接影響。
(4) 依 1.7.3 文中所指出台北航空氣象中心 20 日發布之 SIGMET 2 有效時間爲 1400 至 1800，而 SIGMET 3 係於 21 日 0430 發布，期間約 10 個半小時未有任何有效之 SIGMET 之天氣發布，對於可能遭遇惡劣天候之警訊氣象單位應適時提醒飛行組員，有關惡劣天氣因素應詳述分析並增列入主要肇因項目內。

Attachment 4 Comments on Final Draft from CAA

項目	章節	內容	建議	附註
1	1.7.1 天氣概述 （P32）	依據中央氣象局（CWB）91 年 12 月 20 日 2000 及 0200 之地面天氣圖	依據中央氣象局（CWB）民國 91 年 12 月 20 日 1200UTC 及 1800UTC 之地面天氣圖	建議氣象資料以 UTC 註記，以符合現行民航作業方式。
2	（P32）	由 20 日 2000 及 21 日 0800 之 850 百帕	由 20 日 1200UTC 及 21 日 0000UTC 之 850 百帕	同上
3	（P32）	由 20 日 2000 及 21 日 0800 之 700 百帕	由 20 日 1200UTC 及 21 日 0000UTC 之 700 百帕	同上
4	（P32）	由 20 日 2000 及 21 日 0800 之 500 百帕	由 20 日 1200UTC 及 21 日 0000UTC 之 500 百帕	同上
5	（P32）	由 20 日 2000 及 21 日 0800 之 400 百帕、300 百帕及 200 百帕	由 20 日 1200UTC 及 21 日 0000UTC 之 400 百帕、300 百帕及 200 百帕	同上
6	（P32）	依據台灣電力公司落雷偵測系統資料顯示，於 0120 至 0220	依據台灣電力公司落雷偵測系統資料顯示，於 20 日 1720UTC 至 1820UTC	建議加註日期，時間以 UTC 註記。
7	（P33）	由紅外線衛星雲圖（0131 之雲圖如附錄 3）	由紅外線衛星雲圖（20 日 1731UTC 之雲圖如附錄 3）	同上
8	1.7.2 （P33）	中正國際機場（RCTP，距失事地點東北方 253 公里）：時間 1700 UTC 時間 1800 UTC；類型-整點…	中正國際機場（RCTP，距失事地點東北方 253 公里）：時間 20 日 1700 UTC 時間 20 日 1800 UTC；類型-整點…	建議加註日期

9	（P34）	馬公機場（RCQC，距失事地點東北方 21 公里）：時間 1700 UTC	馬公機場（RCQC，距失事地點東北方 21 公里）：時間 20 日 1700 UTC	同上
10	（P34）	時間 1800 UTC	時間 20 日 1800 UTC	同上
11	（P34）	高雄國際機場（RCKH，距失事地點東南方 137 公里）：時間 1700 UTC	高雄國際機場（RCKH，距失事地點東南方 137 公里）：時間 20 日 1700 UTC	同上
12	（P34）	時間 1800 UTC	時間 20 日 1800 UTC	同上
13	（P34）	嘉義機場（RCKU，距失事地點東方 96 公里）：時間 1800 UTC	嘉義機場（RCKU，距失事地點東方 96 公里）：時間 20 日 1800 UTC	同上
14	（P34）	金門機場（RCBS，距失事地點西北方 151 公里）：時間 1800 UTC	金門機場（RCBS，距失事地點西北方 151 公里）：時間 20 日 1800 UTC	同上
15	1.7.3 飛航天氣資訊（P35）	台北航空氣象中心負責發布航路顯著天氣預測圖	台北航空氣象中心負責發布低（SFC-10,000 呎）、中（FL100-250）、高（FL250 以上）層航路顯著天氣預測圖	建議加註「低、中、高層航路顯著天氣預測圖及其高度」。
16	（P35）	台北航空氣象中心…….，時間為 20 日 1400 至 1800，以及 0430 至 21 日 0830	台北航空氣象中心…….，時間為 20 日 0600 UTC 至 1000 UTC，以及 20 日 2030 UTC 至 21 日 0030 UTC	建議時間以 UTC 註記。
17	（P35）	[台北 SIGMET 2；台北 FIR，有效時間 0600 UTC 至 1000 UTC	[台北 SIGMET 2；台北 FIR，有效時間 20 日 0600 UTC 至 1000 UTC	建議加註日期

18	（P35）	[台北 SIGMET 3；台北 FIR，有效時間 20 日 2030 UTC 至 21 日 0030 UTC；類型—內嵌雷暴；觀測及預報位於北緯 23 度以南…	[台北 SIGMET 3；台北 FIR，有效時間 20 日 2030 UTC 至 21 日 0030 UTC；類型—內嵌雷暴；觀測及預報位於北緯 23 度以北…	北緯 23 度以南翻譯錯誤，應為北緯 23 度以北…
19	（P35-36）	台北航空氣象中心發布之 SIGWX Chart 有效時間至 21 日 0200 及 21 日 0800，…..台北至澎湖地區高空風及溫度為：….香港天文台發布香港管制區….	台北航空氣象中心發布中層（FL100-250）航路顯著天氣預測圖（SIGWX Chart），其有效時間至 20 日 1800 UTC（如附錄 4a）。台北至澎湖地區為有雨天氣，雲狀為高層雲及高積雲，雲量為裂至密雲，雲底高度低於 10,000 呎，雲頂高度大於 25,000 呎，0℃等溫線之高度約於 12,000 呎，惟預報未達中度或以上之積冰或亂流，故不標示中度或以上之積冰或亂流圖示。台北至澎湖地區高空風及溫度為：FL100：風向 230˚～250˚，風速 25～30 浬/時；溫度 2℃~4℃。FL180：風向 240˚～ 250˚，風速 40 ～ 50 浬/時；溫度零下 13℃至零下 12℃。 台北航空氣象中心發布中層（FL100-250）航路顯著天氣預測圖（SIGWX Chart），其有效時間至 21 日 0000 UTC（如附錄 4b）。台北至澎湖地區為有雨天氣，雲狀為高層雲及高積雲，雲量為裂至密雲，雲底高度低於	依據附錄 4，建議修改文字內容。

			10,000 呎，雲頂高度 25,000 呎，0℃等溫線之高度約於 12,000 呎，惟預報未達中度或以上之積冰或亂流，故不標示中度或以上之積冰或亂流圖示。台北至澎湖地區高空風及溫度為：FL100：風向 250˚，風速 15 ~ 20 浬/時；溫度 4℃~5℃。FL180：風向 240˚~ 250˚，風速 45 ~ 50 浬/時;溫度零下 11℃至零下 9℃。	
20	（P37）	香港天文台發布有效時間至 21 日 0200	香港天文台發布有效時間至 20 日 1800UTC	建議時間以 UTC 註記。
21	（P38）	台灣西南部及澎湖地區不在預報範圍之內。有效時間至 21 日 0200 之 SIGWX Chart，台灣中、北部及東北部海域中度積冰位於 FL120 至 FL240、中度亂流位於 FL20 至 FL380；有效時間至 21 日 0800 之 SIGWX Chart，台灣東部及東部海域地區之中度積冰位於 FL80 至 FL220、中度亂流位於 FL20 至 FL320。	台灣西南部及澎湖地區不在預報範圍之內。有效時間至 20 日 1800UTC 之 SIGWX Chart，台灣中、北部及東北部海域中度積冰位於 FL120 至 FL240、中度亂流位於 FL20 至 FL380；有效時間至 21 日 0000UTC 之 SIGWX Chart，台灣東部及東部海域地區之中度積冰位於 FL80 至 FL220、中度亂流位於 FL20 至 FL320。台灣海峽上空預測並無積冰或亂流。	建議時間以 UTC 註記。另加入「台灣海峽上空預測並無積冰或亂流。」
22	1.7.4 駕駛員獲得之天氣資訊（P38）	根據訪談紀錄…香港國際機場（VHHH）1800 之飛航天氣報告…及 FL200 之 0100 高空風及溫度預測圖。	根據訪談紀錄…香港國際機場（VHHH）20 日 1800UTC 之飛航天氣報告…及 FL200 之 20 日 1700UTC 高空風及溫度預測圖。	建議加註日期，時間以 UTC 註記。

23	（P38）	中正國際機場諮詢台提供該機駕駛員之天氣資料如下： 東南亞地區有效時間 20 日 2000 至 21 日 2000 之終端機場預報(TAF)。 2130 紅外線衛星雲圖。 倫敦世界區域預報中心之國際民航組織區域 G（亞洲至歐洲、高度 FL 250-630），有效時間至 0200 之航路顯著危害天氣預測圖（SIGWX Chart）。 華盛頓世界區域預報中心之歐亞地區 FL180 及東亞地區 FL300, FL340 與 FL390 的高空風及溫度預測圖，有效時間至 21 日 0800。 由 FL 180 的高空風及溫度預測圖顯示台灣海峽氣溫為負 10℃。 無證據顯示駕駛員未從中正諮詢台電腦，獲得更新之飛航天氣資訊。	中正國際機場諮詢台供應之天氣資料如下： 東南亞地區有效時間 20 日 1200UTC 至 21 日 1200UTC 之終端機場預報（TAF）。 20 日 1330UTC 紅外線衛星雲圖。 倫敦世界區域預報中心之國際民航組織區域 G（亞洲至歐洲、高度 FL 250-630），有效時間至 20 日 1800UTC 之高層（FL250-630）航路顯著危害天氣預測圖（SIGWX Chart）。 華盛頓世界區域預報中心之歐亞地區 FL180 及東亞地區 FL300, FL340 與 FL390 的高空風及溫度預測圖，有效時間至 21 日 0000UTC。由 FL 180 的高空風及溫度預測圖顯示台灣海峽氣溫為零下 10℃。 無證據顯示駕駛員是否從中正諮詢台電腦獲得更新之飛航天氣資訊。	建議將「該機駕駛員」刪除。 建議將「提供」改為「供應」。 建議加註日期，時間以 UTC 註記。 「負 10℃」改為「零下 10℃」。 並修改部分文字。
24	1.7.5 氣象雷達資訊 （P39）	附錄 8，資料時間為 0100 至 0200。	附錄 8，資料時間為 20 日 1700UTC 至 1800UTC。	建議加註日期，時間以 UTC 註記。

		其上方之雲頂較高，約為35,000呎。航點”CHALI”之前至航點“CANDY”之飛行軌跡位於此區域之上。	其上方之雲頂較高，約為35,000呎。惟澎湖及其附近並無雷達回波。航點”CHALI”之前至航點“CANDY”之飛行軌跡位於此區域之上。	建議插入「惟澎湖及其附近並無雷達回波。」
25	2.3.1 飛航組員所獲天氣資訊 （p132）	該機飛航組員獲得之天氣資訊（如1.7.4節)中，有效期限至21日0800時之「高空風及溫度預測圖」	該機飛航組員獲得之天氣資訊(如1.7.4節）中，有效期限至21日0000UTC之「高空風及溫度預測圖」	建議時間以UTC註記。
26	2.3.2.1 可能形成條件 （p133）	惟自0134時首次啟動機身除冰系統至其失速時，TAT皆在攝氏零下1度至零下4度間。	惟自21日0134L時首次啟動機身除冰系統至其失速時，TAT皆在攝氏零下1度至零下4度間。	建議加註日期。
27	3.1 與可能肇因有關之調查結果 （p174）	2. 台北航空氣象中心發布之中層航路顯著天氣預測圖顯示，台灣海峽於飛航空層180有雲層分佈，氣溫為負9℃。	2. 台北航空氣象中心發布之中層（FL100-250）航路顯著天氣預測圖顯示，台灣海峽於FL180有雲層分佈，氣溫為零下9℃。	建議加「中層（FL100-250）」，「飛航空層」改為「FL」，「負9℃」改為「零下9℃」。
28	（p174-175）	3. 中正國際機場諮詢台提供該機駕駛員倫敦世界區域預報中心之國際民航組織區域G之航路顯著危害天氣預測圖…其中航路顯著危害天氣預測圖無該機可用資訊，FL 180的高空風及溫度預測圖顯示台灣海峽氣溫為負10℃。	3. 中正國際機場諮詢台供應倫敦世界區域預報中心之國際民航組織區域G（FL250-630）之航路顯著危害天氣預測圖…其中高層（FL250-630）航路顯著危害天氣預測圖非該機可用資訊，FL 180的高空風及溫度預測圖顯示台灣海峽氣溫為零下10℃。	建議將「該機駕駛員」刪除，「提供」改為「供應」，並建議插入「（FL250-630）」、「高層（FL250-630）」及作文字之修改。

29	（p175）	5. 無證據顯示駕駛員未於中正國際機場諮詢台的電腦，獲得更新的飛航天氣資訊。	5. 無證據顯示駕駛員是否從中正國際機場諮詢台的電腦獲得更新的飛航天氣資訊。	建議作文字之修改。
30	3.3 其它調查結果 （p177）	7. 雖然台北航空氣象中心發布之中層航路顯著天氣預測圖並未提供給該機駕駛員，但飛安會指出其缺少部份有益的資訊。香港天文台及東京航空氣象服務中心，對於位在結冰高度以上，有可能存在過冷水雲層，標示中度積冰之圖示，提供簽派員及駕駛員對航路上，可能發生積冰警覺，台北航空氣象中心對於非積雨雲的雲區並無相關做法。	7. 台北航空氣象中心發布之中層（FL100-250）航路顯著天氣預測圖，復興航空聯管中心並未提供給該機駕駛員，飛安會指出復興航空缺少該項有益的資訊。香港天文台及東京航空氣象服務中心，對於位在結冰高度以上，有可能存在過冷水雲層，標示中度積冰之圖示，提供簽派員及駕駛員對航路上，可能發生積冰警覺。台北航空氣象中心依據國際民航組織（ICAO）之規定，對於非積雨雲的雲區預測有中度或以上積冰時才標示中度或以上積冰之圖示。	建議作部分文字及內容之修改與增加。
31	4.1.2 致 CAA SEC 1	除國際民航組織規定外，參考香港天文及東京航空氣象服務中心對於顯著天氣預測圖做法，在結冰高度以上，有可能存在過冷水之非積雨雲，標示中度積冰之圖示，增加駕駛員之狀況警覺。		本局目前做法符合國際民航組織規定。 為提昇服務品質，本局已依 貴會建議於本(93)年八月一日起，比照香港與日本的做法配合實施。(奉准簽函如附件一)

32	4.1.2 致 CAA SEC 2	重新檢視復興對駕駛員之訓練，期能有效執行職務。		本局已依 貴會建議執行完畢。（紀錄如附件二）
33	4.1.2 致 CAA SEC 4	持續審視及評估有關結冰偵測系統之技術服務指南（Service Bulletin）、相關之民航通告（Advisory Circular）與適航指令（Airworthiness Directive）。	持續審視及評估有關結冰偵測系統相關之民航通告（Advisory Circular）與適航指令（Airworthiness Directive）。	依 ICAO ANNEX 6 Chapter 8，評估技術服務指南（Service Bulletin）為航空公司之責任，故建議修正文字。

Aviation Safety Council
Taipei, Taiwan

GE 791 Occurrence Investigation Report

VOLUME II

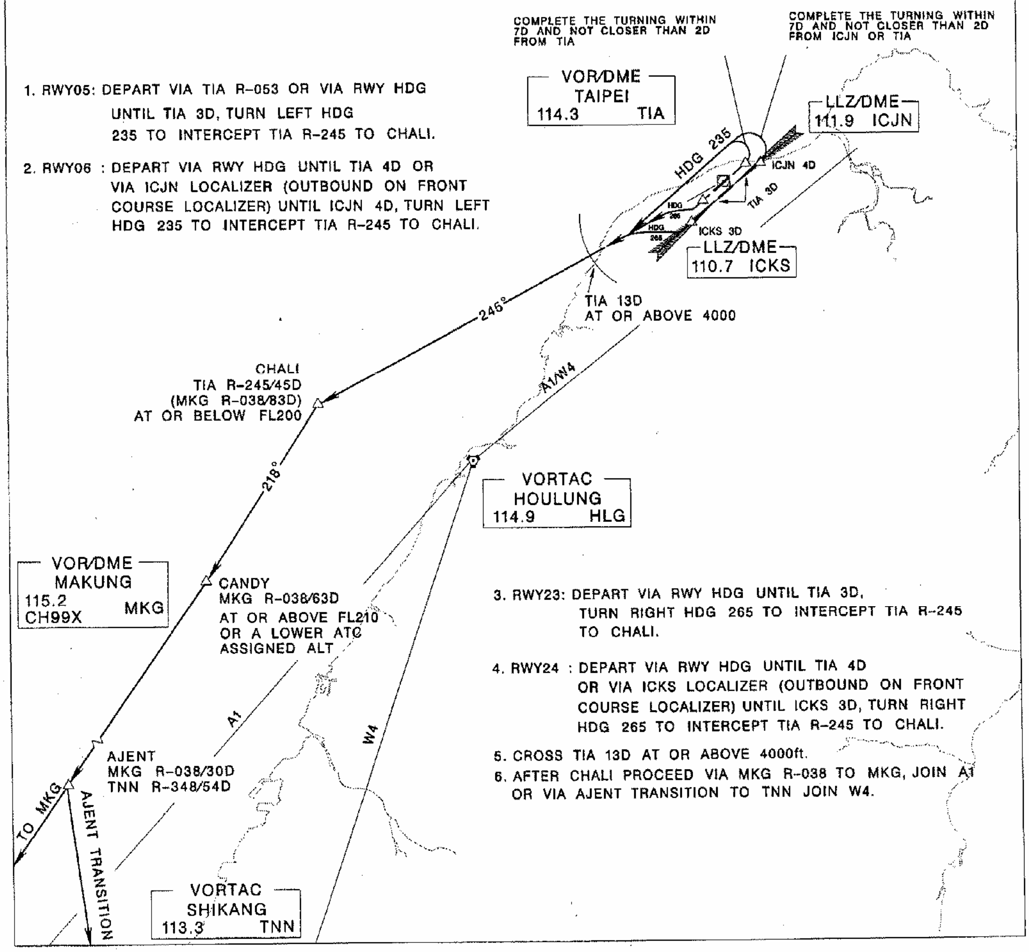
IN-FLIGHT ICING ENCOUNTER AND CRASH INTO THE SEA
TRANSASIA AIRWAYS FLIGHT 791
ATR72-200, B-22708
17 KILOMETERS SOUTHWEST OF MAKUNG CITY,
PENGHU ISLANDS, TAIWAN
DECEMBER 21, 2002

ASC-AOR-05-04-001

Content

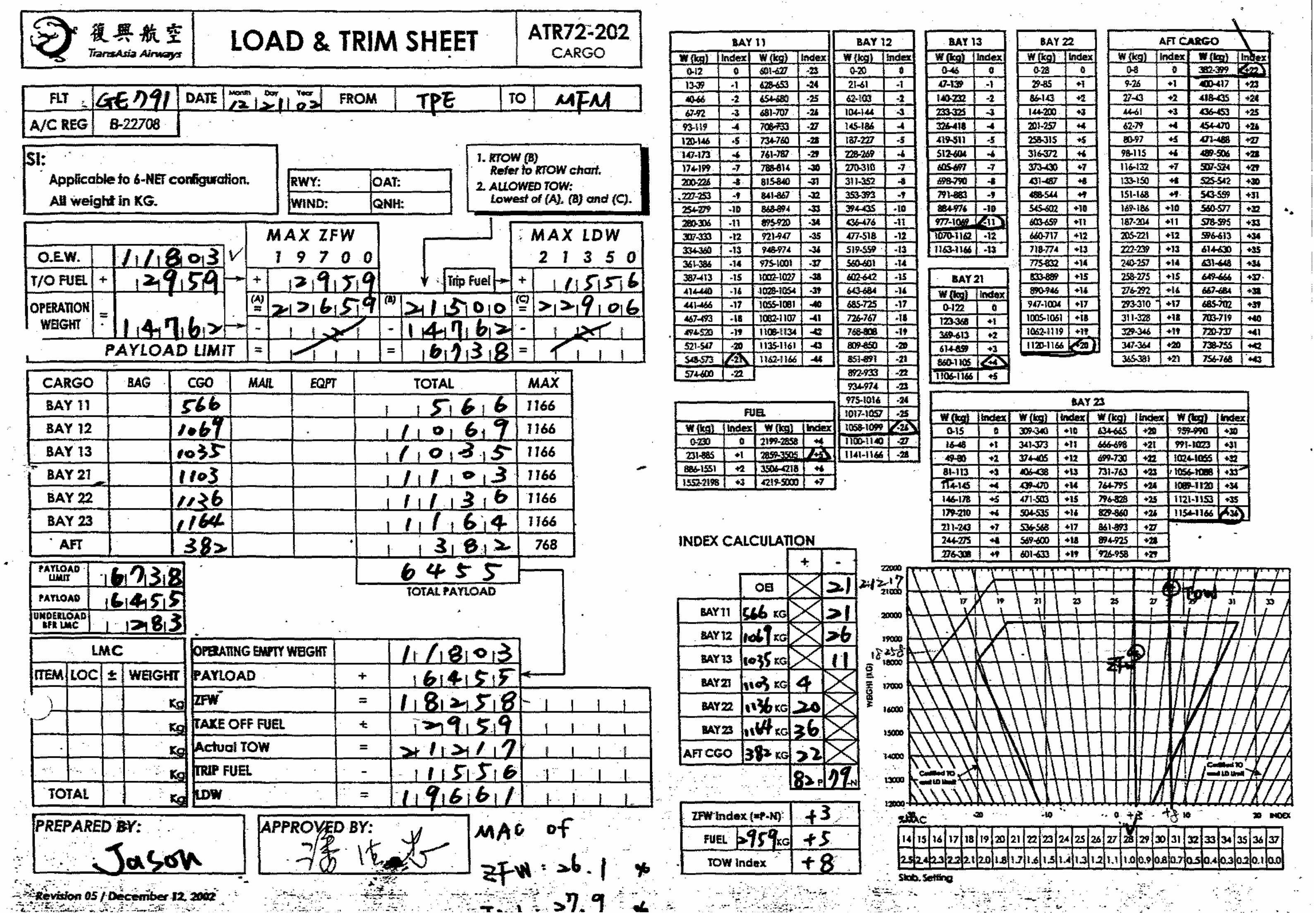
Appendix 1 CANDY ONE Departure, CKS International Airport

CANDY 1號離場
CANDY ONE DEPARTURE (CD1)



1. RWY05: DEPART VIA TIA R-053 OR VIA RWY HDG UNTIL TIA 3D, TURN LEFT HDG 235 TO INTERCEPT TIA R-245 TO CHALI.
2. RWY06 : DEPART VIA RWY HDG UNTIL TIA 4D OR VIA ICJN LOCALIZER (OUTBOUND ON FRONT COURSE LOCALIZER) UNTIL ICJN 4D, TURN LEFT HDG 235 TO INTERCEPT TIA R-245 TO CHALI.
3. RWY23: DEPART VIA RWY HDG UNTIL TIA 3D, TURN RIGHT HDG 265 TO INTERCEPT TIA R-245 TO CHALI.
4. RWY24 : DEPART VIA RWY HDG UNTIL TIA 4D OR VIA ICKS LOCALIZER (OUTBOUND ON FRONT COURSE LOCALIZER) UNTIL ICKS 3D, TURN RIGHT HDG 265 TO INTERCEPT TIA R-245 TO CHALI.
5. CROSS TIA 13D AT OR ABOVE 4000ft.
6. AFTER CHALI PROCEED VIA MKG R-038 TO MKG, JOIN A1 OR VIA AJENT TRANSITION TO TNN JOIN W4.

Appendix 2 GE791 Load and Trim Sheet



復興航空 TransAsia Airways

LOAD & TRIM SHEET

ATR72-202
CARGO

FLT	GE791	DATE	Month 12	Day 21	Year 02	FROM	TPE	TO	MFM
A/C REG	B-22708						

SI:
Applicable to 6-NET configuration.
All weight in KG.

RWY:	OAT:
WIND:	QNH:

1. RTOW (B)
Refer to RTOW chart.
2. ALLOWED TOW:
Lowest of (A), (B) and (C).

				MAX ZFW				MAX LDW
O.E.W.		11803 ✓		19700				21350
T/O FUEL	+	2959	+	2959		Trip Fuel	+	1556
OPERATION WEIGHT	=	14762	(A) =	22659	(B)	21500	(C) =	22906
			-		-	14762	-	
PAYLOAD LIMIT			=		=	6738	=	

CARGO	BAG	CGO	MAIL	EQPT	TOTAL	MAX
BAY 11		566			566	1166
BAY 12		1069			1069	1166
BAY 13		1035			1035	1166
BAY 21		1103			1103	1166
BAY 22		1136			1136	1166
BAY 23		1164			1164	1166
AFT		382			382	768
					6455 TOTAL PAYLOAD	

PAYLOAD LIMIT	6738
PAYLOAD	6455
UNDERLOAD BFR LMC	283

LMC			
ITEM	LOC	±	WEIGHT
			Kg
			Kg
			Kg
			Kg
TOTAL			Kg

OPERATING EMPTY WEIGHT		11803
PAYLOAD	+	6455
ZFW	=	18258
TAKE OFF FUEL	+	2959
Actual TOW	=	21217
TRIP FUEL	-	1556
LDW	=	19661

PREPARED BY: Jason

APPROVED BY:

MAC of
ZFW : 26.1 %
T[illegible] : 27.9 %

Revision 05 / December 12, 2002

BAY 11			
W (kg)	Index	W (kg)	Index
0-12	0	601-627	-23
13-39	-1	628-653	-24
40-66	-2	654-680	-25
67-92	-3	681-707	-26
93-119	-4	708-733	-27
120-146	-5	734-760	-28
147-173	-6	761-787	-29
174-199	-7	788-814	-30
200-226	-8	815-840	-31
227-253	-9	841-867	-32
254-279	-10	868-894	-33
280-306	-11	895-920	-34
307-333	-12	921-947	-35
334-360	-13	948-974	-36
361-386	-14	975-1001	-37
387-413	-15	1002-1027	-38
414-440	-16	1028-1054	-39
441-466	-17	1055-1081	-40
467-493	-18	1082-1107	-41
494-520	-19	1108-1134	-42
521-547	-20	1135-1161	-43
548-573	-21	1162-1166	-44
574-600	-22		

BAY 12	
W (kg)	Index
0-20	0
21-61	-1
62-103	-2
104-144	-3
145-186	-4
187-227	-5
228-269	-6
270-310	-7
311-352	-8
353-393	-9
394-435	-10
436-476	-11
477-518	-12
519-559	-13
560-601	-14
602-642	-15
643-684	-16
685-725	-17
726-767	-18
768-808	-19
809-850	-20
851-891	-21
892-933	-22
934-974	-23
975-1016	-24
1017-1057	-25
1058-1099	-26
1100-1140	-27
1141-1166	-28

BAY 13	
W (kg)	Index
0-46	0
47-139	-1
140-232	-2
233-325	-3
326-418	-4
419-511	-5
512-604	-6
605-697	-7
698-790	-8
791-883	-9
884-976	-10
977-1069	-11
1070-1162	-12
1163-1166	-13

BAY 21	
W (kg)	Index
0-122	0
123-368	+1
369-613	+2
614-859	+3
860-1105	+4
1106-1166	+5

BAY 22	
W (kg)	Index
0-28	0
29-85	+1
86-143	+2
144-200	+3
201-257	+4
258-315	+5
316-372	+6
373-430	+7
431-487	+8
488-544	+9
545-602	+10
603-659	+11
660-717	+12
718-774	+13
775-832	+14
833-889	+15
890-946	+16
947-1004	+17
1005-1061	+18
1062-1119	+19
1120-1166	+20

AFT CARGO			
W (kg)	Index	W (kg)	Index
0-8	0	382-399	+22
9-26	+1	400-417	+23
27-43	+2	418-435	+24
44-61	+3	436-453	+25
62-79	+4	454-470	+26
80-97	+5	471-488	+27
98-115	+6	489-506	+28
116-132	+7	507-524	+29
133-150	+8	525-542	+30
151-168	+9	543-559	+31
169-186	+10	560-577	+32
187-204	+11	578-595	+33
205-221	+12	596-613	+34
222-239	+13	614-630	+35
240-257	+14	631-648	+36
258-275	+15	649-666	+37
276-292	+16	667-684	+38
293-310	+17	685-702	+39
311-328	+18	703-719	+40
329-346	+19	720-737	+41
347-364	+20	738-755	+42
365-381	+21	756-768	+43

FUEL			
W (kg)	Index	W (kg)	Index
0-230	0	2199-2858	+4
231-885	+1	2859-3505	+5
886-1551	+2	3506-4218	+6
1552-2198	+3	4219-5000	+7

BAY 23							
W (kg)	Index	W (kg)	Index	W (kg)	Index	W (kg)	Index
0-15	0	309-340	+10	634-665	+20	959-990	+30
16-48	+1	341-373	+11	666-698	+21	991-1023	+31
49-80	+2	374-405	+12	699-730	+22	1024-1055	+32
81-113	+3	406-438	+13	731-763	+23	1056-1088	+33
114-145	+4	439-470	+14	764-795	+24	1089-1120	+34
146-178	+5	471-503	+15	796-828	+25	1121-1153	+35
179-210	+6	504-535	+16	829-860	+26	1154-1166	+36
211-243	+7	536-568	+17	861-893	+27		
244-275	+8	569-600	+18	894-925	+28		
276-308	+9	601-633	+19	926-958	+29		

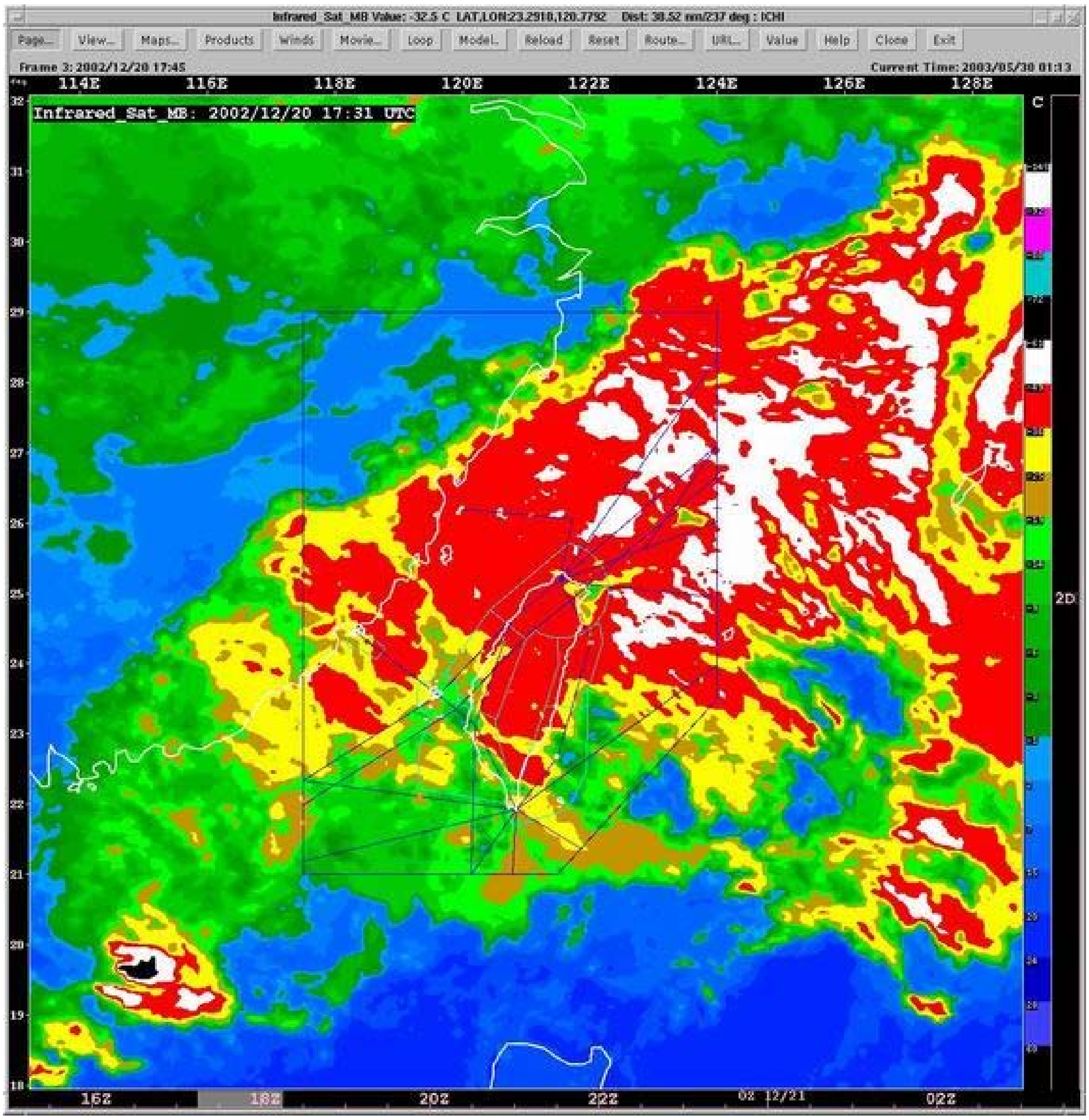
INDEX CALCULATION

		+	-
	OEI	☒	21
BAY 11	566 KG	☒	21
BAY 12	1069 KG	☒	26
BAY 13	1035 KG	☒	11
BAY 21	1103 KG	4	☒
BAY 22	1136 KG	20	☒
BAY 23	1164 KG	36	☒
AFT CGO	382 KG	22	☒
		82 P	79 N

ZFW Index (=P-N)		+3
FUEL	2959 KG	+5
TOW Index		+8

%MAC	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Stab. Setting	2.5	2.4	2.3	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.5	0.4	0.3	0.2	0.1	0.0

Appendix 3 GMS-5 Infrared Satellite Images at 1731 UTC



Infrared_Sat_MB Value: -32.5 C LAT,LON:23.2910,120.7792 Dist: 38.52 nm/237 deg : ICHI

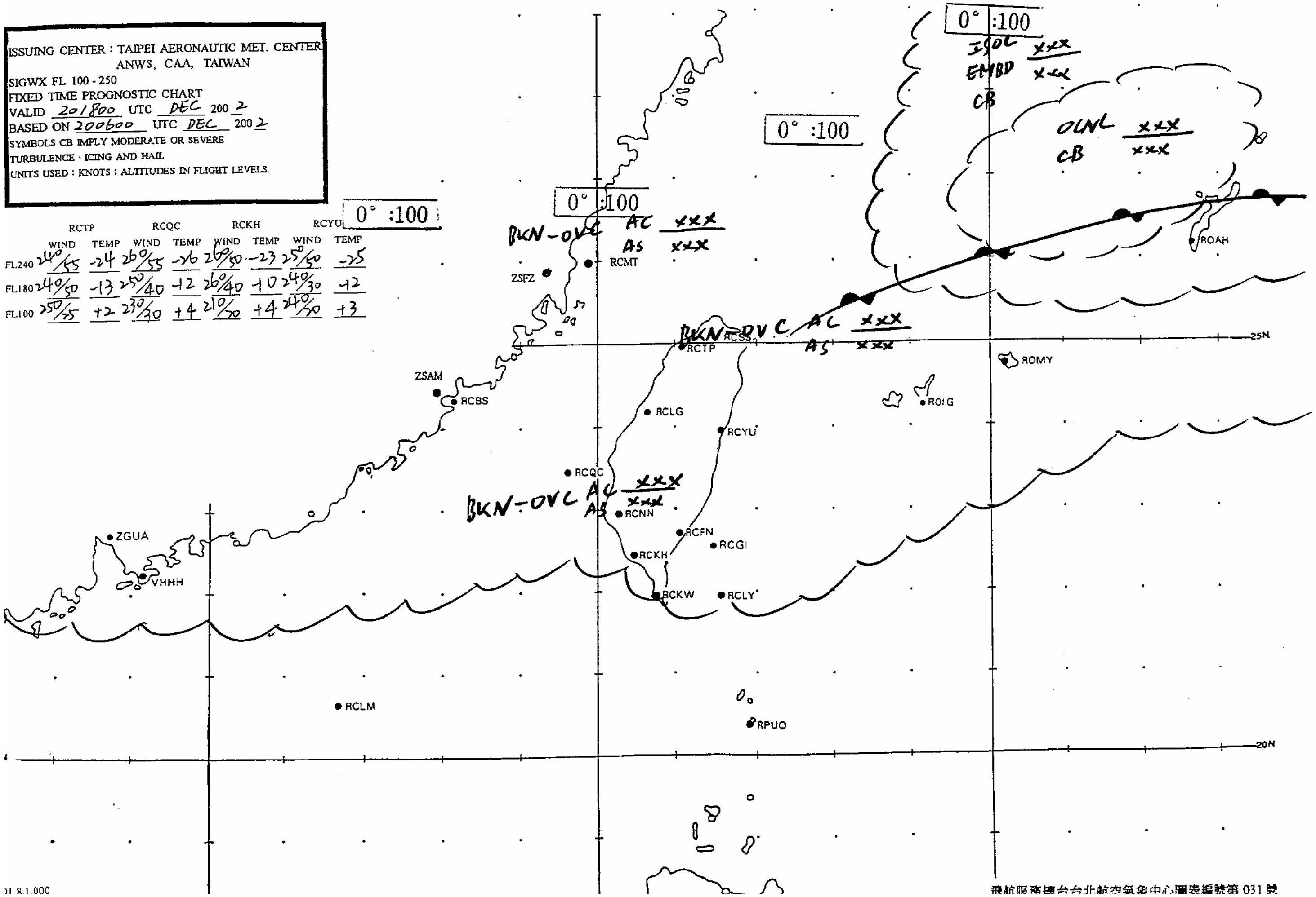
Frame 3: 2002/12/20 17:45

Current Time: 2003/05/30 01:13

Infrared_Sat_MB: 2002/12/20 17:31 UTC

Appendix 4 The SIGWX Chart Issued from TAMC for FL100-FL250

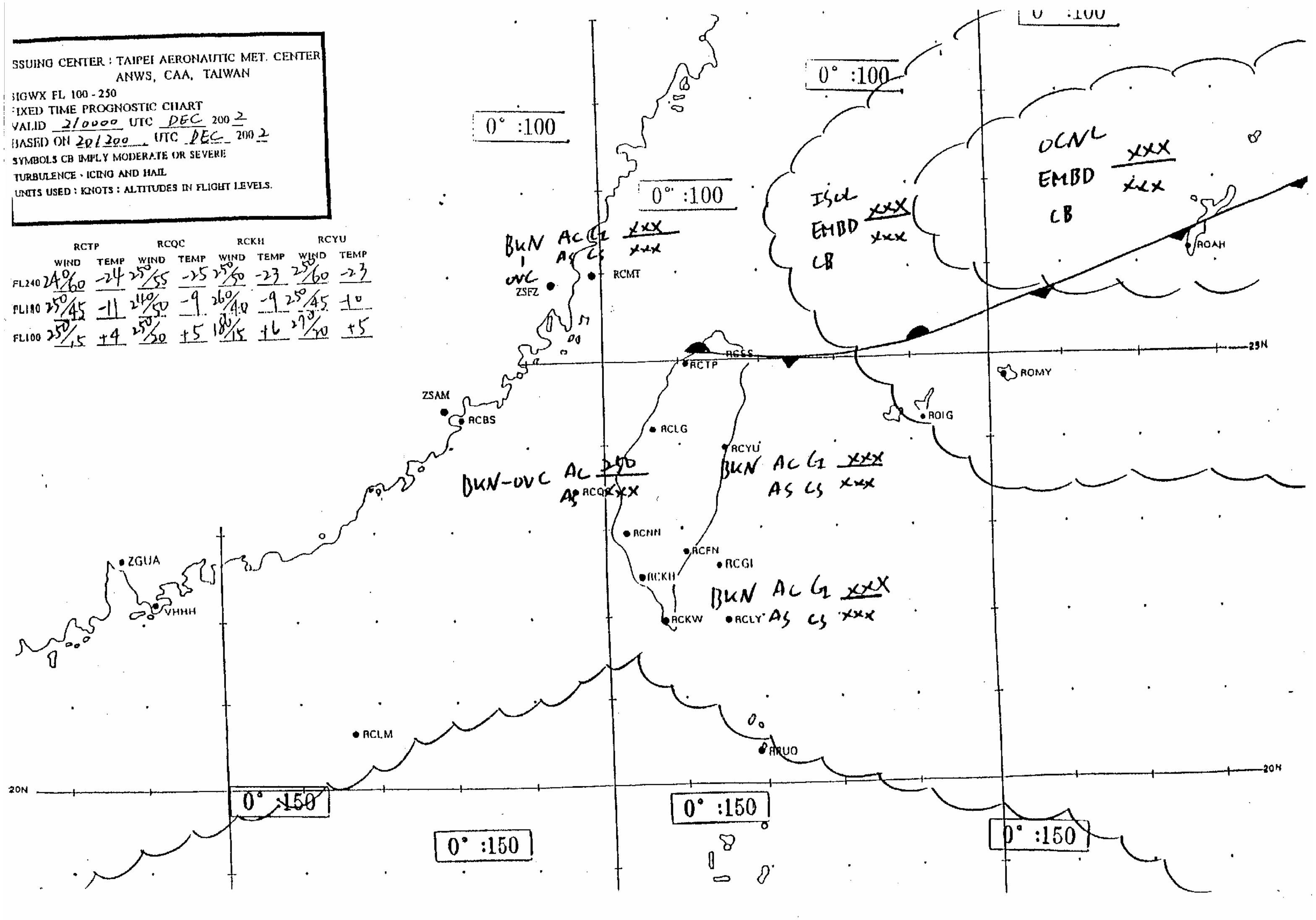
The SIGWX Chart Issued from TAMC for FL100-FL250 and was Valid at 1800 UTC, Dec 20



ISSUING CENTER : TAIPEI AERONAUTIC MET. CENTER
ANWS, CAA, TAIWAN
SIGWX FL 100 - 250
FIXED TIME PROGNOSTIC CHART
VALID 201800 UTC DEC 2002
BASED ON 200600 UTC DEC 2002
SYMBOLS CB IMPLY MODERATE OR SEVERE
TURBULENCE · ICING AND HAIL
UNITS USED : KNOTS : ALTITUDES IN FLIGHT LEVELS.

	RCTP		RCQC		RCKH		RCYU	
	WIND	TEMP	WIND	TEMP	WIND	TEMP	WIND	TEMP
FL240	240/55	-24	260/55	-26	260/50	-23	250/50	-25
FL180	240/50	-13	250/40	-12	260/40	-10	240/30	-12
FL100	250/25	+2	230/30	+4	210/20	+4	240/20	+3

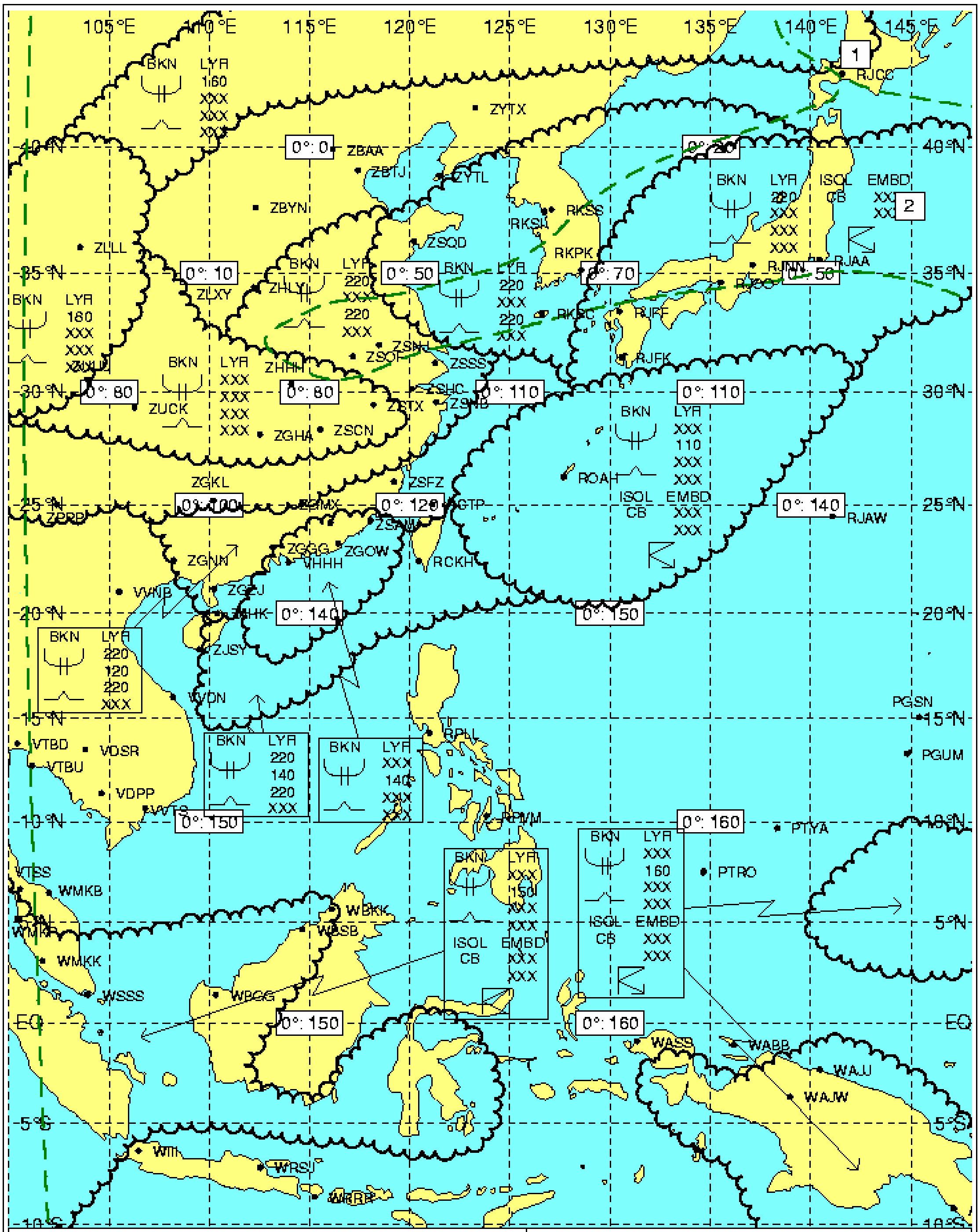
The SIGWX Chart Issued from TAMC for FL100-FL250 and was Valid at 0000 UTC, Dec 21



SSUING CENTER : TAIPEI AERONAUTIC MET. CENTER
ANWS, CAA, TAIWAN
IGWX FL 100 - 250
IXED TIME PROGNOSTIC CHART
VALID 210000 UTC DEC 2002
BASED ON 201200 UTC DEC 2002
SYMBOLS CB IMPLY MODERATE OR SEVERE
TURBULENCE · ICING AND HAIL
UNITS USED : KNOTS : ALTITUDES IN FLIGHT LEVELS.

	RCTP		RCQC		RCKH		RCYU	
	WIND	TEMP	WIND	TEMP	WIND	TEMP	WIND	TEMP
FL240	240/60	-24	250/55	-25	250/50	-23	250/60	-23
FL180	250/45	-11	240/50	-9	260/40	-9	250/45	-10
FL100	250/15	+4	250/20	+5	180/15	+6	270/20	+5

Appendix 5 The SIGWX Charts Issued from HKO for FL100-FL250 and was Valid at 1800 UTC



香港天文台
HONG KONG OBSERVATORY

SIGNIFICANT WEATHER PROGNOSTIC FL 100 - 250
VALID FOR 1800 UTC ON FRI 20 DEC 2002
ISSUED BY HONG KONG AIRPORT METEOROLOGICAL OFFICE
AT 0900 UTC ON 20 DEC 2002 BY TLC/CML

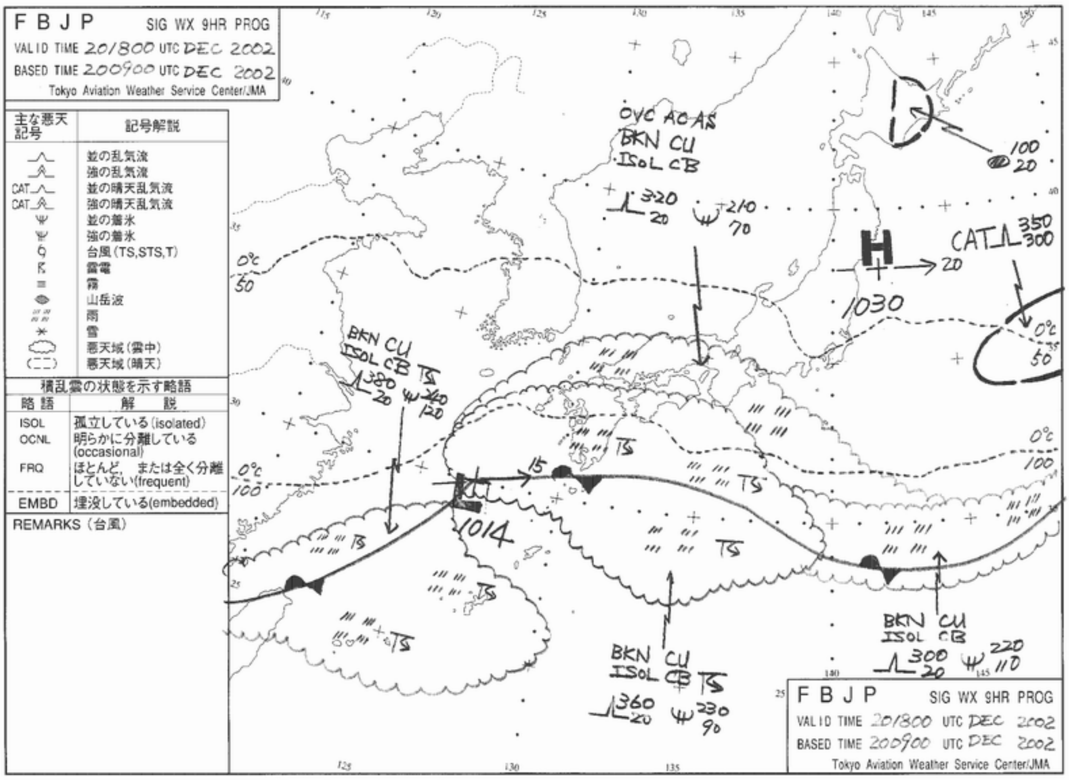
LEGEND OF UNITS HEIGHT IN FLIGHT LEVELS
PROJECTION MERCATOR

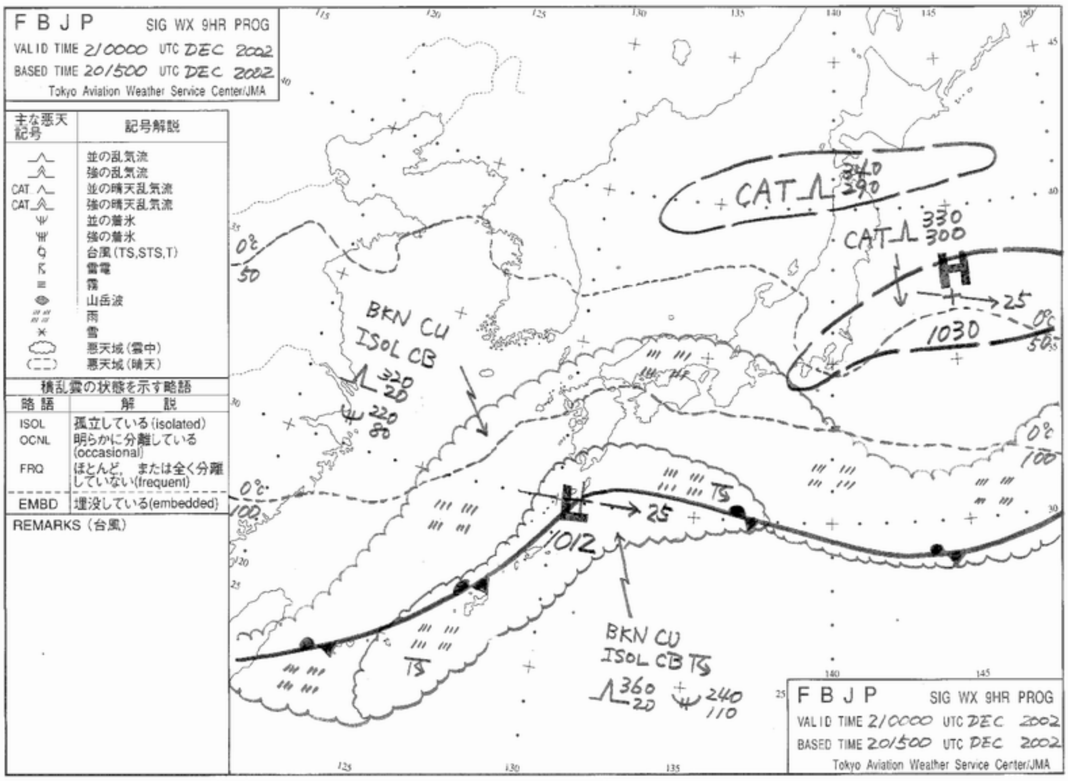
CAT Areas

1 XXX 180

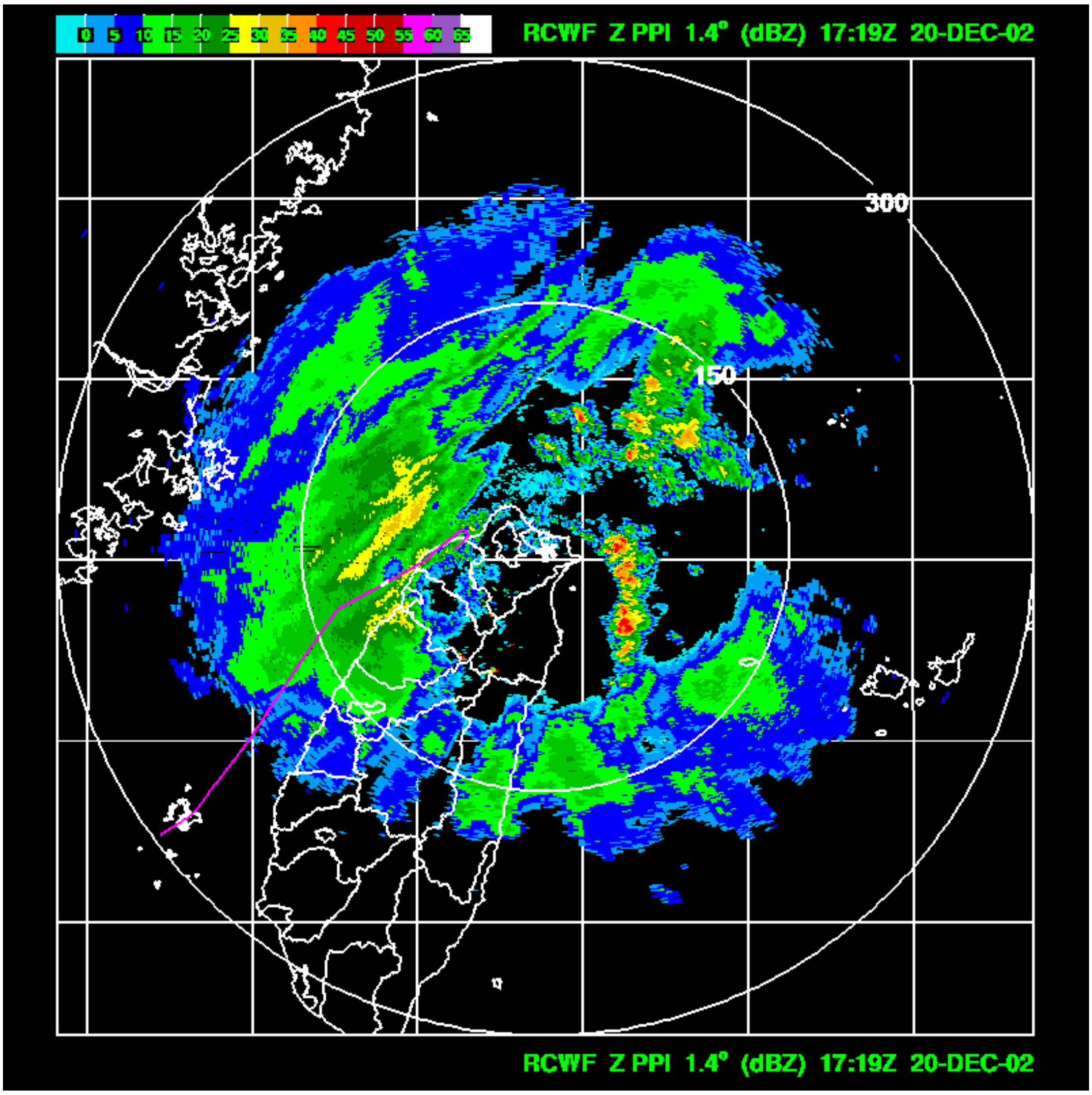
2 OCNL XXX 230

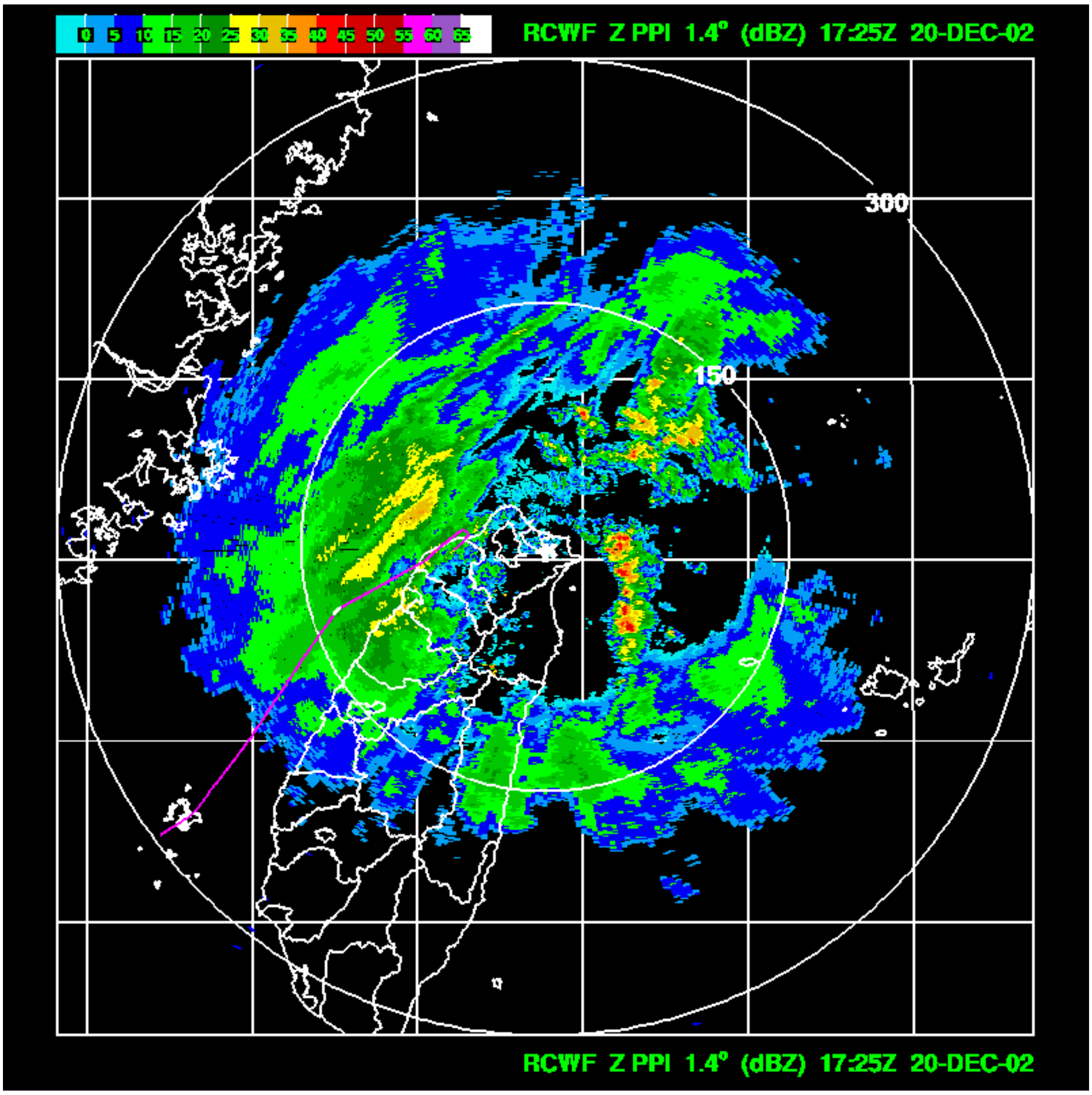
Appendix 6 The SIGWX Charts Issued from TAWSC for SFC to 14,000 meters and was Valid at 1800 UTC on Dec. 20 and 0000 UTC on Dec. 21

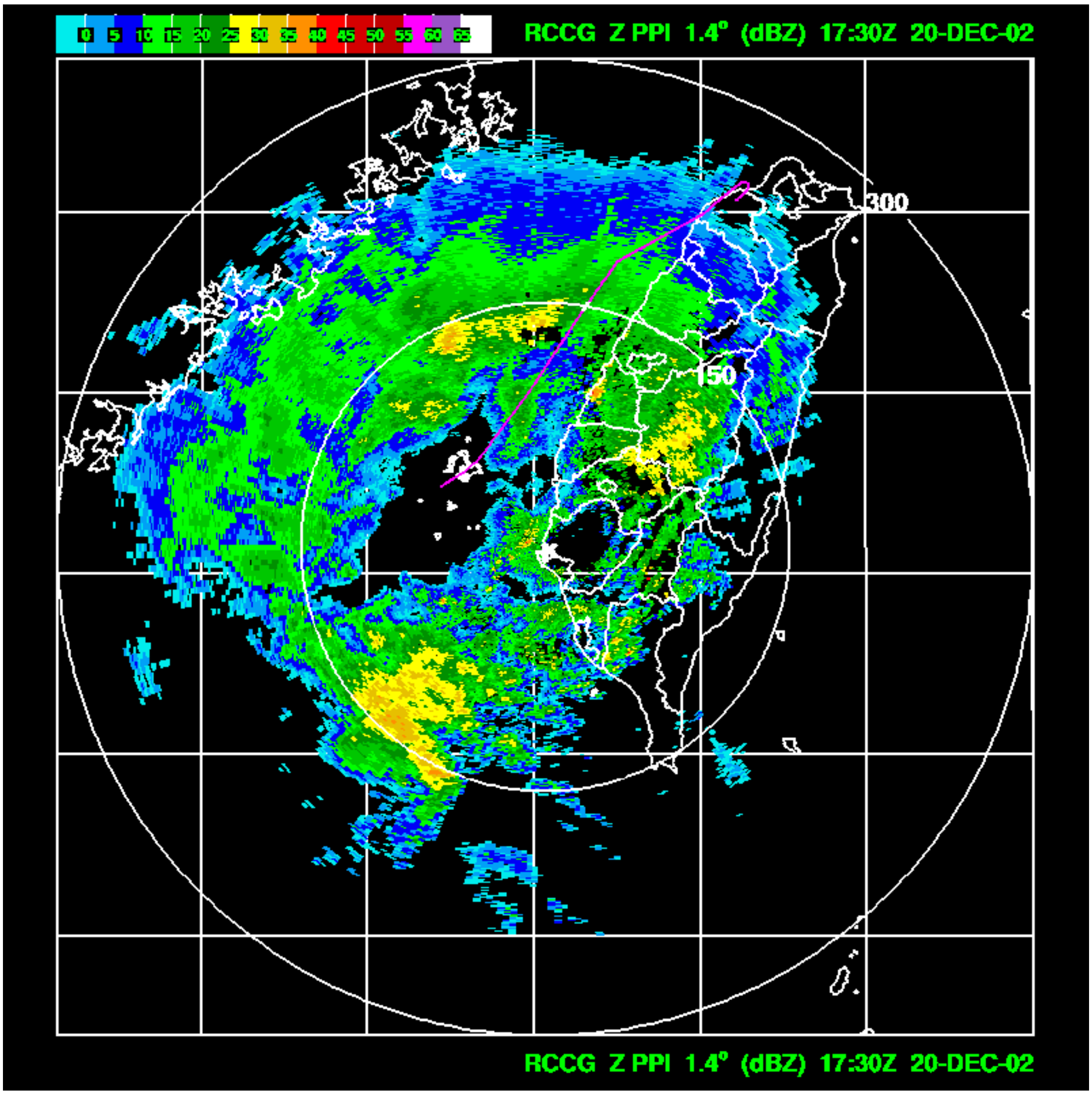

F B J P SIG WX 9HR PROG
VALID TIME 20/800 UTC DEC 2002
BASED TIME 200900 UTC DEC 2002
Tokyo Aviation Weather Service Center/JMA
主な悪天記号
記号解説
並の乱気流
強の乱気流
CAT 並の晴天乱気流
CAT 強の晴天乱気流
並の着氷
強の着氷
台風(TS,STS,T)
雷電
霧
山岳波
雨
雪
悪天域(雲中)
悪天域(晴天)
積乱雲の状態を示す略語
略語
解説
ISOL 孤立している(isolated)
OCNL 明らかに分離している(occasional)
FRQ ほとんど、または全く分離していない(frequent)
EMBD 埋没している(embedded)
REMARKS（台風）
OVC AC AS
BKN CU
ISOL CB
320 20
210 70
100 20
H
1030
20
CAT 350 300
0°C 50
0°C 50
BKN CU
ISOL CB TS
380 20
240 120
0°C 100
0°C 100
15
L
1014
TS
TS
TS
TS
TS
BKN CU
ISOL CB TS
360 20
230 90
BKN CU
ISOL CB
300 20
220 110
F B J P SIG WX 9HR PROG
VALID TIME 201800 UTC DEC 2002
BASED TIME 200900 UTC DEC 2002
Tokyo Aviation Weather Service Center/JMA

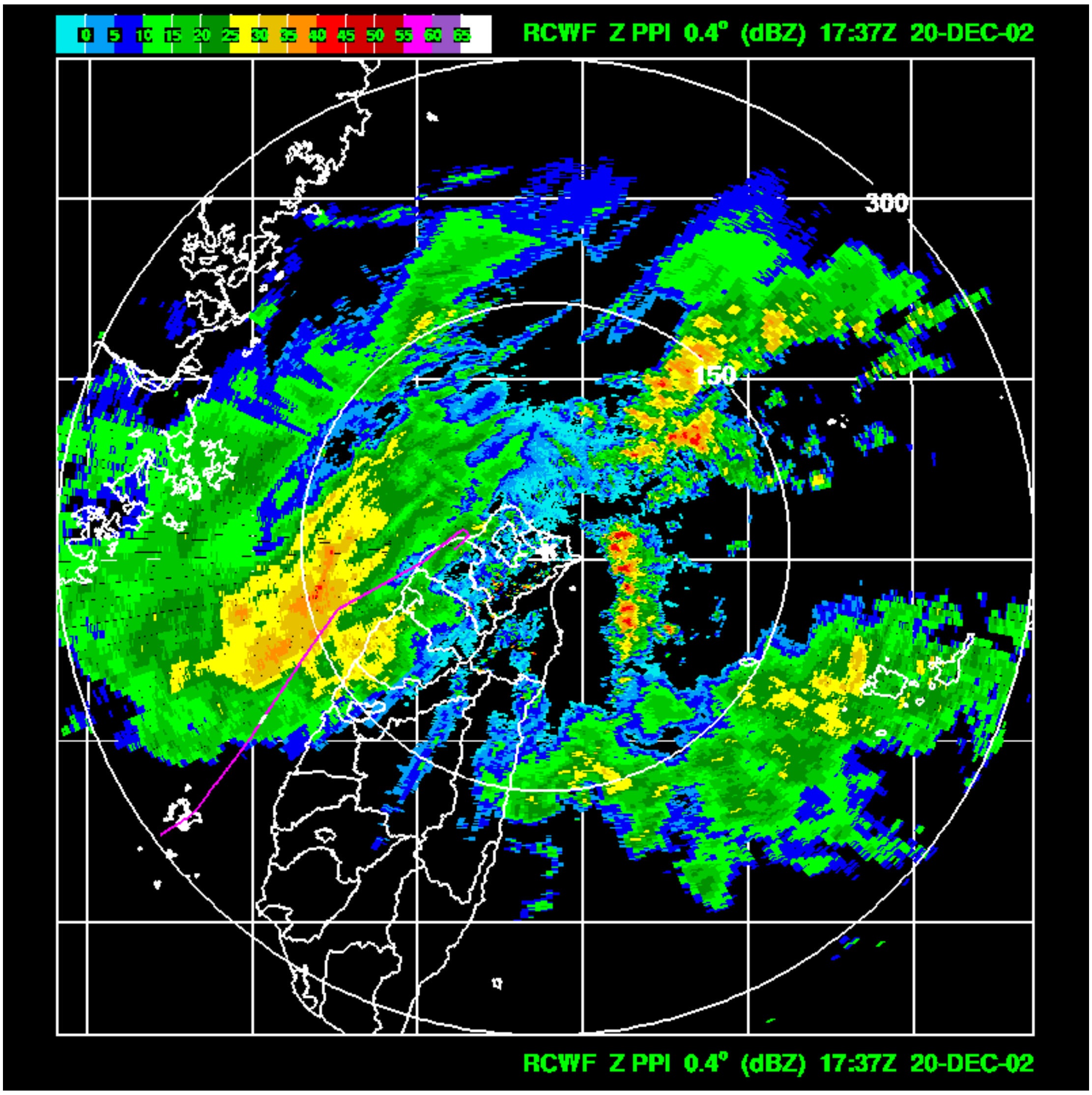

F B J P SIG WX 9HR PROG
VALID TIME 2/0000 UTC DEC 2002
BASED TIME 20/500 UTC DEC 2002
Tokyo Aviation Weather Service Center/JMA
主な悪天記号
記号解説
並の乱気流
強の乱気流
CAT 並の晴天乱気流
CAT 強の晴天乱気流
並の着氷
強の着氷
台風(TS,STS,T)
雷電
霧
山岳波
雨
雪
悪天域(雲中)
悪天域(晴天)
積乱雲の状態を示す略語
略語
解説
ISOL 孤立している(isolated)
OCNL 明らかに分離している(occasional)
FRQ ほとんど、または全く分離していない(frequent)
EMBD 埋没している(embedded)
REMARKS（台風）
CAT 340 390
CAT 330 300
H
25
1030
0°C 50
0°C 50
BKN CU
ISOL CB
320 20
220 80
0°C 100
0°C 100
L
25
1012
TS
TS
BKN CU
ISOL CB TS
360 20
240 110
F B J P SIG WX 9HR PROG
VALID TIME 2/0000 UTC DEC 2002
BASED TIME 20/500 UTC DEC 2002
Tokyo Aviation Weather Service Center/JMA

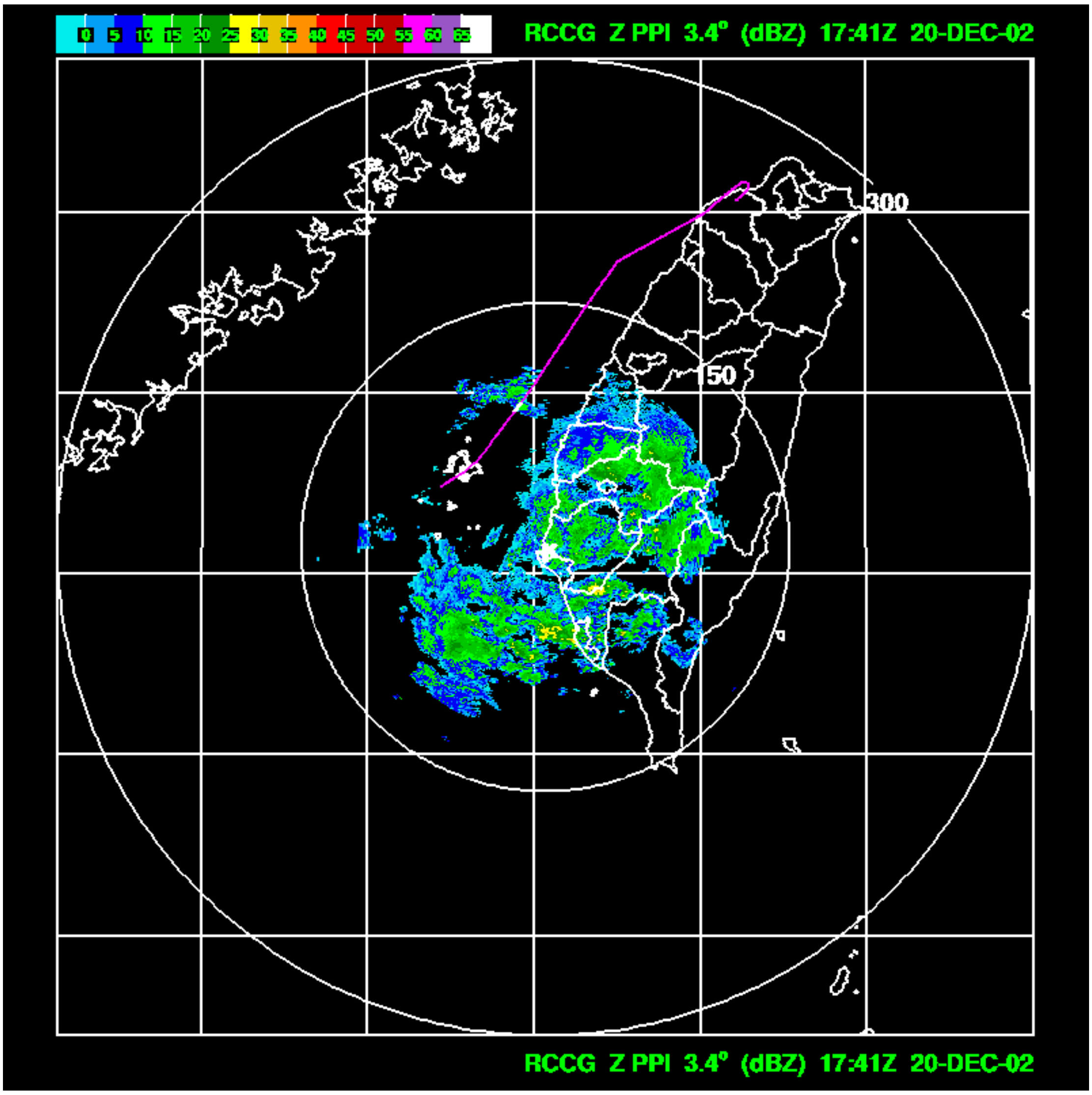
Appendix 7 The PPI of Radar Images with the Ground Track of GE791 Superimposed

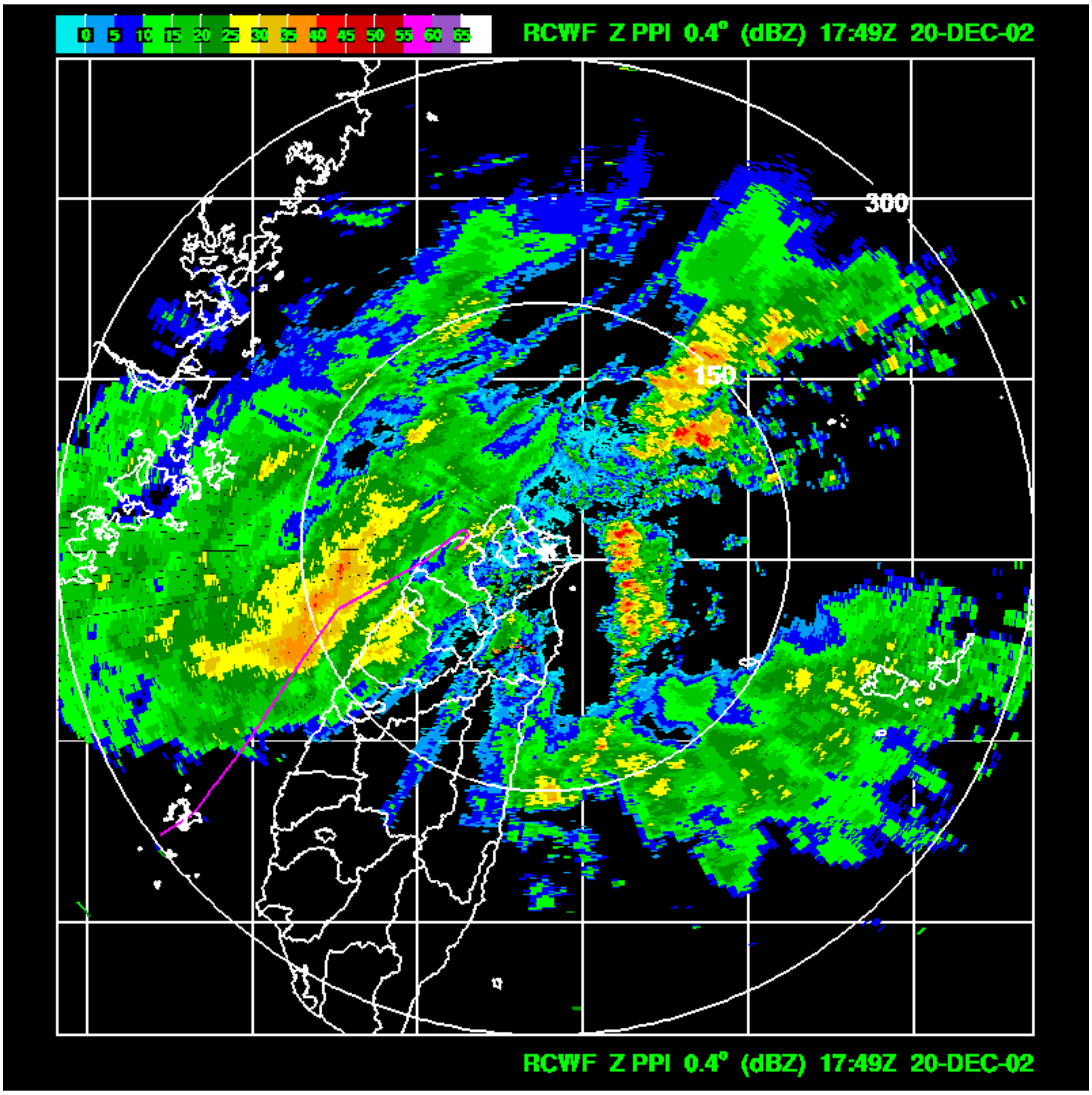

0 5 10 15 20 25 30 35 40 45 50 55 60 65
RCWF Z PPI 1.4° (dBZ) 17:19Z 20-DEC-02
300
150
RCWF Z PPI 1.4° (dBZ) 17:19Z 20-DEC-02

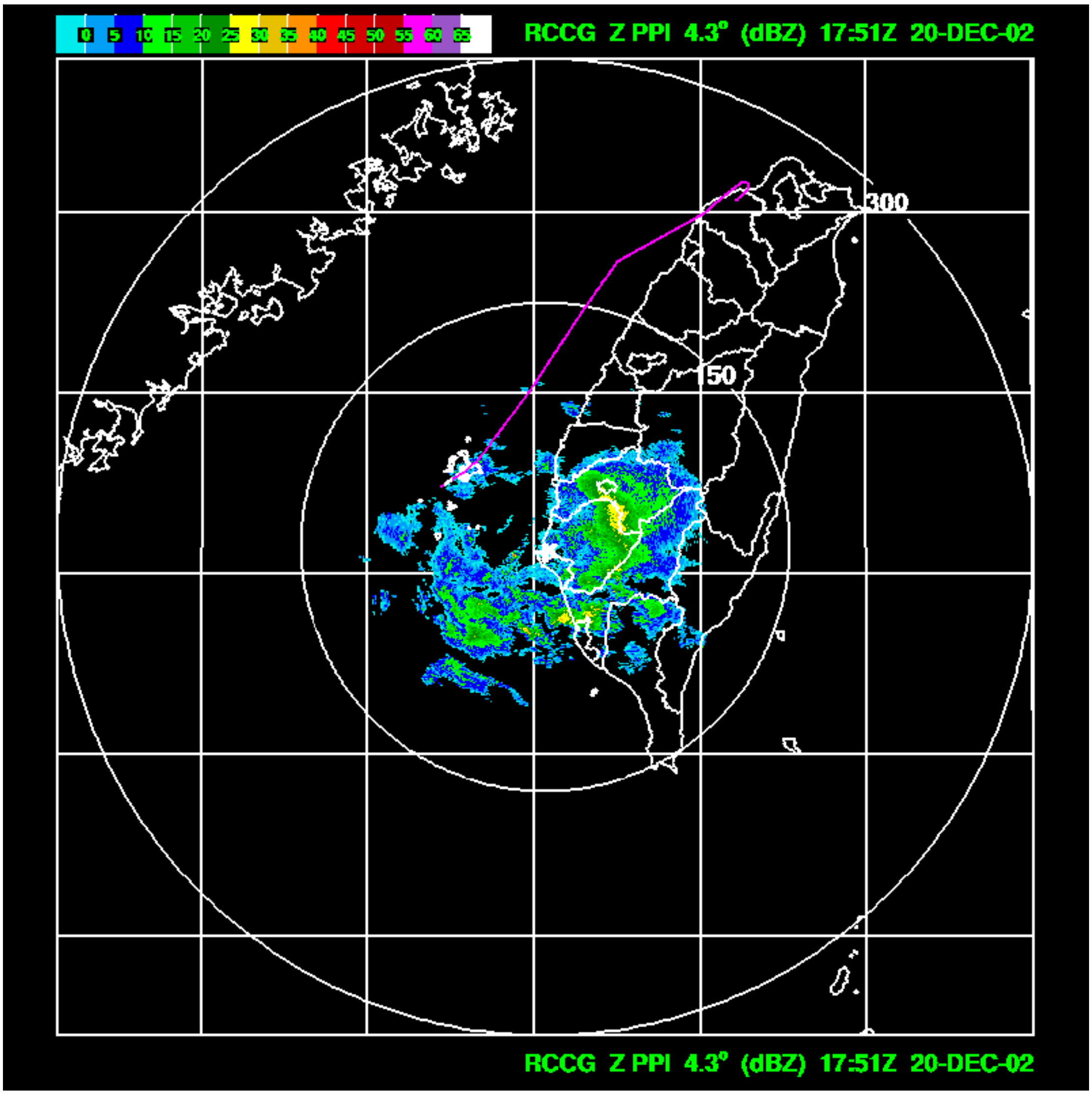

0 5 10 15 20 25 30 35 40 45 50 55 60 65
RCWF Z PPI 1.4° (dBZ) 17:25Z 20-DEC-02
300
150
RCWF Z PPI 1.4° (dBZ) 17:25Z 20-DEC-02


0
5
10
15
20
25
30
35
40
45
50
55
60
65
RCCG Z PPI 1.4° (dBZ) 17:30Z 20-DEC-02
300
150
RCCG Z PPI 1.4° (dBZ) 17:30Z 20-DEC-02

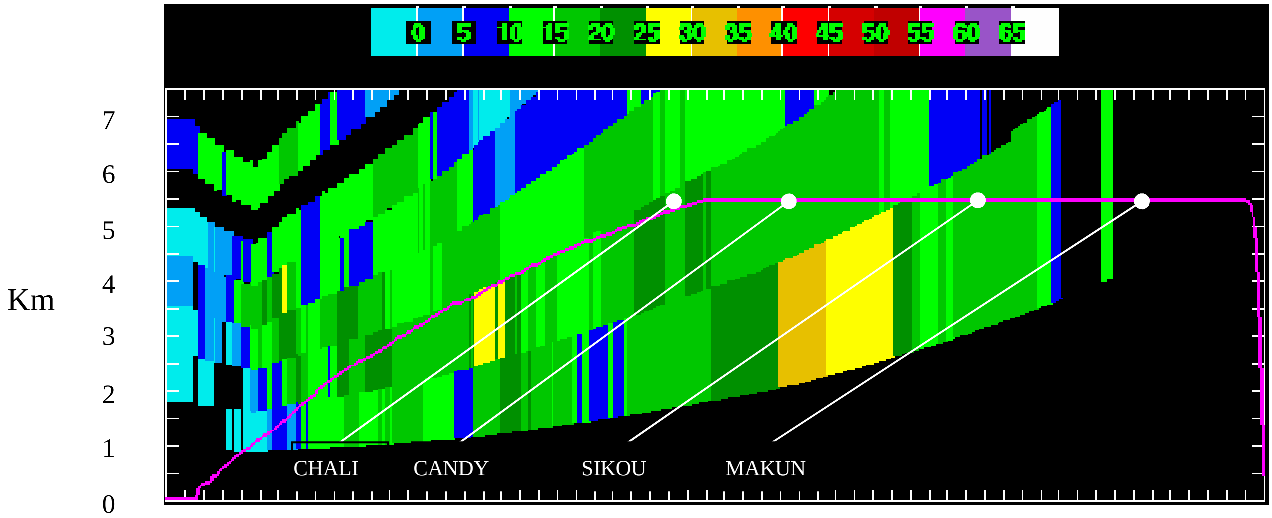

0
5
10
15
20
25
30
35
40
45
50
55
60
65
RCWF Z PPI 0.4° (dBZ) 17:37Z 20-DEC-02
300
150
RCWF Z PPI 0.4° (dBZ) 17:37Z 20-DEC-02


0 5 10 15 20 25 30 35 40 45 50 55 60 65
RCCG Z PPI 3.4° (dBZ) 17:41Z 20-DEC-02
300
150
RCCG Z PPI 3.4° (dBZ) 17:41Z 20-DEC-02

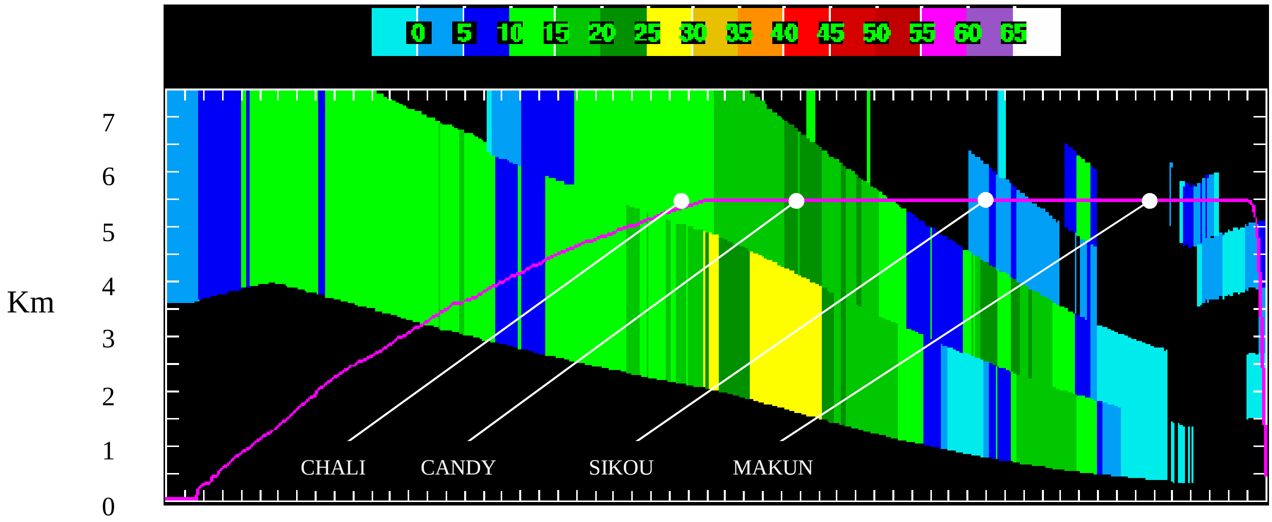

0
5
10
15
20
25
30
35
40
45
50
55
60
65
RCWF Z PPI 0.4° (dBZ) 17:49Z 20-DEC-02
300
150
RCWF Z PPI 0.4° (dBZ) 17:49Z 20-DEC-02


0 5 10 15 20 25 30 35 40 45 50 55 60 65
RCCG Z PPI 4.3° (dBZ) 17:51Z 20-DEC-02
300
150
RCCG Z PPI 4.3° (dBZ) 17:51Z 20-DEC-02

Appendix 8 The Cross Section Chart of Radar Images with the Track of GE791 Superimposed


0
5
10
15
20
25
30
35
40
45
50
55
60
65
Km
7
6
5
4
3
2
1
0
CHALI
CANDY
SIKOU
MAKUN

RCWF


0
5
10
15
20
25
30
35
40
45
50
55
60
65
Km
7
6
5
4
3
2
1
0
CHALI
CANDY
SIKOU
MAKUN

RCCG

Appendix 9 GE791 CVR Transcript

Legend

CM1: identified as Captain’s voice from Captain’s channel

CM2: identified as First Officer’s Voice from First Officer’s channel

CAM: sound from Cockpit Area Microphone (CAM)

CAM1: identified as Captain’s voice from CAM

CAM2: identified as First Officer’s Voice from CAM

ATC: Taipei Area Controller

SOC: Tran Asia Airlines Operations Center

BR6225, BR6856, CI065, CI614D: identified as radio sources of other flights

---: unknown source

…: unintelligible words

***: expletives

( ): explanation of sound or some editorial insertions

Note:

Time reference of this transcript is in Makung radar UTC time.

Local time＝UTC time＋08:00:00

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:21:58		(beginning of recording)	
17:21:58	ATC	climb and maintain flight level one eight zero	
17:22:00	CM2	climb and maintain flight level one eight zero transasia seven niner one	
17:22:03	CM2	climb and maintain flight level one eight zero	
17:22:05	CM1	好	Ok
17:22:24	CM1	那天我們頂頭風嗎五六十海浬	The other day we had head wind about fifty or sixty knots
17:22:30	CM2	現在還算好 等下上去才知道	It's ok now we'll know when we go up there
17:22:37	CM1	回來飛一點五十 一點五十五 去飛了兩點三十五	Coming back takes one hour fifty one hour fifty five going there takes two hours thirty five
17:22:48	CM1	差那麼多耶…	So much difference
17:22:54	CAM1	(sound of yawning)	
17:22:56	CAM2	一般來講回來比較累 因為回來都快睡著了	Usually the return flight is more tiring because it's almost sleep time
17:22:58	CAM1	耶...	Yeah
17:23:04	CAM	(sound of altitude alert)	
17:23:08	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:13	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:14	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:14	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:23:25	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:27	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:31	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:36	BR6856	(communication between ATC and BR6856)	
17:23:40	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:55	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:56	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:23:56	ATC	(communication between ATC and BR6856)	
17:23:59	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:24:00	BR6856	(communication between ATC and BR6856)	
17:24:05	ATC	(communication between ATC and BR6856)	
17:24:08	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:24:08	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:24:26	CAM1	(sound of yawning)	
17:24:47	CAM1	氣流還好啦	Airflow is ok
17:25:00	CAM2	altitude star	
17:25:01	CAM1	好	Good
17:25:05	CAM2	教官你要不要喝咖啡我去拿水來	Captain do you want coffee I'll get the water
17:25:08	CAM1	哦 咖啡我不喝啦 我	Oh I won't take coffee I
17:25:11	CAM2	我拿那個礦泉水	I'll get mineral water

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:25:11	CAM1	礦泉水就好	Mineral water is ok
17:25:12	CAM2	杯子…	Cup…
17:25:12	CAM	(unidentified sound)	
17:25:14	CAM1	好	Ok
17:25:15	CAM2	教官 你的杯子	Captain your cup
17:25:17	CAM1	有三明治哦	Sandwich
17:25:18	CAM2	我拿一個…牛奶給你	I'll take one you have the milk
17:25:21	CAM1	牛奶我不要 牛奶你喝啊	I don't want milk you have the milk
17:25:30	CAM	(unidentified sound)	
17:25:32	CAM	(unidentified sound)	
17:25:34	ATC	(communication between ATC and CI065) (unable to read from cockpit due to radio garble)	
17:25:36	CAM1	(sound of yawning)	
17:25:38	CI065	(communication between ATC and CI065) (unable to read from cockpit due to radio garble)	
17:25:40	ATC	(communication between ATC and CI065) (unable to read from cockpit due to radio garble)	
17:25:47	CI065	(communication between ATC and CI065) (unable to read from cockpit due to radio garble)	
17:26:20	CAM1	有兩個 VG 的 你的你的是肉的	There are two VGs yours yours is with meat
17:26:24	CAM2	這兩個都…	These two are all
17:26:26	CAM1	這兩個都是 VG 的 它有幾個四個還是兩個	These two are all VGs how many are there four or

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
			two
17:26:28	CAM2	四個	Four
17:26:31	CAM2	它有…VG 因為我現在 (sound of laughing)	It’s got…VG because now I (sound of laughing)
17:26:36	CAM1	哦***的 好啦	Oh heck ok
17:26:38	CAM2	那個 VG 的很難吃耶哦	The VG is disgusting right
17:26:40	CAM1	還好啦	It’s ok
17:26:51	CAM1	嗬 肚子餓了	Oh I’m hungry
17:27:00	CAM	(unidentified sound)	
17:27:12	CAM	(unidentified sound)	
17:27:27	ATC	transasia ...(sound similar to radio garble)	
17:27:35	---	(sound similar to radio garble)	
17:27:42	CM1	radio garble say again	
17:27:44	ATC	transasia seven ...(sound similar to radio garble)	
17:27:55	CM1	taipei control transasia seven niner one confirm calling me	
17:28:00	ATC	transasia seven niner one ...(sound similar to radio garble)	
17:28:05	CAM2	…	
17:28:06	CAM1	…	
17:28:07	CM1	sorry unable i can’t hear you transasia seven niner one	
17:28:24	CAM	(unidentified sound)	
17:28:31	CAM	(unidentified sound)	

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:28:33	CAM	(unidentified sound)	
17:28:34	CAM1	它可能到某個距離 接收不到了	May be it can’t receive after a certain distance
17:29:15	CAM	(unidentified sound)	
17:30:01	CAM1	沒有嘔吐袋哦	No air sickness bag
17:30:11	CAM	(unidentified sound)	
17:30:25	---	(sound of radio garble for 12 seconds)	
17:30:38	CAM1	…	
17:30:45	CAM	(sound of changing radio frequency)	
17:30:53	CM1	Taipei control transasia seven niner one radio check over	
17:31:01	CAM2	他剛才叫我們是由哪一個…	Which one did he call us from
17:31:02	CAM1	嗯	Mmn….
17:31:03	---	(sound similar to radio garble)	
17:31:06	CAM2	是 one two niner point one 吧	It’s one two niner point one right
17:31:08	CAM	(sound of changing radio frequency)	
17:31:12	CAM1	我知道他在叫我們但是呢 (sound of changing radio frequency) 聽不到了	I know he is calling us but (sound of changing radio frequency) can’t hear
17:31:15	CAM2	聽不到	Can’t hear
17:31:21	CAM1	radio check 好了	Radio check ok
17:31:31	CI065	(communication between ATC and CI065)	
17:31:36	ATC	(communication between ATC and CI065)	
17:31:42	CI065	(communication between ATC and CI065)	

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:31:51	BR6856	(communication between ATC and BR6856)	
17:31:54	ATC	(communication between ATC and BR6856)	
17:31:56	BR6856	(communication between ATC and BR6856)	
17:32:02	ATC	(communication between ATC and BR6856)	
17:32:14	BR6856	(communication between ATC and BR6856)	
17:32:35	CAM2	那好像結冰…看我這裡你那邊也有結冰嘛對不對	Looks like it’s iced up….look at my side your side is also iced up right
17:32:59	CAM	(unidentified sound)	
17:33:32	CAM1	外面水氣不夠 負十二度	There’s not enough moisture outside minus twelve degrees
17:34:29	CAM	(sound of single chime)	
17:34:29	CAM1	哦 結冰囉	Oh it’s icing up
17:34:32	CAM2	…	
17:34:32	CAM	(sound of single chime)	
17:34:42	CAM	(unidentified sound)	
17:35:19	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:35:22	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:35:28	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:35:29	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:35:30	ATC	(communication between ATC and BR6856)	
17:35:32	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:35:33	BR6856	(communication between ATC and BR6856)	

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:35:36	ATC	(communication between ATC and BR6856)	
17:35:40	BR6856	(communication between ATC and BR6856)	
17:35:43	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:35:44	ATC	(communication between ATC and BR6856)	
17:35:48	BR6856	(communication between ATC and BR6856)	
17:35:57	ATC	(communication between ATC and BR6856)	
17:36:02	BR6856	(communication between ATC and BR6856)	
17:36:45	CM2	taipei control transasia seven niner one radio check	
17:36:49	ATC	transasia seven niner one read you five by five how do you read	
17:36:53	CM2	read you loud and clear	
17:36:55	ATC	thank you	
17:36:56	CM2	thank you	
17:37:01	CAM2	好啦	It’s ok
17:37:24	CAM1	又沒有啦	It’s gone again
17:37:48	ATC	(communication between ATC and BR6856)	
17:37:54	BR6856	(communication between ATC and BR6856)	
17:38:00	CAM1	(sound similar to singing)	
17:38:42	CAM	(unidentified sound)	
17:39:33	BR6856	(communication between ATC and BR6856)	
17:39:41	ATC	(communication between ATC and BR6856)	
17:39:43	BR6856	(communication between ATC and BR6856)	

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:40:28	CAM1	還有兩個鐘頭還要飛啊 (sound of laughing) 將近兩個鐘頭 晚上還要被切切切是吧	Two more hours to fly (sound of laughing) almost two hours tonight still going for …… right
17:40:34	BR6856	(communication between ATC and BR6856)	
17:40:41	ATC	(communication between ATC and BR6856)	
17:40:59	CAM	(unidentified sound)	
17:41:21	CAM	(sound of single chime)	
17:42:11	---	…	
17:42:22	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:26	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:28	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:29	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:32	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:35	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:40	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:44	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:45	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:48	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:42:58	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:43:01	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:43:05	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:43:09	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:43:18	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:43:19	CI614D	taipei control good morning dynasty six one four delta	
17:43:20	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:43:24	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:43:26	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:43:26	ATC	nippon cargo four two seven standby one	
17:43:29	ATC	dynasty six one four delta taipei control roger maintain flight level two seven zero	
17:43:34	CI614D	wilco we'll maintain two seven zero five seven miles to elato and estimate elato at five one and we request one zero miles right of track for weather	
17:43:46	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:43:48	ATC	standby one	
17:43:50	ATC	dynasty six one four delta approved reported clear	
17:43:53	CI614D	wilco one zero miles right of track approved dynasty six one four delta	
17:44:01	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:44:03	ATC	(communication between ATC and NIPPON CARGO 427)	
17:44:04	CAM2	(與本次飛航無關之談話)	(conversation not related to this flight)
17:44:05	CAM1	(與本次飛航無關之談話)	(conversation not related to this flight)
17:44:16	CAM1	(sound of coughing)	
17:44:26	ATC	(communication between ATC and NIPPON CARGO	

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
		427)	
17:44:33	ATC	(communication between ATC and NIPPON CARGO 427)	
17:44:47	CAM1	那結冰了 蠻大坨的	It’s iced up quite a huge chunk
17:45:10	ATC	(communication between ATC and BR6856)	
17:45:13	BR6856	(communication between ATC and BR6856)	
17:45:15	ATC	(communication between ATC and BR6856)	
17:45:19	BR6856	(communication between ATC and BR6856)	
17:45:24	CAM1	(sound of laughing)	
17:45:30	BR6856	(communication between ATC and BR6856)	
17:45:36	ATC	(communication between ATC and BR6856)	
17:45:40		(no sound for 0.3 second)	
17:45:42	BR6856	(communication between ATC and BR6856)	
17:45:47	ATC	(communication between ATC and BR6856)	
17:45:50	BR6856	(communication between ATC and BR6856)	
17:45:52	ATC	(communication between ATC and BR6856)	
17:47:04	ATC	(communication between ATC and BR6856)	
17:47:10	BR6856	(communication between ATC and BR6856)	
17:47:14	ATC	(communication between ATC and BR6856)	
17:47:17	BR6856	(communication between ATC and BR6856)	
17:47:21	ATC	(communication between ATC and BR6856)	
17:47:29	BR6856	(communication between ATC and BR6856)	

Makung Radar UTC	**SOURCE**	**CONTENT**	**TRANSLATION**
17:47:35	BR6225	(communication between ATC and BR6225)	
17:47:42	ATC	(communication between ATC and BR6225)	
17:47:50	BR6225	(communication between ATC and BR6225)	
17:47:56	ATC	(communication between ATC and BR6856)	
17:48:01	BR6856	(communication between ATC and BR6856)	
17:48:07	CI614D	(communication between ATC and CI614 delta)	
17:48:12	ATC	(communication between ATC and CI614 delta)	
17:48:14	CI614D	(communication between ATC and CI614 delta)	
17:48:22	ATC	(communication between ATC and CI614 delta)	
17:48:29	CI614D	(communication between ATC and CI614 delta)	
17:48:33	ATC	(communication between ATC and CI614delta)	
17:48:40	CI614D	(communication between ATC and CI614 delta)	
17:48:47	CAM	(sound of changing radio frequency)	
17:48:53	CM2	復興聯管復興拐玖么	transasia operation transasia seven niner one
17:49:04	SOC	復興拐玖么清海請說	Transasia seven niner one Chinghai please come in
17:49:07	CM2	明華辛苦了我們現在在馬公 macau ETA 么玖肆陸現在請問 macau 天氣如何	Hello MingHwa we are now at Makung Macau ETA nineteen forty six. How's the weather in Macau
17:49:16	SOC	啊都正常正常	All normal normal
17:49:19	CM2	好謝謝你 good night	Ok thank you good night
17:49:20	SOC	辛苦了飛行愉快	Have a pleasant flight
17:49:23	CM2	good night	

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:49:24	---	Standby	
17:49:33	CAM	(sound of changing radio frequency)	
17:50:03	ATC	(communication between ATC and BR6225)	
17:50:07	BR6225	(communication between ATC and BR6225)	
17:50:29	CAM1	哇塞 好大一坨哦	Wow it’s a huge chunk
17:50:31	CAM2	什麼冰哦	What an ice
17:50:49	ATC	(communication between ATC and CI614 delta)	
17:50:55	CAM1	這速度越來越小囉 本來一百 二百哦一百九現在一百七哦	This speed is getting slower it was a hundred two hundred one hundred and ninety now one hundred seventy
17:51:01	CI614D	(communication between ATC and CI614 delta)	
17:51:13	ATC	(communication between ATC and CI614 delta)	
17:51:15	CAM1	會不會我們空速管被糊住囉 堵死囉	Is our pitot-static tube going to get blocked get stuck
17:51:18	CAM2	啊怎樣	What
17:51:18	CAM1	空速管會不會被	Is pitot-static tube going to be
17:51:20	CAM1	會不會糊到囉等一下 autopilot 會跳掉喔	Going to get blocked then autopilot would be trip
17:51:20	CI614D	(communication between ATC and CI614 delta)	
17:51:25	CAM1	要飛傳統儀表哦	Have to use instrumental flight
17:51:27	CAM2	飛高一點	Go higher
17:51:28	ATC	(communication between ATC and BR6225)	
17:51:30	CAM1	飛低一點啦 高一點沒有用啦	Go lower no use going higher

Makung Radar UTC	**SOURCE**	**CONTENT**	**TRANSLATION**
17:51:33	BR6225	(communication between ATC and BR6225)	
17:51:35	CAM2	只要不要在(再)有水氣因為我們現在有水氣	Just as long as no more moisture because we have moisture now
17:51:38	CAM	(Unidentified sound)	
17:51:38	CAM2	那你是要高還是要啊嚴重結冰了	So do you want to move up or ah severe icing up
17:51:41	CAM1	耶要低啦	Yeah move down
17:51:42	CAM2	要下降	Move down
17:51:43	CAM1	下降 對	Move down yes
17:51:44	CAM2	可是我們下降高度可能會收不到訊號喔 要高還是要低哦	But we may receive no transmission when we move down up or down
17:51:47	CAM1	低低低低低 趕快通知	Down down down down down notify them quickly
17:51:48	CAM2	大概要多低	How low
17:51:49	CAM1	一萬六	Sixteen thousand
17:51:51	CM2	taipei control transasia seven niner one request descend maintain flight level one six zero	
17:51:55	ATC	transasia seven niner one roger descend and maintain flight level one six zero	
17:51:59	CM2	maintain flight level one six zero seven niner one	
17:52:02	CAM1	看到沒有	Do you see that
17:52:08	CAM1	嚴重結冰了	It’s severe icing up
17:52:10	CAM2	教官	Captain
17:52:10	CAM	(Sound similar to stick shaker)	

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:52:11	CAM	(Sound of stall warning and stick shaker)	
17:52:13	CAM	(Sound of autopilot disengage)	
17:52:14	CAM	(Sound similar to stick shaker)	
17:52:15	CAM	(Sound of stall warning and stick shaker)	
17:52:16	CAM	(Sound of single chime)	
17:52:17	CAM	(Sound similar to stick shaker)	
17:52:17	CAM	(Sound of continuous repetitive chime)	
17:52:18	CAM	(Unidentified sound)	
17:52:19	CAM	(Sound of stall warning and stick shaker)	
17:52:21	CAM	(Sound of altitude alert)	
17:52:21	CAM	(Unidentified sound)	
17:52:22	CAM	(Sound of stall warning)	
17:52:23	CAM	(Sound of single chime)	
17:52:23	CAM	(Sound similar to stick shaker)	
17:52:25	CAM	(Sound of continuous repetitive chime)	
17:52:25	CAM2	教官拉起來	Captain pull up
17:52:26	CAM	(Sound of altitude alert)	
17:52:28	CAM	(Sound of single chime)	
17:52:29	CAM	(Sound similar to stick shaker)	
17:52:29	CAM	(Sound of overspeed warning)	
17:52:30	CAM	(Sound of stall warning)	
17:52:31	CAM	(Sound of overspend warning)	

Makung Radar UTC	SOURCE	CONTENT	TRANSLATION
17:52:31	CAM	(Unidentified sound)	
17:52:34	CAM	(Unidentified sound)	
17:52:40	CAM	(Unidentified sound)	
17:52:46	CAM	(Unidentified sound)	
17:52:51		*(End of recording)*	

Appendix 10 GE791 FDR Parameter List

ATR-72, F800, 17M800-261 FDR Parameter List	
FICHIER : ~/etal/a443a330	
FICH. ETAL A/R SFIM FDAU P/N ED34A330 (CAPABLE OMEGA/GPS)ATR42-400/500 NOTE REF:420.0049/96 ED55	
1	AC ELEC. BUS STATUS 1 0=OFF
2	AC ELEC. BUS STATUS 2 0=OFF
3	ADVISORY DISPLAY UNIT CAUTION ACTIVE
4	AILERON TRIM (>0 TAB DOWN LH AIL. UP)
5	AIRCRAFT CONFIG.(ENGINE TYPE & PROPELLER TYPE)
6	AIRCRAFT NUMBER (AIRLINE RANK)
7	AIR-FLOW CONTROL O=HIGH ON
8	AIRFRAME DE-ICING
9	ALL GEARS SQUAT SWITCH 1=ON GROUND
10	ALTITUDE ELAB. B12/26+29
11	ALTITUDE CAPTURE
12	ALTITUDE COARSE SCALE
13	ALTITUDE FINE SCALE
	ANTI-ICE PROPELLER ENGINE.1 [optional equipment, no data source for this flight]
	ANTI-ICE PROPELLER ENGINE.2 [optional equipment, no data source for this flight]
14	ASYMMETRICAL FLAPS 1=NORMAL
15	AUTO-PILOT ABNORMAL DISCONNECT
16	AUTO-PILOT STATUS
17	BACK-COURSE ARMED
18	BACK-COURSE CAPTURE
	CALCULATED MACH NUMBER *****************
	CALCULATED STATIC AIR TEMPERATURE ******
	CALCULATED TRUE AIRSPEED ***************
	COPILOT CONTROL COLUMN EFFORT SENSITIVITY
19	CPTR DE CYCLE POUR SUPER-FRAME
20	DATE DAY TEN + UNIT
21	DATE MONTH TEN + UNIT
22	DATE YEAR TEN + UNIT
23	DC ELEC. BUS STATUS 1 0=OFF
24	DC ELEC. BUS STATUS 2 0=OFF

25	DEGRADE (GPS)
26	DESIRED TRACK
27	DRIFT ANGLE provision (GPS)
28	ELEVATOR TRIM POSITION (>0 NOSE DOWN TAB UP)
29	EVENT MARKER PUSH BUTTON 1=EVENT
30	FDAU B.I.T.E
31	FLAPS POSITION
32	FLIGHT DATA ENTRY PANEL PIN-PROG 0=ACARS PRESENT
33	FLIGHT NUMBER ELAB.
34	FLIGHT NUMBER TEN + UNIT
35	FLIGHT NUMBER THOUS + HUND
	FUEL QUANTITY 1 (no correct source data)
	FUEL QUANTITY 2 (no correct source data)
	FUEL QUANTITY TANK 1 *** OK IF ACARS INSTALLED
	FUEL QUANTITY TANK 2 *** OK IF ACARS INSTALLED
36	G.P.W.S STATUS 0=WARNING
37	GLIDESLOPE ARMED
38	GLIDESLOPE CAPTURE
39	GLIDESLOPE DEV.ILS.1 (>0 ABOVE BEAM)
40	GLIDESLOPE DEV.ILS.2 (>0 ABOVE BEAM)
41	GMT
	GMT HR
	GMT MIN
	GMT SEC
42	GO-AROUND CAPTURE
43	GROUND SPEED provision (GPS)
44	HEADING CAPTURE
45	HEADING HOLD
46	HEADING SITUATION INDICATOR SELECTED STS
47	HF 0=IN SEND MODE
48	HIGHT PRESS TUR. SPEED ENG.1
49	HIGHT PRESS TUR. SPEED ENG.2
50	HYD. AUX. LOW PRESSURE
51	HYD. BLUE LOW PRESSURE
52	HYD. GREEN LOW PRESSURE
	ICE DETECTION STATUS [optional equipment, no data source for this flight]
	ICING AOA B105

53	INDICATED AIRSPEED
54	INDICATED AIRSPEED CAPTURE
55	INNER MARKER 1=MARKER
56	INTER TURBINE TEMPERATURE ENG.1
57	INTER TURBINE TEMPERATURE ENG.2
58	LANDING GEAR SEL. POS. 1=GEAR SEL. DOWN
59	LAT. MODE ACTIVE CAP/TRACK
60	LATERAL ACCEL. >0=RIGHT SIDE SLIP
61	LATPOS
62	LATITUDE POS. ELAB LSB nouvelle definition
63	LATITUDE POS. ELAB MSB nouvelle definition
64	LEFT AILERON POSITION (>0 TURN RIGHT)
65	LEFT ELEVATOR POSITION (>0 NOSE DOWN)
66	LH HP AIR FLOW VALVE 0=VALVE OPEN
67	LH LOCAL ANGLE OF ATTACK >0=UP
68	LH PACK AIR FLOW VALVE 0=VALVE OPEN
69	LH SPOILER POS.
70	LOCALIZER ARMED
71	LOCALIZER CAPTURE
72	LOCALIZER DEV.ILS.1 (>0 LH OF BEAM)
73	LOCALIZER DEV.ILS.2 (>0 LH OF BEAM)
74	LONGI. MODE ACTIVE CAP/TRACK
75	LONGPOS
76	LONGITUDE POS. ELAB LSB nouvelle definition
77	LONGITUDE POS. ELAB MSB nouvelle definition
78	LONGITUDINAL ACCEL. <0=ACCELERATION
79	LOW PITCH ENGINE 1 0=NORMAL TRACTION
80	LOW PITCH ENGINE 2 0=NORMAL TRACTION
81	MAGNETIC HEADING
82	MAIN GEAR SQUAT SWITCH 1=ON GROUND
83	MASTER WARNING RED LINE 0=WARNING
84	MIDDLE MARKER 1=MARKER
85	MLS/ILS SELECT 1
86	MLS/ILS SELECT 2
87	MODE HOTEL TEN + UNIT OF MN
88	MODE HOTEL THOU + HUND OF MN
89	MULTIFONCTION COMPUTER 1-A STATUS

90	MULTIFONCTION COMPUTER 1-B STATUS
91	MULTIFONCTION COMPUTER 2-A STATUS
92	MULTIFONCTION COMPUTER 2-B STATUS
93	NP1 PROPELLER SPEED ENG.1
94	NP2 PROPELLER SPEED ENG.2
95	OUTER MARKER 1=MARKER
	PILOT CONTROL COLUMN EFFORT SENSITIVITY [no source data input]
96	PITCH ANGLE (>0 NOSE UP)
97	PLA POWER LEVER ANGLE ENG.1
98	PLA POWER LEVER ANGLE ENG.2
99	PROPELLER BRAKE CTL 0=BRAKE ENGAGED
100	RADIO-HEIGHT R/A.1
101	RH HP AIR FLOW VALVE 0=VALVE OPEN
102	RH LOCAL ANGLE OF ATTACK >0=UP
103	RH PACK AIR FLOW VALVE 0=VALVE OPEN
104	RH SPOILER POS.
	RIGHT AILERON POSITION (<0 TURN RIGHT) [optional equipment, no data source for this flight]
105	ROLL ATTITUDE (>0 RH WING DOWN)
106	RUDDER POSITION (>0 TURN LEFT)
107	RUDDER TRIM POSITION (>0 TAB ON THE RIGHT RUDD LEFT)
108	SECONDE BCD GMT ED55R1
109	SELECTED AIR DATA COMPUTER
110	SELECTED ALTITUDE
111	SELECTED BARO SETTING LSB
112	SELECTED COURSE
113	SELECTED DECISION HEIGHT
114	SELECTED HEADING
115	SELECTED INDICATED AIRSPEED
116	SELECTED VERTICAL SPEED V/S
117	SYNC1
118	SYNC2
119	SYNC3
120	SYNC4
121	TORQUE ENG.1
122	TORQUE ENG.2
123	TOTAL AIR TEMPERATURE

124	TOUCH CONTROL STEERING ACTIVE
125	VERTICAL ACCEL. >0=UP
126	VERTICAL/SPEED CAPTURE
127	VHF.1 0=IN SEND MODE
128	VHF.2 0=IN SEND MODE
129	VHF.3 **IF ACARS INSTALLED** 0=IN SEND MODE
130	VOR ARMED
131	VOR CAPTURE
132	YAW DAMPER STATUS

Appendix 11 Flight Data Diagram

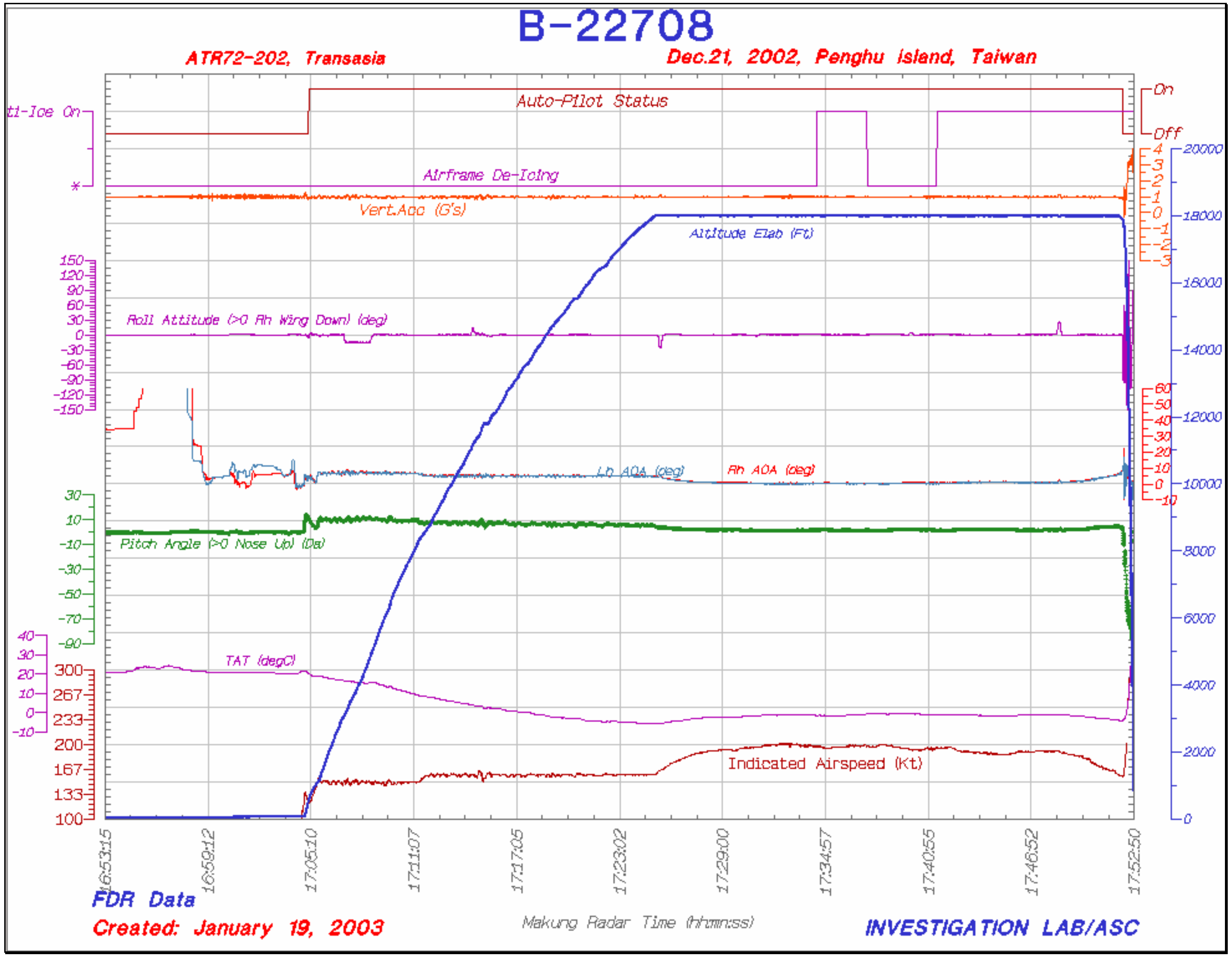
Note:

Time reference of this transcript is in Makung radar UTC time.

Local time＝UTC time＋08:00:00

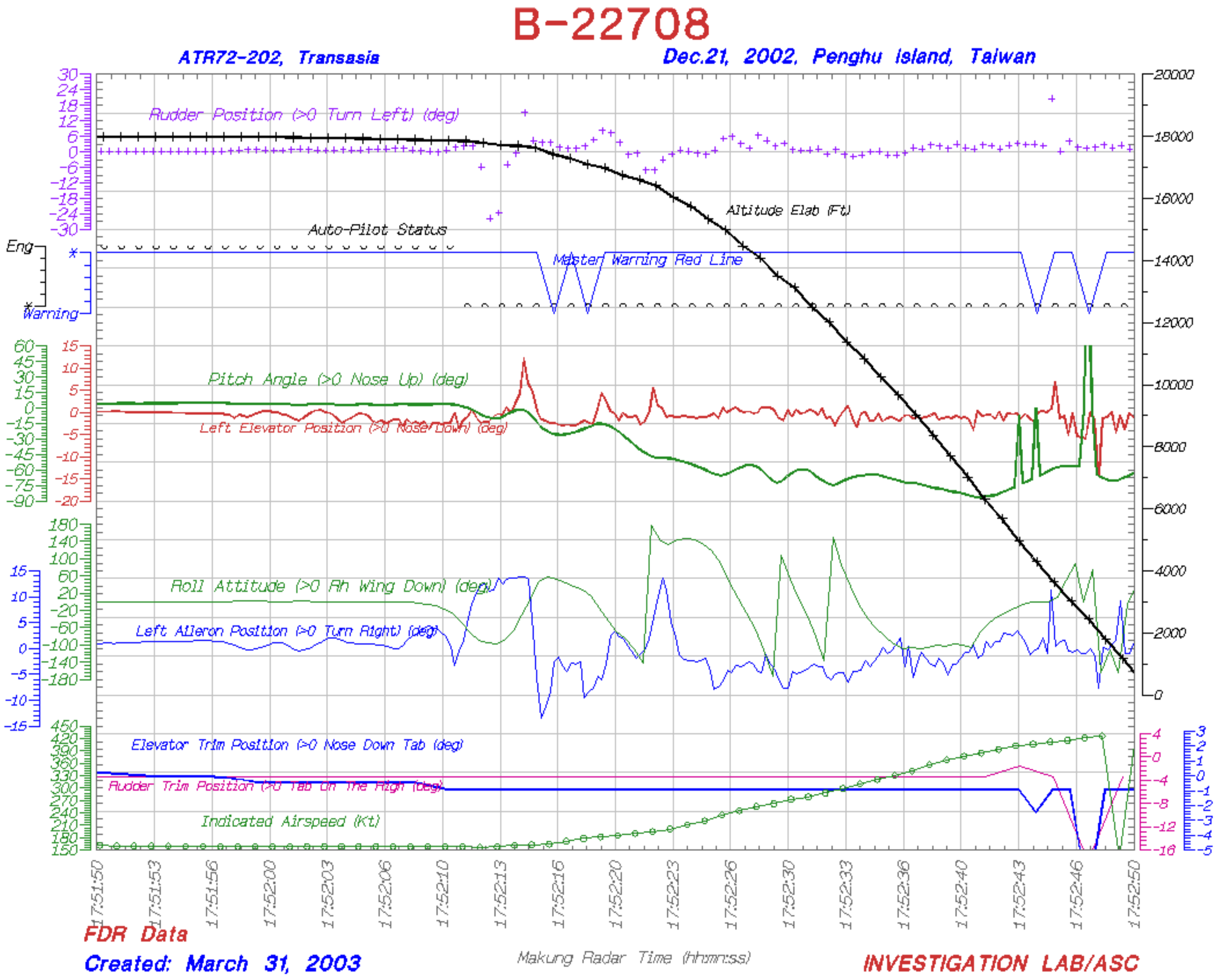
The flight data of GE791 from 1653:15 to 17:52:50

（pressure altitude, IAS, pitch, roll, AOA, icing condition, AP, Acceleration, total temperature）



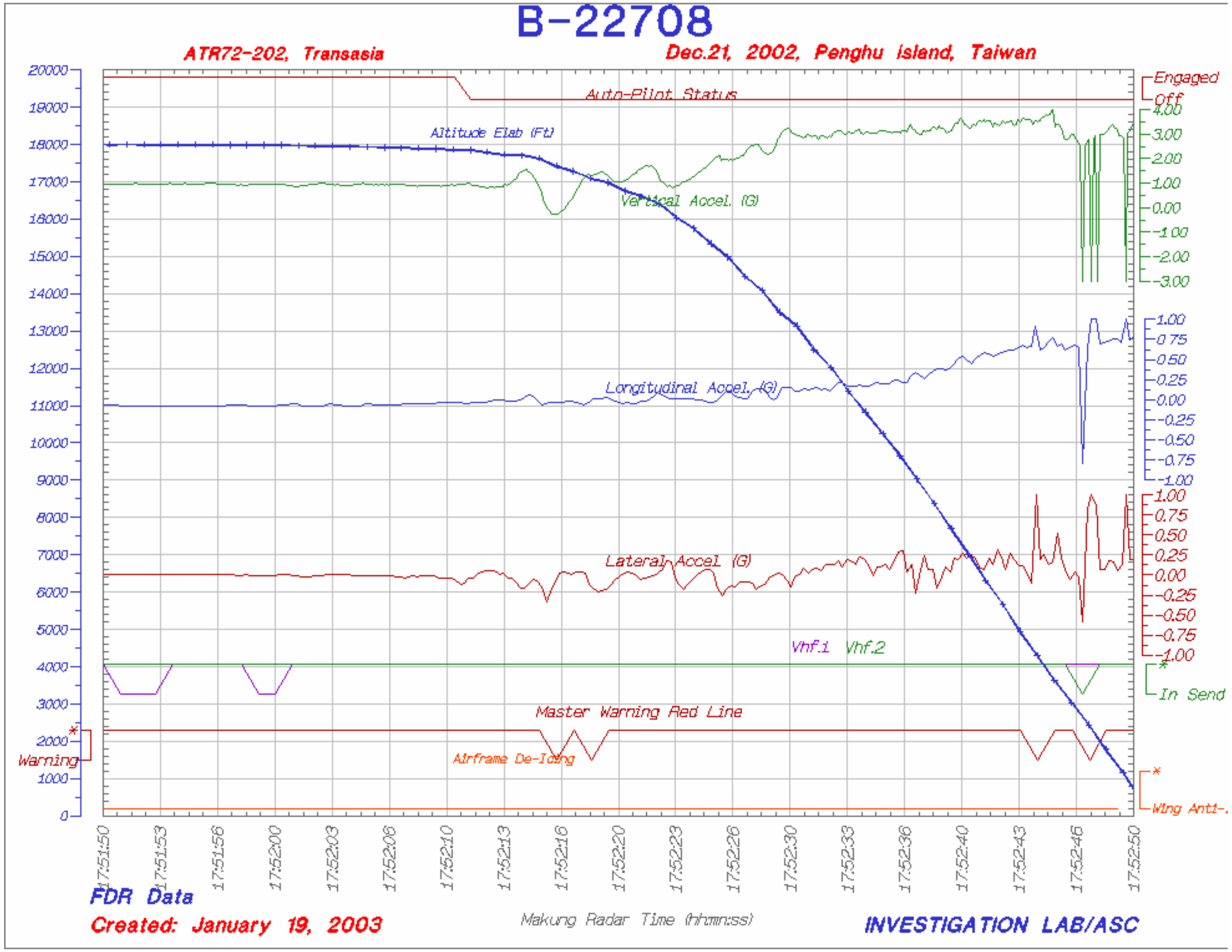
The flight data of the last one minute of GE791 (17:51:50~17:52:50)

（pressure altitude, IAS, pitch, roll, AOA, AP, master warning, elevator, eileron, rudde）



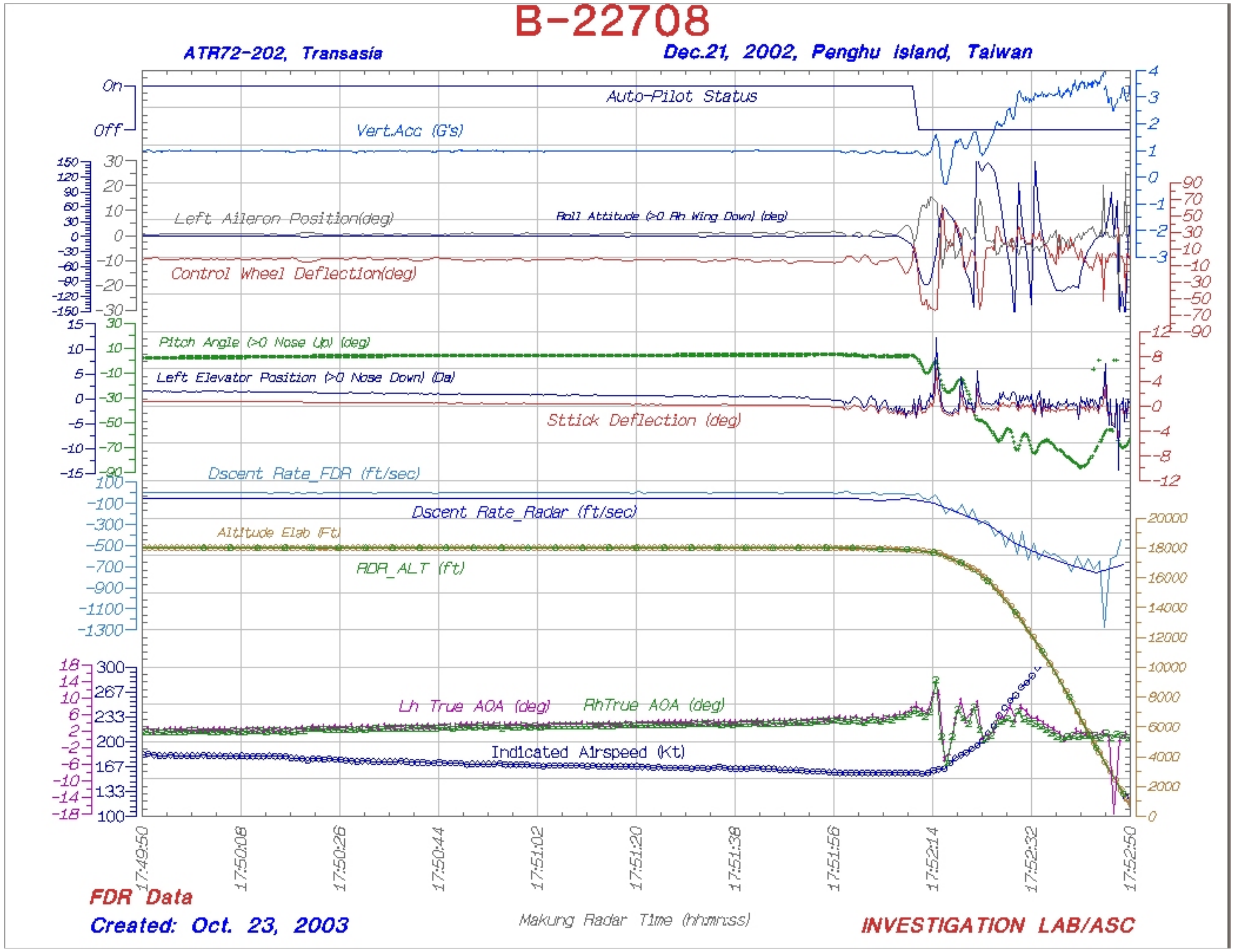
The flight data of the last one minute of GE791 (17:51:50~17:52:50)

（pressure altitude, AP, master warning, three-dimensional accelerations）



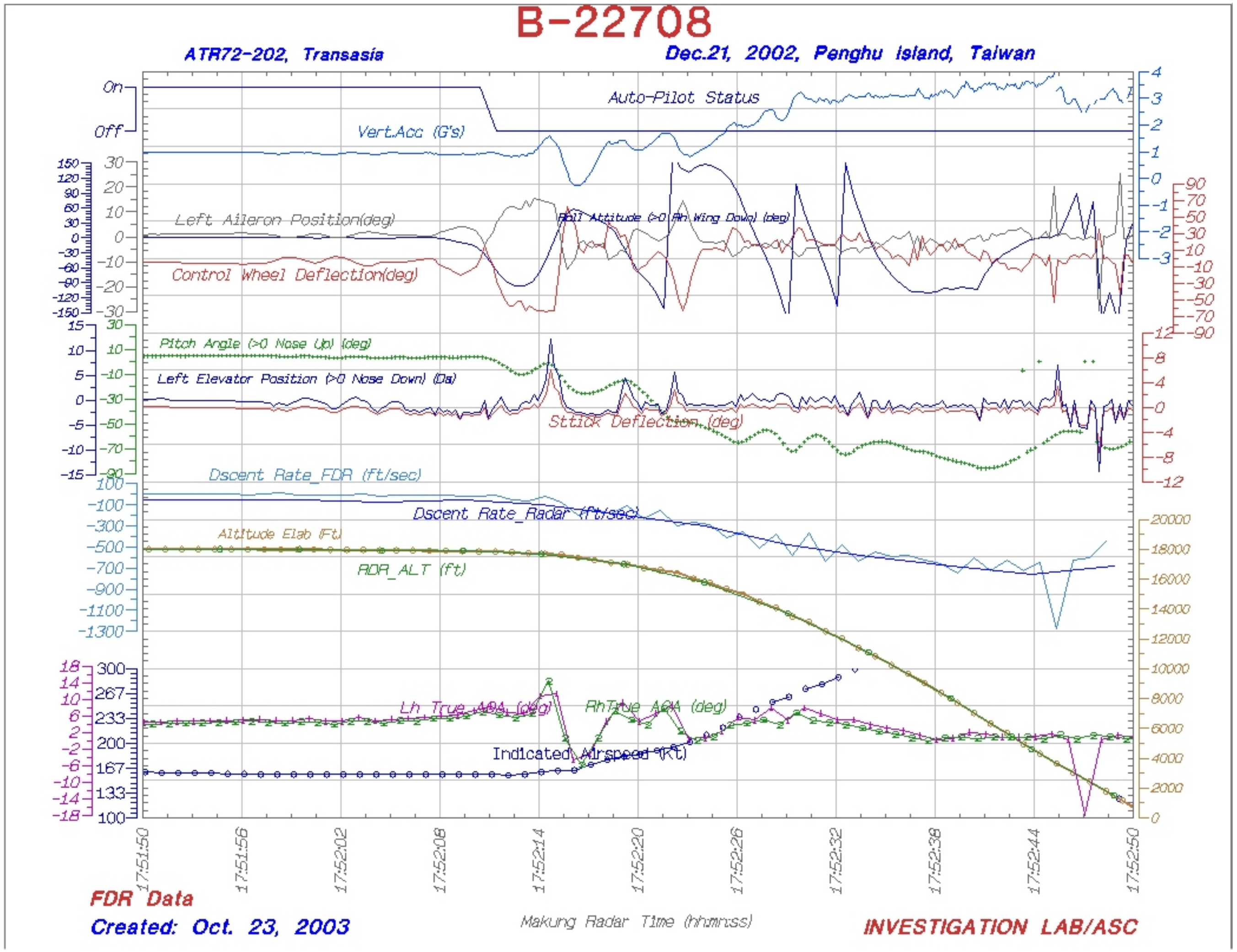
The calibrated flight data of the last 3 minutes of GE791 (17:49:50~17:52:50)

（pressure and Mode-C altitudes, IAS, pitch, roll, CCD and CWD deflections, AP, local and true AOAs, descent rate and vertical Acc）

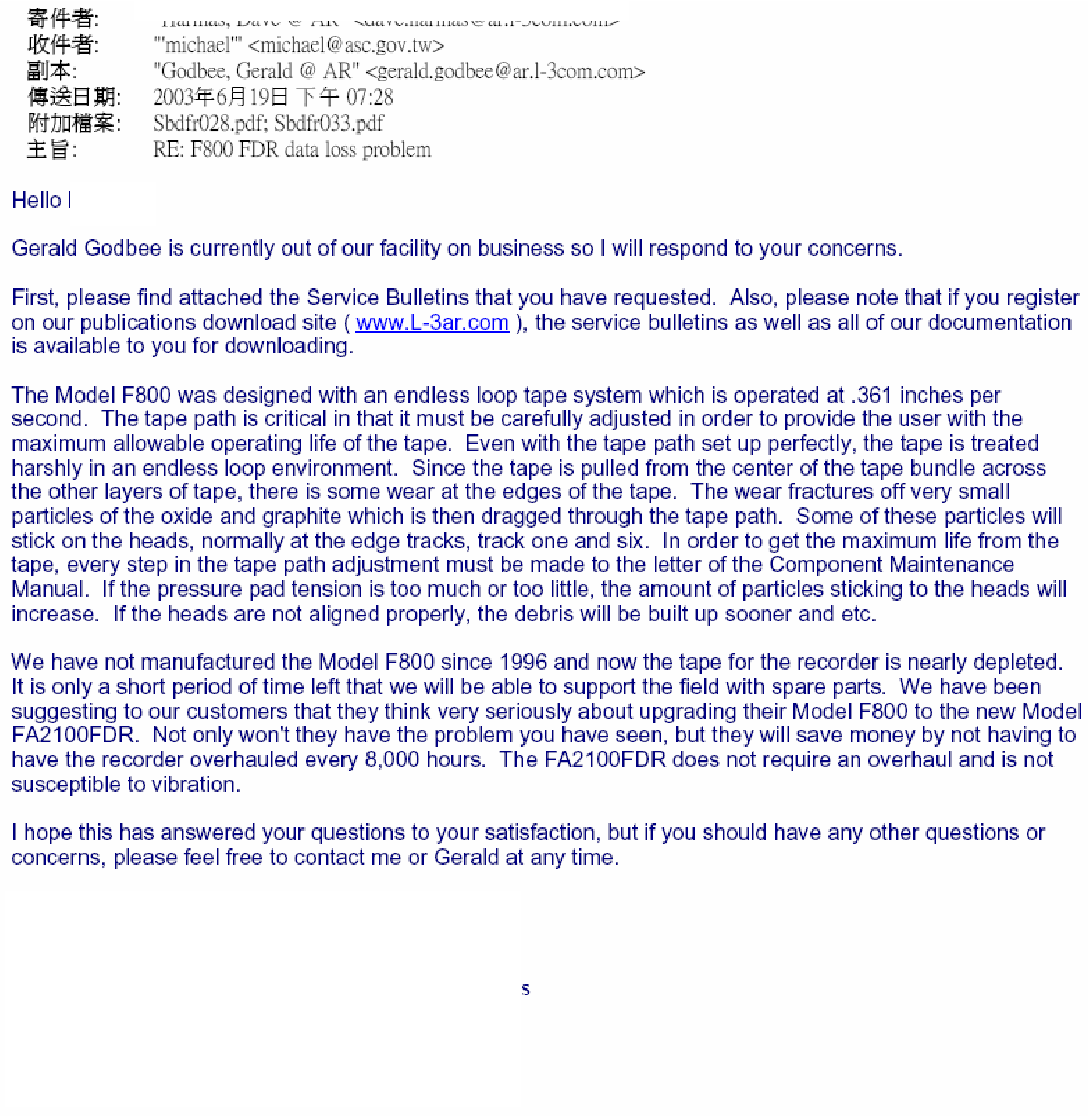


The calibrated flight data of last one minutes of GE791 (17:50:50~17:52:50)

（pressure and Mode-C altitudes, IAS, pitch, roll, CCD and CWD deflections, AP, local and true AOAs, descent rate and vertical Acc）



Appendix 12 Comments from L3 Communications for the Data Lost of Track 1&2 of Model F800 DFDR Tape (1)



寄件者: Harmas, Dave @ AR <dave.harmas@ar.l-3com.com>
收件者: "'michael'" <michael@asc.gov.tw>
副本: "Godbee, Gerald @ AR" <gerald.godbee@ar.l-3com.com>
傳送日期: 2003年6月19日 下午 07:28
附加檔案: Sbdfr028.pdf; Sbdfr033.pdf
主旨: RE: F800 FDR data loss problem

Hello !

Gerald Godbee is currently out of our facility on business so I will respond to your concerns.

First, please find attached the Service Bulletins that you have requested. Also, please note that if you register on our publications download site (www.L-3ar.com), the service bulletins as well as all of our documentation is available to you for downloading.

The Model F800 was designed with an endless loop tape system which is operated at .361 inches per second. The tape path is critical in that it must be carefully adjusted in order to provide the user with the maximum allowable operating life of the tape. Even with the tape path set up perfectly, the tape is treated harshly in an endless loop environment. Since the tape is pulled from the center of the tape bundle across the other layers of tape, there is some wear at the edges of the tape. The wear fractures off very small particles of the oxide and graphite which is then dragged through the tape path. Some of these particles will stick on the heads, normally at the edge tracks, track one and six. In order to get the maximum life from the tape, every step in the tape path adjustment must be made to the letter of the Component Maintenance Manual. If the pressure pad tension is too much or too little, the amount of particles sticking to the heads will increase. If the heads are not aligned properly, the debris will be built up sooner and etc.

We have not manufactured the Model F800 since 1996 and now the tape for the recorder is nearly depleted. It is only a short period of time left that we will be able to support the field with spare parts. We have been suggesting to our customers that they think very seriously about upgrading their Model F800 to the new Model FA2100FDR. Not only won't they have the problem you have seen, but they will save money by not having to have the recorder overhauled every 8,000 hours. The FA2100FDR does not require an overhaul and is not susceptible to vibration.

I hope this has answered your questions to your satisfaction, but if you should have any other questions or concerns, please feel free to contact me or Gerald at any time.

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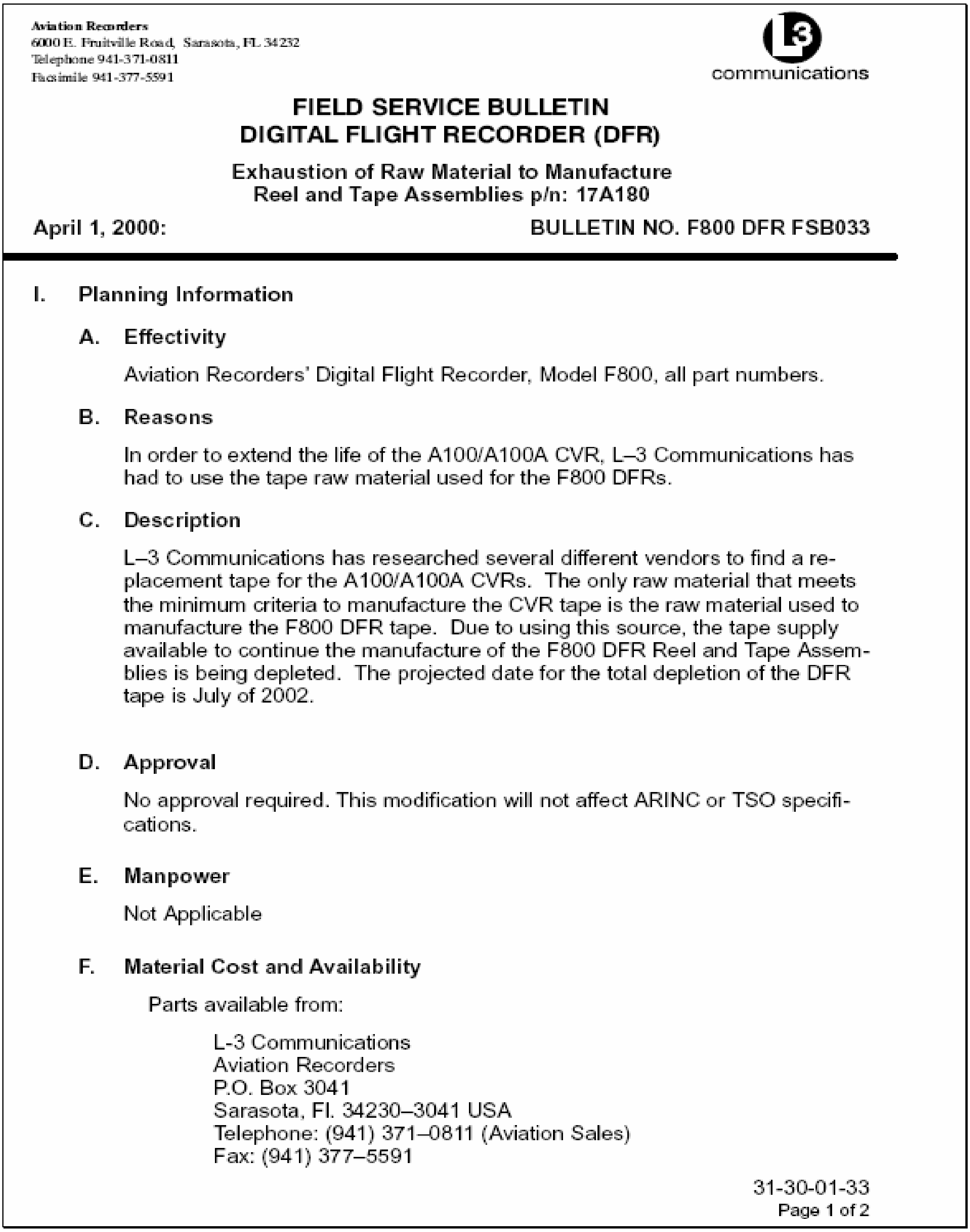
Appendix 13 Comments from L3 Communications for the Data Lost of Track 1&2 of Model F800 DFDR Tape (2)



Aviation Recorders
6000 E. Fruitville Road, Sarasota, FL 34232
Telephone 941-371-0811
Facsimile 941-377-5591

FIELD SERVICE BULLETIN
DIGITAL FLIGHT RECORDER (DFR)

Exhaustion of Raw Material to Manufacture Reel and Tape Assemblies p/n: 17A180

April 1, 2000: **BULLETIN NO. F800 DFR FSB033**

I. Planning Information

A. Effectivity

Aviation Recorders' Digital Flight Recorder, Model F800, all part numbers.

B. Reasons

In order to extend the life of the A100/A100A CVR, L–3 Communications has had to use the tape raw material used for the F800 DFRs.

C. Description

L–3 Communications has researched several different vendors to find a replacement tape for the A100/A100A CVRs. The only raw material that meets the minimum criteria to manufacture the CVR tape is the raw material used to manufacture the F800 DFR tape. Due to using this source, the tape supply available to continue the manufacture of the F800 DFR Reel and Tape Assemblies is being depleted. The projected date for the total depletion of the DFR tape is July of 2002.

D. Approval

No approval required. This modification will not affect ARINC or TSO specifications.

E. Manpower

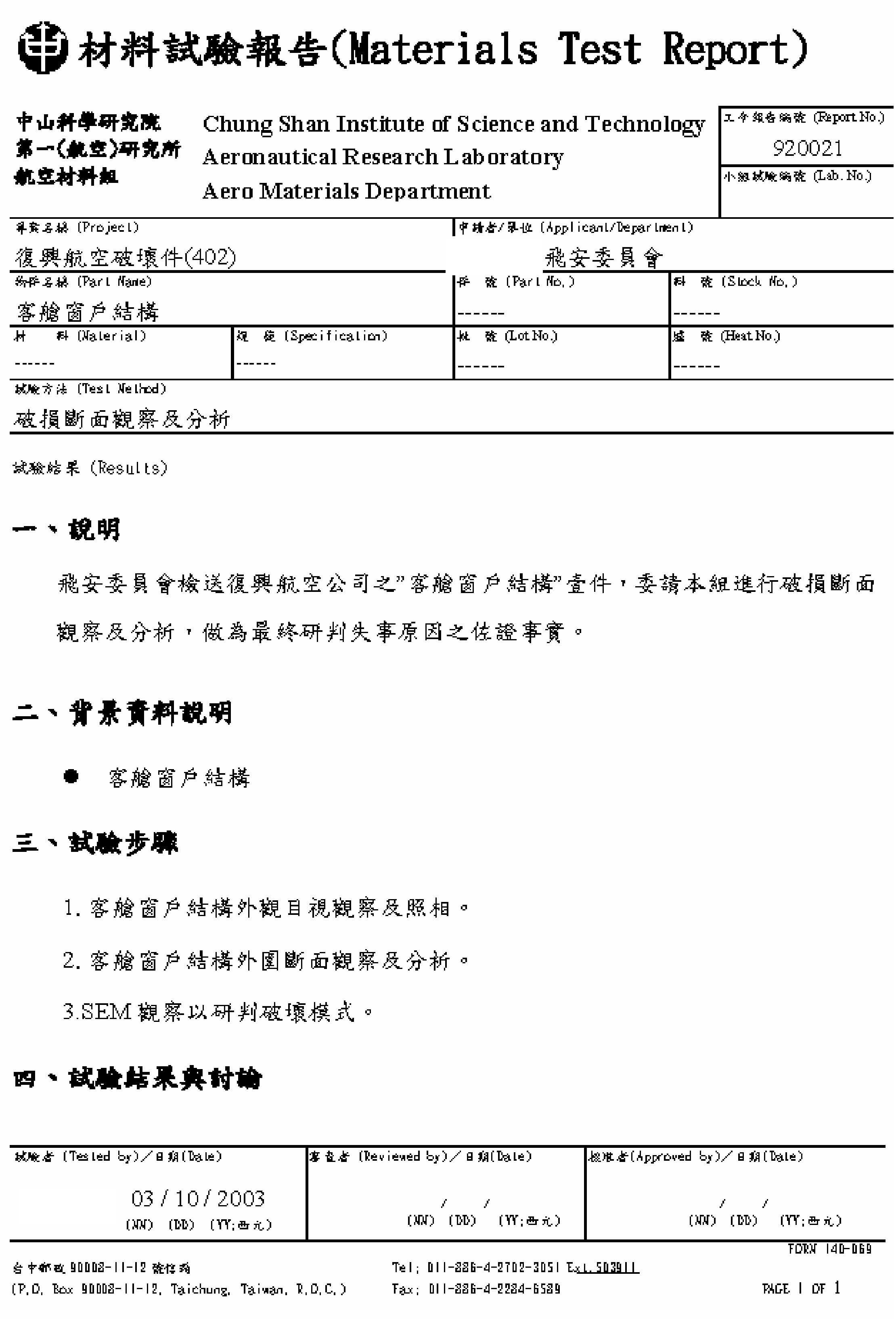
Not Applicable

F. Material Cost and Availability

Parts available from:

L-3 Communications
Aviation Recorders
P.O. Box 3041
Sarasota, Fl. 34230–3041 USA
Telephone: (941) 371–0811 (Aviation Sales)
Fax: (941) 377–5591

Appendix 14 The CSIST Materials Test Report



材料試驗報告(Materials Test Report)

中山科學研究院
第一(航空)研究所
航空材料組

Chung Shan Institute of Science and Technology
Aeronautical Research Laboratory
Aero Materials Department

工令報告編號 (Report No.)
920021
小組試驗編號 (Lab. No.)

專案名稱 (Project) 復興航空破壞件(402)	申請者/單位 (Applicant/Department) 飛安委員會

物件名稱 (Part Name) 客艙窗戶結構		件號 (Part No.) ------	料號 (Stock No.) ------
材料 (Material) ------	規範 (Specification) ------	批號 (Lot No.) ------	爐號 (Heat No.) ------

試驗方法 (Test Method)

破損斷面觀察及分析

試驗結果 (Results)

一、說明

飛安委員會檢送復興航空公司之"客艙窗戶結構"壹件，委請本組進行破損斷面觀察及分析，做為最終研判失事原因之佐證事實。

二、背景資料說明

- 客艙窗戶結構

三、試驗步驟

1. 客艙窗戶結構外觀目視觀察及照相。
2. 客艙窗戶結構外圍斷面觀察及分析。
3. SEM觀察以研判破壞模式。

四、試驗結果與討論

試驗者 (Tested by)／日期(Date)	審查者 (Reviewed by)／日期(Date)	核准者(Approved by)／日期(Date)
03 / 10 / 2003 (MM) (DD) (YY;西元)	/ / (MM) (DD) (YY;西元)	/ / (MM) (DD) (YY;西元)

FORM 140-069

台中郵政90008-11-12號信箱
(P.O. Box 90008-11-12, Taichung, Taiwan, R.O.C.)

Tel: 011-886-4-2702-3051 Ext.503911
Fax: 011-886-4-2284-6589

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1.外觀目視觀察

圖 1(a)、(b)分別為客艙窗戶結構損壞件之內面及外面的外觀觀察，其外圍輪廓斷面均呈現崎嶇不平的斷面形態，尤其是右邊斷面(編號 2 端朝上，從窗戶結構外面往裡瞧)呈現很大的變形及撕裂的破壞形態。

2.門樑斷面觀察及分析

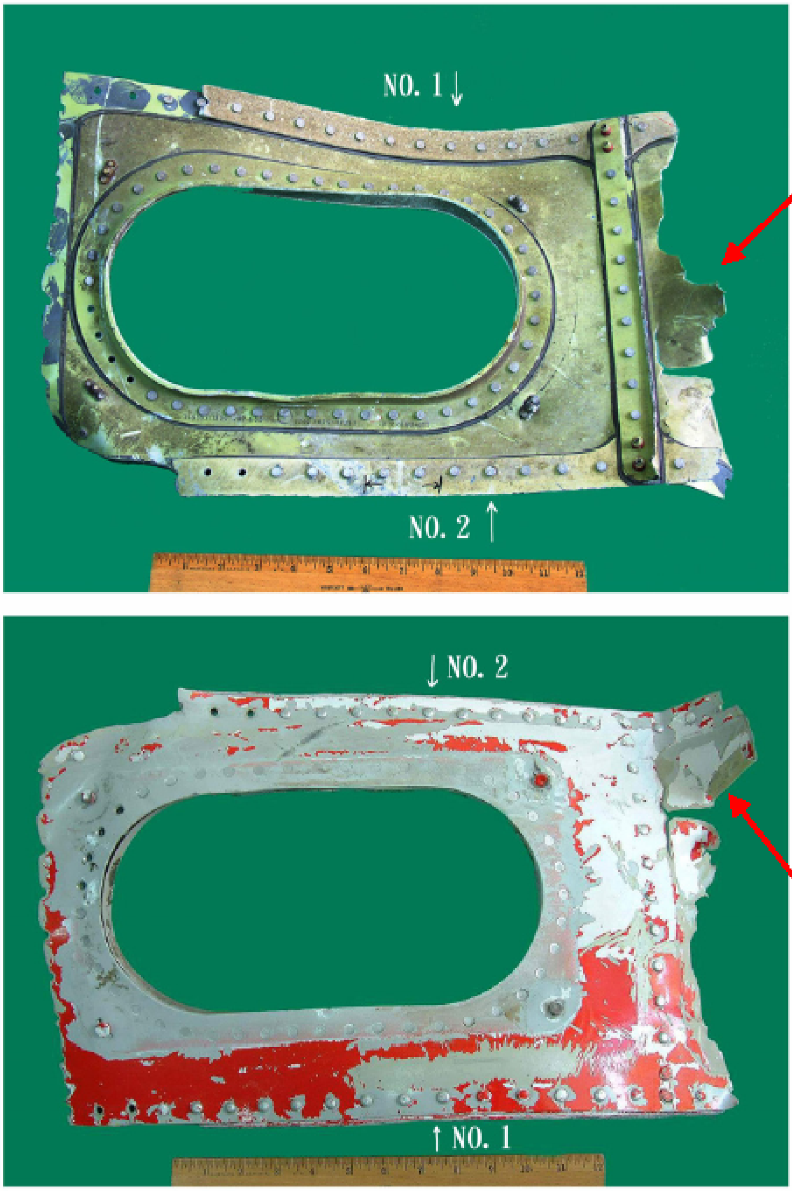
如圖 2～圖 8 分別為斷面編號 1-1、1-2、1-3、1-4、1-5、1-6，及 1-7 之斷面巨觀觀察，斷面從頭到尾均呈現崎嶇不平的斷裂形態。而圖 9～圖 13 則分別為斷面編號 2-1、2-2、2-3、2-4，及 2-5 之斷面巨觀觀察，斷面從頭到尾也是呈現崎嶇不平的斷裂形態。至於破壞模式須由 SEM 確認。

3. SEM 觀察

圖 14 為客艙窗戶結構破損件編號 2-3 端斷面的 SEM 照片，本破損件係由海中撈起所以表面已覆蓋壹層嚴重氧化物，不利 SEM 觀察。圖 15 為圖 14 上斷面 A 點區域的 SEM 觀察，明顯可見其凹渦組織(DIMPLE STRUCTURE)的痕跡，屬過負荷斷裂。

五、結論

1.客艙窗戶結構破損件的破壞模式為過負荷斷裂。



(a)內面(0.33X)(b)外面(0.33X)

圖 1. 客艙窗戶結構破損件之外觀觀察。

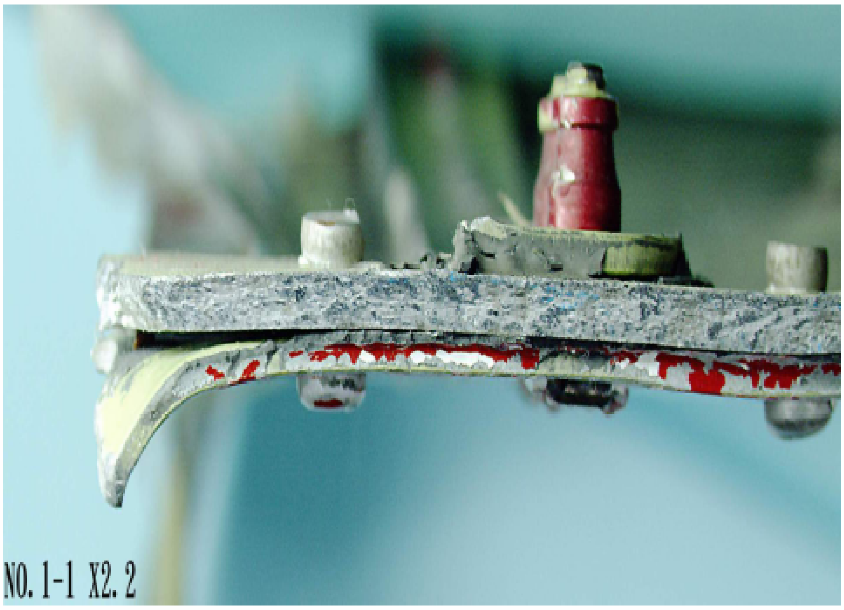


圖 2. 客艙窗戶結構破損件編號 1-1 端斷面的巨觀觀察。(2.2X)

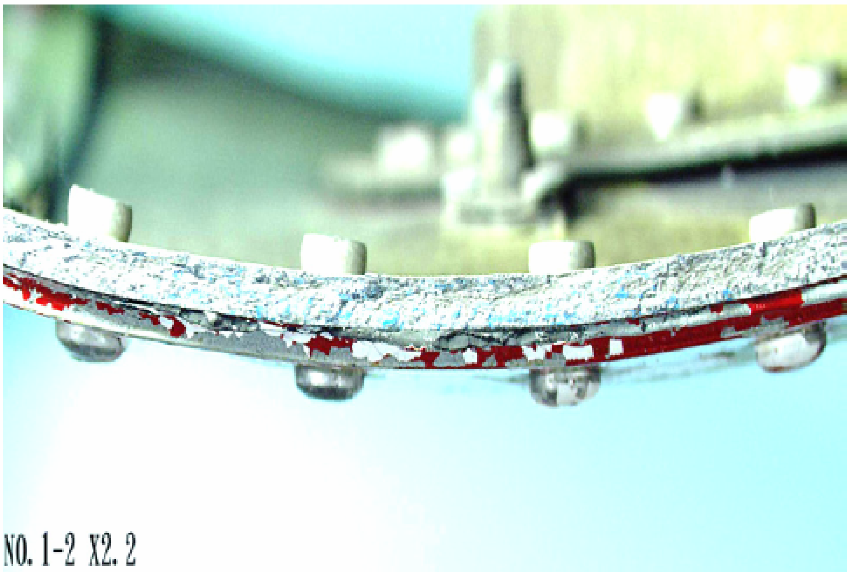


圖 3. 客艙窗戶結構破損件編號 1-2 端斷面的巨觀觀察。(2.2X)

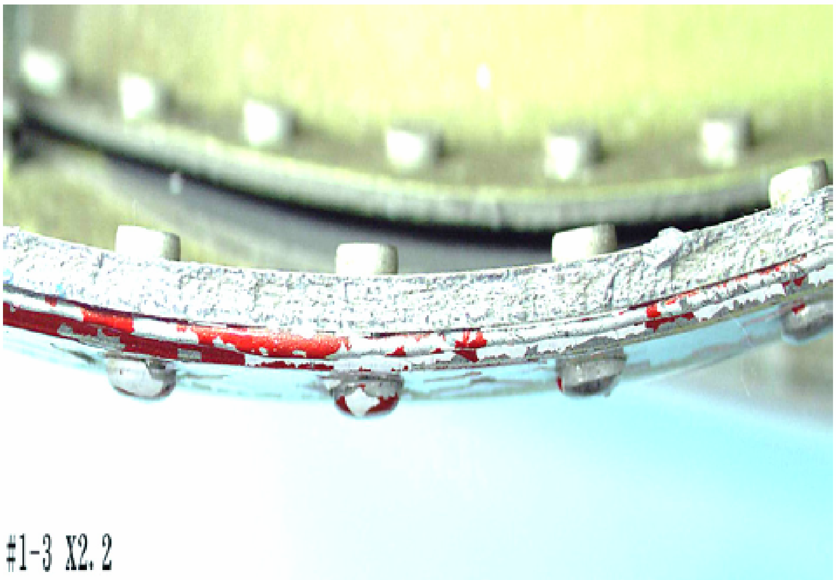


圖 4. 客艙窗戶結構破損件編號 1-3 端斷面的巨觀觀察。(2.2X)

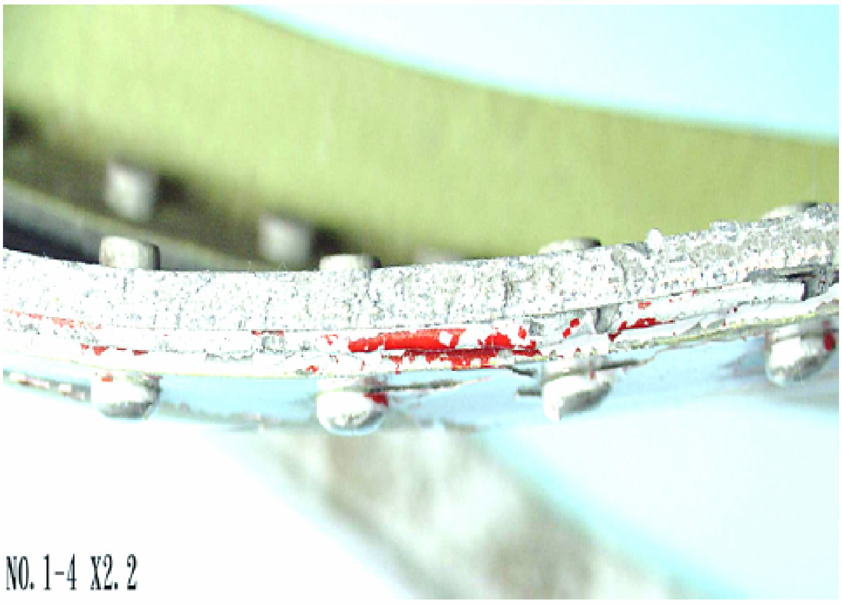


圖 5. 客艙窗戶結構破損件編號 1-4 端斷面的巨觀觀察。(2.2X)

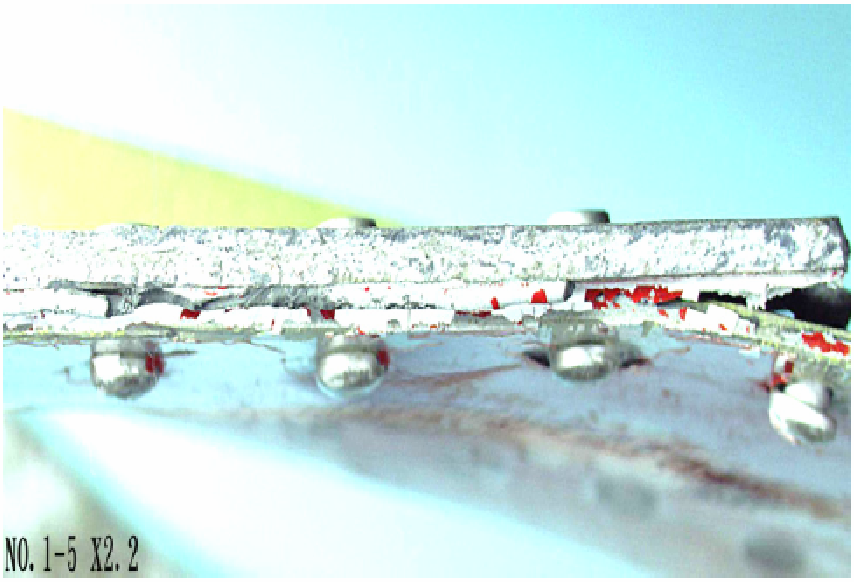


圖 6.　客艙窗戶結構破損件編號 1-5 端斷面的巨觀觀察。(2.2X)

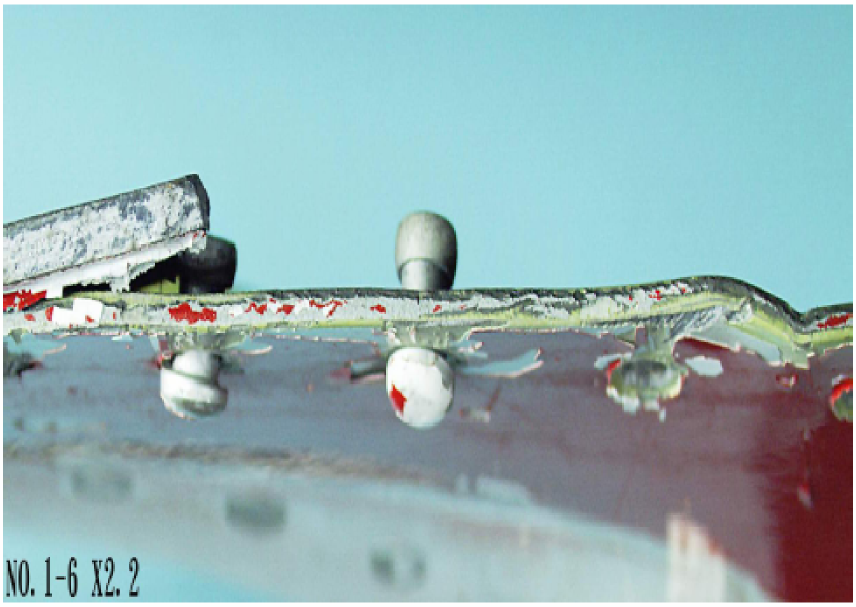


圖 7.　客艙窗戶結構破損件編號 1-6 端斷面的巨觀觀察。(2.2X)

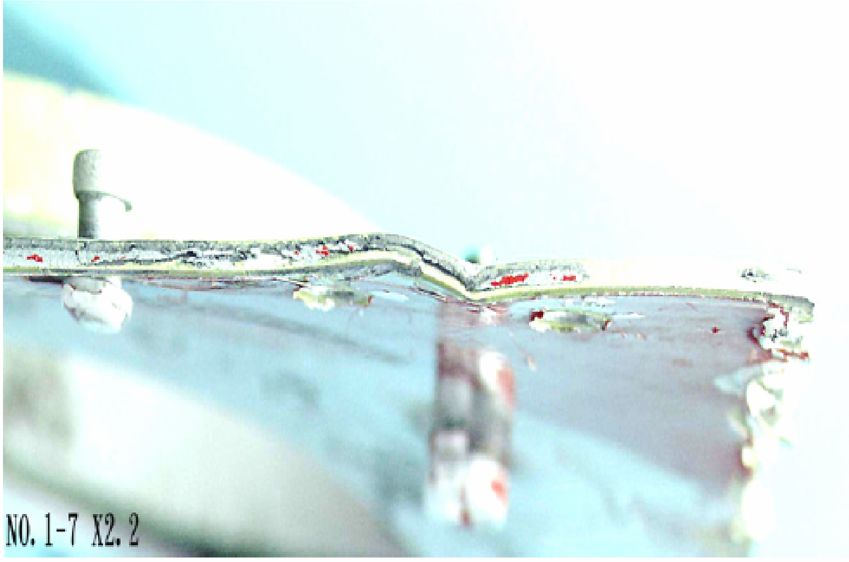


圖 8.　客艙窗戶結構破損件編號 1-7 端斷面的巨觀觀察。(2.2X)

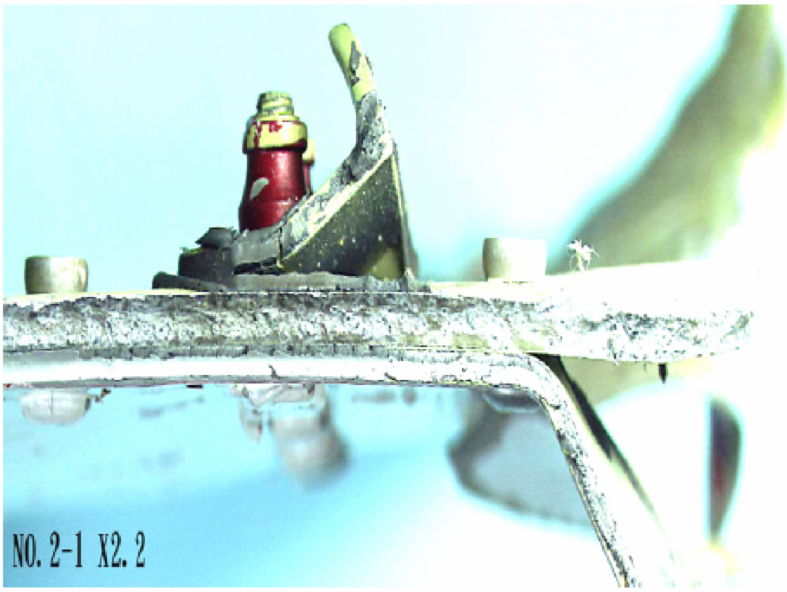


圖 9.　客艙窗戶結構破損件編號 2-1 端斷面的巨觀觀察。(2.2X)

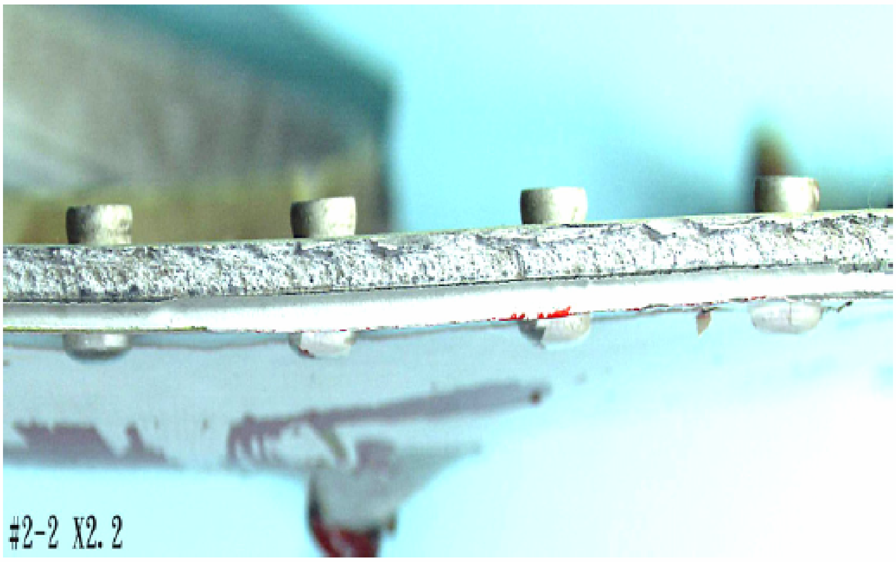


圖 10. 客艙窗戶結構破損件編號 2-2 端斷面的巨觀觀察。(2.2X)

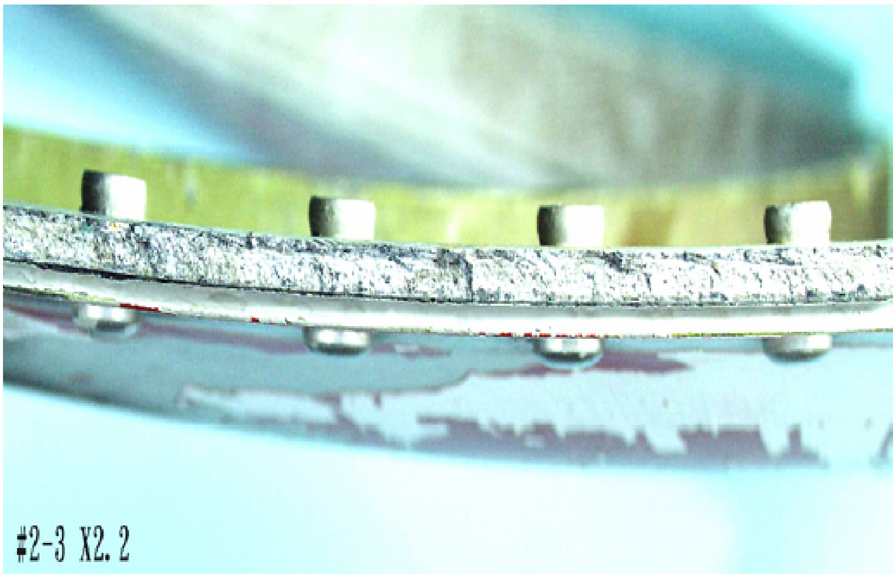


圖 11. 客艙窗戶結構破損件編號 2-3 端斷面的巨觀觀察。(2.2X)

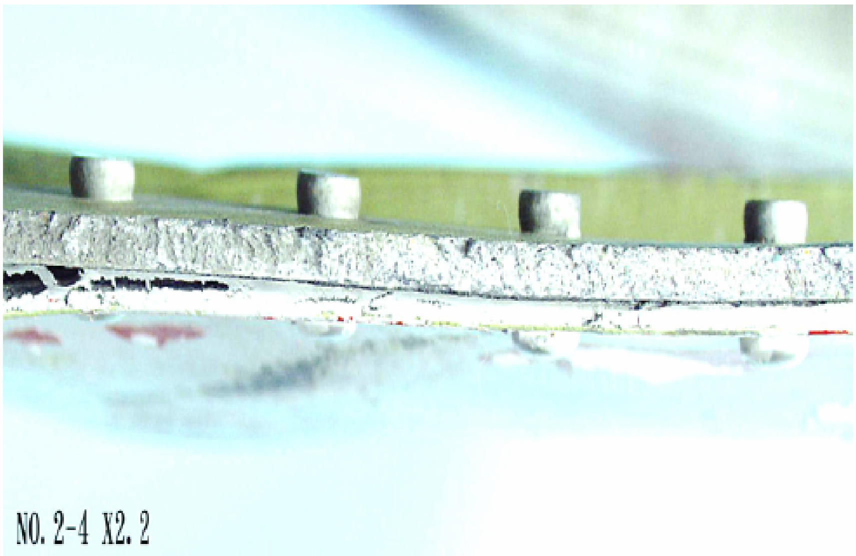


圖 12. 客艙窗戶結構破損件編號 2-4 端斷面的巨觀觀察。(2.2X)

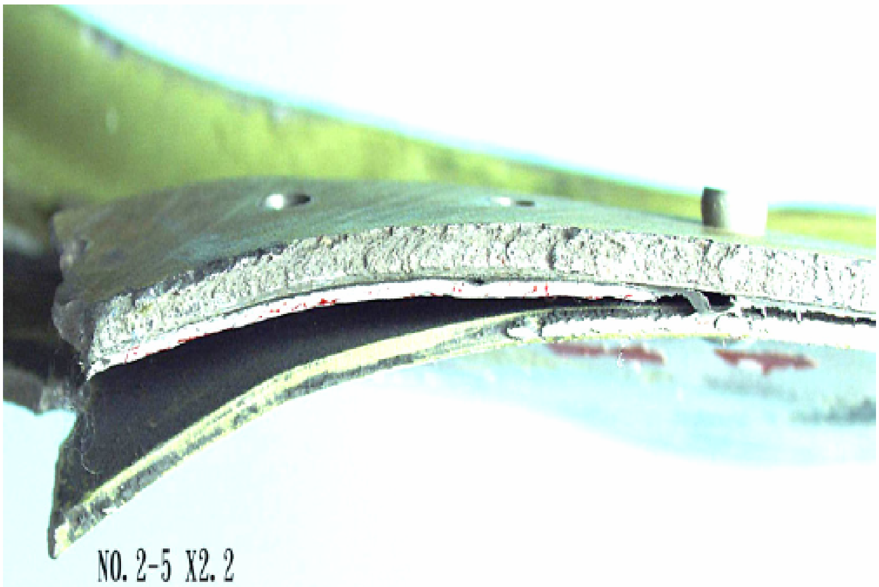


圖 13. 客艙窗戶結構破損件編號 2-5 端斷面的巨觀觀察。(2.2X)

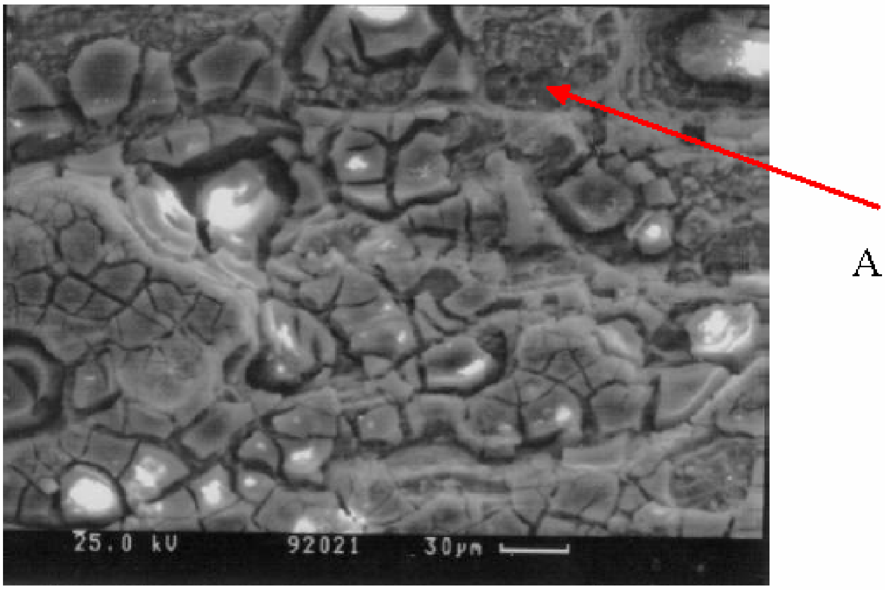


圖 14. 客艙窗户結構破損件編號 2-3 端斷面的 SEM 觀察。(340X)

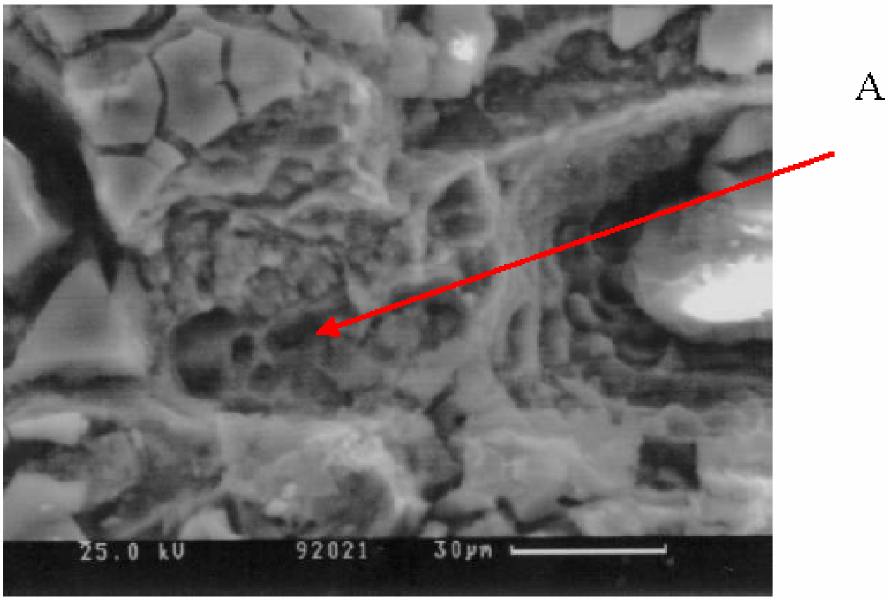


圖 15. 圖 14 上 A 點的 SEM 觀察，凹渦組織明顯可見。(790X)

Appendix 15 Wreckage List

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No.	Date	Time	Latitude	Longitude	Zone	Description	ATA	Station From/To	Section From/To	Stringer From/To	Len
001	21/12/02	0600	23.21	119.23	Floating	Cargo Track	53		141/142		50c
002	21/12/02	0840	23.25	119.26	Floating	V.STAB Skin PNL	55		322/324		115
003	21/12/02	0840	23.25	119.26	Floating	V.STAB Skin PNL	55		322/324		150
004	21/12/02	0840	23.25	119.26	Floating	V.STAB Skin PNL	55		322/324		83c
005	21/12/02	0600	23.21	119.23	Floating	V.STAB Skin PNL	55		322/324		66c
006	21/12/02	1100	23.23	119.22	Floating	V.STAB Skin PNL	55		322/324		45c
007	21/12/02	1100	23.23	119.22	Floating	V.STAB Skin PNL	55		322/324		53c
008	21/12/02	0810	23.25	119.26	Floating	V.STAB Skin PNL	55		322/324		70c
009	21/12/02	0600	23.21	119.23	Floating	V.STAB Skin PNL	55		322/324		86c
010	21/12/02	0600	23.21	119.23	Floating	V.STAB Skin PNL	55		322/324		25c
011	21/12/02	1100	23.23	119.22	Floating	V.STAB Skin PNL	55		322/324		39c
012	21/12/02	1100	23.23	119.22	Floating	V.STAB Skin PNL	55		322/324		74c
013	21/12/02	0810	23.25	119.26	Floating	RUD L/E	55		326		103
014	21/12/02	0600	23.21	119.23	Floating	RUD Skin PNL	55		327		73c
015	21/12/02	0600	23.21	119.23	Floating	RUD Skin PNL	55		327		33c
016	21/12/02	0800	23.25	119.24	Floating	RUD Skin PNL	55		327		106
017					Floating	RUD Skin PNL	55		327		59c
018					Floating	RUD Skin PNL	55		327		37c
019					Floating	RUD Skin PNL	55		327		49c
020	22/12/02	0930	23.23	119.30	Floating	RUD Skin PNL	55		327		40c
021	22/12/02	0930	23.23	119.30	Floating	RUD Skin PNL	55		327		30c
022	21/12/02	0810	23.25	119.26	Floating	RUD Trim Tab	55		328		69c
023	21/12/02	0600	23.21	119.23	Floating	RUD Trim Tab	55		328		45c
024	22/12/02	1545	水垵村西洞尾沿岸		Floating	RUD Trim Tab	55		328		70c
025	21/12/02	0600	23.21	119.23	Floating	SPLR	57		543/643		49c

034	21/12/02	1430	23.22	119.26	Floating	Tail Cone Skin	53		313/314		110
035	21/12/02	0800	23.25	119.27	Floating	Tail Cone Skin	53		313/314		87
036	21/12/02	1350	23.27	119.23	Floating	Tail Cone Skin	53		313/314		80
037	21/12/02	1258	23.27	119.24	Floating	Fairing	53		191/195		40
038	21/12/02	0600	23.21	119.23	Floating	Fairing	53		191/195		47
039	21/12/02	0810	23.25	119.26	Floating	Fairing	53		293/294		62
040	21/12/02	0600	23.21	119.23	Floating	Fairing	53		191/195		62
041	21/12/02	0600	23.21	119.23	Floating	Fairing	53		191/195		30
042	21/12/02	0600	23.21	119.23	Floating	Fairing	53		191/195		36
043	21/12/02	0800	23.25	119.24	Floating	Fairing	53		191/195		41
044	21/12/02	0800	23.25	119.24	Floating	Fairing	53		191/195		29
045	21/12/02	1100	23.23	119.22	Floating	Fairing	53		191/195		68
046	21/12/02	1100	23.23	119.22	Floating	Fairing	53		191/195		27
047	22/12/02	0930	23.23	119.30	Floating	Fairing	53		191/195		53
048	21/12/02	0600	23.21	119.23	Floating	Fairing	53		191/195		62
049	21/12/02	1245	23.28	119.24	Floating	Cargo Floor PNL	25		141/142		32
050	21/12/02	0600	23.21	119.23	Floating	Cargo Floor PNL	25		141/142		33
051	21/12/02	0600	23.21	119.23	Floating	Cargo Floor PNL	25		141/142		28
052	21/12/02	0600	23.21	119.23	Floating	Cargo Floor PNL	25		141/142		43
053	21/12/02	0600	23.21	119.23	Floating	Cargo Floor PNL	25		141/142		20
054	21/12/02	0600	23.21	119.23	Floating	Cargo Floor PNL	25		141/142		95
055	21/12/02	0800	23.25	119.24	Floating	Cargo & Floor	25		141/142		210
056	21/12/02	0800	23.25	119.24	Floating	Cargo Floor PNL	25		141/142		42
057	21/12/02	0600	23.21	119.23	Floating	PAX Door Step	52		834		53
058	21/12/02	1330	23.27	119.24	Floating	PAX Door Step	52		834		53
059	21/12/02	1135	23.27	119.24	Floating	ADF#1 ANT	34		253		45
060	21/12/02	1135	23.27	119.24	Floating	COM HF Coupler	23		264		31

069	21/12/02	0600	23.21	119.23	Floating	Flap Skin PNL	57		541/542		37
070	21/12/02	0600	23.21	119.23	Floating	Flap Skin PNL	57		541/542		27
071	21/12/02	0600	23.21	119.23	Floating	Flap Skin PNL	57		541/542		42
072	21/12/02	1100	23.23	119.22	Floating	Flap Skin PNL	57		541/542		44
073	21/12/02	1430	23.22	119.26	Floating	Flap Skin PNL	57		541/542		43
074	22/12/02	0930	23.23	119.30	Floating	Flap Skin PNL	57		541/542		39
075					Floating	Flap Skin PNL	57		541/542		60
076					Floating	Flap Skin PNL	57		541/542		65
077					Floating	Flap Skin PNL	57		541/542		110
078					Floating	Flap Skin PNL	57		541/542		63
079					Floating	Flap Skin PNL	57		541/542		74
080	21/12/02	0600	23.21	119.23	Floating	Wing T/E PNL	57		530/533		44
081	21/12/02	1100	23.23	119.22	Floating	Wing T/E PNL	57		530/533		45
082	21/12/02	1100	23.23	119.22	Floating	Wing T/E PNL	57		530/533		36
083	21/12/02	1100	23.23	119.22	Floating	Wing T/E PNL	57		530/533		44
084					Floating	Wing T/E PNL	57		530/533		40
085					Floating	Wing T/E PNL	57		530/533		45
086					Floating	Wing T/E PNL	57		530/533		37
087	21/12/02	0600	23.21	119.23	Floating	AFT UP ENG Cowl	54		475/476		30
088	12/01/03	F:0626 T:0640	23˚28.760'	119˚26..296'		DFDR S/N 3490	31		FR46		30
89	13/01/03	F:1640 T:1550	23˚28.7569'	119˚26..2954'		CVR P/N 93A100	31		FR46		35
90	16/01/03	16:45	23˚28.7593'	119˚26.3004'		FIRE WALL	70		475/485		100
91	16/01/03	16:45	23˚28.7593'	119˚26.3004'		Propeller Blade	61		412/422		130
92	16/01/03	16:45	23˚28.7593'	119˚26.3004'		Landing Gear and Fuselage Panel	32		741		120

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The second phase: Fish boat operation

No.	Date	Time	Latitude	Longitude	Zone	Description	ATA	Station From/To	Section From/To	Stringer From/To	Length	Width	Height	Remarks
098	18/02/03				Sea Bed	Wing Skin PNL	57		520/620		86cm	30cm	3cm	漁 001
099	18/02/03				Sea Bed	Wing Structure	57		500/600		55cm	5cm	4cm	漁 002
100	18/02/03				Sea Bed	Pipe	28		500/600		54cm	22cm	3cm	漁 003
101	21/02/03				Sea Bed	L/G	32		731/741		60cm	14cm	4cm	漁 004
102	21/02/03				Sea Bed	Wing Skin PNL	57		520		167cm	41cm	3cm	漁 005
103	21/02/03				Sea Bed	Exhaust Pipe	71		479/489		65cm	34cm	24cm	漁 006
104	21/02/03				Sea Bed	Window Frame	53		200		56cm	40cm	2cm	漁 007
105	21/02/03				Sea Bed	V.STAB Skin	55		320		102cm	44cm	23cm	漁 008
106	22/02/03				Sea Bed	Bleed Duct	36		FR23		110cm	54cm	2cm	漁 009
107	22/02/03				Sea Bed	RUD L/E	55		320		54cm	34cm	13cm	漁 010
108	22/02/03				Sea Bed	V.STAB Structure	55		320		97cm	38cm	15cm	漁 011
109	22/02/03				Sea Bed	A/C Skin	53		200		46cm	36cm	3cm	漁 012
110	22/02/03				Sea Bed	A/C Skin	53		200		43cm	33cm	8cm	漁 013
111	22/02/03				Sea Bed	A/C Skin	53		200		70cm	35cm	1cm	漁 014
112	22/02/03				Sea Bed	A/C Skin	53		200		85cm	50cm	10cm	漁 015
113	23/02/03				Sea Bed	A/C Skin	53		200		80cm	30cm	10cm	漁 016
114	23/02/03				Sea Bed	A/C Skin	53		200		60cm	39cm	10cm	漁 017
115	26/02/03				Sea Bed	Wing Skin PNL	57		520		103cm	46cm	7cm	漁 018

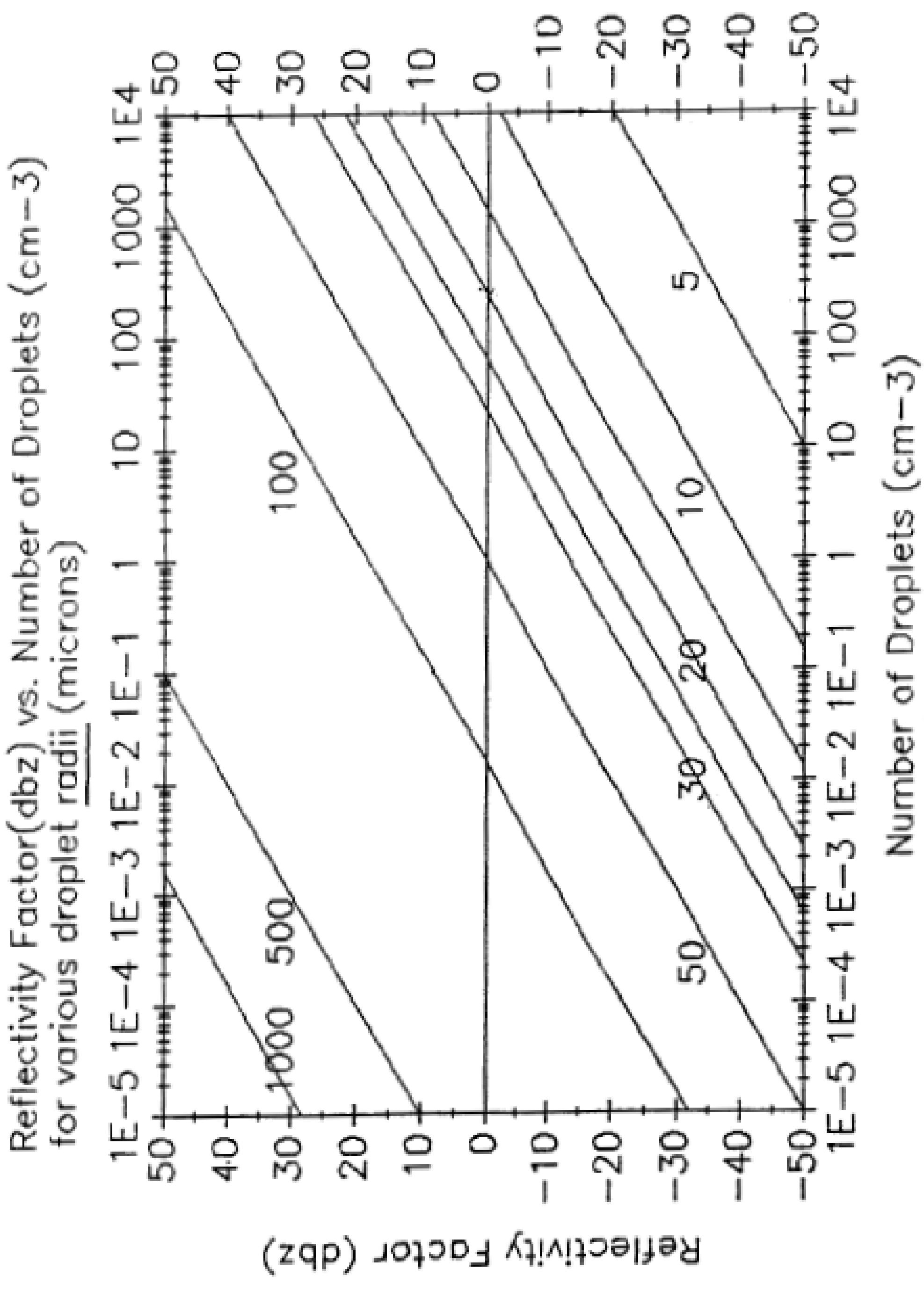
116	26/02/03				Sea Bed	Wing Structure	57		540/640		110cm	33cm	6cm	漁 019
117	26/02/03				Sea Bed	Wing Structure	57		520/620		60cm	38cm	7cm	漁 020
118	26/02/03				Sea Bed	SVC Door	52		840		108cm	46cm	4cm	漁 021
119	26/02/03				Sea Bed	Wheel	32		731/741		39cm	29cm	14cm	漁 022
120	26/02/03				Sea Bed	A/C Structure	53		FR25		75cm	39cm	4cm	漁 023
121	26/02/03				Sea Bed	MECH Rod	53		540/640		56cm	3cm	8cm	漁 024
122	26/02/03				Sea Bed	A/C Structure	53		FR47		135cm	6cm	1cm	漁 025
123	26/02/03				Sea Bed	A/C Skin	53		200		30cm	9cm	2cm	漁 026
124	26/02/03				Sea Bed	V.STAB Structure	55		320		65cm	54cm	20cm	漁 027
125	27/02/03				Sea Bed	ENG Tail Cowl	71		477/487		40cm	38cm	0.5cm	漁 028
126	27/02/03				Sea Bed	No SMK Sign PNL	25		FR39		40cm	34cm	0.5cm	漁 029
127	27/02/03				Sea Bed	A/C Skin	53		200		37cm	17cm	0.3cm	漁 030
128	27/02/03				Sea Bed	A/C Structure	53		FR38		88cm	29cm	0.3cm	漁 031
129	27/02/03				Sea Bed	A/C Structure	53		FR39		60cm	16cm	3cm	漁 032
130	27/02/03				Sea Bed	Wing Structure	57		620		166cm	75cm	4cm	漁 033
131	27/02/03				Sea Bed	Wing Structure	57		FR26		184cm	75cm	4cm	漁 034
132	27/02/03				Sea Bed	Wing Structure	57		540/640		84cm	34cm	4cm	漁 035
133	28/02/03				Sea Bed	Cargo Track	53		141/142		48cm	9cm	3cm	漁 036
134	28/02/03				Sea Bed	Wing Structure	57		520/620		48cm	4cm	1cm	漁 037
135	28/02/03				Sea Bed	A/C Skin	53		FR40		200cm	94cm	16cm	漁 038
136	28/02/03				Sea Bed	Wheel and BRK	32		731/741		73cm	45cm	20cm	漁 039
137	28/02/03				Sea Bed	A/C Structure	53		200		49cm	6cm	0.3cm	漁 040

138	28/02/03				Sea Bed	A/C Structure	53		200		75cm	9cm	1cm	渔 041
139	28/02/03				Sea Bed	Wing Structure	57		530/630		50cm	13cm	10cm	渔 042
140	28/02/03				Sea Bed	Cargo Track	53		141/142		55cm	8cm	5cm	渔 043
141	28/02/03				Sea Bed	A/C Skin	53		200		34cm	10cm	0.2cm	渔 044
142	28/02/03				Sea Bed	Wing Structure	57		530/630		36cm	16cm	0.3cm	渔 045
143	28/02/03				Sea Bed	Fairing	57		550/650		25cm	18cm	6cm	渔 046
144	28/02/03				Sea Bed	Fairing	53		191/195		56cm	22cm	0.3cm	渔 047
145	28/02/03				Sea Bed	A/C Skin	53		200		56cm	22cm	14cm	渔 048
146	28/02/03				Sea Bed	Cargo Liner	25		141/142		55cm	37cm	0.2cm	渔 049
147	28/02/03				Sea Bed	RCAU Cover	23		FR12		21cm	13cm	0.3cm	渔 050
148	28/02/03				Sea Bed	A/C Structure	53		200		85cm	50cm	30cm	渔 051
149	28/02/03				Sea Bed	Cargo					120cm	9cm	4cm	渔 052
150	28/02/03				Sea Bed	Window Frame	53		FR19		72cm	21cm	3cm	渔 053
151	28/02/03				Sea Bed	Wing Structure	57		530/630		79cm	40cm	0.4cm	渔 054
152	28/02/03				Sea Bed	A/C Structure	53		200		24cm	8cm	0.2cm	渔 055
153	01/03/03				Sea Bed	A/C Skin	53		FR40		158cm	151cm	73cm	渔 056
154	01/03/03				Sea Bed	HYD Pipe	29				78cm	0.5cm	0.5cm	渔 057
155	01/03/03				Sea Bed	Bundle	24				101cm	0.3cm	0.3cm	渔 058
156	01/03/03				Sea Bed	A/C Skin	53		200		39cm	20cm	0.2cm	渔 059
157	01/03/03				Sea Bed	A/C Structure	53		200		45cm	8cm	3cm	渔 060
158	01/03/03				Sea Bed	Flap Structure	57		550/650		52cm	43cm	8cm	渔 061
159	01/03/03				Sea Bed	A/C Structure	53		200		79cm	19cm	6cm	渔 062

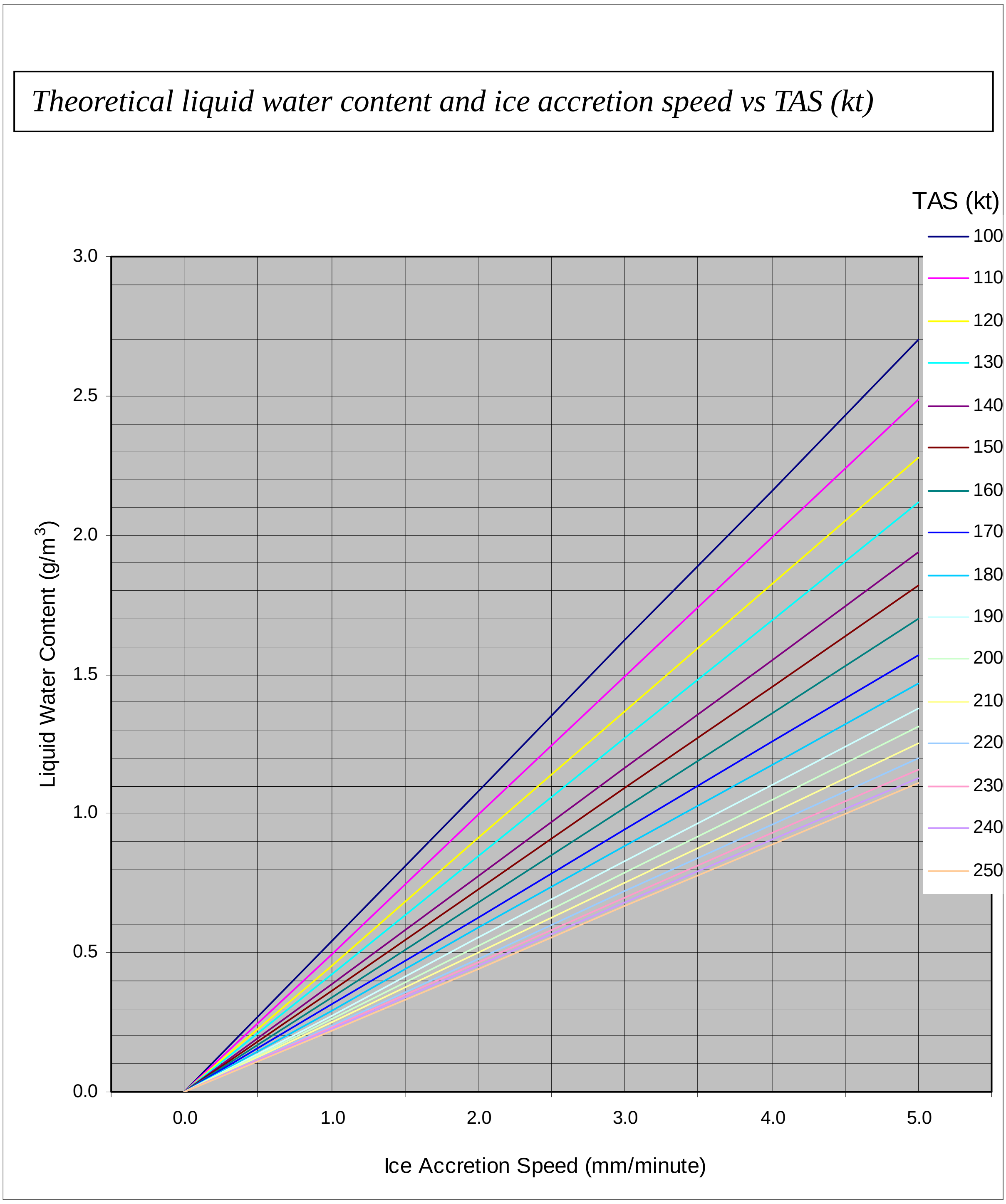
160	01/03/03				Sea Bed	A/C Structure	53		FR24		98cm	42cm	13cm	漁 063
161	01/03/03				Sea Bed	A/C Skin	53		200		36cm	30cm	17cm	漁 064
162	01/03/03				Sea Bed	Tire	32		731/741		74cm	25cm	6cm	漁 065
163	01/03/03				Sea Bed	A/C Structure	53		200		98cm	11cm	5cm	漁 066
164	01/03/03				Sea Bed	A/C Skin	53		200		55cm	28cm	12cm	漁 067
165	01/03/03				Sea Bed	A/C Structure	53		FR25		142cm	72cm	8cm	漁 068
166	01/03/03				Sea Bed	Flap Structure	57		630		148cm	44cm	27cm	漁 069
167	01/03/03				Sea Bed	A/C Skin	53		FR21		59cm	46cm	0.3cm	漁 070
168	01/03/03				Sea Bed	A/C Skin	53		200		30cm	24cm	0.2cm	漁 071
169	01/03/03				Sea Bed	A/C Skin	53		FR23		85cm	70cm	12cm	漁 072
170	01/03/03				Sea Bed	A/C Skin	53		FR42		82cm	6cm	14cm	漁 073
171	01/03/03				Sea Bed	Wing Structure	57		520/620		150cm	5cm	4cm	漁 074
172	01/03/03				Sea Bed	A/C Structure	53		200		90cm	5cm	4cm	漁 075
173	01/03/03				Sea Bed	A/C Structure	53		200		37cm	19cm	2cm	漁 076
174	01/03/03				Sea Bed	Plate	53		FR41		74cm	7cm	0.2cm	漁 077
175	02/03/03				Sea Bed	A/C Skin	53		200		28cm	19cm	0.2cm	漁 078
176	02/03/03				Sea Bed	A/C Skin	53		200		86cm	34cm	0.3cm	漁 079
177	02/03/03				Sea Bed	Wing Skin	57		530/630		60cm	24cm	6cm	漁 080
178	02/03/03				Sea Bed	A/C Structure	53		200		65cm	29cm	7cm	漁 081
179	02/03/03				Sea Bed	A/C Structure	53		200		64cm	15cm	5cm	漁 082
180	02/03/03				Sea Bed	A/C Structure	53		200		87cm	46cm	8cm	漁 083
181	02/03/03				Sea Bed	A/C Structure	53		FR46		97cm	71cm	29cm	漁 084

182	02/03/03				Sea Bed	Plate	53		FR41		60cm	25cm	2cm	漁 085
183	02/03/03				Sea Bed	A/C Skin	53		FR43		100cm	40cm	9cm	漁 086
184	02/03/03				Sea Bed	Plate	53		FR38		69cm	18cm	3cm	漁 087
185	02/03/03				Sea Bed	Wing Structure	57		520/620		42cm	30cm	12cm	漁 088
186	02/03/03				Sea Bed	Wing Structure	57		520/620		56cm	19cm	2cm	漁 089
187	02/03/03				Sea Bed	A/C Structure	53		FR37		57cm	19cm	3cm	漁 090
188	02/03/03				Sea Bed	A/C Skin	53		200		45cm	33cm	3cm	漁 091
189	02/03/03				Sea Bed	A/C Skin	53		FR41		63cm	43cm	13cm	漁 092
190	02/03/03				Sea Bed	A/C Skin	53		FR40		109cm	53cm	5cm	漁 093
191	02/03/03				Sea Bed	DE-ICE PR SW	30		435/445		22cm	11cm	3cm	漁 094
192	02/03/03				Sea Bed	DE-ICE Boot	30		510/610		29cm	17cm	0.2cm	漁 095
193	02/03/03				Sea Bed	Wing Structure	57		530/630		51cm	30cm	0.3cm	漁 096
194	02/03/03				Sea Bed	A/C Structure	53		200		33cm	24cm	3cm	漁 097
195	02/03/03				Sea Bed	Wing Structure	57		530/630		63cm	29cm	0.2cm	漁 098
196	02/03/03				Sea Bed	A/C Skin	53		200		45cm	30cm	0.2cm	漁 099
197	02/03/03				Sea Bed	Pilot Seat Structure	25		FR8		34cm	18cm	1cm	漁 100
198	05/03/03				Sea Bed	A/C Structure	53		FR45		205cm	135cm	6cm	漁 101
199	13/03/03				Sea Bed	Flap Structure	57		550/650		140cm	30cm	3cm	漁 102

Appendix 16 "Penn State University" Diagram

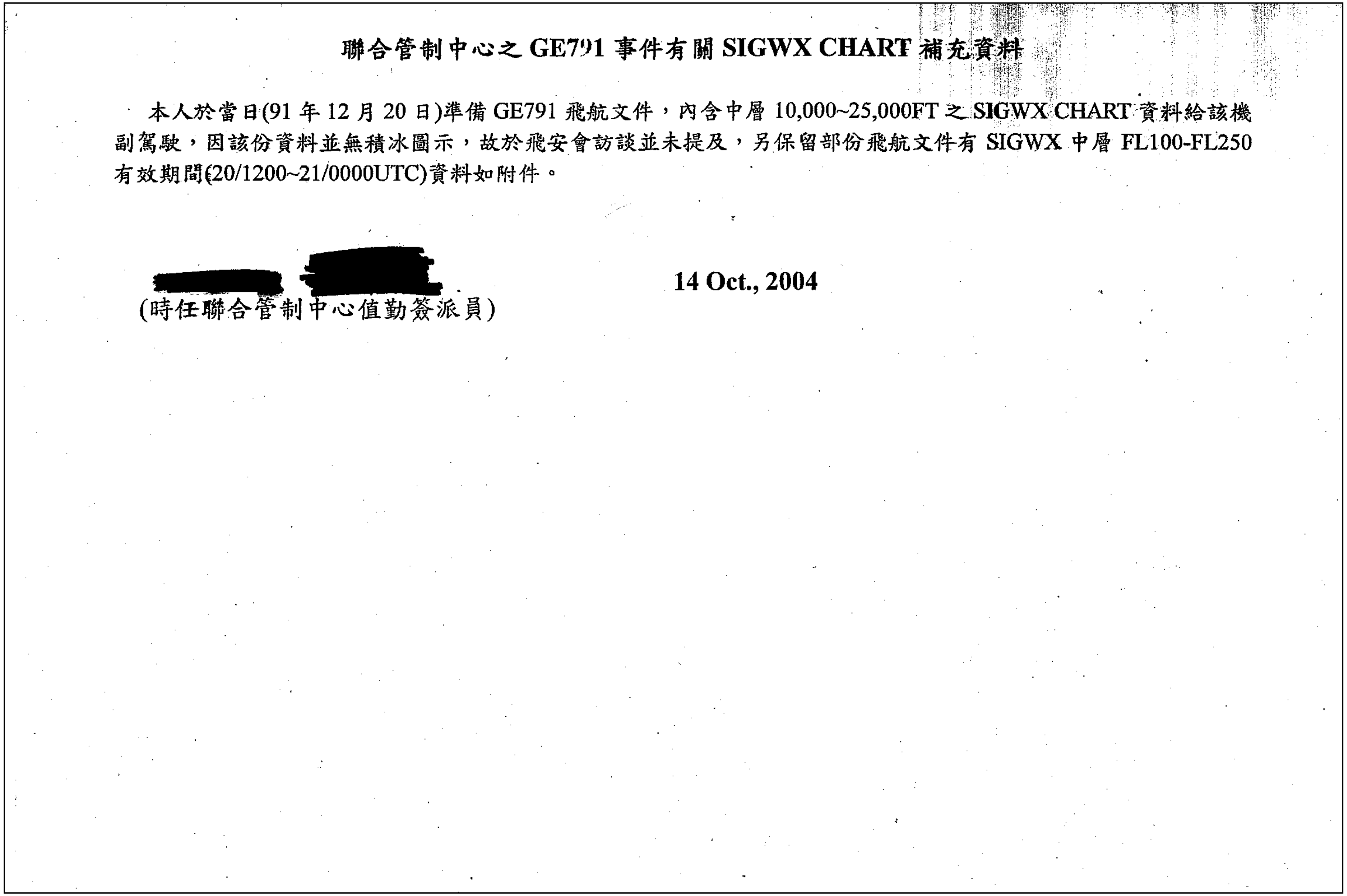


Appendix 17 "Lucas Aerospace" Diagram



Theoretical liquid water content and ice accretion speed vs TAS (kt)

Appendix 18 The Dispatcher’s statement provided by TNA



聯合管制中心之 GE791 事件有關 SIGWX CHART 補充資料

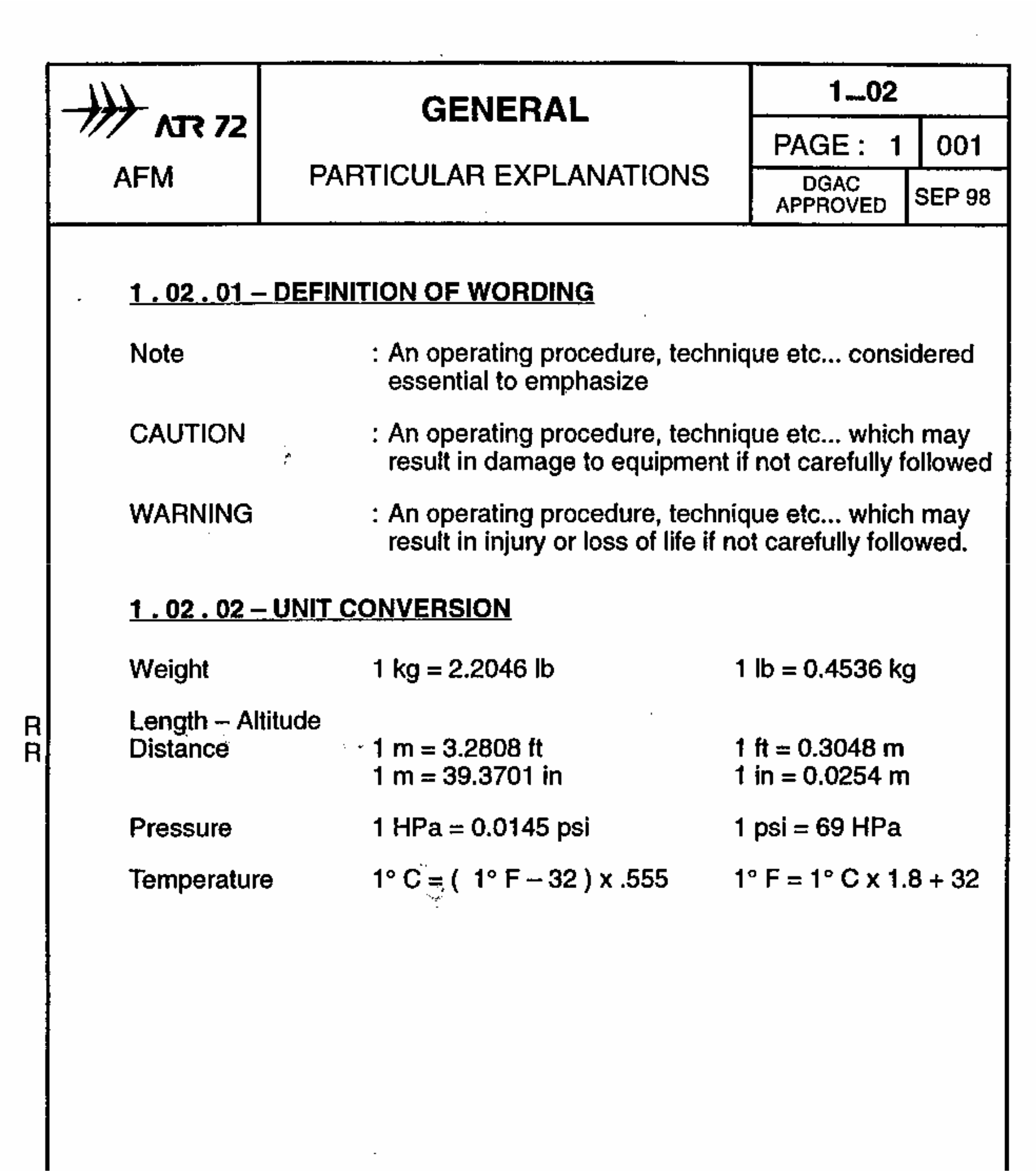
本人於當日(91 年 12 月 20 日)準備 GE791 飛航文件，內含中層 10,000~25,000FT 之 SIGWX CHART 資料給該機副駕駛，因該份資料並無積冰圖示，故於飛安會訪談並未提及，另保留部份飛航文件有 SIGWX 中層 FL100-FL250 有效期間(20/1200~21/0000UTC)資料如附件。

[redacted] [redacted]
(時任聯合管制中心值勤簽派員)

14 Oct., 2004

Appendix 19 Information About Severe Icing

Airplane Flight Manual



ATR 72 AFM	**GENERAL** PARTICULAR EXPLANATIONS	1 – 02	
		PAGE : 1	001
		DGAC APPROVED	SEP 98

1 . 02 . 01 – DEFINITION OF WORDING

Note	: An operating procedure, technique etc... considered essential to emphasize
CAUTION	: An operating procedure, technique etc... which may result in damage to equipment if not carefully followed
WARNING	: An operating procedure, technique etc... which may result in injury or loss of life if not carefully followed.

1 . 02 . 02 – UNIT CONVERSION

	Weight	1 kg = 2.2046 lb	1 lb = 0.4536 kg
R R	Length – Altitude Distance	1 m = 3.2808 ft 1 m = 39.3701 in	1 ft = 0.3048 m 1 in = 0.0254 m
	Pressure	1 HPa = 0.0145 psi	1 psi = 69 HPa
	Temperature	1° C = (1° F – 32) x .555	1° F = 1° C x 1.8 + 32

2 . 06 . 01 – ICING CONDITIONS

- **Atmospheric icing conditions exist when**
  - OAT on the ground and for take–off is at or below 5°C or when TAT in flight is at or below 7°C,
  - and visible moisture in any form is present (such as clouds, fog with visibility of less than one mile, rain, snow, sleet and ice crystals).
- **Ground icing conditions exist when**
  - OAT on the ground is at or below 5°C,
  - and surface snow, standing water or slush is present on the ramps taxiways and runways.

Take–off is prohibited when frost, snow or ice is adhering to the wings, control surfaces or propellers.

- Operation in atmospheric icing conditions :

  NP setting below 86 % is prohibited.

  All icing detection lights must be operative prior to flight at night .

  NOTE :This supersedes any relief provided by the Master Minimum Equipment List (MMEL).

  The ice detector must be operative.

  Refer to 3.04.01 for associated procedures and 6.06.02 for performance data.
- Operation in ground icing conditions :

  Refer to 3.04.01 for associated procedures and to FCOM part 3 and to AFM section 7.03 for advisory information on contaminated runways penalties.

…/…

2 . 06 . 01 – ICING CONDITIONS (cont'd)

- **Severe icing :**

  WARNING :

  Severe icing may result from environmental conditions outside of those for which the airplane is certificated. Flight in freezing rain, freezing drizzle, or mixed icing conditions (supercooled liquid water and ice crystals) may result in ice build–up on protected surfaces exceeding the capability of the ice protection system, or may result in ice forming aft of the protected surfaces. This ice may not be shed using the ice protection systems, and may seriously degrade the performance and controllability of the airplane.

  – During flight, severe icing conditions that exceed those for which the airplane is certificated shall be determined by the following :

  Visual cue identified with severe icing is characterized by ice covering all or a substantial part of the unheated portion of either forward side window, possibly associated with water splashing and streaming on the windshield.

  and / or

  Unexpected decrease in speed or rate of climb.

  and / or

  The following secondary indications :

  . Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.

  . Accumulation of ice on the lower surface of the wing aft of the protected area.

  . Accumulation of ice on the propeller spinner farther aft than normally observed.

  If one of these phenomena is observed, immediately request priority handling from Air Traffic Control to facilitate a route or an altitude change to exit the icing conditions. Apply procedure specified in the Emergency Procedures chapter.

  – Since the autopilot may mask tactile cues that indicate adverse changes in handling characteristics, use of the autopilot is prohibited when the severe icing defined above exists, or when unusual lateral trim requirements or autopilot trim warnings are encountered while the airplane is in icing conditions.

3 . 04 . 01 – ICING CONDITIONS

- DEFINITION
  Refer to 2 .06 .01

Procedure for operation in atmospheric icing conditions :

- As soon as and as long as atmospheric icing conditions exist, the following procedures must be applied :
  ANTI–ICING (propellers, horns, side–windows) .... ON
  PROP MODE SEL .... According to SAT
  NP .... set ≥ 86 %
  Minimum maneuver/operating
  icing speed .... BUGGED AND OBSERVED
  ICE ACCRETION .... MONITOR

  NOTE : horns anti icing selection triggers the illumination of the "ICING AOA" green light, and lowers the AOA stall warning threshold.

R
- At first visual indication of ice accretion and as long as atmospheric icing conditions exist, the following procedure must be applied :
  – ENG START rotary selector .... CONT RELIGHT
  – ANTI ICING (propellers, horns, side windows) ...... CONFIRM ON
  – DE ICING ENG 1 + 2 .... ON
  – AIRFRAME DE ICING .... ON
  – Eng and airframe MODE SEL .... ACCORDING TO SAT
  – Minimum maneuver/operating
  icing speed .... CONFIRM BUGGED AND OBSERVED

  NOTE : Be alert to severe icing detection.
  In case of severe icing refer to Emergency Procedures 4.05.05.

R
- When leaving icing conditions, CONT RELIGHT, DE ICING and ANTI ICING may be switched OFF.
- When the aircraft is visually verified clear of ice, ICING AOA caption may be cancelled and normal speeds may be used.

  NOTE : Experience has shown that the last part to clear is the ice evidence probe. As long as this condition is not reached the icing speeds must be observed and the ICING AOA caption must not be cancelled.

4 . 05 . 05 – SEVERE ICING

DETECTION

Visual cue identified with severe icing is characterized by ice covering all or a substantial part of the unheated portion of either forward side window, possibly associated with water splashing and streaming on the windshield.

and / or

Unexpected decrease in speed or rate of climb.

and / or

The following secondary indications :

- Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.
- Accumulation of ice on the lower surface of the wing aft of the protected area.
- Accumulation of ice on the propeller spinner farther aft than normally observed.

The following weather conditions may be conducive to severe in flight icing :

- Visible rain at temperatures close to 0 degrees Celsius ambient air temperature.
- Droplets that splash or splatter on impact at temperatures close to 0 degrees Celsius ambient air temperature

EXIT THE SEVERE ICING ENVIRONMENT :

This procedure is applicable to all flight phases from initial climb to landing. Monitor the ambient air temperature. While severe icing may form at temperatures as cold as –18 degrees Celsius, increased vigilance is warranted at temperatures around freezing with visible moisture present.

■ **If severe icing, as determined above, is encountered :**

–Immediately increase and bug the minimum maneuver/operating icing speeds by 10 kt. Increase power up to MAX CONT, if needed.

–Request priority handling from Air Traffic Control to facilitate a route or an altitude change to exit the severe icing conditions in order to avoid extended exposure to flight conditions more severe than those for which the airplane has been certificated.

–Avoid abrupt and excessive maneuvering that may exacerbate control difficulties.

4 . 05 . 05 – SEVERE ICING (Cont'd)

- Do not engage the autopilot.

■ **If the autopilot is engaged, hold the control wheel firmly and disengage the autopilot.**

■ **If the flaps are extended, do not retract them until the airframe is clear of ice.**

■ **If an unusual roll response or uncommanded roll control movement is observed maintain the roll controls at the desired position and reduce the angle of attack by :**

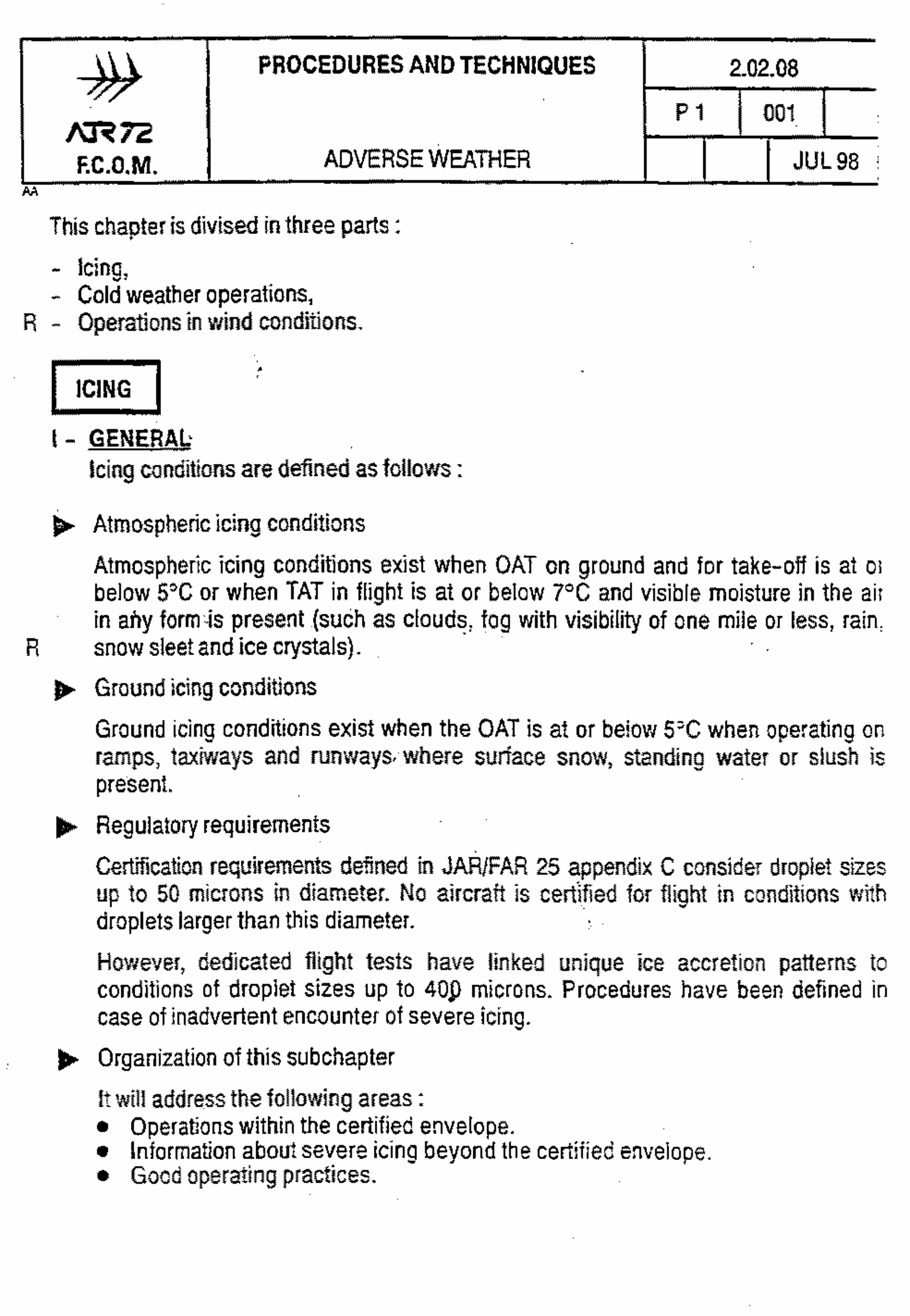
  - Pushing on the wheel as needed,
  - Extending flaps to 15,
  - Increasing power, up to MAX CONT if needed.

■ **If the aircraft is not clear of ice :**

  - Maintain flaps 15 for approach and landing, with "reduced flaps APP/LDG icing speed"+ 5 kt.
  - Multiply landing distance flaps 30 by 1.91 R

- Report these weather conditions to Air Traffic Control

Flight Crew Operating Manual



ATR72
F.C.O.M.

PROCEDURES AND TECHNIQUES

ADVERSE WEATHER

2.02.08
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This chapter is divised in three parts :

- Icing,
- Cold weather operations,

R - Operations in wind conditions.

ICING

I - GENERAL

Icing conditions are defined as follows :

▶ Atmospheric icing conditions

Atmospheric icing conditions exist when OAT on ground and for take-off is at o below 5°C or when TAT in flight is at or below 7°C and visible moisture in the ai in any form is present (such as clouds, fog with visibility of one mile or less, rain,
R snow sleet and ice crystals).

▶ Ground icing conditions

Ground icing conditions exist when the OAT is at or below 5°C when operating on ramps, taxiways and runways where surface snow, standing water or slush is present.

▶ Regulatory requirements

Certification requirements defined in JAR/FAR 25 appendix C consider droplet sizes up to 50 microns in diameter. No aircraft is certified for flight in conditions with droplets larger than this diameter.

However, dedicated flight tests have linked unique ice accretion patterns to conditions of droplet sizes up to 400 microns. Procedures have been defined in case of inadvertent encounter of severe icing.

▶ Organization of this subchapter

It will address the following areas :

- Operations within the certified envelope.
- Information about severe icing beyond the certified envelope.
- Good operating practices.

II – OPERATIONS WITHIN THE CERTIFIED ICING ENVELOPE

PREAMBLE

Icing conditions should never be assessed with complacency. Although the aircraft is adequately protected for most of the encountered cases, any severe icing exposure should be minimized by a correct evaluation and proper avoiding actions.

A) GENERAL

Operations in atmospheric icing conditions require SPECIAL ATTENTION since ice accretion on airframe and propellers SIGNIFICANTLY modifies their aerodynamic characteristics.

The primarily considerations are as follows :

a – Even small quantities of ice accretions, which may be difficult to detect visually, may be sufficient to affect the aerodynamic efficiency of an airfoil. For this reason, ALL ANTI ICING PROCEDURES and SPEED LIMITATIONS MUST BE COMPLIED WITH as soon as and as long as ICING CONDITIONS are met and even before ice accretion actually takes place.

b – Main effects of ice accretion on airfoils are :

- Maximum achievable LIFT is reduced.
- For a given angle of attack, LESS LIFT and MORE DRAG are generated.
  In order to maintain a SAFE MARGIN AGAINST STALL, which will occur at a higher speed when ice accretion spoils the airfoil :
  - the stall warning threshold must be reset to a lower value of angle of attack,
  - the stick pusher activation threshold is lowered accordingly.

These lowered thresholds are effective when switching horns anti icing ON and illuminating the ICING AOA green caption.

> THE LOWER AOA OF STALL WARNING THRESHOLD AND THE LOWER STICK PUSHER ACTIVATION THRESHOLD DEFINED FOR ICING REMAIN ACTIVE AS LONG AS THE « ICING AOA » CAPTION IS ILLUMINATED.

- Accordingly, the minimum maneuver / operating speeds defined for normal (no icing) conditions (see FCOM 2.02.01) MUST BE INCREASED.
  These new minimum speeds are called « MINIMUM ICING SPEEDS ». They are defined further in paragraph B.

III - SEVERE ICING

A) GENERAL

Severe icing may result from environmental conditions outside of those for which the airplane is certificated. Flight in freezing rain, freezing drizzle or mixed icing conditions (supercooled liquid water and ice crystals) may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or may result in ice forming aft of the protected surfaces. All the ice not shed by using the ice protection systems may seriously degrade the performance and controllability of the airplane.

B) CONDITIONS OF FORMATION

The airplane is certificated for a range of droplet diameter, a range of icing temperature and a range of water content in the icing cloud.
If one or more of these main parameters is exceeded, the flight is performed outside the certification frame.
Three phenomena may lead to surpass the ice protection capabilities :

1) Mechanical phenomenon : droplet diameter

The droplet diameter may be up to 3 to 30 times greater than the upper limit of the certification envelope in freezing drizzle/freezing rain conditions. The inertia of droplets is such that the ice may cover all the frontal surface of airfoil exposed to the cloud, outside of the protected areas.
Depending on the angle of attack of the airfoil, a ridge may form mainly on the upper side of the airfoil (e.g. flaps 15) or a granular pattern may accrete on the lower surface of the airfoil up to 50 % of the chord (e.g. flaps 0).
Freezing rain and freezing drizzle conditions are found typically at low altitudes with a static air temperature around – 4°C (3000 ft) and associated with temperature inversion.
However, freezing drizzle conditions may be found at higher altitudes (up to 15000 ft) with a static air temperature down to – 18°C. They may be the consequence of the turbulence effect which leads to a coalescence process of small droplets into large droplets. It may be encountered on top of stratiform clouds.

2) Thermal phenomenon : skin temperature and/or liquid water content

When the flight in icing conditions is such that the total air temperature is above 0°C with a static air temperature close to 0°C, droplets cannot freeze on the leading edge because the skin temperature is positive, they roll along the chord till they encounter a surface at a negative temperature. The leading edge is free of ice but a ridge or rivelets may be formed aft of the protected areas. The rivelets are oriented in the airstream direction. They accrete on the lower and upper surfaces.
This phenomenon may occur also with colder temperatures but when a large amount of water is present in the cloud. The structure of the leading edge is not cold enough to freeze the whole water amount and the remaining droplets freeze with delay behind protected parts.

3) **Mixed icing condition**

Mixed icing condition may be encountered in the range of temperatures −10°C/0°C. It is basically an unstable condition, it is extremely temperature dependent and it may change quite rapidly. This condition may surpass the ice protection capabilities because the aggregate of impinging ice crystal/snow and water droplet can adhere rapidly to the airframe surpassing the system capabilities to shed ice, causing significant reduction in airplane performance as in case of system failure.

C) CONSEQUENCES OF SEVERE ICE ACCRETION

The consequences of severe ice accretions are ice location dependent.

If the pollution extension occurs on the lower surface of the wing, it increases the drag and the airplane speed decreases. It may lead to stall if no action is taken to recover a correct speed.

If the pollution occurs first on the upper part of the wing, the drag is not affected noticeably but controllability anomalies may be encountered.

Severe roll anomalies may be encountered with "flaps 15" accretions flown with flaps 0 setting. It should be emphasized that it is not the flaps 15 configuration itself that is detrimental, but the low angle of attack that may result from such a setting, especially close to VFE. This low or negative AOA increases the wing upper side exposure to large droplet impingement. This is why holding with any flaps extended is prohibited in icing conditions (except for single engine operations).

R

.../...

AA

R **D) DETECTION**

- During flight, severe icing conditions that exceed those for which the airplane
R is certificated shall be determined by the following :

Severe icing is characterized by ice covering all or a substantial part of the unheated portion of either forward side window, possibly associated with water splashing and streaming on the windshield.

Note : This cue is visible after a very short exposure (about 30 seconds). At night, this pattern is put forward by the pilot's reading lights oriented towards the side window.

R and / or

R Unexpected decrease in speed or rate of climb

R and / or

R The following secondary indications :
. Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.
. Accumulation of ice on the lower surface of the wing aft of the protected areas.
. Accumulation of ice on the propeller spinner farther aft than normally observed.

- The following weather conditions may be conducive to severe in–flight icing :
R . Visible rain at temperatures close to 0°C ambient air temperature (SAT).
. Droplets that splash or splatter on impact at temperature close to 0°C ambient air temperature (SAT).

- The occurence of rain when SAT is below freezing temperature should always trigger the alertness of the crew.

R EXIT THE SEVERE ICING ENVIRONMENT

There are no regulatory requirements to certify an aircraft beyond JAR/FAR 25 Appendix C. However, in case of inadvertent encounter with such conditions "severe icing" procedure must be applied (refer to 2.04.05).

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IV – GOOD OPERATING PRACTICES

Aircraft certification requirements describe the icing conditions likely to be encountered in commercial aviation. However, as demonstrated by experience, icing remains one of the major causes of incidents and accidents, and good airmanship prohibit any complacency in this area.

The following basic rules should therefore be applied :

▶ Know as much about your operating environment as you can.
Carefully review weather packages for Pilot reports of icing conditions, tops reports, temperatures aloft forecasts and forecasts of icing, freezing drizzle and freezing rain. Monitor both Total Air Temperature and Static Air Temperature during climb and while en route. Use the weather radar. Areas of precipitation which will paint on the radar will be of sufficient droplet size to produce freezing rain when encountered in freezing temperatures or on a cold soaked aircraft.

▶ Marginal freezing temperatures and icing conditions should create a heightened state of awareness. Remember, severe ice can still be incurred at temperatures down to approximately – 18° C, at high altitude.

R ▶ Be alert to severe icing cues defined pages 12/13.

R ▶ When severe icing is encountered, take appropriate steps to leave the conditions. Since these unique conditions are usually small in area and associated with very specific temperatures conditions, a change in altitude of just a couple thousand feet may place you in a totally different environment.

▶ Make reports to ATC and Company.
There is no better operational tool available today than first hand reports of these conditions. Remember that because these are localized areas and extremely temperature dependent, another aircraft passing through the same area at a different airspeed may experience different conditions. For example, a laboratory test showed for a specific, yet normal condition, rime ice up to about 150 kt, mixed ice as speed was increased to about 200 kt, glaze ice between 200 and 360 kt, and no accretion above 360 kt.

<u>Note</u> : *Reporting of icing conditions as defined in the FAA's Airman's information Manual (AIM) :*

Trace *: Ice becomes perceptible. Rate of accumulation is slightly greater than the rate of sublimation. It is not hazardous even though de–icing/anti–icing equipment is not utilized unless encountered for an extended period of time (over 1 hour).*

Light *: The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour). Occasional use of de–icing/anti–icing equipment removes/prevents accumulation. It does not present a problem if the de–icing/anti–icing equipement is used.*

Moderate *: The rate of accumulation is such that even short encounters become potentially hazardous and use of de–icing/anti–icing equipment or flight diversion is necessary.*

Severe *: The rate of accumulation is such that de–icing/anti–icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary.*

GENERAL

The emergency procedures have been established for application in the event of a serious failure. They are applied according to the « READ AND DO » principle except for memory items.

R

PRESENTATION

The procedures are presented in the basic checklist format with an adjacent expanded part which provides :
- indication of the particular failure (alert condition)
- explanation for actions where the reason is not self evident
- additional background information.

The abbreviation used are identical to the nomenclature on the cockpit panels. All actions are printed in capital letters.

Memory items are BOXED for identification.

If actions depend on a precondition, a preceding black square ■ is used to identify the precondition.

A preceding black dot • is used to indicate the moment when actions have to be applied.

TASK SHARING

For all procedures the general task sharing stated below is applicable.
The pilot flying remains pilot flying throughout the emergency procedure.

PF – Pilot flying	Responsible for : . PL . Flight path and airspeed control . Aircraft configuration . Navigation
PNF – Pilot non flying	Responsible for : . Check list reading . Execution of required actions . Actions on OVHD panel . CL . Communications

The AFCS is always coupled to the PF side (CPL selection).

SEVERE ICING

This procedure is applicable to all flight phases from initial climb to landing.
Monitor the ambient air temperature (SAT).
While severe icing may form at temperatures as cold as - 18°C, increased vigilance is warranted at temperatures around freezing with visible moisture present.

DETECTION

Visual cue identified. with severe icing is characterized by ice covering all or a substantial part of the unheated portion of either forward side window, possibly associated with water splashing and streaming on the windshield.

and / or

Unexpected decrease in speed or rate of climb

and / or

The following secondary indications :

. Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.
. Accumulation of ice on the lower surface of the wing aft of the protected areas.
. Accumulation of ice on the propeller spinner farther aft than normally observed.

- The following weather conditions may be conducive to severe in-flight icing :
  . Visible rain at temperatures close to 0°C ambient air temperature (SAT).
  . Droplets that splash or splatter on impact at temperature close to 0°C ambient air temperature (SAT).

PROCEDURE

SEVERE ICING

■ **If severe icing as determined above is encountered accomplish the following :**

- Immediately increase and bug the minimum maneuver/operating icing speeds by 10 kt. Increase power, up to MAX CONT if needed
- Request priority handling from Air Traffic Control to facilitate a route or an altitude change to exit the severe icing conditions.
- Avoid abrupt and excessive maneuvering that may exacerbate control difficulties.
- Do not engage the autopilot.

■ **If the autopilot is engaged,** hold the control wheel firmly and disengage the autopilot.

■ **If the flaps are extended,** do not retract them until the airframe is clear of ice.

■ **If an unusual roll response or uncommanded roll control movement is observed,** maintain the roll controls at the desired position and reduce the angle of attack by :

- Pushing on the wheel as needed,
- Extending flaps to 15,
- Increasing power, up to MAX CONT if needed.

■ **If the aircraft is not clear of ice :**

- Maintain flaps 15, for approach and landing, with "reduced flaps APP/LDG icing speed "+ 5 kt.
- R Multiply landing distance flaps 30 by 1.91

- Report these weather conditions to Air Traffic Control.

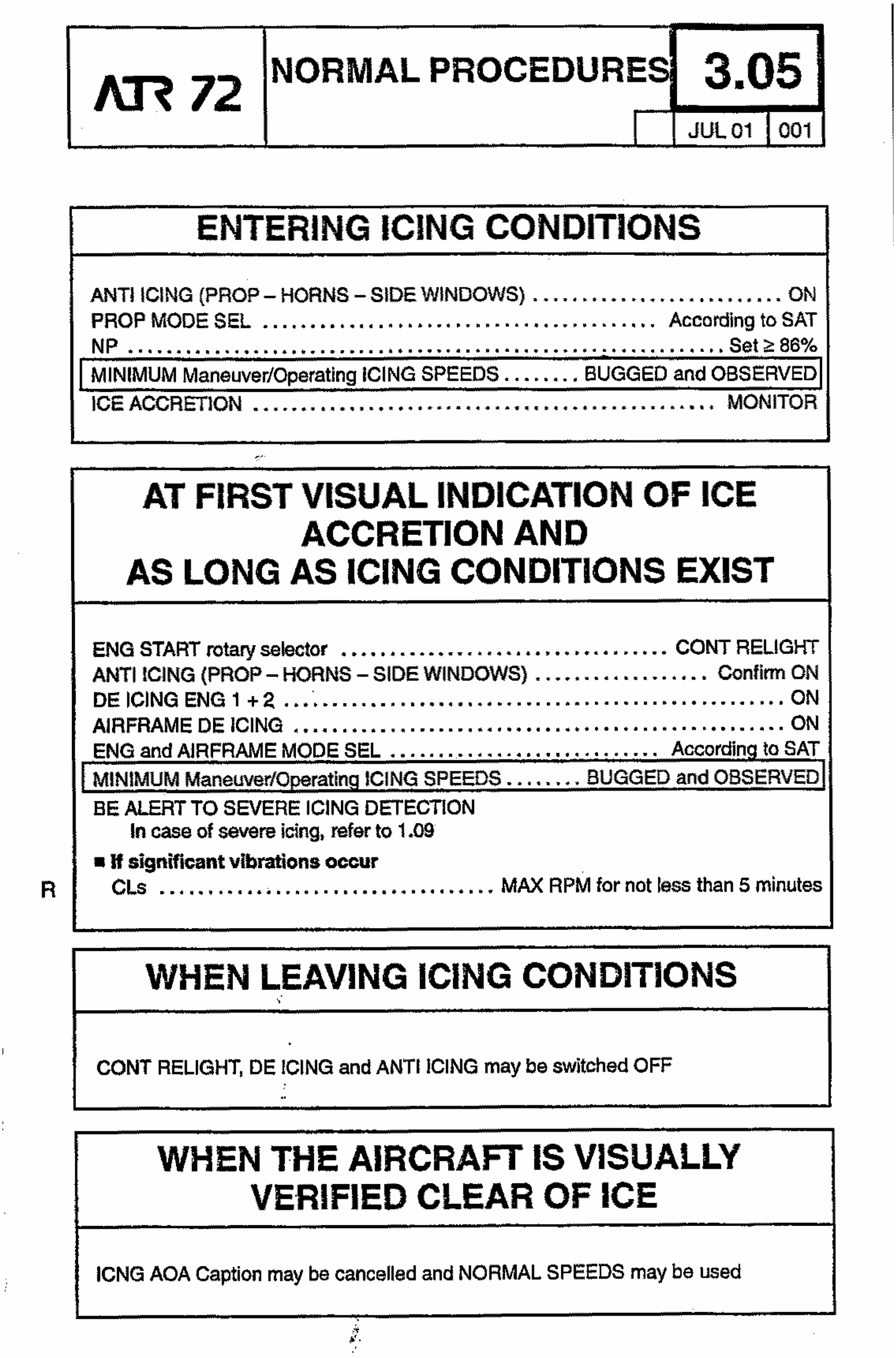
COMMENTS

- Since the autopilot may mask tactile cues that indicate adverse changes in handling characteristics, use of the autopilot is prohibited when the severe icing defined above exists, or when unusual lateral trim requirements or autopilot trim warnings are encountered while the airplane is in icing conditions.

- Due to the limited volume of atmosphere where icing conditions usually exists, it is possible to exit those conditions either :

  . by climbing 2000 or 3000 ft, or
  . if terrain clearance allows, by descending into a layer of air temperature above freezing, or
  . by changing course based on information provided by ATC.

Quick Reference Hand Book



ATR 72 | **NORMAL PROCEDURES** | **3.05**

JUL 01 | 001

ENTERING ICING CONDITIONS

ANTI ICING (PROP – HORNS – SIDE WINDOWS) .... ON
PROP MODE SEL .... According to SAT
NP .... Set ≥ 86%
MINIMUM Maneuver/Operating ICING SPEEDS .... BUGGED and OBSERVED
ICE ACCRETION .... MONITOR

AT FIRST VISUAL INDICATION OF ICE ACCRETION AND AS LONG AS ICING CONDITIONS EXIST

ENG START rotary selector .... CONT RELIGHT
ANTI ICING (PROP – HORNS – SIDE WINDOWS) .... Confirm ON
DE ICING ENG 1 + 2 .... ON
AIRFRAME DE ICING .... ON
ENG and AIRFRAME MODE SEL .... According to SAT
MINIMUM Maneuver/Operating ICING SPEEDS .... BUGGED and OBSERVED
BE ALERT TO SEVERE ICING DETECTION
In case of severe icing, refer to 1.09

■ **If significant vibrations occur**

R CLs .... MAX RPM for not less than 5 minutes

WHEN LEAVING ICING CONDITIONS

CONT RELIGHT, DE ICING and ANTI ICING may be switched OFF

WHEN THE AIRCRAFT IS VISUALLY VERIFIED CLEAR OF ICE

ICNG AOA Caption may be cancelled and NORMAL SPEEDS may be used

SEVERE ICING

This procedure is applicable to all flight phases from initial climb to landing.
Monitor the ambient air temperature (SAT).
While severe icing may form at temperatures as cold as –18°C, increased vigilance is warranted at temperatures around freezing with visible moisture present.

DETECTION

Visual cue identified with severe icing is characterized by ice covering all or a substantial part of the unheated portion of either side window, possibly associated with water splashing and streaming on the windshield.

and / or

Unexpected decrease in speed or rate of climb.

and / or

The following secondary indications :

- .Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.
- .Accumulation of ice on the lower surface of the wing aft of the protected areas.
- .Accumulation of ice on the propeller spinner farther aft than normally observed.

The following weather conditions may be conducive to severe in–flight icing :

- .Visible rain at temperatures close to 0°C ambient air temperature (SAT).
- .Droplets that splash or splatter on impact at temperature close to 0°C ambient air temperature (SAT).

PROCEDURE

■ **If severe icing as determined above is encountered, accomplish the following :**
- –Immediately increase and bug the minimum maneuver/operating icing speeds by 10 kt. Increase power up to MAX CONT if needed.
- –Request priority handling from Air Traffic Control to facilitate a route or an altitude change to exit the severe icing conditions.
- –Avoid abrupt and excessive maneuvering that may exacerbate control difficulties.
- –Do not engage the autopilot.

■ **If the autopilot is engaged, hold the control wheel firmly and disengage the autopilot.**

■ **If the flaps are extended, do not retract them until the airframe is clear of ice.**

■ **If an unusual roll response or uncommanded roll control movement is observed, maintain the roll controls at the desired position and reduce the angle of attack by :**
- –Pushing on the wheel as needed,
- –Extending flaps to 15,
- –Increasing power, up to MAX CONT if needed.

■ **If the aircraft is not clear of ice :**
- –Maintain flaps 15 for approach and landing with “reduced flaps APP/ LDG icing speed” + 5 kt.
- R –Multiply landing distance flaps 30 by 1.91

–Report these weather conditions to Air Traffic Control.

Appendix 20 ATR 72-200：TRANSASIA AIRWAYS MSN 322 – Accident Analysis

An Alenia Aeronautica and EADS joint venture

ATR

DEPARTEMENT : DO/TF
SECTION : 557
GO : DO/TF

PROGRAMME : ATR42/72
OU AFFAIRE :
DATE : 02/06/2003

REFERENCE : DO/TF-2524/03
EDITION : 01
PROJET :
REF. PROJET :
O.F. :
ATA : - -
CLIENT :

TOME :

REV :

TITRE : **ATR 72-200 : TRANSASIA AIRWAYS MSN 322 – Accident analysis**

AUTEUR(S) : [redacted]

RESUME :

The purpose of this note is to analyze the flight GE 791 dated December 21st 2002 of the ATR 72-200, MSN 322 operated by TRANSASIA Airways. The aircraft was performing a cargo flight between Taipei and Macao when, in cruise and in recognized icing condition, significant speed decay was experienced. Finally, the aircraft crashed into the sea near PENG HU islands.

This note addresses performance issues and in particular aircraft speed behavior up to autopilot disconnection by analyzing and comparing data from:

- Flight GE 791 DFDR read out
- Flight GE 791 CVR transcription
- Simulations

The DFDR and CVR analyses supported by simulation show that the MSN 322 encountered severe icing conditions, ice accretion resulted in an increase of drag with subsequent speed decay. The crew, which observed the ice building up and the loss of speed, established later a relationship between the ice effects on aircraft performances and the speed decay.

The non-compliance by the crew of the icing speeds led the aircraft to attitudes, where on wings polluted by severe ice, aerodynamic anomalies appear.

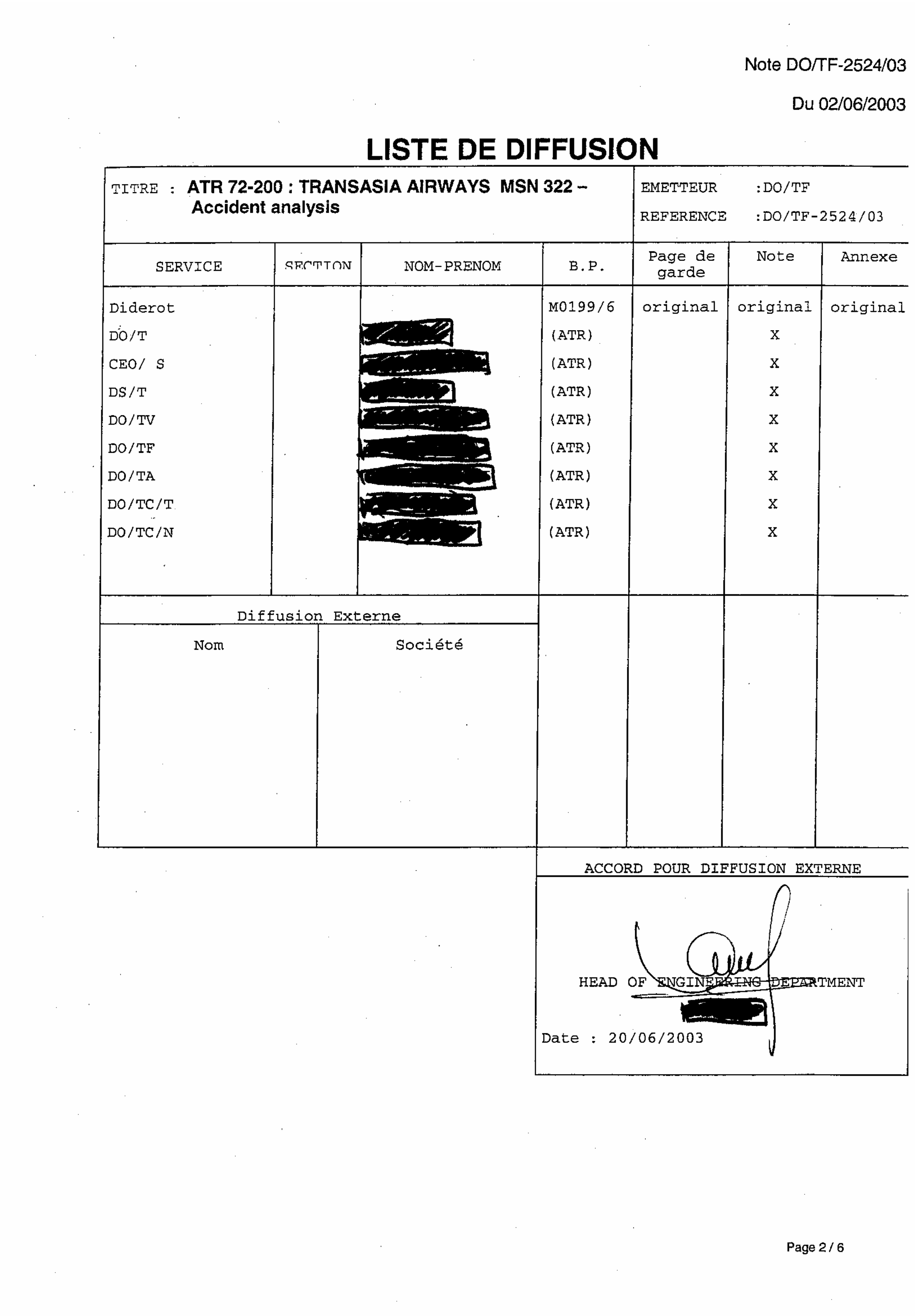
The aircraft behavior from few seconds before autopilot disconnection up to the loss of control by the crew is matter of different note.

MOTS CLES :

LIENS :

NATURE : NT	LANGUE : A	ANNULE REMPLACE : N	PAGES A ARCHIVER : 32

DOCUMENT EXTERNE	APPROBATION TECHNIQUE	APPROBATION CVE
EMETTEUR : EDITION : REF. : DATE :	Nom : [redacted] Sigle : DO/TF Date : 02/06/2003 Visa :	Nom : Sigle : Date : Visa :



Note DO/TF-2524/03

Du 02/06/2003

LISTE DE DIFFUSION

TITRE : **ATR 72-200 : TRANSASIA AIRWAYS MSN 322 – Accident analysis**	EMETTEUR :DO/TF REFERENCE :DO/TF-2524/03

SERVICE	SECTION	NOM-PRENOM	B.P.	Page de garde	Note	Annexe
Diderot			M0199/6	original	original	original
DO/T		[redacted]	(ATR)		X	
CEO/ S		[redacted]	(ATR)		X	
DS/T		[redacted]	(ATR)		X	
DO/TV		[redacted]	(ATR)		X	
DO/TF		[redacted]	(ATR)		X	
DO/TA		[redacted]	(ATR)		X	
DO/TC/T		[redacted]	(ATR)		X	
DO/TC/N		[redacted]	(ATR)		X	

Diffusion Externe

Nom	Société

ACCORD POUR DIFFUSION EXTERNE

HEAD OF ENGINEERING DEPARTMENT

[redacted]

Date : 20/06/2003

Note DO/TF-2524/03

Du 02/06/2003

1. Purpose:

The purpose of this note is to analyze the flight GE 791 dated December 21st 2002 of the ATR 72-200, MSN 322 operated by TRANSASIA Airways. The aircraft was performing a cargo flight between Taipei and Macao when, in cruise and in recognized icing condition, significant speed decay was experienced. Finally, the aircraft crashed into the sea near PENG HU islands.

This note addresses performance issues and in particular aircraft speed behavior up to autopilot disconnection by analyzing and comparing data from:

- Flight GE 791 DFDR read out
- Flight GE 791 CVR transcription
- Simulations

The aircraft behavior from few seconds before autopilot disconnection up to the loss of control by the crew is matter of different note.

2. Factual analysis:

a) General

- Aircraft

Type	ATR 72-202
Serial number	MSN 322
Registration	B-22708
Airline	Transasia airways
Airline flight number	GE 791

- Airport:

From:	Taipee
To:	Macao

- Take off Conditions

Weight	21219 Kg
Previous trip fuel	1556 Kg
CG	28%

b) DFDR observations:

- During take-off, acceleration and climb flight phases there is no agreement between Makung radar time and DFDR GMT time. Consequently in those phases the DFDR events will be described without time indication.

- The DFDR Sheets presented in annex show no abnormal events until the flight level (180) selected by the crew is reached. The crew performed climb with autopilot engaged in IAS mode (160 Kt) and climb power (Np:86%, PLA in the notch).

  Note: Above the level 110 the static temperature crossed under 0° and before reaching the level 180 the vertical load factor activities shows moderate turbulence, indicating clouds encounter.

c) DFDR read out:

- Flight level 180 (Capture):
  - ➢ 17h 24mn 57s (see Figure 1)

    Altitude capture is activated and IAS mode is deactivated

    Altitude 17948Ft, IAS 159 Kt, TS -12°

- Flight level 180 (acceleration):
  - ➢ 17h 24mn 57s to 17h 32mn 38s (see Figure 1)

    After the capture of the selected altitude (18000Ft) the aircraft accelerated to 202 Kt which is the target speed of the aircraft, according to QRH Manual at ISA + 10 and an estimate weight of 20800 Kg.

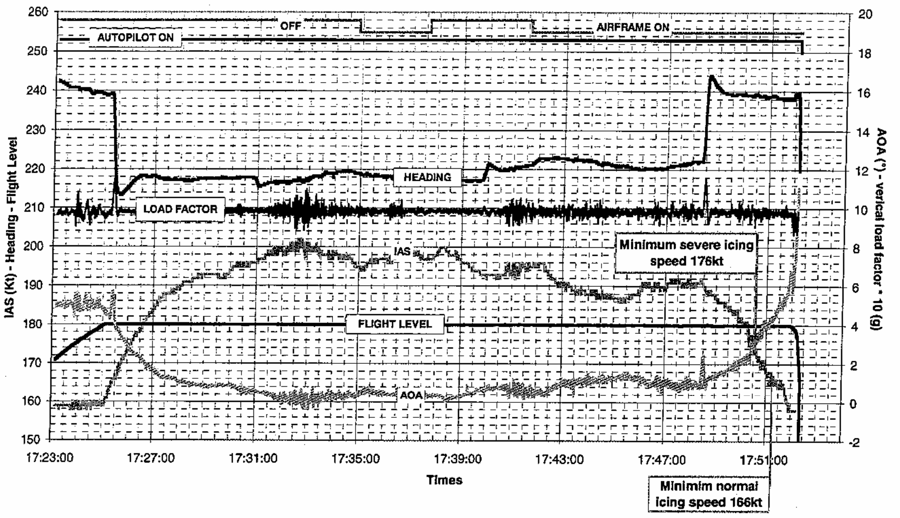
    The following table gives QRH information at Level 180 and ISA + 10

QRH Information	Weight 20000Kg	Weight 21000Kg
RPM (%)	86	86
Torque (%)	73,2	73
IAS target (Kt)	204	202
Minimum icing speed (kt)	164	168

Note: At this time there is no ice accretion appreciable effect on the speed. The vertical load factor activities show that the aircraft encountered moderate turbulence, indicating clouds presence.

- Flight level 180: Speed decay (see figure 1)

Figure: 1



- 17h 32mn 38s to 17h 35mn 05s

The aircraft decelerated to 194Kt (-8kt) due to ice accretion (see vertical load factor activities). This deceleration has been stopped by the crew intervention to select level 3 of de-icing system (Airframe ON from 17h 34mn 52s to 17h 37mn 38)

- 17h 35mn 05s to 17h 38mn 08s

The aircraft increased speed up to 200Kt. The expected nominal speed was not completely recovered because the airframe de-icing system was selected off.

- 17h 38mn 08s to 17h 48mn 24s

  With airframe de-icing system OFF the aircraft decelerated again to 192Kt. The crew reactivated the airframe only when the load factor activities appeared (17h 41mn 36s) but the speed continued to decrease up to 186Kt. After that the aircraft did not increase speed above 190Kt until an heading change initiated by the crew (17h 48mn 24s)

- 17h 48mn 24s to 17h 52mn 11s

  Remind: with an aircraft weight estimated at 20600Kg, the minimum icing speeds are:

  - *normal icing 166Kt,*
  - *severe icing 176 Kt.*

  At the beginning of this time sequence the crew performed an heading change using high bank and increased the angle of attack (from 1° to 2.4) and consequently the drag. This drag increase caused a further speed reduction and:

  - At 17h 50mn 20s the severe icing speed was reached.
  - At 17h 51mn 20s the normal icing speed was reached
  - At 17h 51mn 55s the mode altitude hold was deselected and the mode vertical speed was activated. The aircraft speed was 159Ktat that time.
  - At 17h 52mn 10.5s the auto pilot disconnected
  - At 17h 52mn 11s the lowest speed reached was 157Kt

d) CVR transcription:

- **Audio alarms: (See figure 2)**

  Few seconds before the selection by the crew of the de-icing system (Airframe ON) the CVR recorded three single chimes, which appear to be the signal of ice detector.

- **Crew's conversation: (See figure 2)**

Note: Only the crew's conversation concerning icing events is reported on figure 2 and figure 3

The CVR transcription confirms that a single chime is the signal of ice detector because the first officer says just after the first single chime " Oh it's icing up". After both chime signals, crew action selected airframe de-icing system ON

Figure: 2

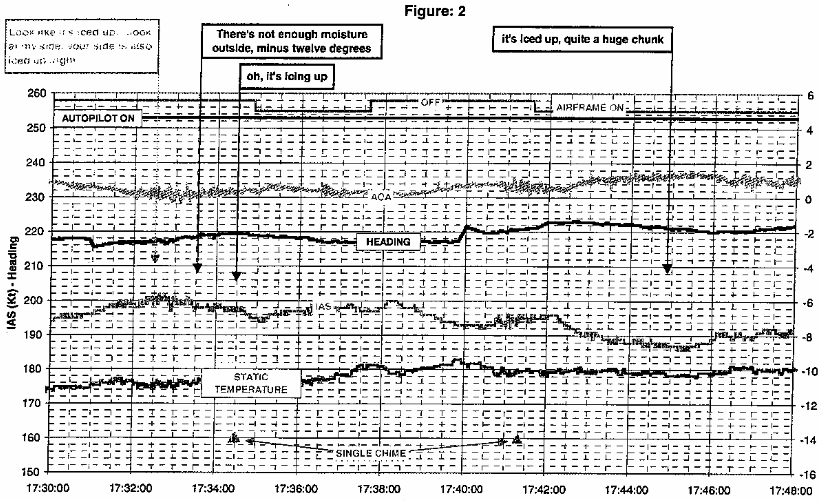
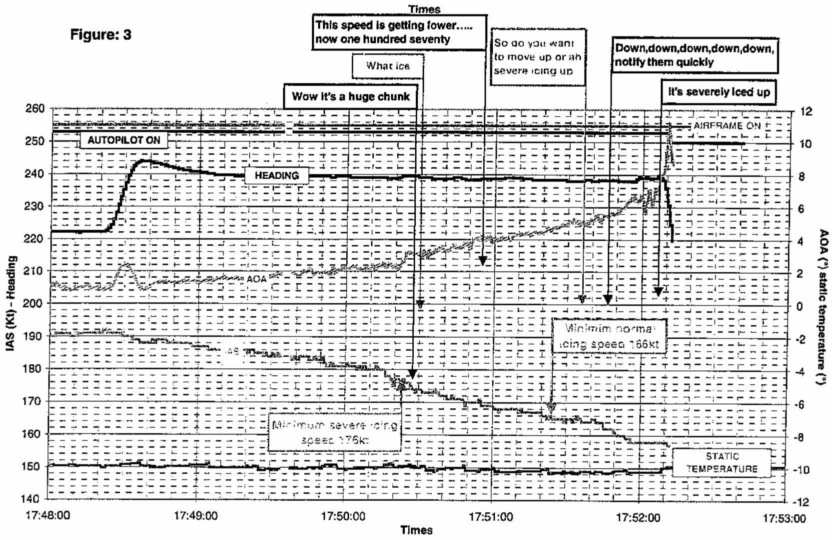


Figure: 3



The following table gives in addition of the limited crew's conversation reported on the figure 3 the total CVR information concerning the icing events.

UTC Time	Crew	Translation
17:50:28	Captain	Wow it's a huge chunk
17:50:30	First officer	What ice
17:50:54	Captain	The speed is getting lower it was one hundred two hundred, one hundred and ninety now one hundred seventy
17:50:54	Captain	Is it possible our pilot-static tube going to get blocked, get stuck
17:51:17	First officer	Ah what
17:51:17	Captain	Is pilot-static tube going to be
17:51:19	Captain	Going to get blocked, then autopilotwould trip
17:51:24	Captain	Must fly using conventional strument flight
17:51:24	First officer	Go higher
17:51:29	Captain	Go lower, no use going higher
17:51:34	First officer	As long as no more moisture, because we have moisture now
17:51:34	First officer	So do you want to move up or ah severe icing up
17:51:40	Captain	Yeah move down
17:51:41	First officer	Move down
17:51:42	Captain	Move down yes
17:51:43	First officer	But we may receive no transmission when we move down, up or down
17:51:46	Captain	Down down down down down, notify them quickly
17:51:47	First officer	How long
17:51:48	Captain	Sixteen thousand
17:52:01	Captain	Do you see that
17:52:07	Captain	It's severely iced up
17:52:09	First officer	Sir

The CVR analysis shows that:

- The crew visually recognized the ice building up phenomenon and the loss of speed but they did not establish a relationship between the ice effects on aircraft performances and the speed decay.
- The captain recognized later the severe icing conditions calling for a decrease of altitude.
- The first officer did not understood that the aircraft have to go lower in altitude.
- The crew never mentioned "Icing speed maintain" prescription.

Simulation analysis:

The aim of simulation is to reproduce DFDR parameters in order to provide adequate elements for a better understanding of the speed decay during cruise.

- Performances analysis:

  The performance analysis is obtained through a comparison between actual DFDR parameters and simulation results computed with the clean aerodynamic model.

  - 17h 23mn 09s to 17h 24mn 59s

    Clean model (See chart 1)

    This chart shows that during the end of climb the aircraft is not nominal in terms of performances. The rate of climb given by the model is about 625ft/mnn compared to 425ft/mn in flight.

    Clean model + Drag due to ice (See chart 2)

    The chart 2 gives the delta Drag (DELTA CX) added to the clean model to match the rate of climb of the flight. The maximum delta drag obtained is about 100 drag counts.

- 17h 25mn 15s to 17h 31mn 45s

  Clean model (See chart 3)

  During the aircraft acceleration to level flight 180 the chart 3 shows a loss of speed in flight (about 10kt)

  Clean model + Drag due to ice (See chart 4)

  This chart gives the delta drag necessary to match correctly the recorded flight speed.

  Note: For the next flight periods simulations, except the last one, only charts with delta drag are provided;

- 17h 32mn 55s to 17h 33mn 55s

  Clean model + Drag due to ice (See chart 5)

- 17h 37mn 25s to 17h 38mn 25s

  Clean model + Drag due to ice (See chart 6)

- 17h 38mn 34s to 17h 39mn 34s

  Clean model + Drag due to ice (See chart 7)

- 17h 41mn 04s to 17h 42mn 04s

  Clean model + Drag due to ice (See chart 8)

- 17h 42mn 19s to 17h 43mn 19s

  Clean model + Drag due to ice (See chart 9)

- 17h 44mn 53s to 17h 45mn 43s

  Clean model + Drag due to ice (See chart 10)

- 17h 45mn 38s to 17h 46mn 38s

  Clean model + Drag due to ice (See chart 11)

- 17h 47mn 23s to 17h 48mn 23s

Clean model + Drag due to ice (See chart 12)

- 17h 48mn 03s to 17h 48mn 53s

  Clean model + Drag due to ice (See charts 13 and14)

  Those charts show that during the heading change the aircraft behavior is normal despite the important increasing on drag.

- 17h 48mn 03s to 17h 48mn 53s

  Clean model + Drag due to ice (See chart 15)

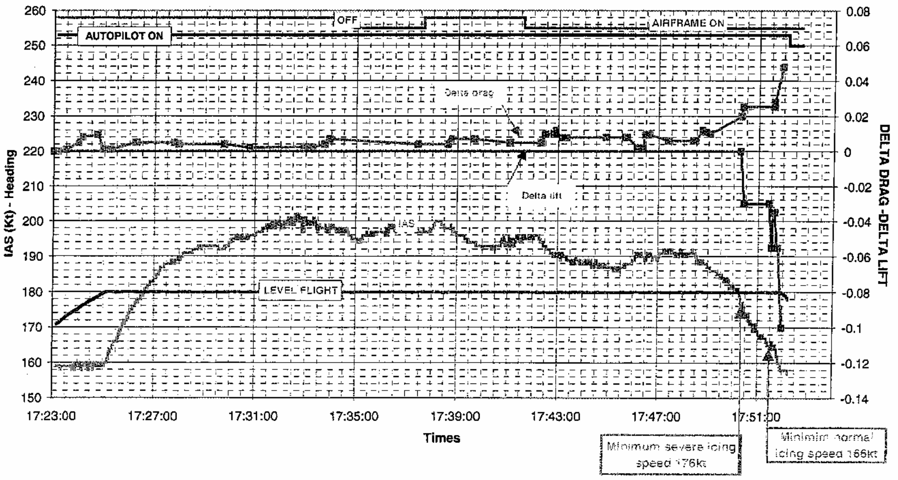
  Clean model + Drag + lift due to ice (See chart 16)

  A loss of lift (DELTA CZ) has been added on the clean model to correctly match the angle of attack.

- The figure 4 gives versus time the delta drag and lift due to ice accretion.

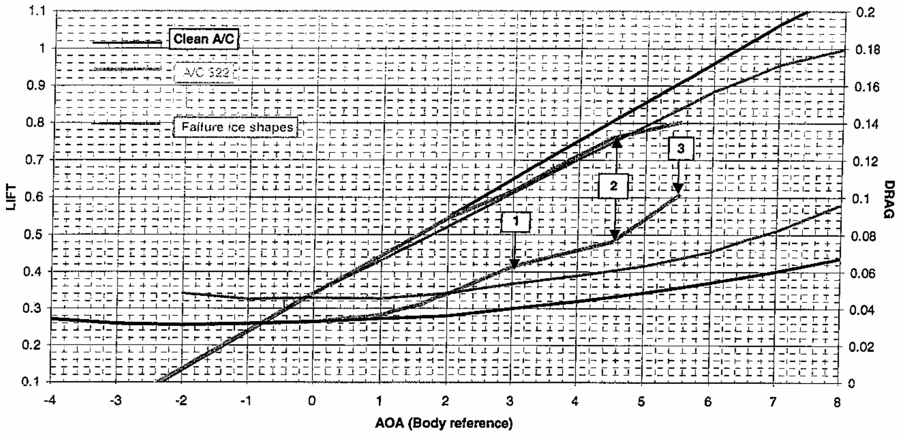
  The figure 4 shows that the aircraft staid exposed to icing conditions during 29mn. During the first 25 minutes the drag increased slowly (within 100 counts) inducing a speed diminishing about 10Kts. After that, the drag increased quickly and the speed dropped to 158 Kts in 4 minutes.

Figure: 4



This Figure 5 shows the drag and lift computed during the 30mn before autopilot disconnection compared to the drag and lift obtained in aircraft certification with and without normal icing.

Figure: 5
Performances comparison



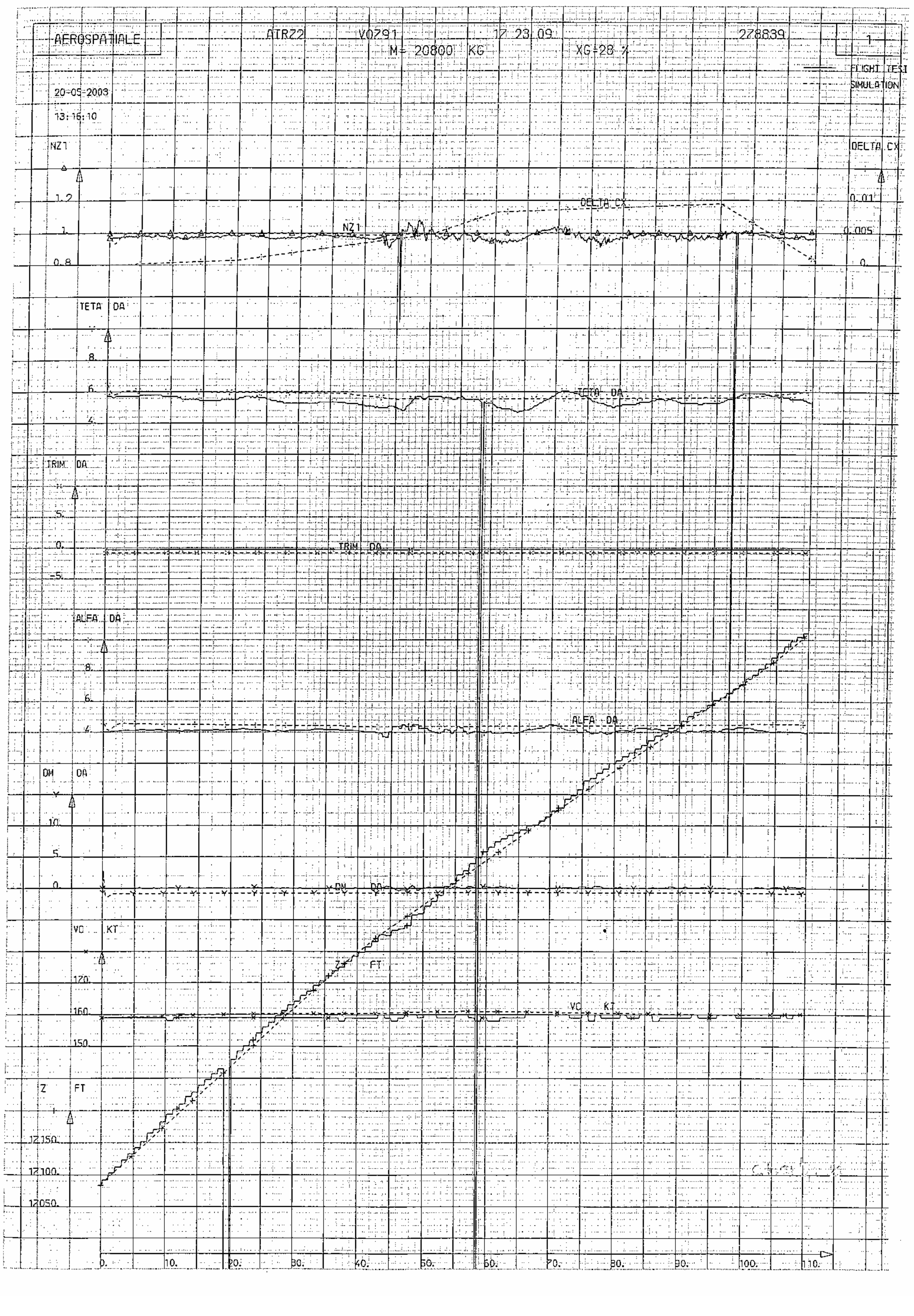
Between points 1 and 2 the aircraft 322 has the lift gradient corresponding to an aircraft polluted with ice shapes due to boots not operating (as per certification requirements Appendix C). At the same time the drag increase is more important (about the double) for the MSN 322. This difference is a sign that the aircraft faced a severe icing exposure whose effects were even bigger than ice shapes corresponding to inoperative boots.

At the point 2, at about 4.5° of angle of attack, the severe ice produces a flow separation on the wing, which induces a loss of lift and a further drag increase.

At the point 3, at about 5.5° of angle of attack and few seconds before the auto-pilot disconnection, the loss of lift and the drag increase indicate that the aircraft is approaching stall conditions with wings polluted by severe ice.

Conclusion:

The DFDR and CVR analyses supported by simulation show that the MSN 322 encountered severe icing conditions, ice accretion resulted in an increase of drag with subsequent speed decay. The crew, which observed the ice building up and the loss of speed, established late a relationship between the ice effects on aircraft performances and the speed decay.


AEROSPATIALE
ATRZ2
V0Z91
17 23 09
278839
1
M= 20800 KG
XG=28 %
FLIGHT TEST
SIMULATION
20-05-2003
13:16:10
NZ1
1.2
1
0.8
DELTA CX
0.01
0.005
0.
TETA DA
8.
6.
4.
TRIM DA
5.
0.
-5.
ALFA DA
8.
6.
4.
DM DA
10.
5.
0.
VC KT
170.
160.
150.
Z FT
12150.
12100.
12050.
0.
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.
110.

ANNEX 1 : SIMULATIONS

1) Parameters:

Z	**Pressure altitude (ft)**
VC	**IAS (Kt)**
DM	**Left elevator (°)**
TRIM	**Pitch trim (°)**
ALFA	**Angle of attack - body reference (°)**
TETA	**Pitch attitude (°)**
NZ1	**vertical load factor (g)**
DELTA CZ	**Delta Lift**
DELTA CX	**Delta Drag**
DN	**Rudder (°)**
DLD	**Right aileron (°)**
PSI	**Heading (°)**
NY	**Lateral load factor (g)**
PHI	**Bank angle(°)**

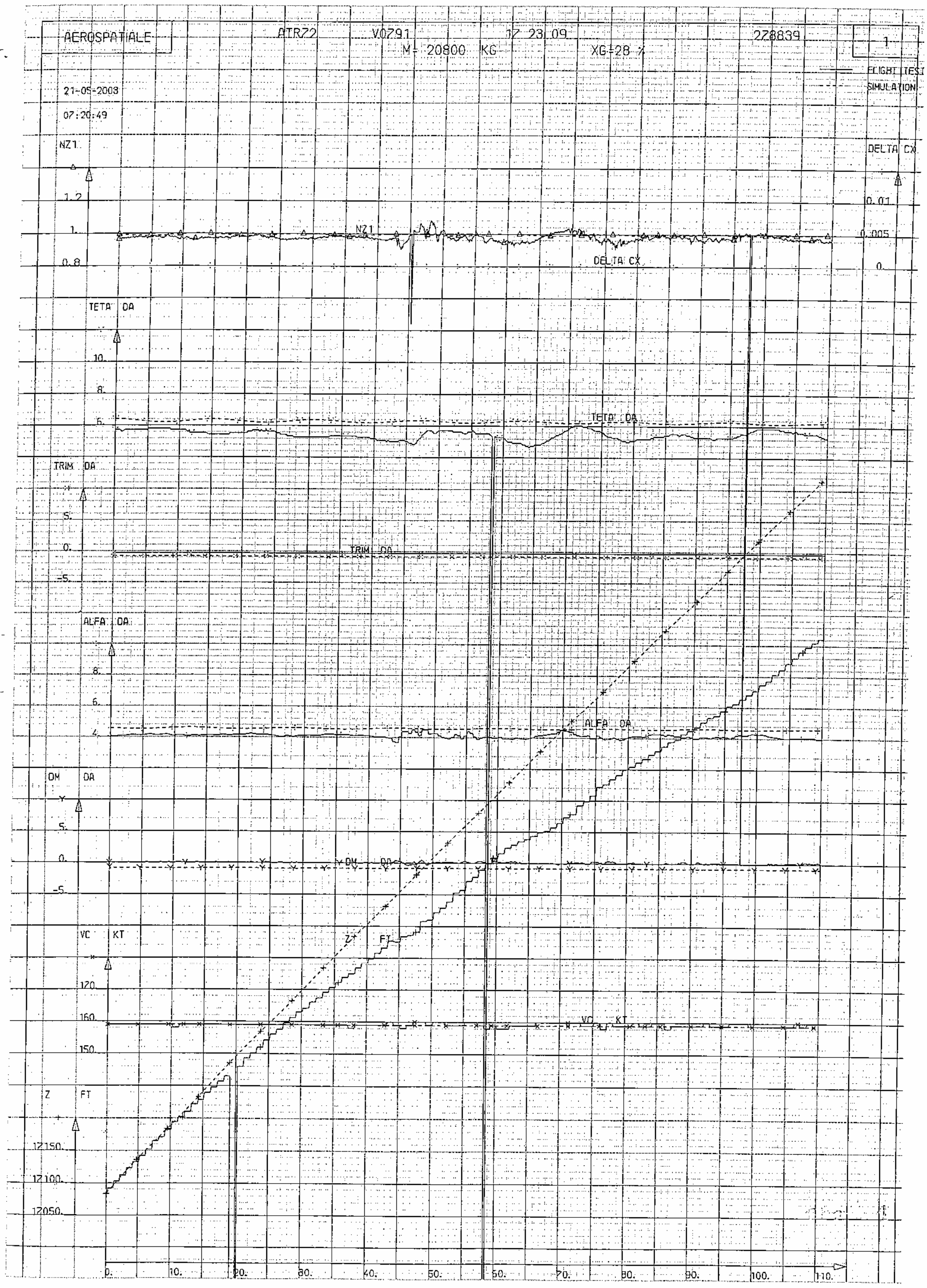
2) Simulations:

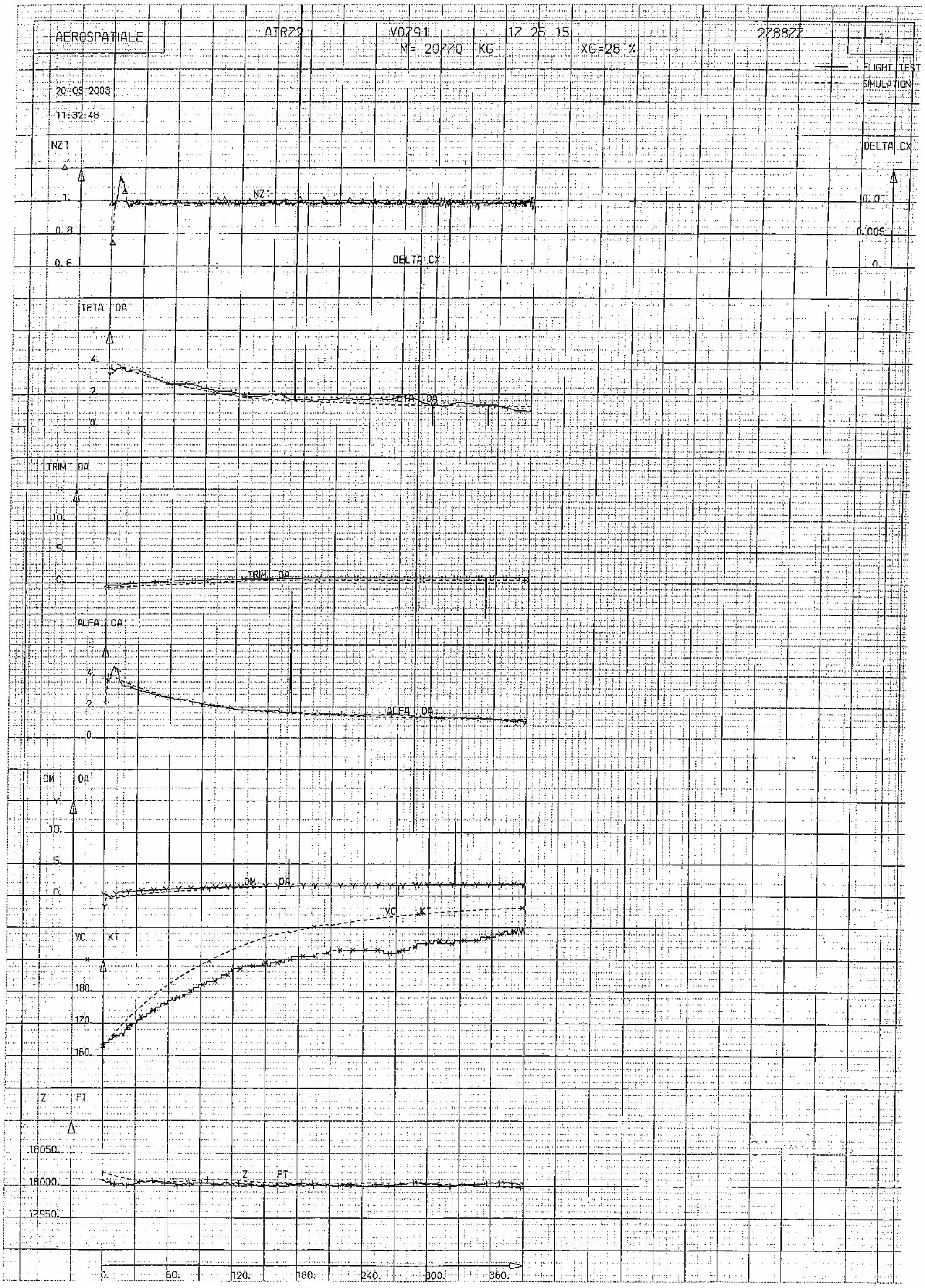
Charts 1 to 15

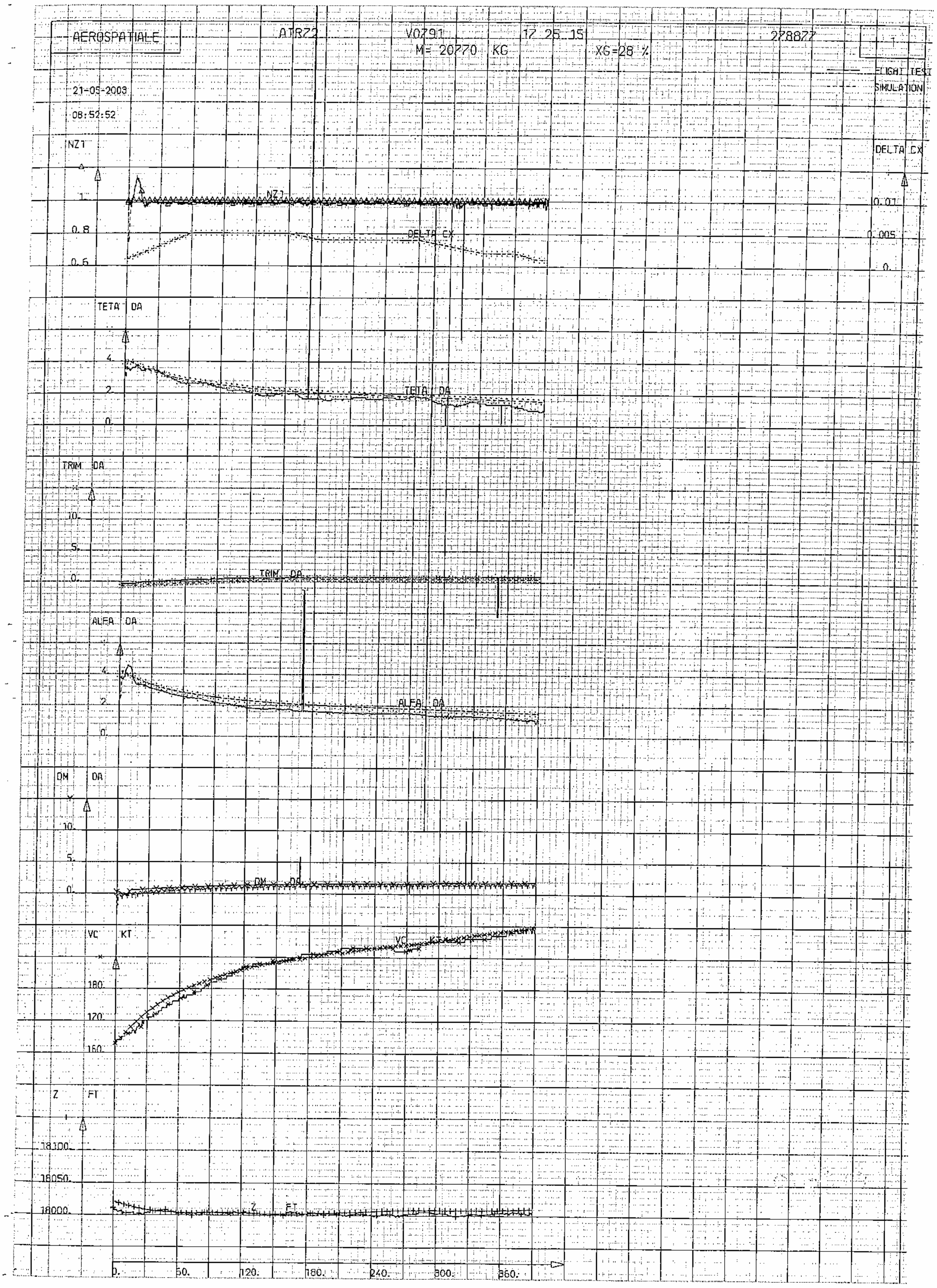
ANNEX 2 : DFDR

DFDR parameters

Figure 1 and 2


AEROSPATIALE
ATR72
V0791
17 23 09
278839
1
M= 20800 KG
XG=28 %
FLIGHT TEST
SIMULATION
21-05-2003
07:20:49
NZ1
1.2
1.
0.8
NZ1
DELTA CX
0.01
0.005
0.
DELTA CX
TETA DA
10.
8.
6.
TETA DA
TRIM DA
5.
0.
-5.
TRIM DA
ALFA DA
8.
6.
4.
ALFA DA
DM DA
5.
0.
-5.
DM DA
VC KT
170
160
150
VC KT
Z FT
17150
17100
17050
Z FT
0.
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.
110.


AEROSPATIALE
ATR72
V0791
M= 20770 KG
17 25 15
XG=28 %
278872
1
FLIGHT TEST
SIMULATION
20-05-2003
11:32:48
NZ1
1.
0.8
0.6
NZ1
DELTA CX
0.01
0.005
0.
DELTA CX
TETA DA
4.
2.
0.
TETA DA
TRIM DA
10.
5.
0.
TRIM DA
ALFA DA
4.
2.
0.
ALFA DA
OM DA
10.
5.
0.
OM DA
VC KT
180.
170.
160.
VC KT
Z FT
18050.
18000.
17950.
Z FT
0.
60.
120.
180.
240.
300.
360.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278872
M= 20770 KG
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1
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0.6
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0.01
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0.
TETA DA
4
2
0
TETA DA
TRIM DA
10.
5.
0.
TRIM DA
ALFA DA
4
2
0
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DM DA
10.
5.
0.
DM DA
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170
160
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18000
Z FT
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120.
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240.
300.
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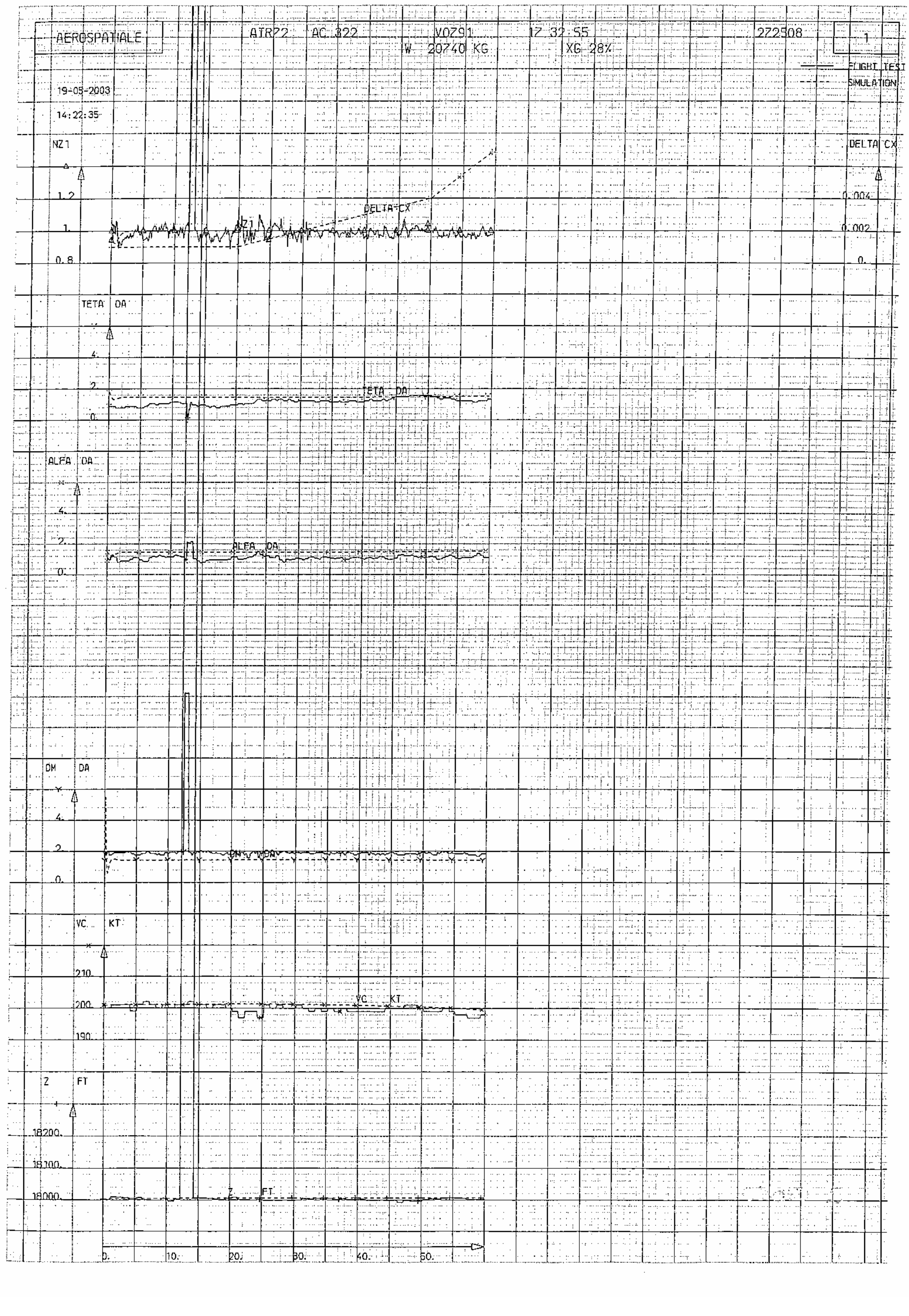
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VOZ91
W 20740 KG
17 32 55
XG 28%
272508
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14:22:35
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1.2
1.
0.8
NZ1
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DELTA CX
0.004
0.002
0.
TETA DA
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TETA DA
ALFA DA
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0.
ALFA DA
DM DA
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2.
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DM DA
VC KT
210.
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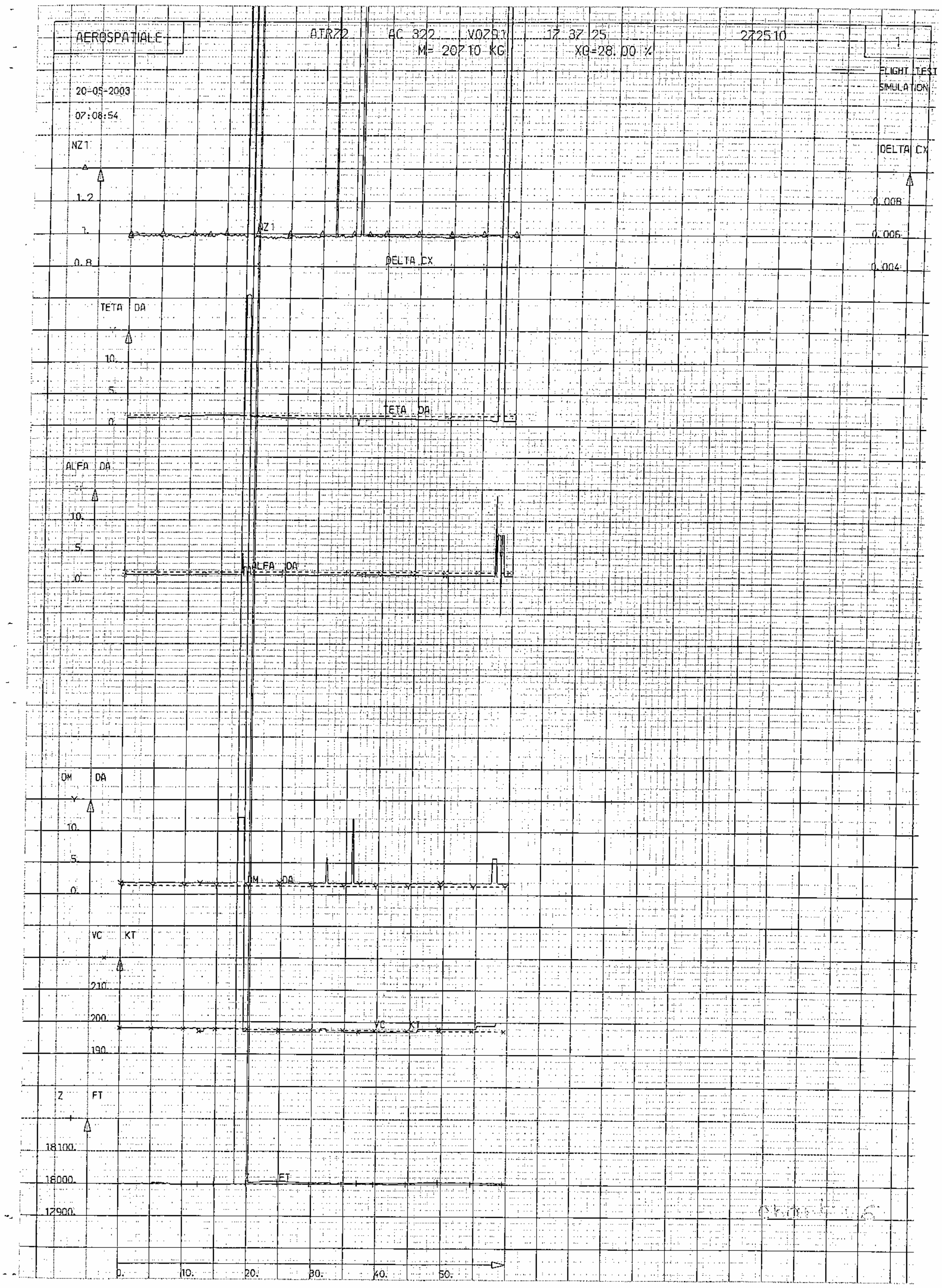
50.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AC 322
V0291
17 37 25
272510
1
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XG=28.00 %
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20-05-2003
07:08:54
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1.2
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0.006
0.004
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TETA DA
ALFA DA
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5.
0.
ALFA DA
DM DA
10.
5.
0.
DM DA
VC KT
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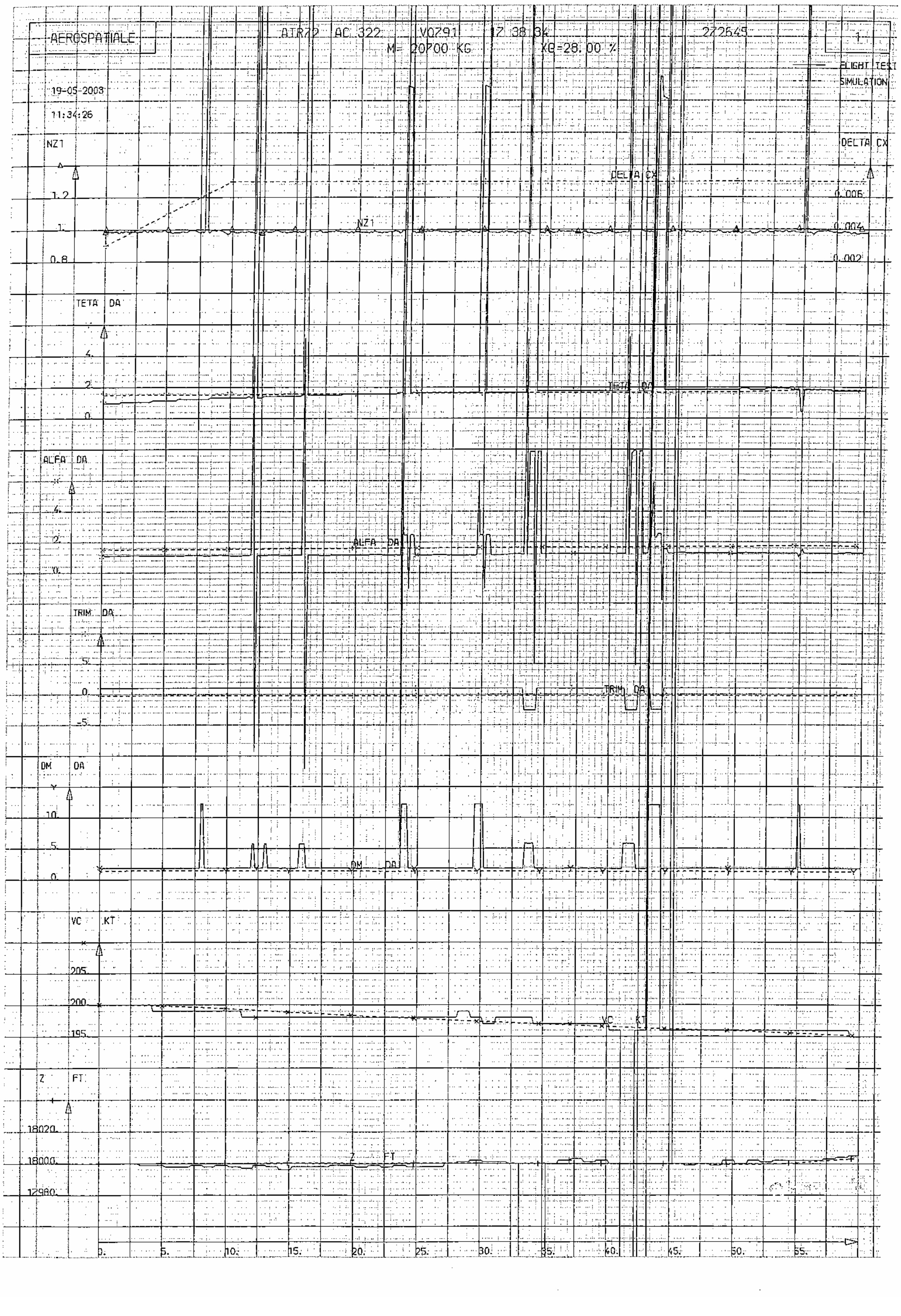
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0.002
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0
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5
0
-5
DM DA
10
5
0
VC KT
205
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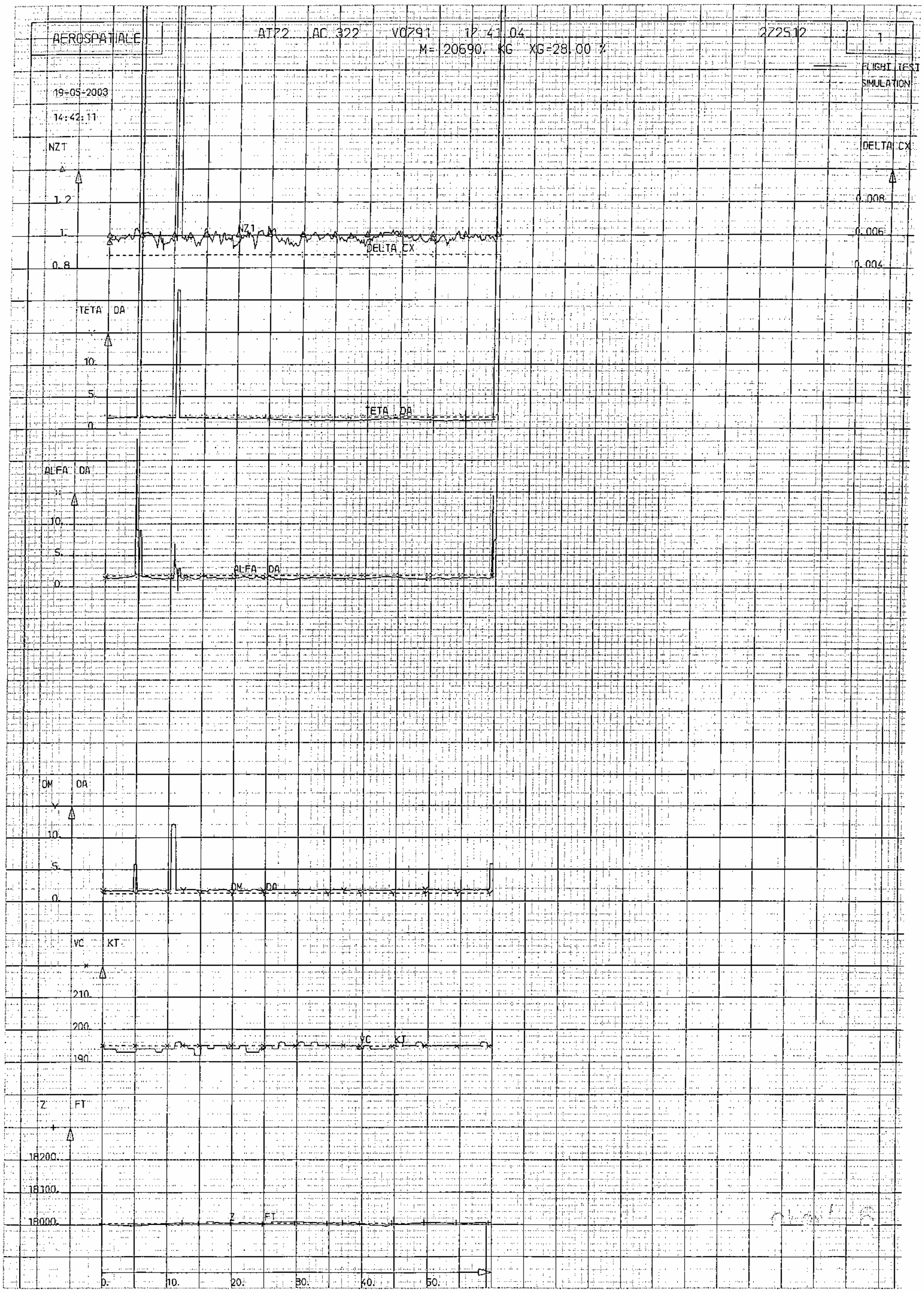
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1.
0.8
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0.006
0.004
TETA DA
10.
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5.
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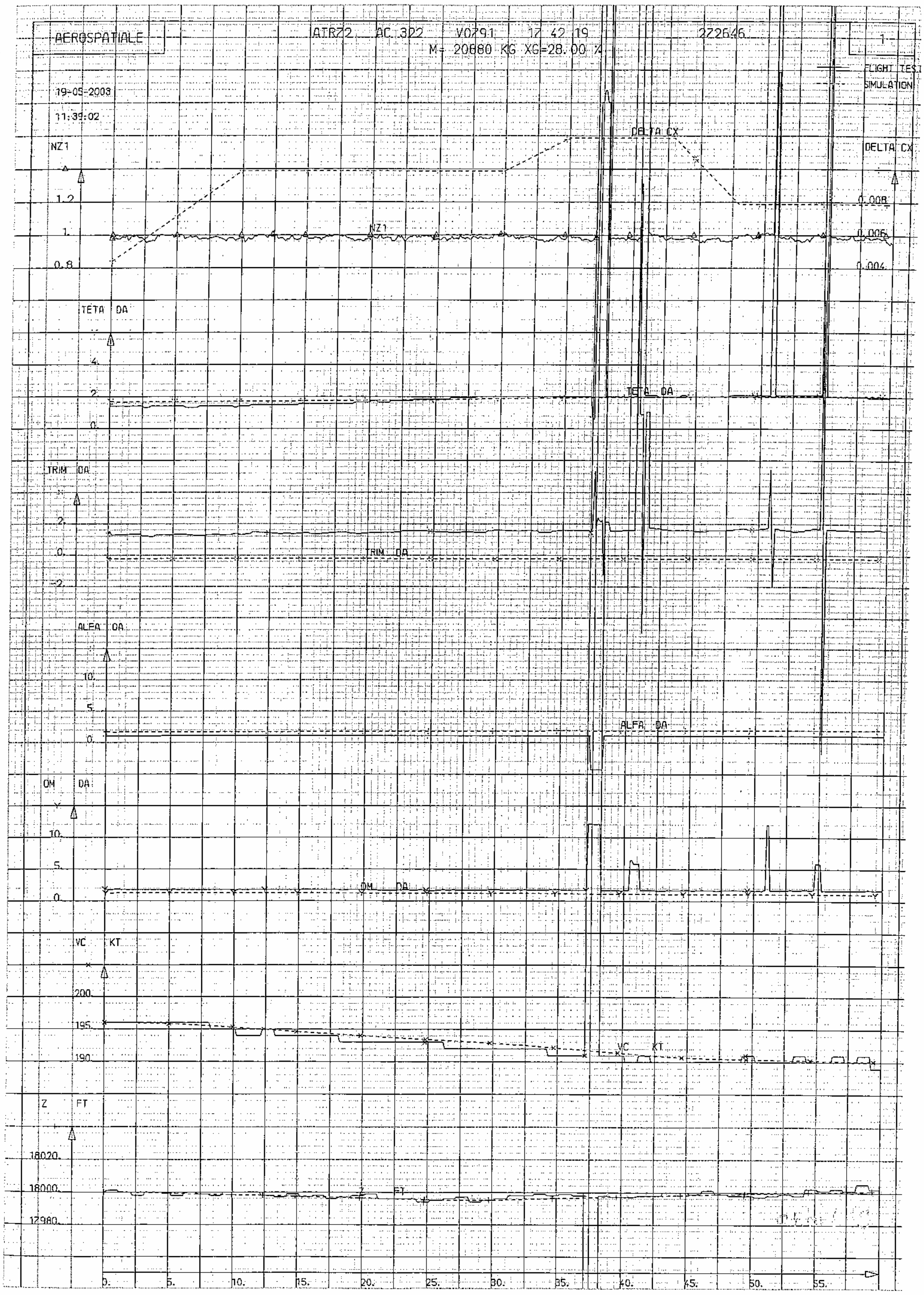
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222646
M= 20880 KG XG=28.00 %
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1.2
1.
0.8
NZ1
DELTA CX
DELTA CX
0.008
0.006
0.004
TETA DA
4.
2.
0.
TETA DA
TRIM DA
2.
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-2.
TRIM DA
ALFA DA
10.
5.
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ALFA DA
OM DA
10.
5.
0.
OM DA
VC KT
200.
195.
190.
VC KT
Z FT
18020.
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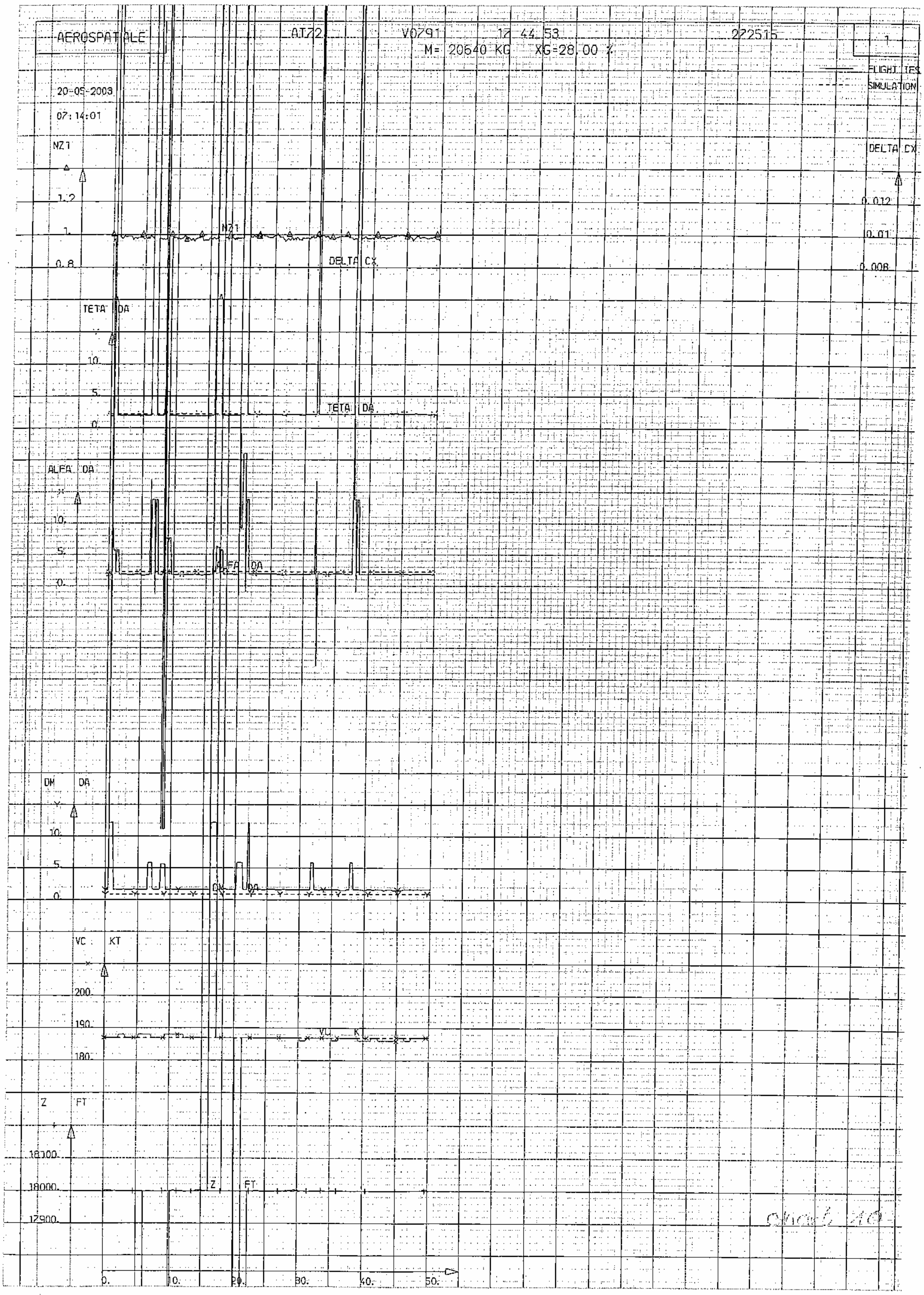
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10.
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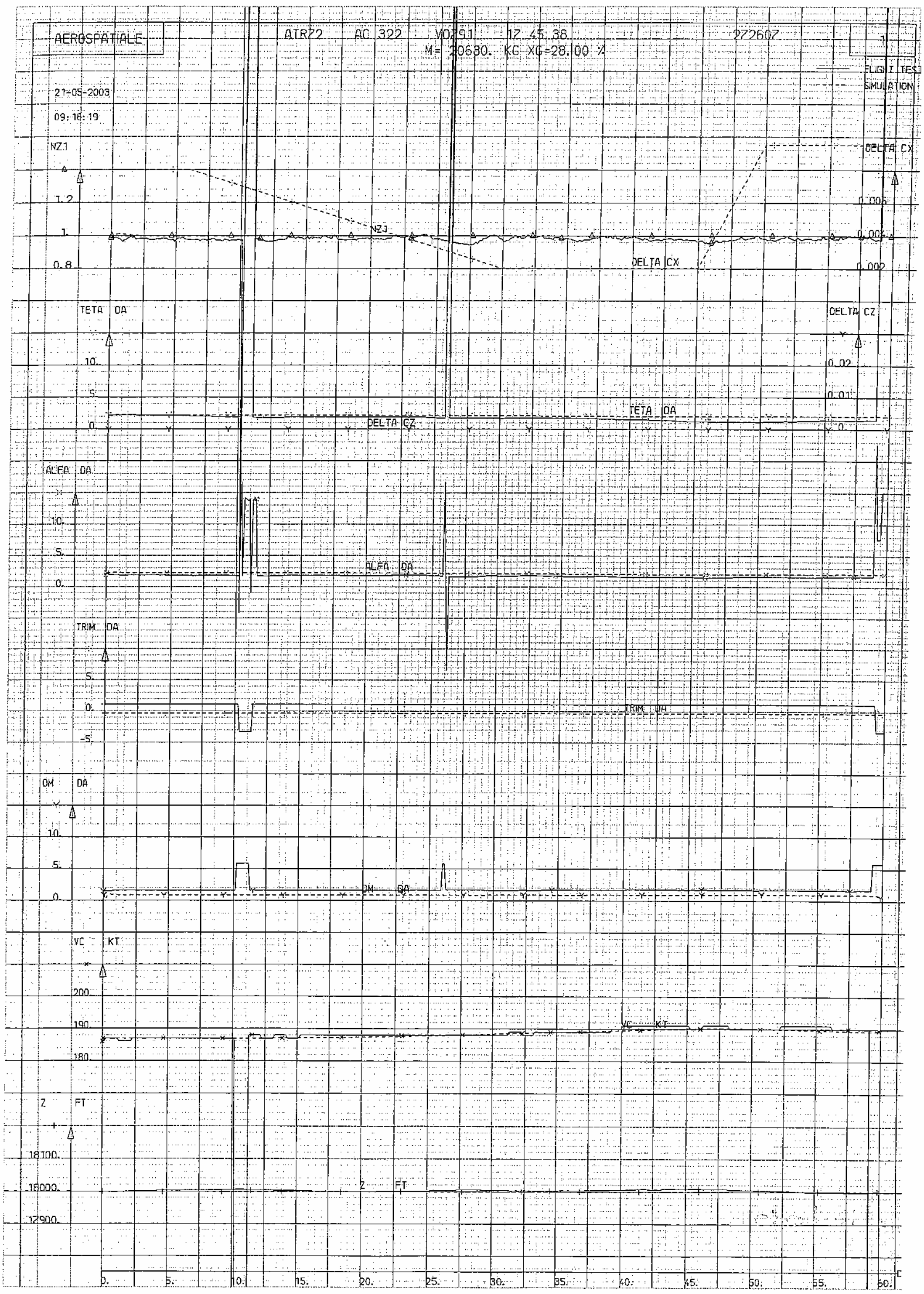
Anexa 10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DELTA CZ
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0.
-5.
TRIM DA
OM DA
10.
5.
0.
OM DA
VC KT
200.
190.
180.
VC KT
Z FT
18100.
18000.
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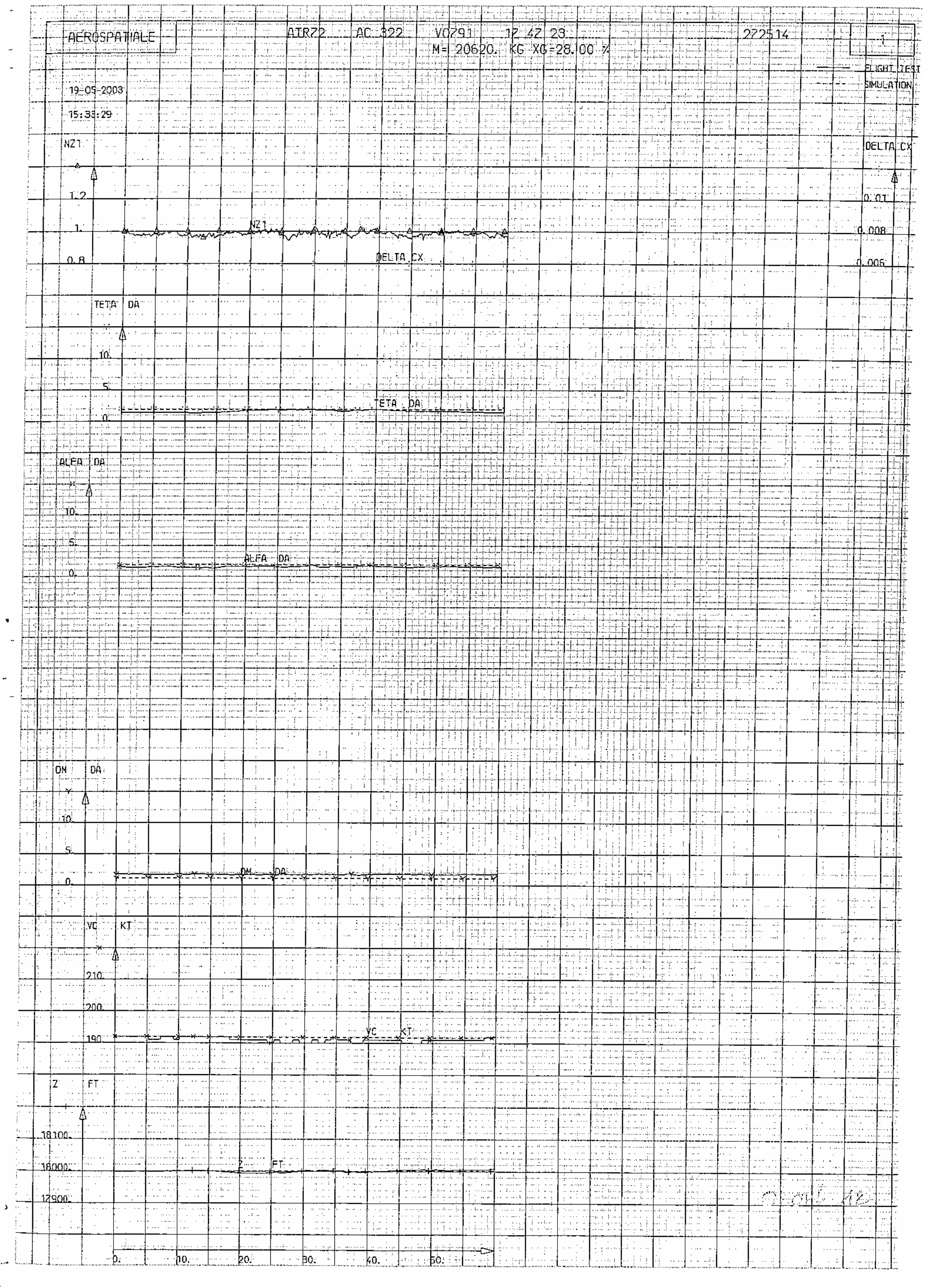
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0.8
DELTA CX
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0.008
0.006
TETA DA
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ALFA DA
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5.
0.
DM DA
10.
5.
0.
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190.
Z FT
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18000.
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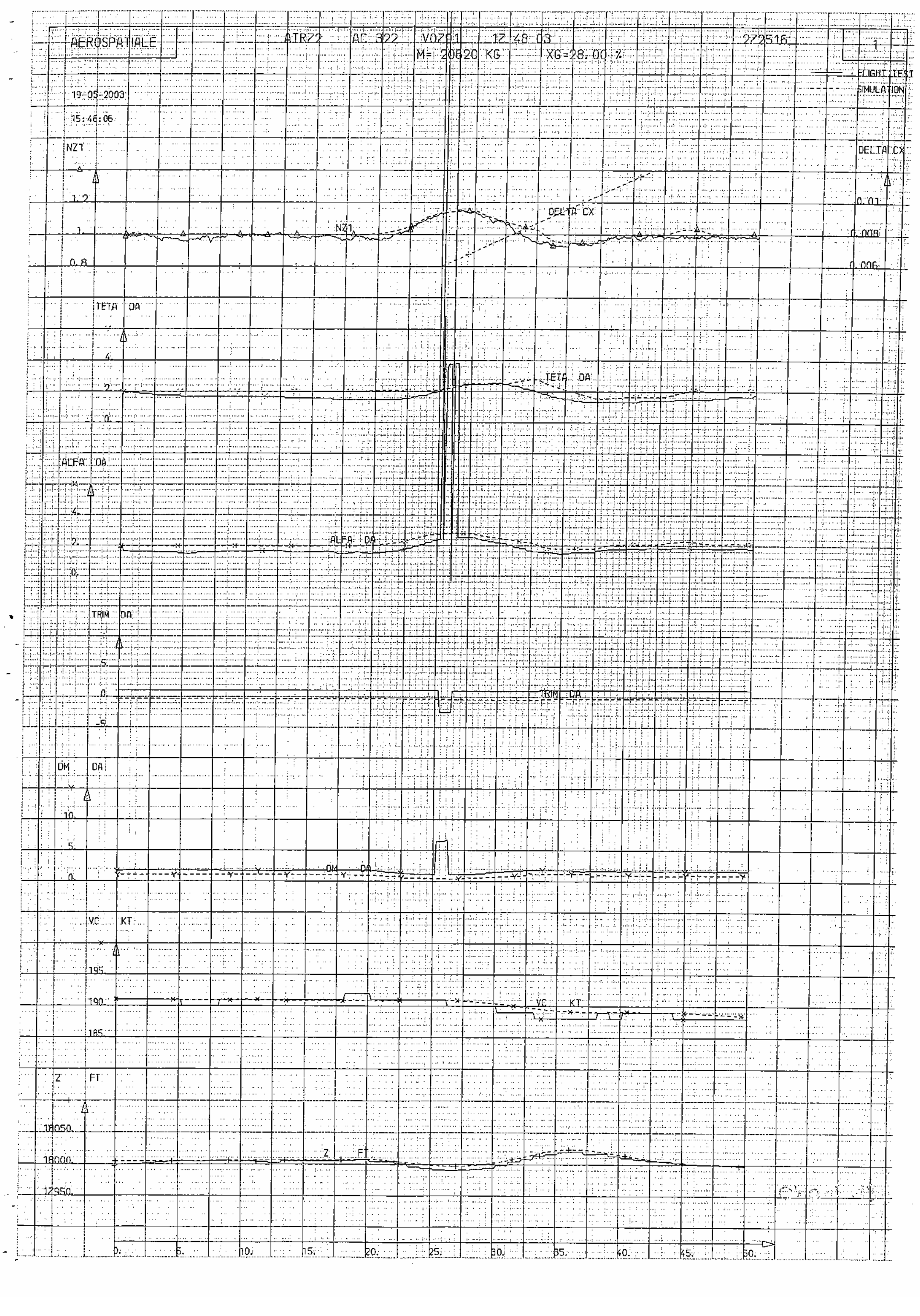
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0.008
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4
2
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ALFA DA
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ALFA DA
TRIM DA
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0
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TRIM DA
DM DA
10
5
0
DM DA
VC KT
195
190
185
VC KT
Z FT
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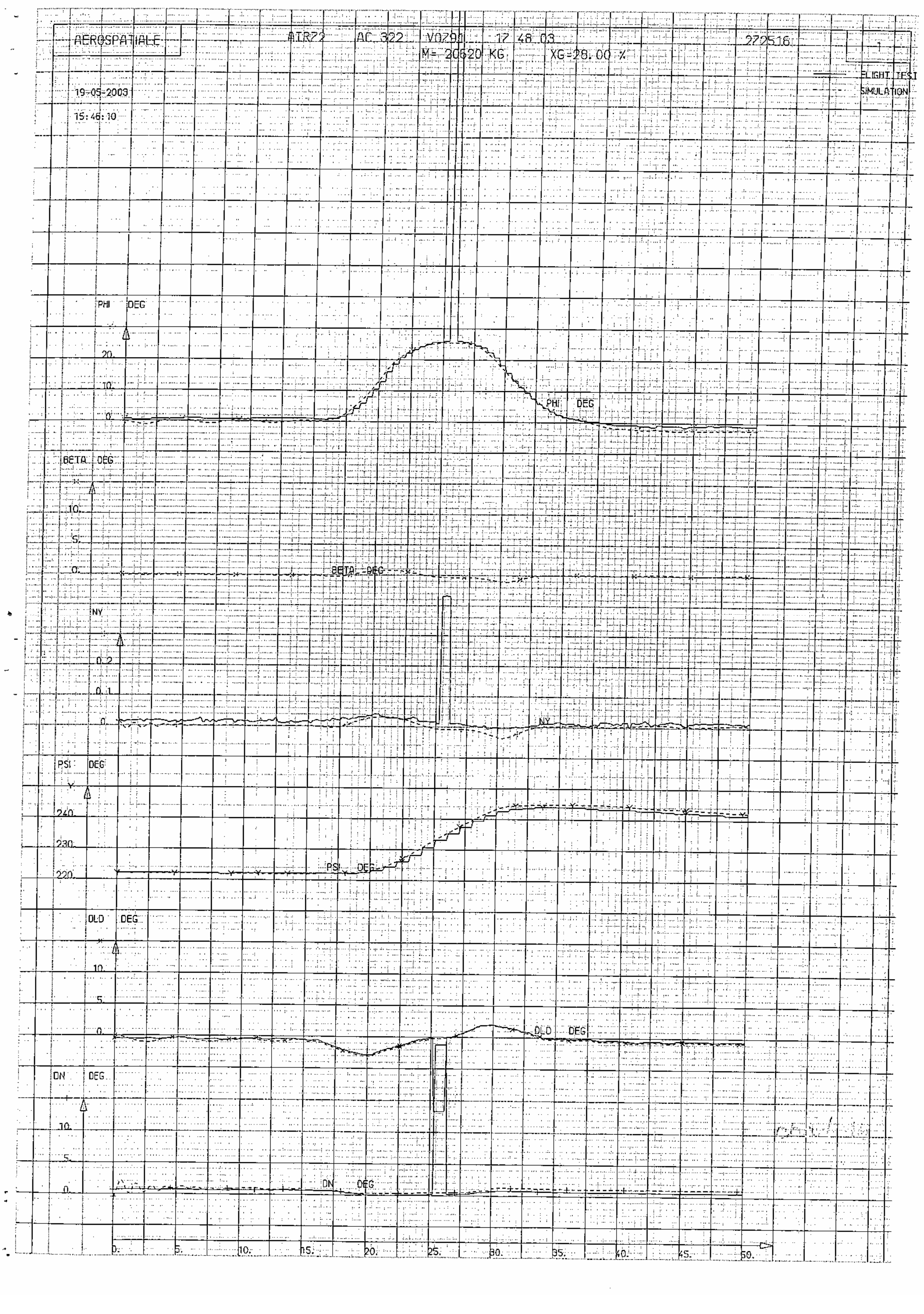
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PHI DEG
20
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BETA DEG
10
5
0
BETA DEG
NY
0.2
0.1
0
NY
PSI DEG
240
230
220
PSI DEG
DLD DEG
10
5
0
DLD DEG
DN DEG
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5
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DN DEG
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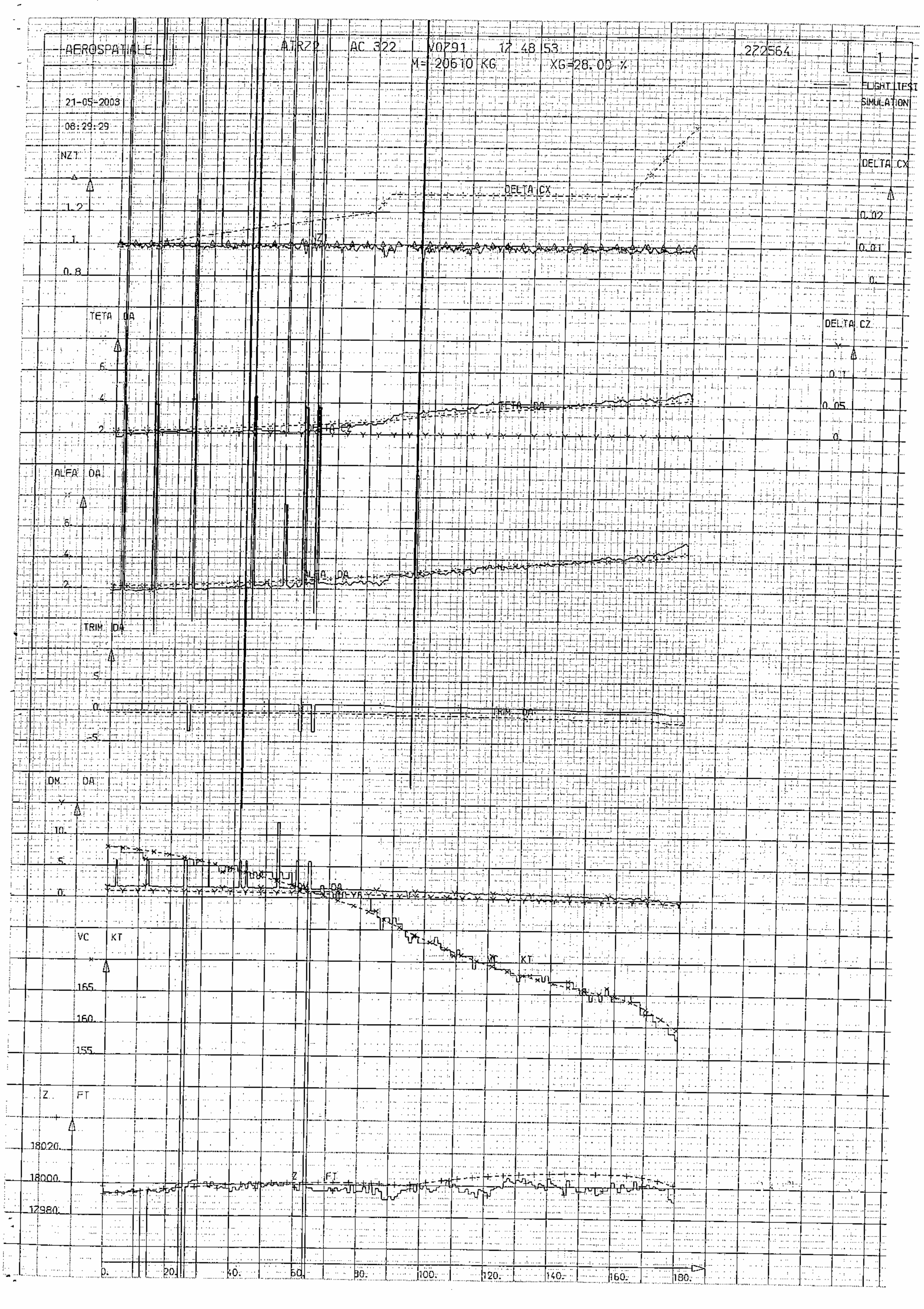
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1.2
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0.8
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0.01
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4.
2.
TETA DA
DELTA CZ
DELTA CZ
0.1
0.05
0.
ALFA DA
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4.
2.
ALFA DA
TRIM DA
5.
0.
-5.
TRIM DA
DM DA
10.
5.
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DM DA
VC KT
165.
160.
155.
KT
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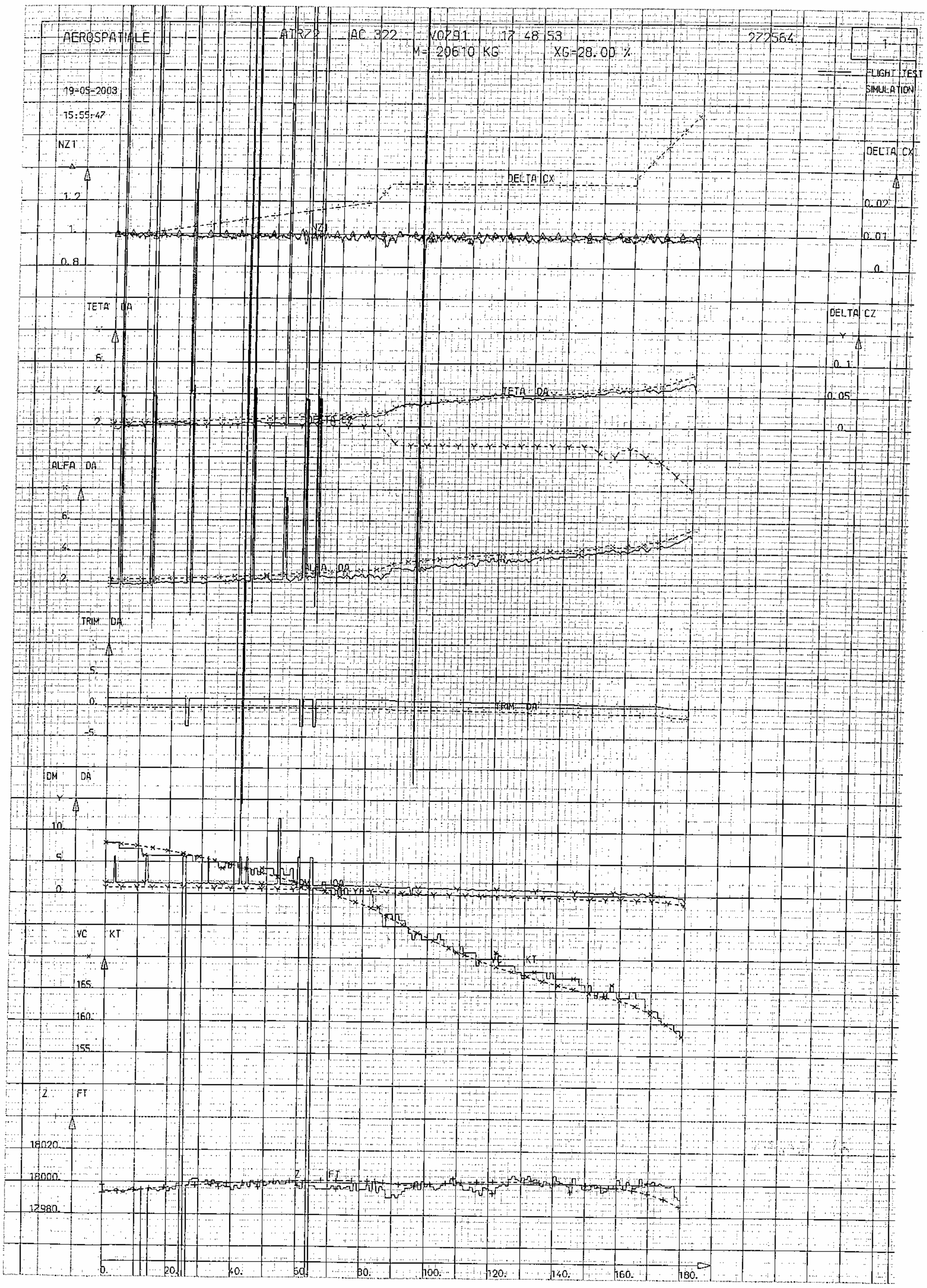
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V0791
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1
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DELTA CX
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TETA DA
6
4
2
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DELTA CZ
DELTA CZ
0.1
0.05
0
ALFA DA
8
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4
2
ALFA DA
TRIM DA
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TRIM DA
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VC KT
165
160
155
VC KT
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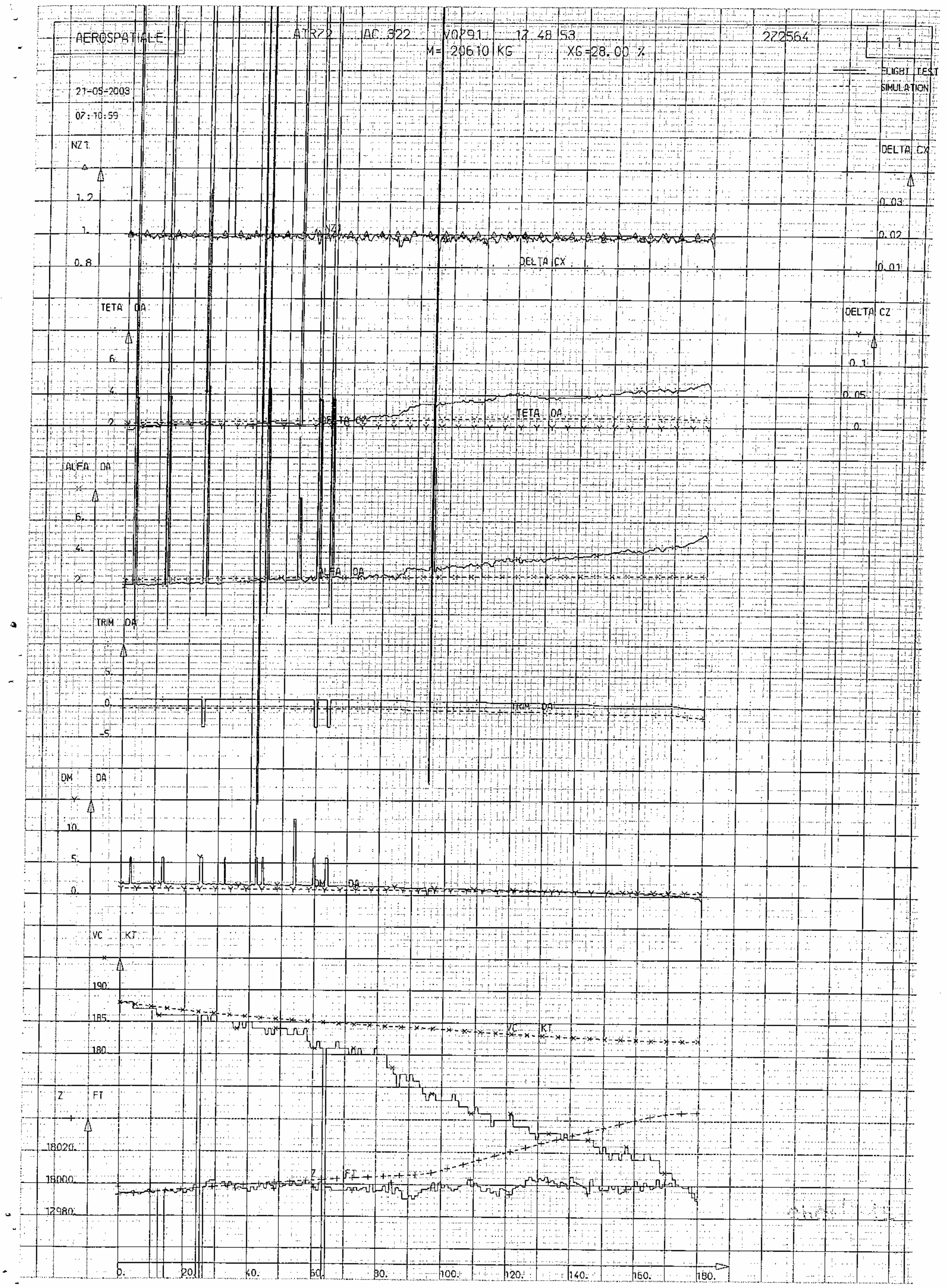
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0.01
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4.
2.
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DELTA CZ
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0.05
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TRIM DA
DM DA
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DM DA
VC KT
190.
185.
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VC KT
Z FT
18020.
18000.
17980.
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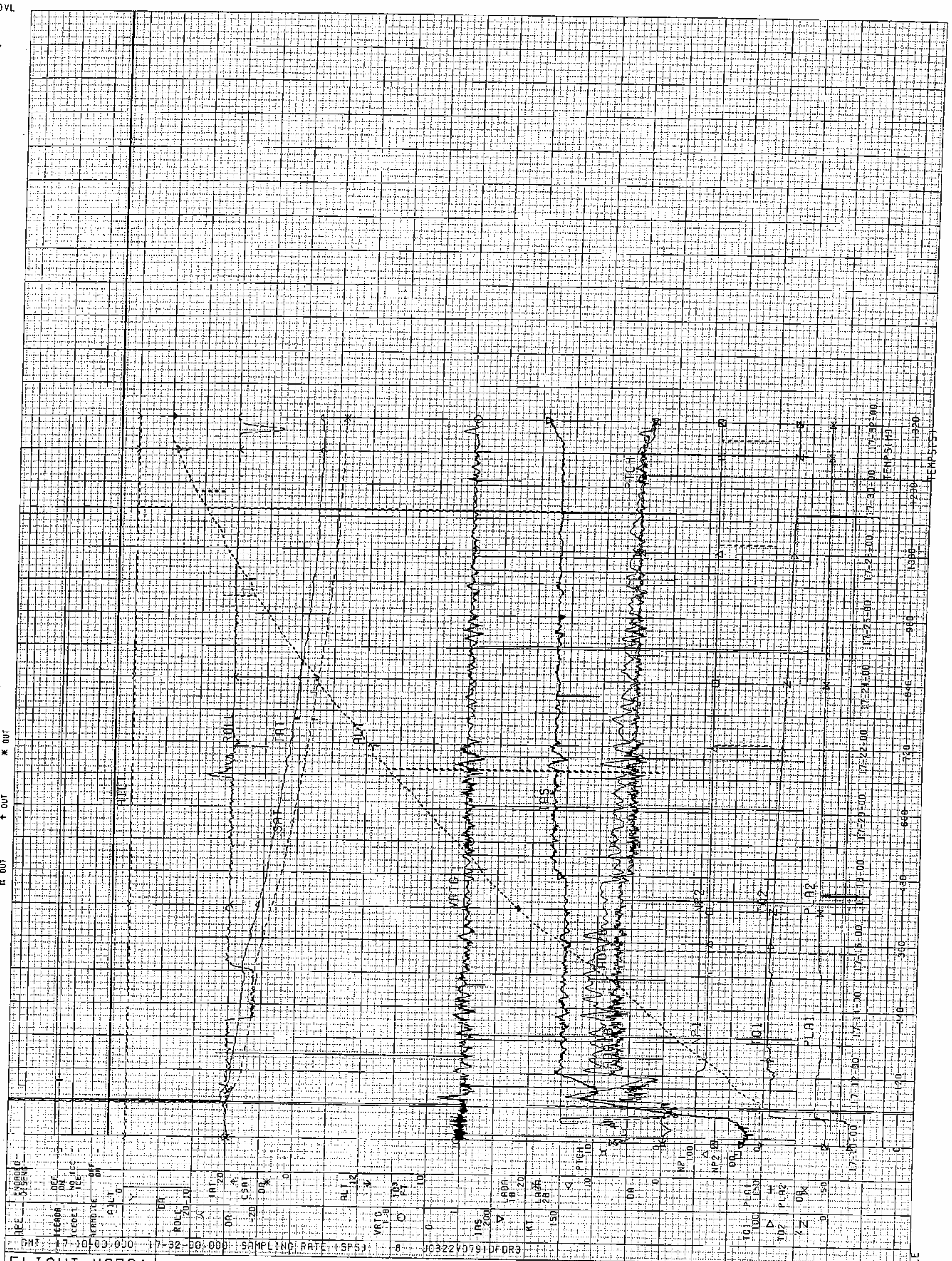
180.

ANNEX 2 : DFDR

DFDR parameters

Figure 1 and 2



FLIGHT V0791

TRANSASIA AIRWAYS - MSN 322 - ATR72-200

CLIMB

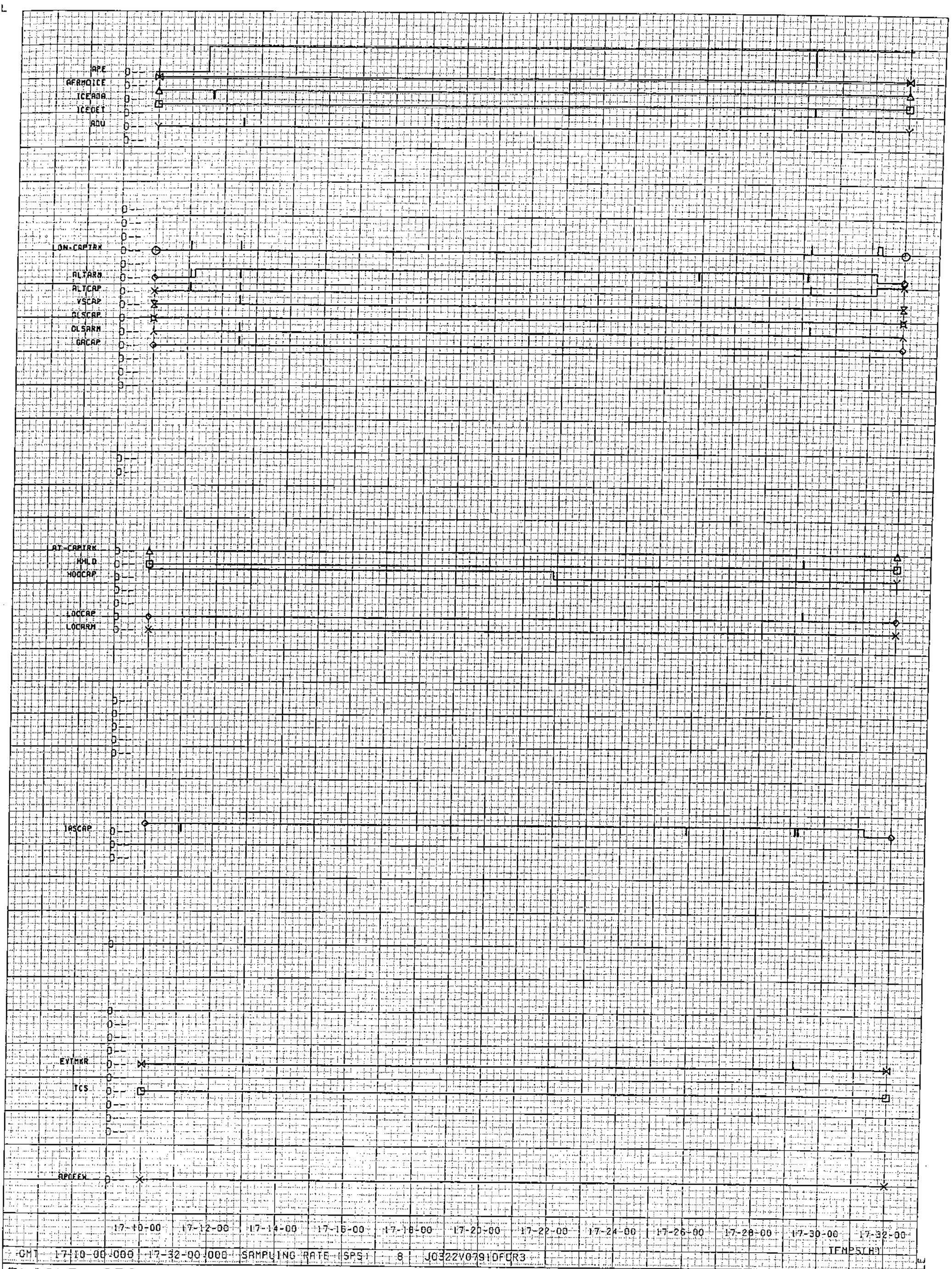
CRUISE (LONGITUDINAL AXIS)

AEROSPATIALE
FLIGHT TESTS

AIRCRAFT JD322 FIGURE 1

(C) AEROSPATIALE

SERIE/ATR/CUSTOM.AD



FLIGHT V0791 TRANSASIA AIRWAYS - MSN 322 - ATR72-200

CLIMB

AP MODES

AEROSPATIALE
FLIGHT TESTS

AIRCRAFT J0322 FIGURE 3

SERIE/ATR/CUSTOM.AD

Note DO/TF-2524/03

Du 02/06/2003

LISTE DE DIFFUSION

TITRE : **ATR 72-200 : TRANSASIA AIRWAYS MSN 322 – Accident analysis**

EMETTEUR :DO/TF

REFERENCE :DO/TF-2524/03

SERVICE	SECTION	NOM-PRENOM	B.P.	Page de garde	Note	Annexe
Diderot			M0199/6	original	original	original
DO/T		C. ORSI	(ATR)		X	
CEO/ S		E. D'ANIELLO	(ATR)		X	
DS/T		D. VALAX	(ATR)		X	
DO/TV		E. DELESALLE	(ATR)		X	
DO/TF		G. PETIT (2)	(ATR)		X	
DO/TA		G. CALDARELLI	(ATR)		X	
DO/TC/T		D. CAILHOL	(ATR)		X	
DO/TC/N		Y. OTTOGALI	(ATR)		X	

Diffusion Externe

Nom	Société

ACCORD POUR DIFFUSION EXTERNE

HEAD OF ENGINEERING DEPARTMENT

C. ORSI

Date : 20/06/2003

Appendix 21 ATR 72 Full Flight Simulator Test Report. SUBJECT: Report of Simulation Session with ASC and BEA

SUBJECT : Report of simulation session with Taïwan ASC and BEA.

1. Introduction.

A Full Flight Simulator session has been organized by ATR in aid of Taiwan ASC and French BEA, in order to help the investigation on MSN 322 accident.

This session took place on 28th of March 2003 in ATC FFS nb2, with the following persons:

Left pilot: ATR Representative #1

Right pilot: ASC Representative #1

Engineer: ATR Representative #2

Observers:

ASC Representative #2

BEA Representative #1

Simulator Engineer: ATR Representative #3

At the end of the session, the records of the runs were given to ASC representatives.

2. Tests performed.

Four different scenarios were demonstrated from the same initial conditions, close to those of MSN322 accident :

Weight : 20,5 t

CG : 28 %

Altitude : FL 180

Indicated airspeed : 200 Kt

Severe icing conditions

Power setting : Np 86%, max cruise TQ

For each scenario, the pilot first let the aircraft follow its natural behavior before initiating any maneuver :

Stick-shaker and AP disconnection

Roll motion until ~45° of bank angle

Scenario 1 : Pilot off the loop

This run intended to demonstrate the natural behavior of the aircraft without any action of the pilot.

As expected, the rolling motions are increasing, and so does the negative pitch angle.

Scenario 2 : Recovery attempt with roll control only

MSN 322 DFDR data showed that the stick was kept around pitch neutral position, except during a very short instant at the activation of the stick pusher, and the pilot only made roll inputs trying to bring back the wings level.

So for this scenario, the pilot flew the simulator reproducing the same flying techniques, applying only roll inputs and keeping the stick in pitch neutral position.

The result is that the aircraft is maintained in stall conditions : by fighting on the roll axis, the bank angle may be kept in reasonable margins, but there are still erratic roll motions, and the full control is never regained.

Scenario 3 : Recovery by pushing the stick.

This recovery technique is the most natural one : the loss of control is due to a high angle of attack (AOA), and pushing the stick immediately decreases the AOA and allows the speed to increase.

Two demonstrations were made and showed the efficiency of this technique.

ASC and BEA representatives performed themselves this type of maneuver.

Scenario 4 : Recovery by flaps extension.

The extension of flaps 15° is another procedure recommended by ATR : as soon as the flaps begin to extend, the AOA immediately decreases for the same stick position and speed.

Two demonstrations showed that the recovery is immediate, with the advantage that the loss of altitude is minimized compared with the preceding technique.

3. Conclusion.

This simulator session allowed to demonstrate the main following points:

- Severe icing conditions induce speed decay;
- If the pilot does not observe the minimum speed recommended by the procedure, a stall may occur, with unwanted roll motions;
- The stalling conditions are maintained if the pilot only counteracts the roll motions, keeping the stick around the neutral position;
- The control of the aircraft is immediately regained when applying either of the recovery techniques recommended by ATR.

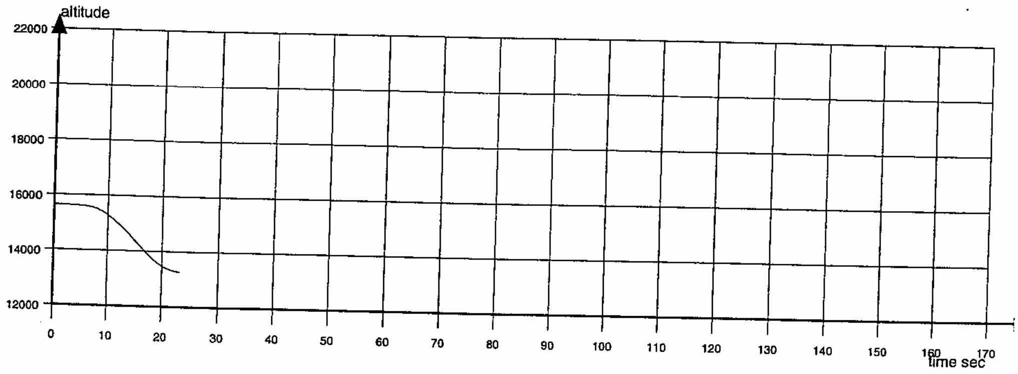
Flaps 0° (Gerard Petit)

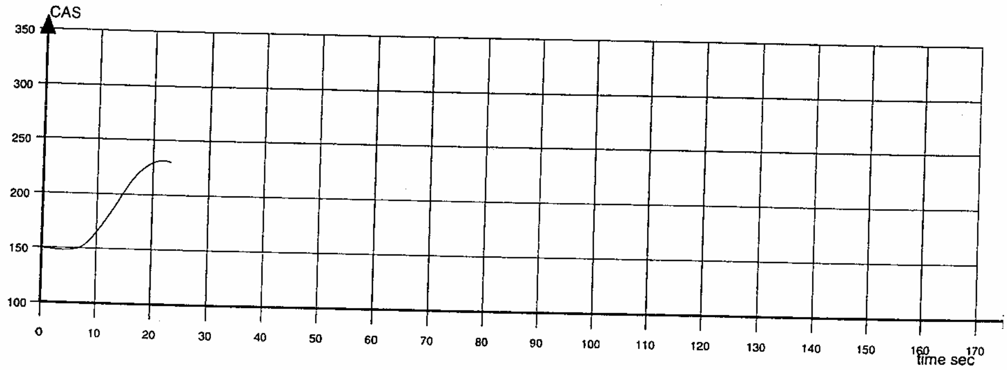
THOMSON-CSF - TSS

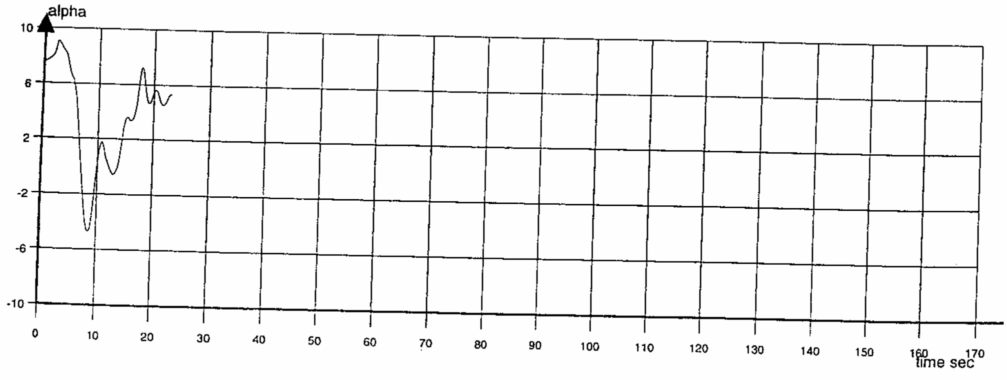
RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____

#1







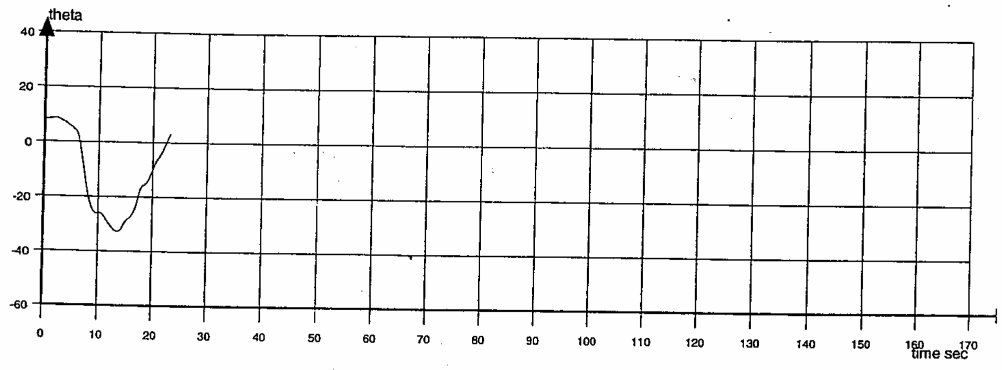
28/3/103 18:13:58

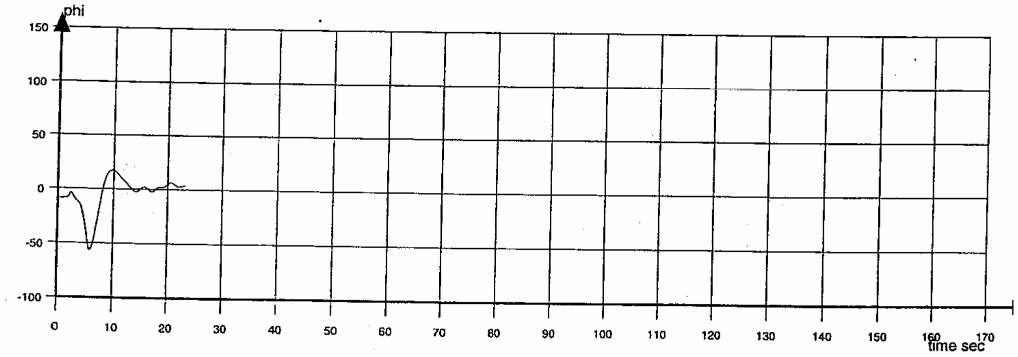
page 1

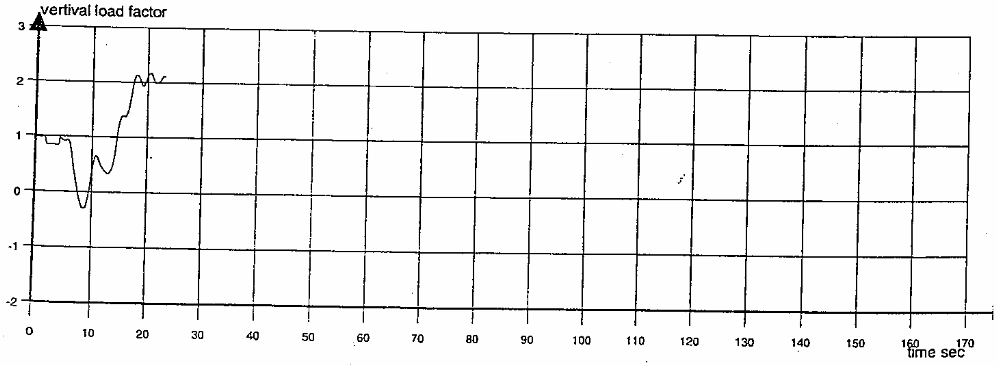
THOMSON-CSF - TSS

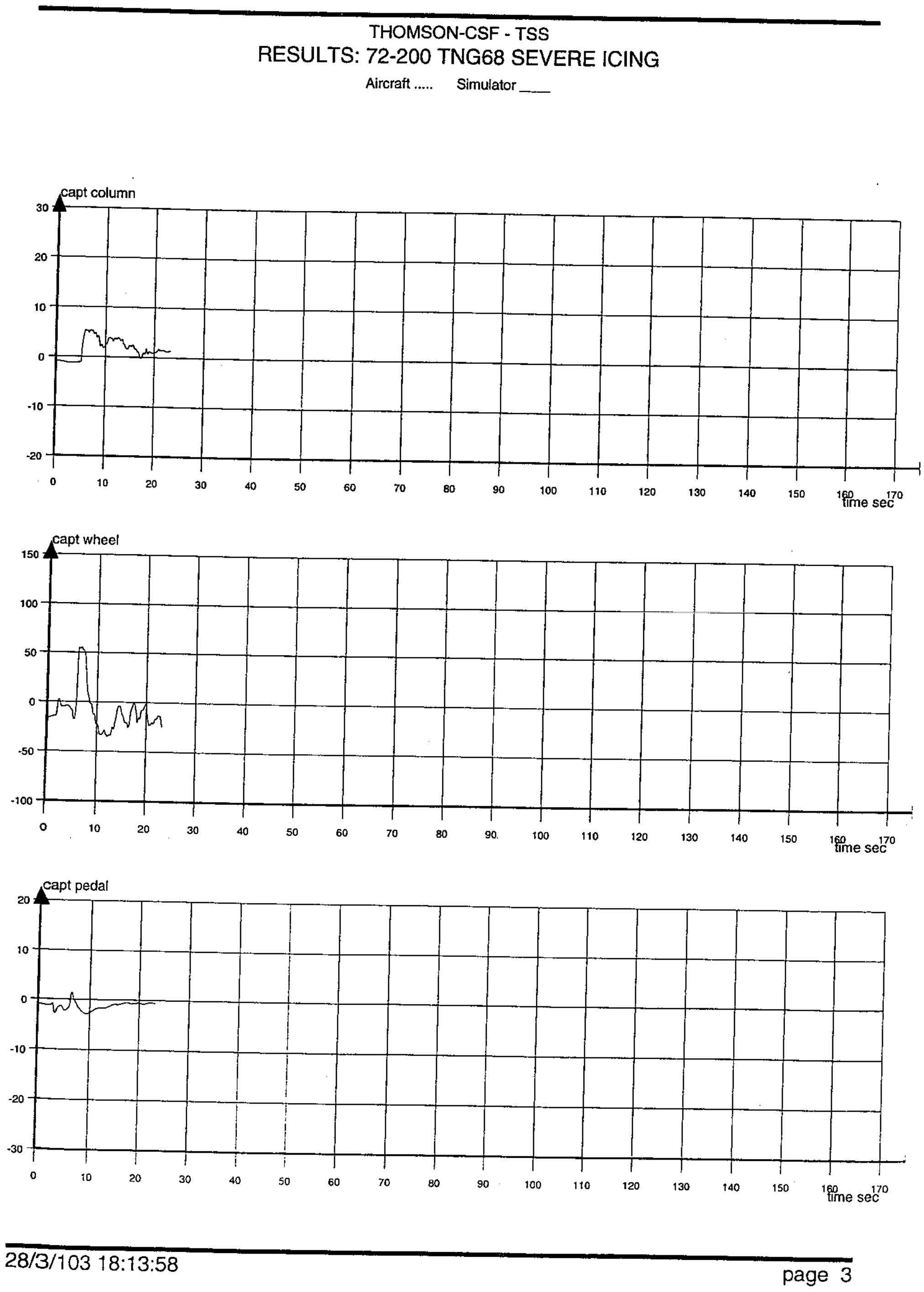
RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____









THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____

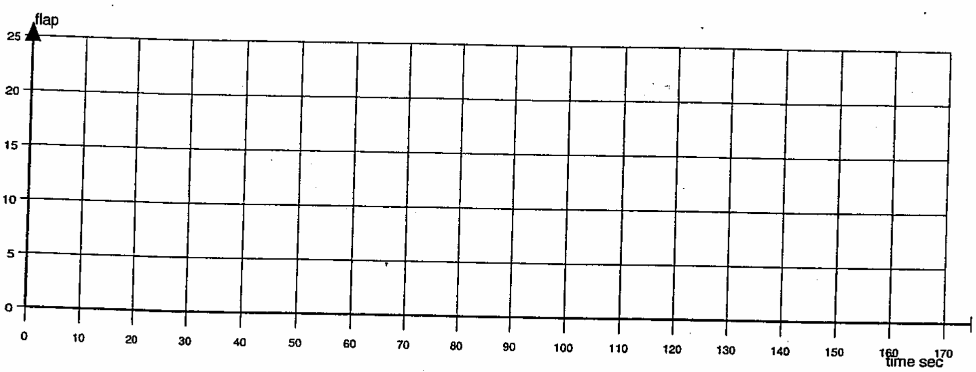
28/3/103 18:13:58

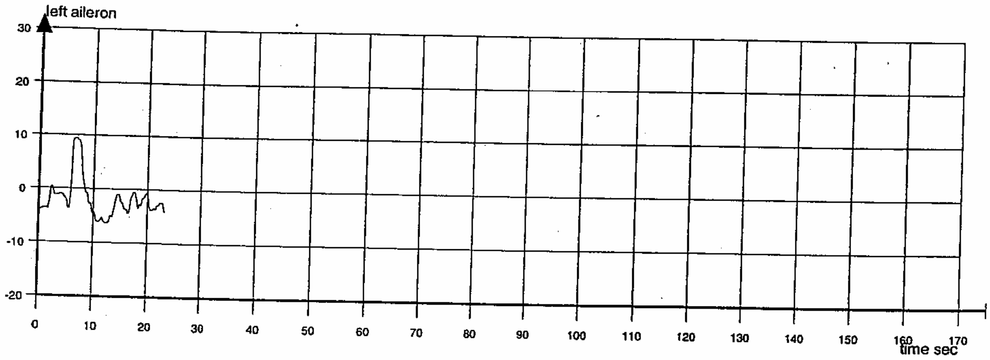
page 3

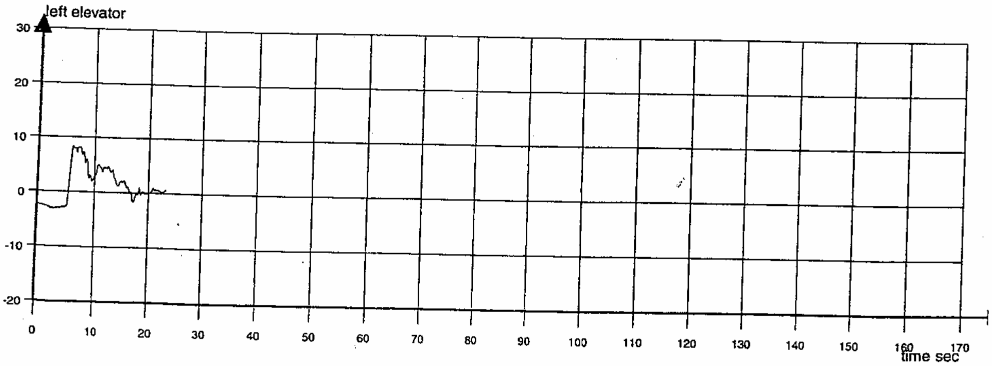
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____







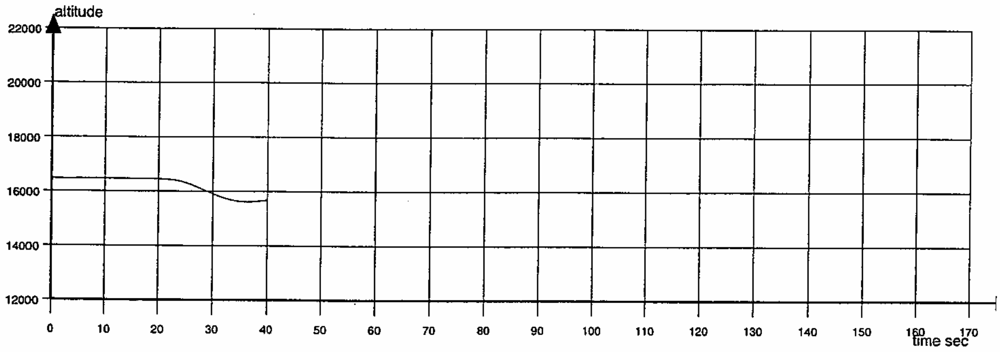
Flaps 15° (Gerard [illegible])

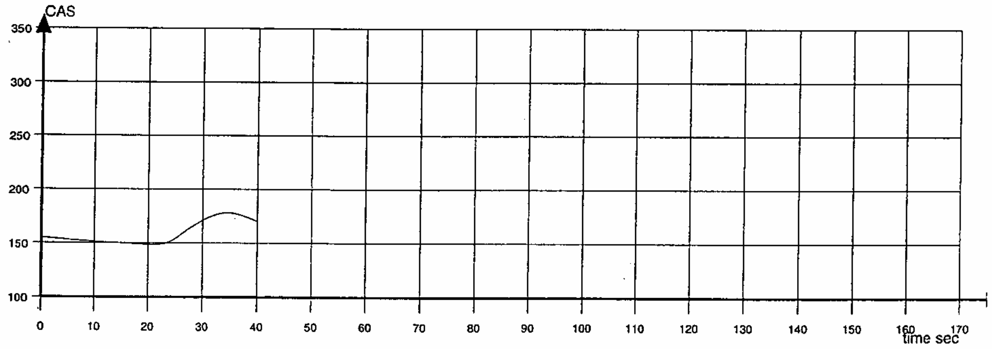
THOMSON-CSF - TSS

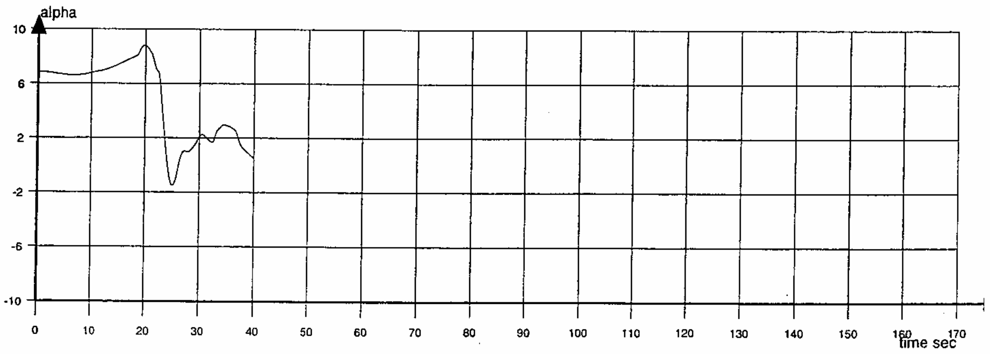
RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft .....   Simulator ____

#2





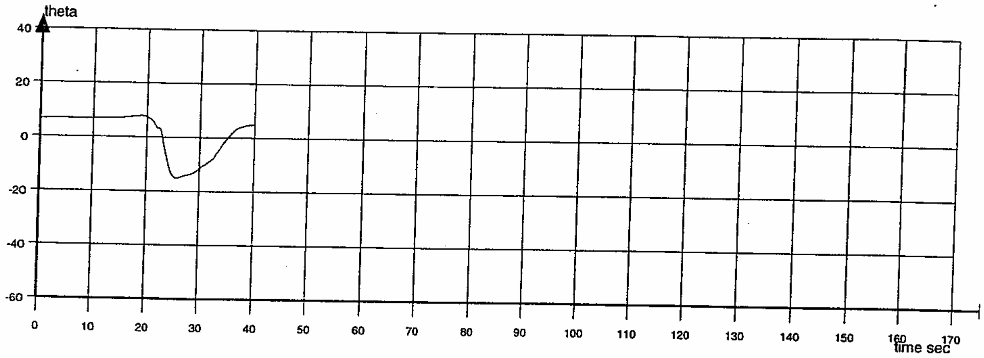


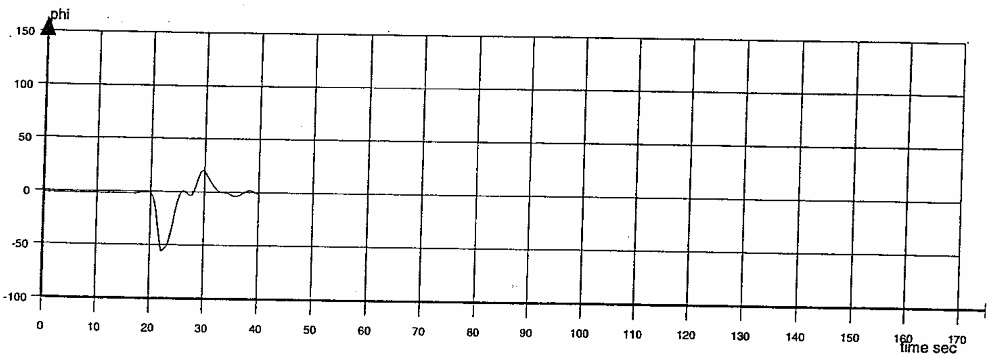
28/3/103 18:25:7

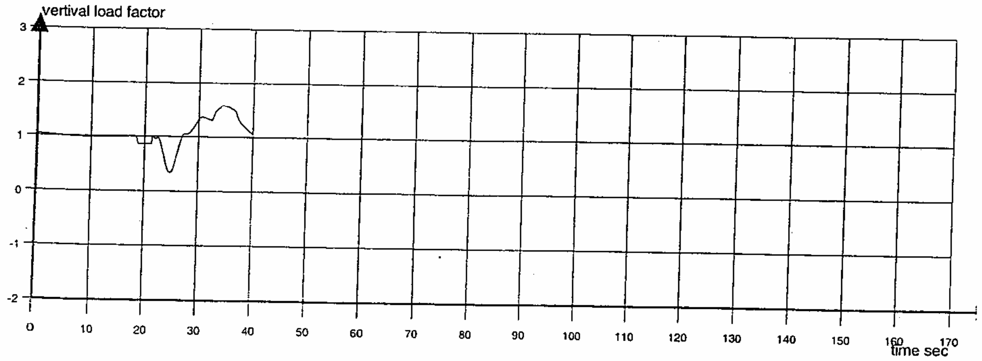
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____





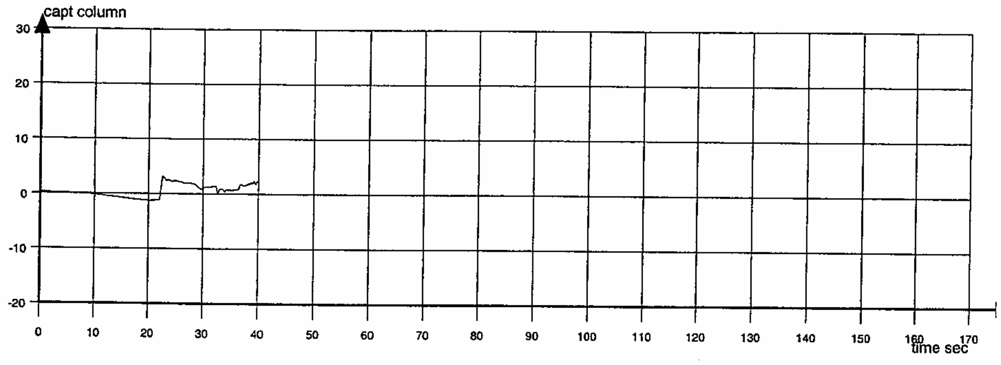


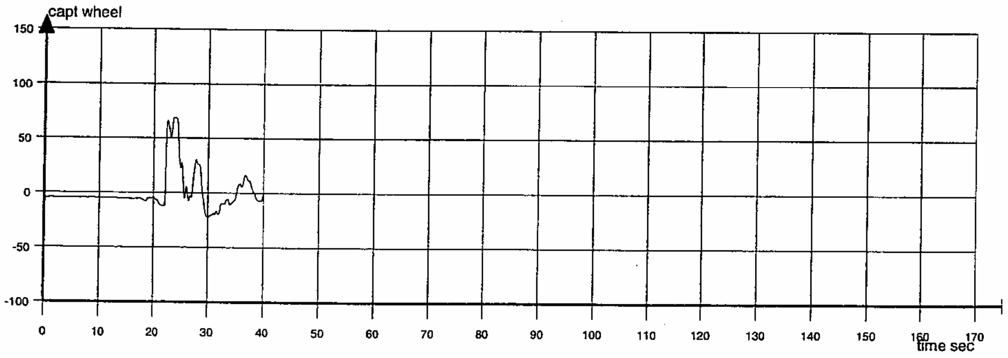
28/3/103 18:25:7

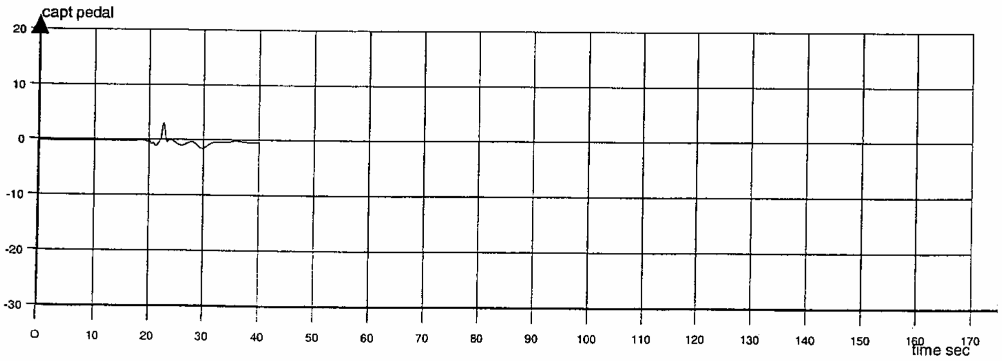
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____



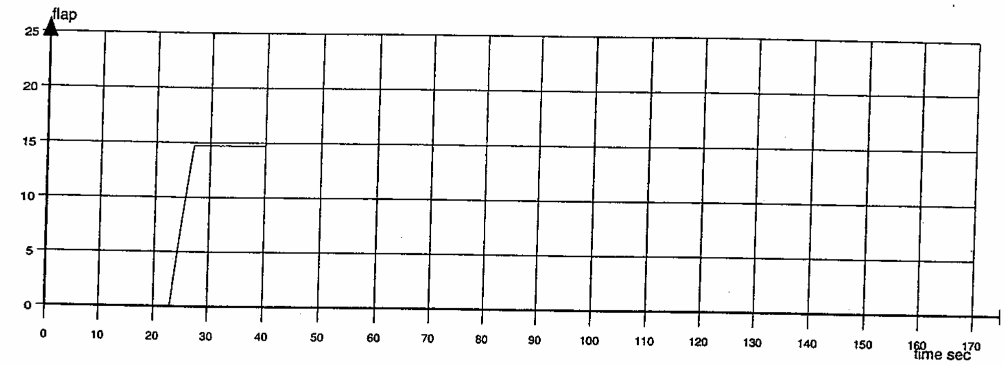


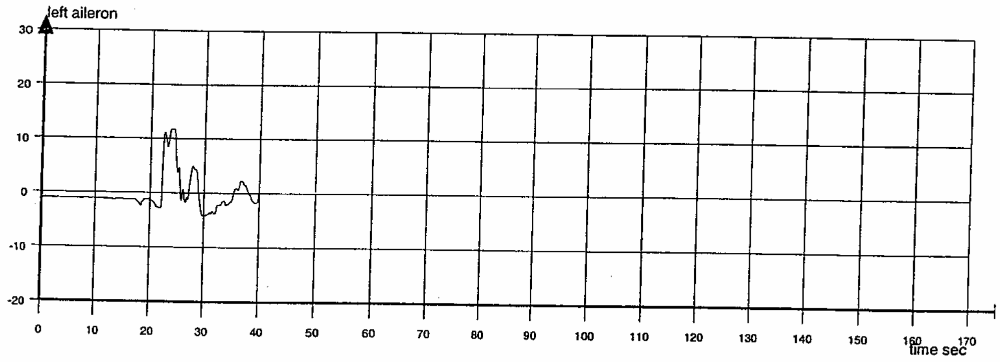


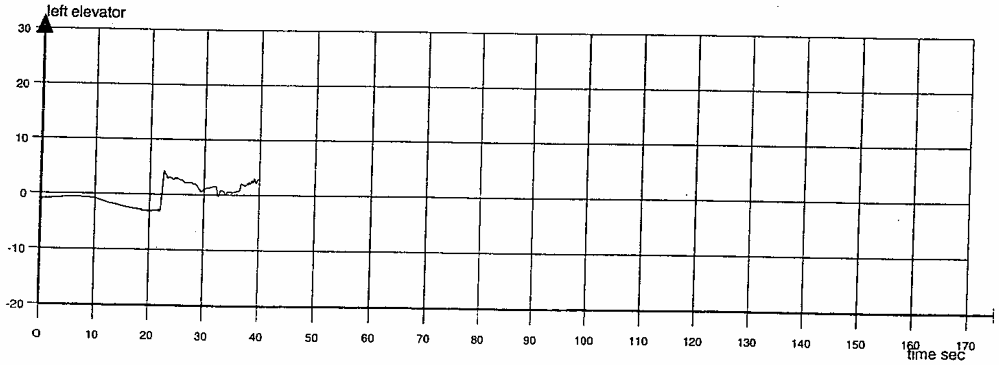
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____







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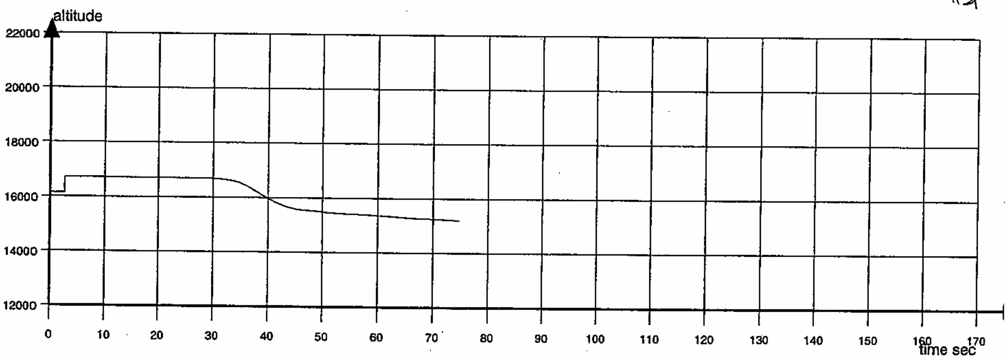
Flaps 0 (brake release)

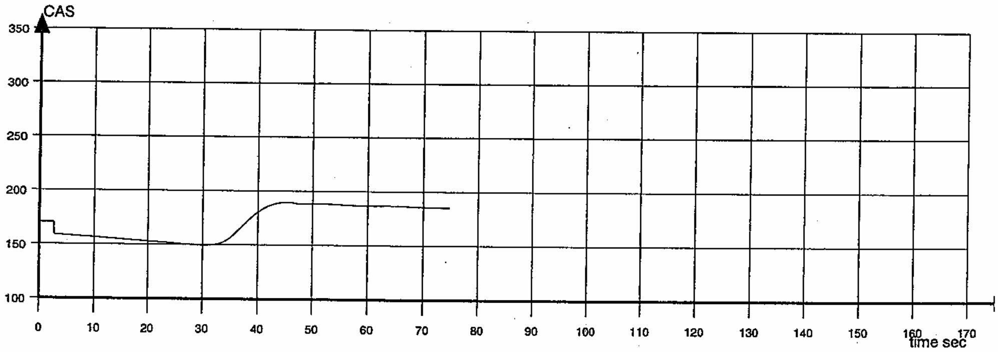
THOMSON-CSF - TSS

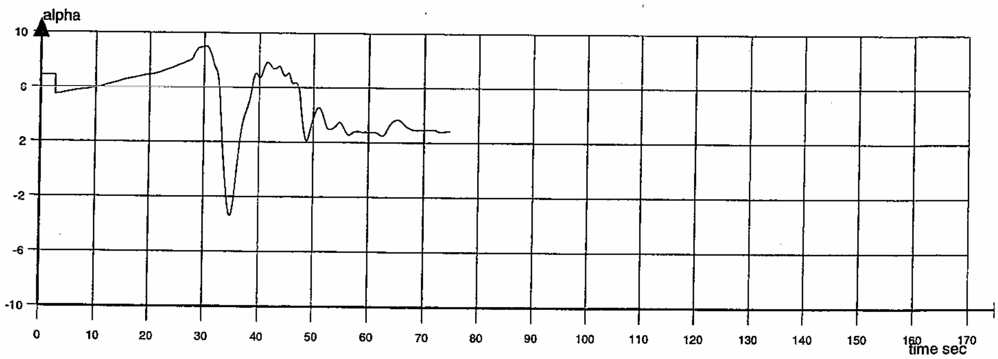
RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft .....   Simulator ____

#3

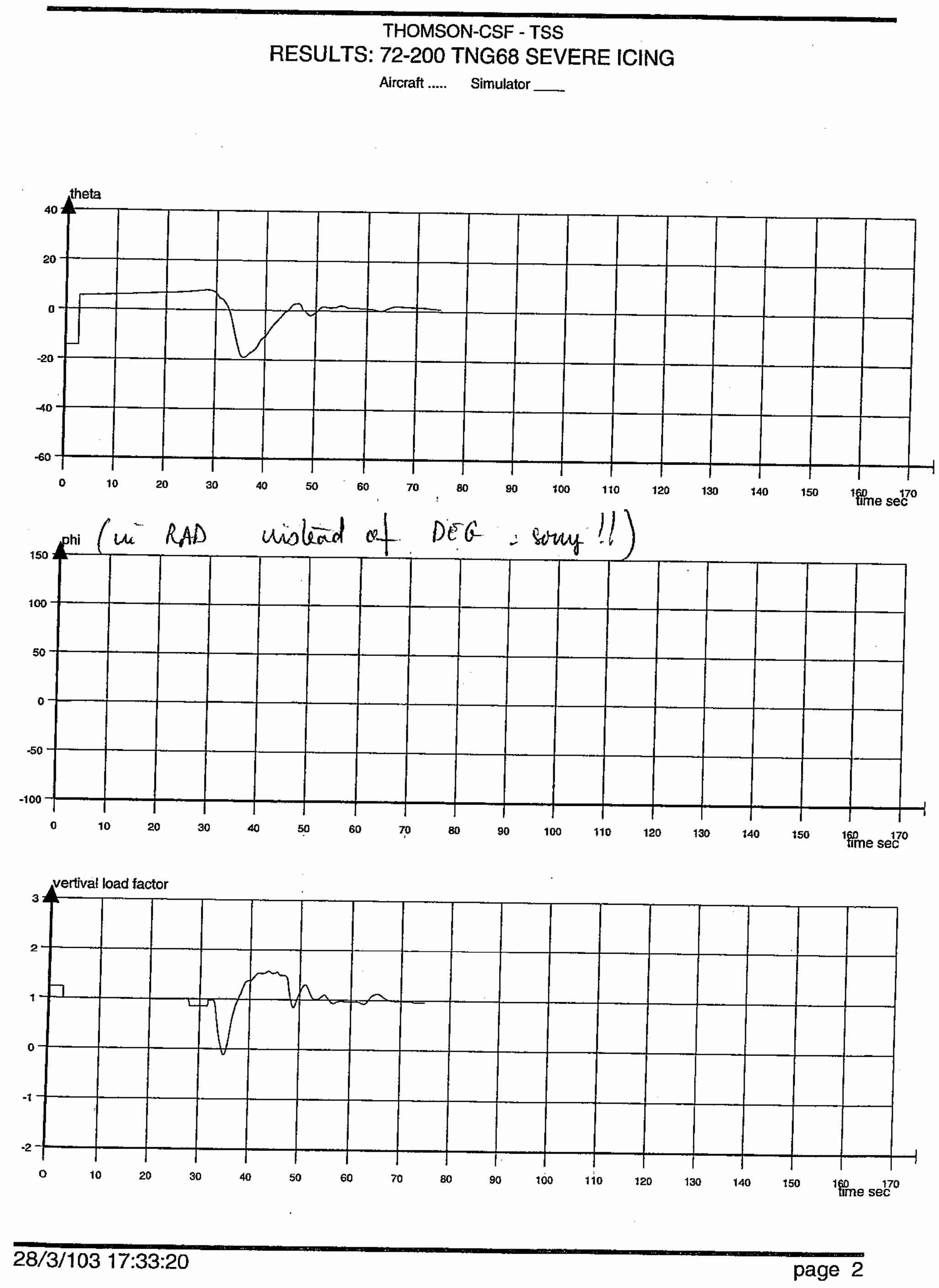






28/3/103 17:33:20

page 1



THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____

(in RAD instead of DEG : sorry !!)

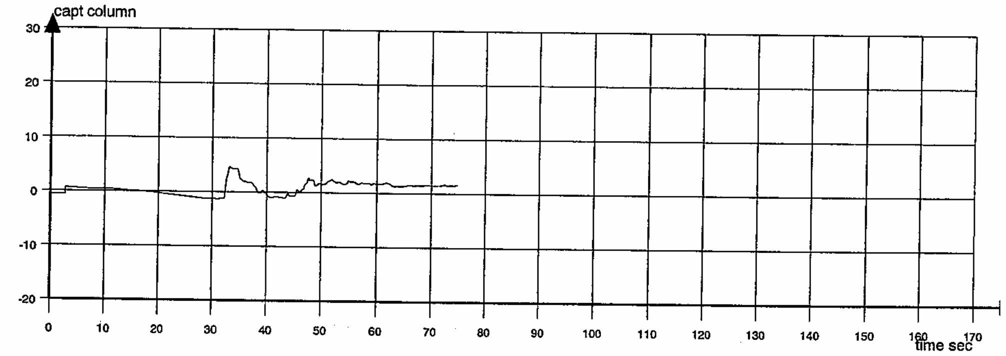
28/3/103 17:33:20

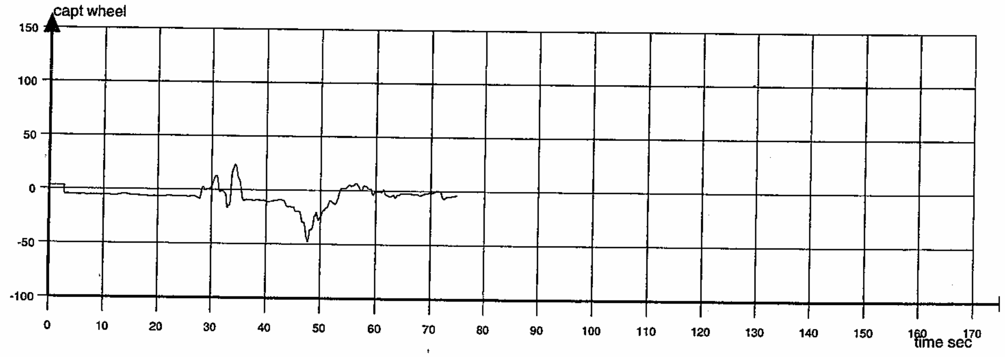
page 2

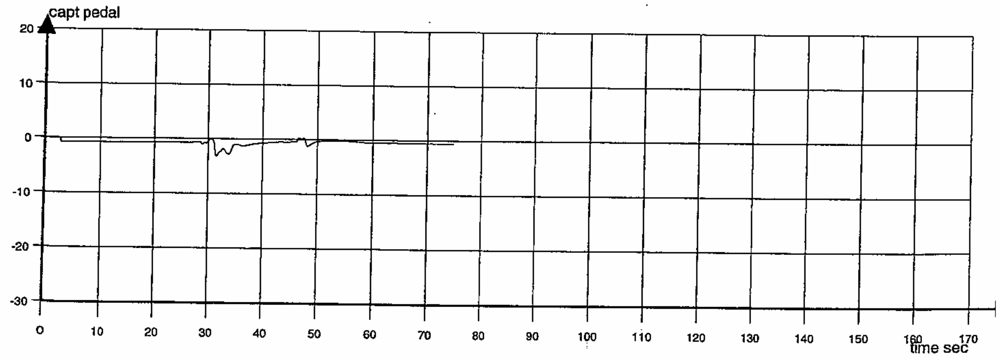
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____



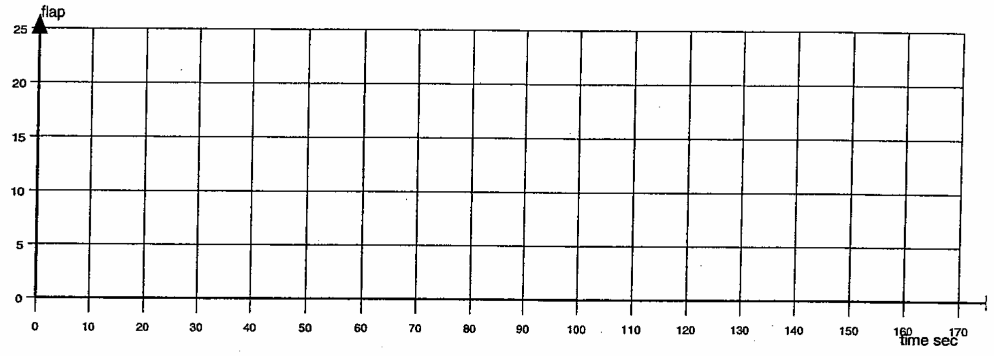


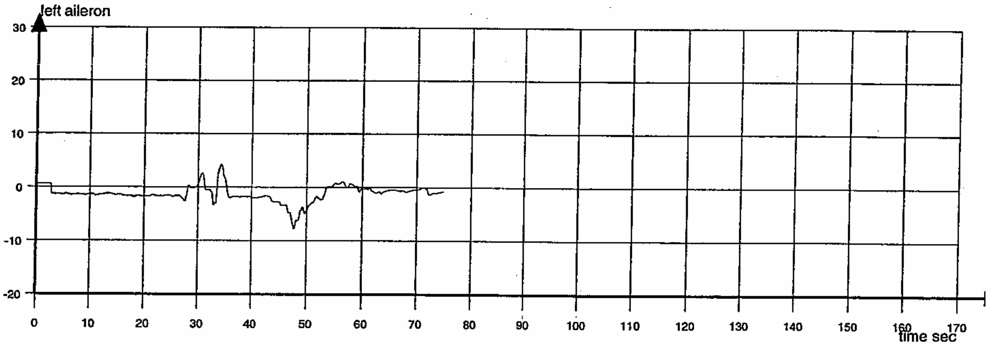


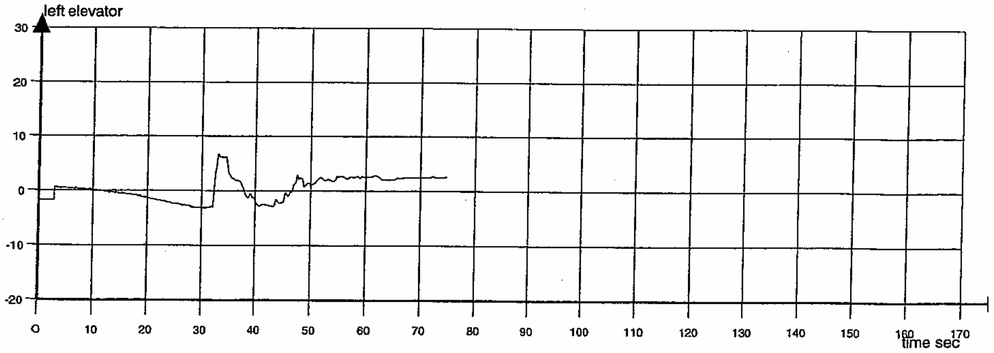
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____







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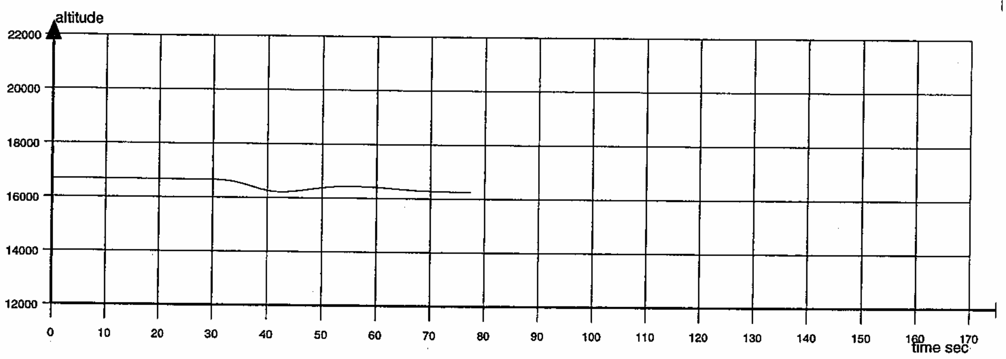
Flaps 15 (ERC version)

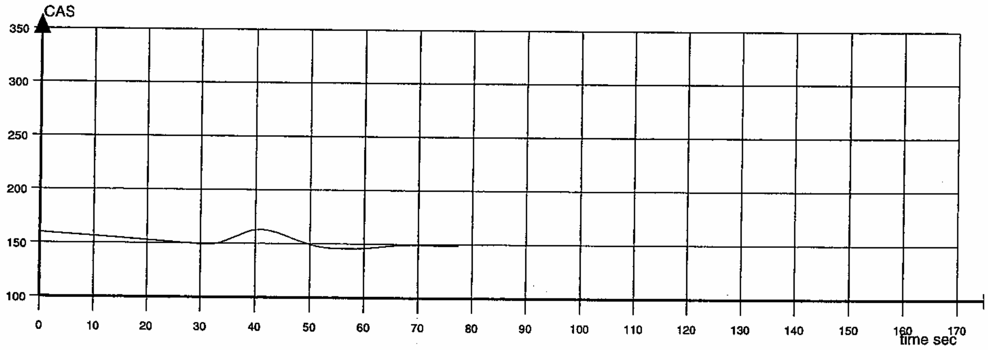
THOMSON-CSF - TSS

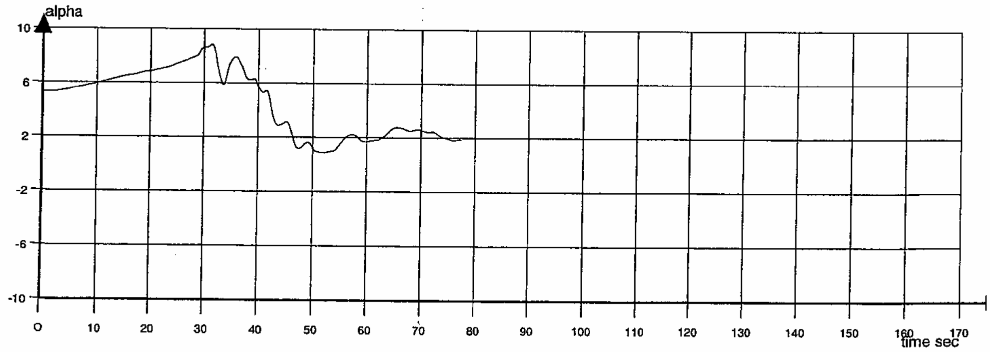
RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____

#4







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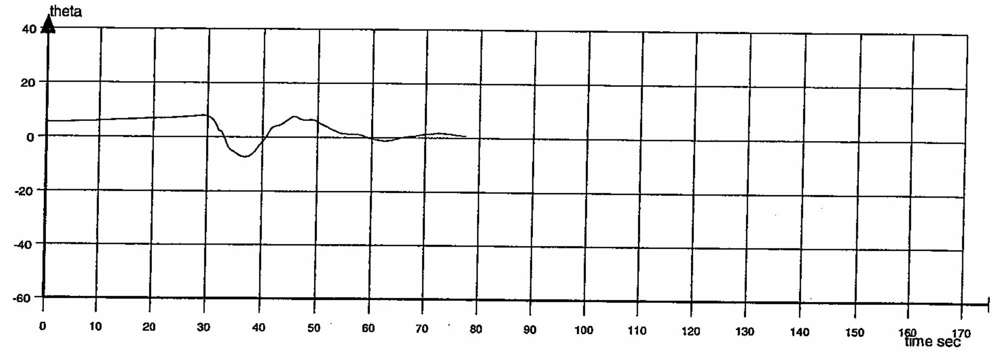
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____



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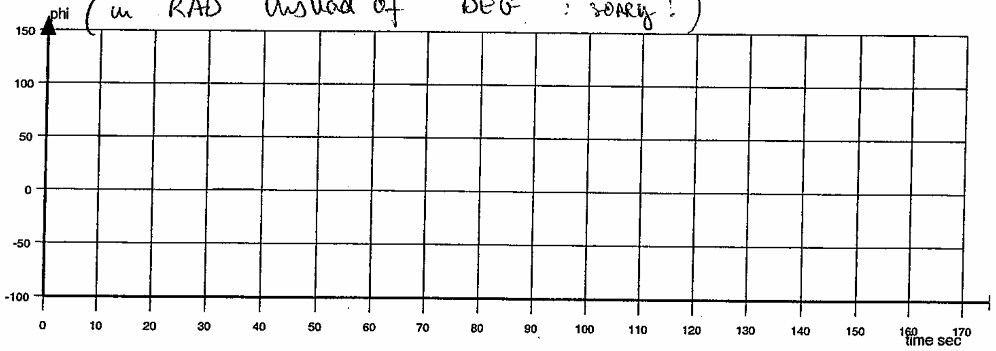
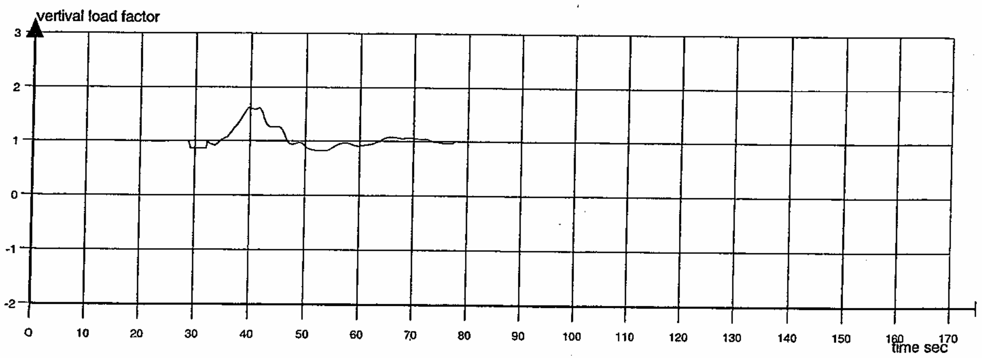
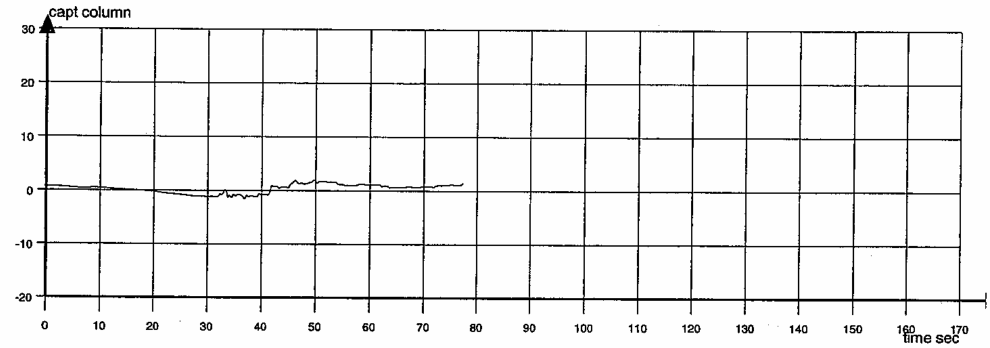


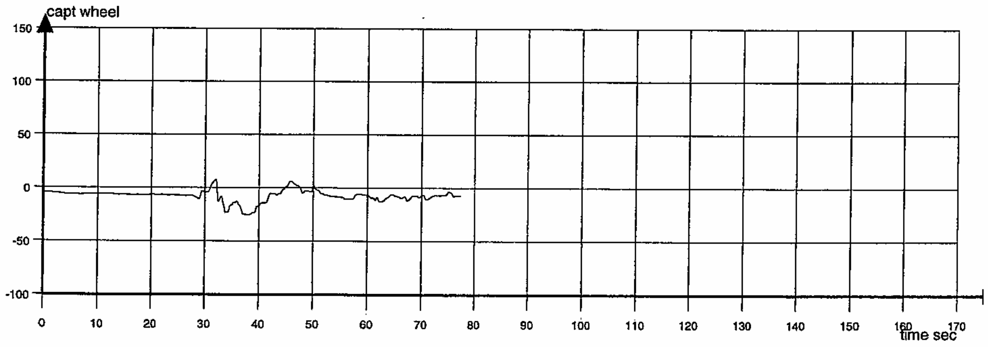


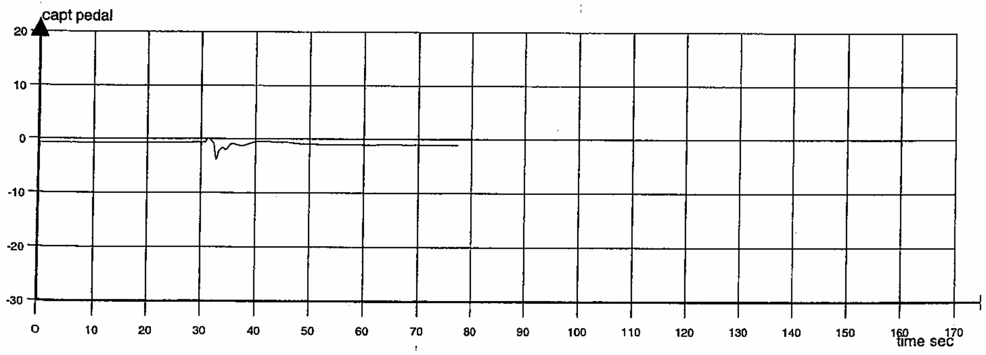
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____







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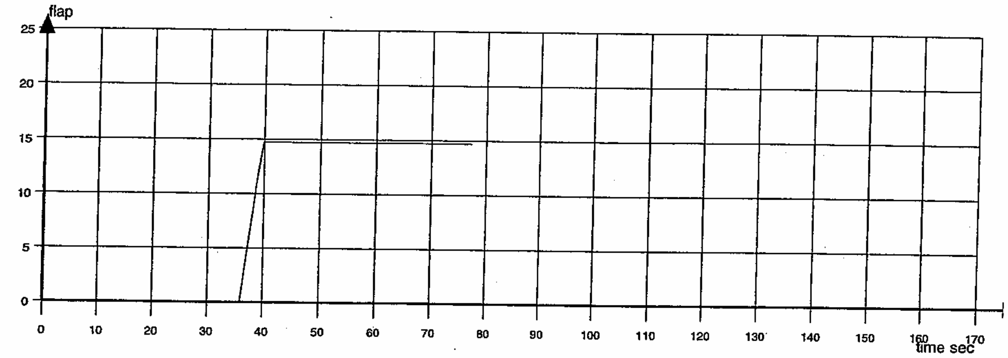
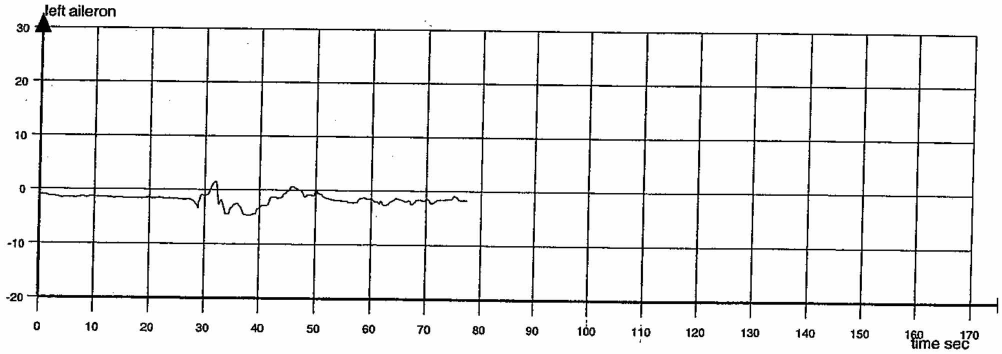
page 3

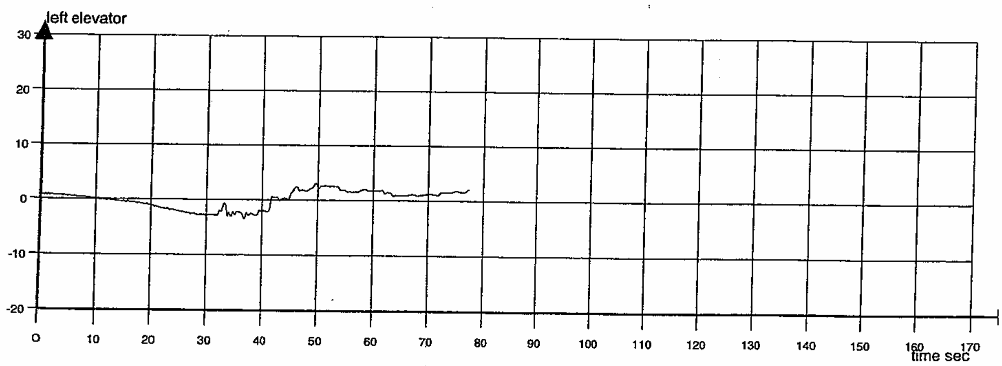
THOMSON-CSF - TSS

RESULTS: 72-200 TNG68 SEVERE ICING

Aircraft ..... Simulator ____







28/3/103 17:39:22

Appendix 22 Simulation Analysis Performed by ATR in 2004

Subject: Simulation analysis

July, 2004

The simulation study reproduced the FDR parameters and provides adequate elements for a better understanding of the roll excursion and the loss of control of the aircraft.
The figures from 1 to 4 show that the simultaneous application of AFM procedure in the same accident flight conditions leads to the recovery of the correct flight attitude.

The figure 1 shows the elevator pitch down command and the effect on the pitch angle. The angle of attach is reduced and the recovery is easily attained.
The figure 2 shows the aileron command and the effect on the bank. The actions on the aileron combined with the angle of attach reduction obtained with elevator push down leads to complete recovery.

The figure 3 shows the effect of flap extension on the recovery. The effect on the pitch angle is immediate.
The figure 4 shows the aileron command combined with flap maneuver and the effect on the bank.
The actions on the aileron combined with the angle of attach reduction generated by flap extension leads to complete recovery.

Conclusions:

Both flight recorders analyze show that the after second activation of airframe de-icing system, the aircraft engaged the autopilot and continued in icing environment about 11 minutes. The Loss of control of the GE791 has been initiated by an asymmetrical lift between right and left wing due to a long exposure to severe icing conditions. This asymmetrical lift induced a consequential left roll when the autopilot disconnected. Large rudder input during the roll

induced a further increase of angle of attack, which produced stick pusher activation. This was immediately counteracted keeping high the angles of attach in conflicting to what required by the recovery procedure which was never been applied.
The aircraft after a first left roll followed by a right roll, continued to roll left, increasing the speed and diving until the crash into the sea.

The Safety Council, after analysis of FDR and CVR data, believes that the GE791 probably encountered a severe icing condition, which was worse than icing certification requirements of FAR/JAR 25 Appendix C.
In fact the continued flight in such conditions caused a drag increase of 500 counts which is 130% greater than the expected drag for this aircraft model in cruise and 100% more the normal ice condition. Both lift-drag ratio and airspeed decayed rapidly and caused the mishap from which the aircraft did not recover for lack of application of the recovery procedure.

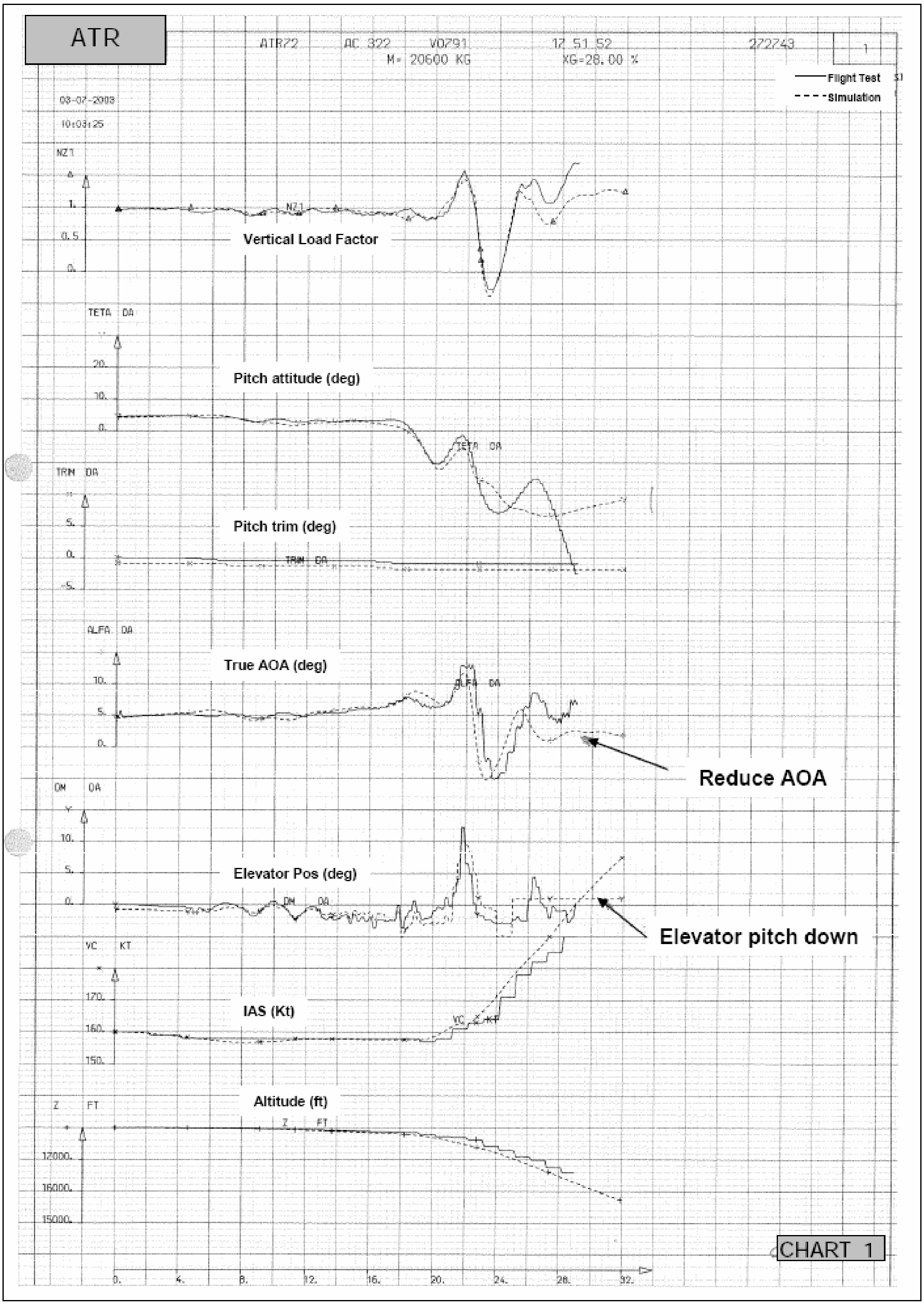

ATR
ATR72
AC 322
V0791
12 51 52
272743
1
M= 20600 KG
XG=28.00 %
Flight Test
Simulation
03-07-2003
10:03:25
NZ1
1.
0.5
0.
Vertical Load Factor
TETA DA
20.
10.
0.
Pitch attitude (deg)
TRIM DA
5.
0.
-5.
Pitch trim (deg)
ALFA DA
10.
5.
0.
True AOA (deg)
Reduce AOA
DM DA
10.
5.
0.
Elevator Pos (deg)
Elevator pitch down
VC KT
170.
160.
150.
IAS (Kt)
Z FT
Altitude (ft)
17000.
16000.
15000.
CHART 1
0.
4.
8.
12.
16.
20.
24.
28.
32.

Fig. 1

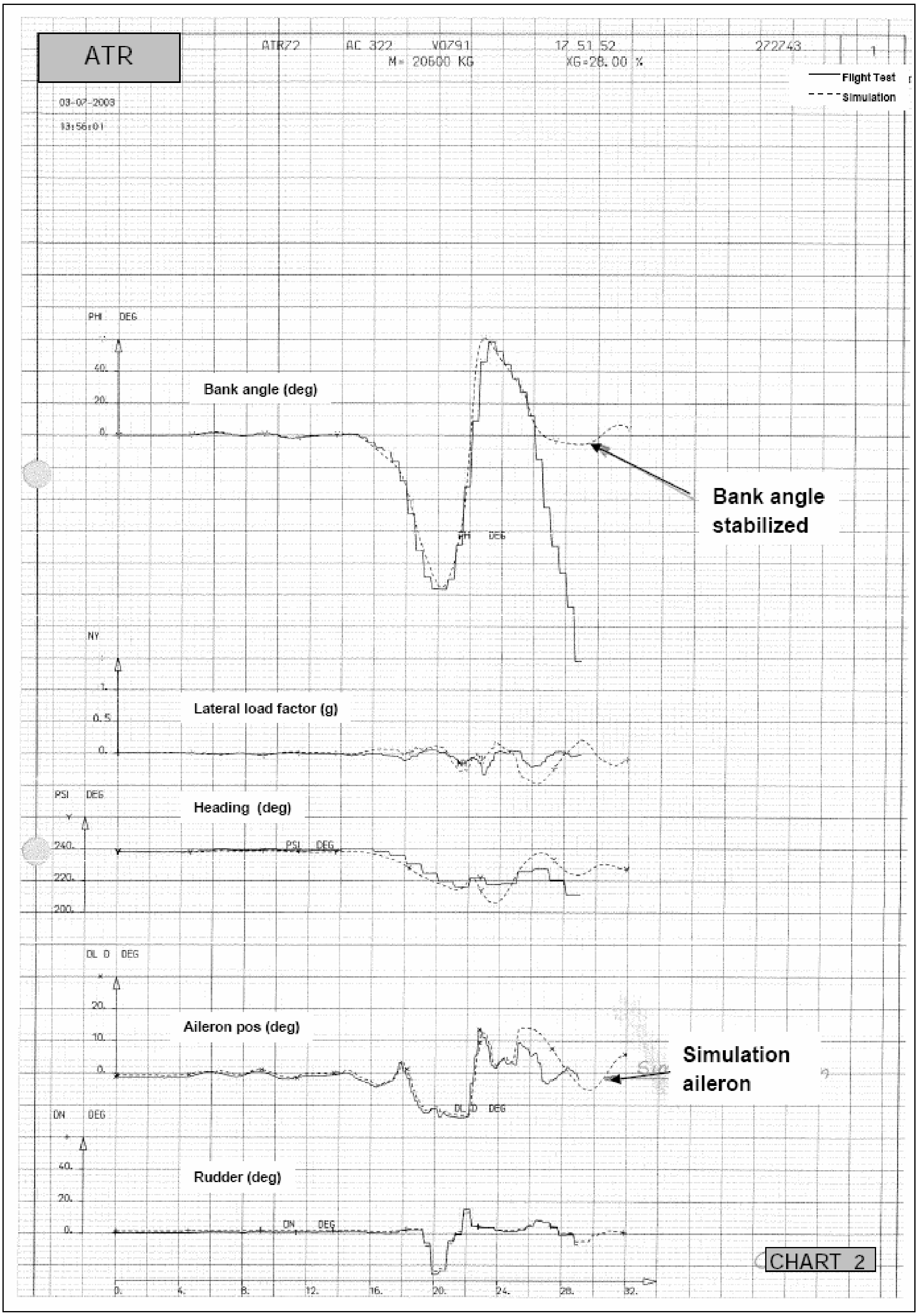

ATR
ATR72
AC 322
V0791
17 51 52
272743
1
M= 20600 KG
XG=28.00 %
Flight Test
Simulation
03-07-2003
13:56:01
PHI DEG
40.
20.
0.
Bank angle (deg)
Bank angle stabilized
PHI DEG
NY
1.
0.5
0.
Lateral load factor (g)
PSI DEG
Heading (deg)
240.
220.
200.
PSI DEG
DL D DEG
20.
10.
0.
Aileron pos (deg)
Simulation aileron
DL D DEG
DN DEG
40.
20.
0.
Rudder (deg)
DN DEG
CHART 2
0.
4.
8.
12.
16.
20.
24.
28.
32.

Fig. 2

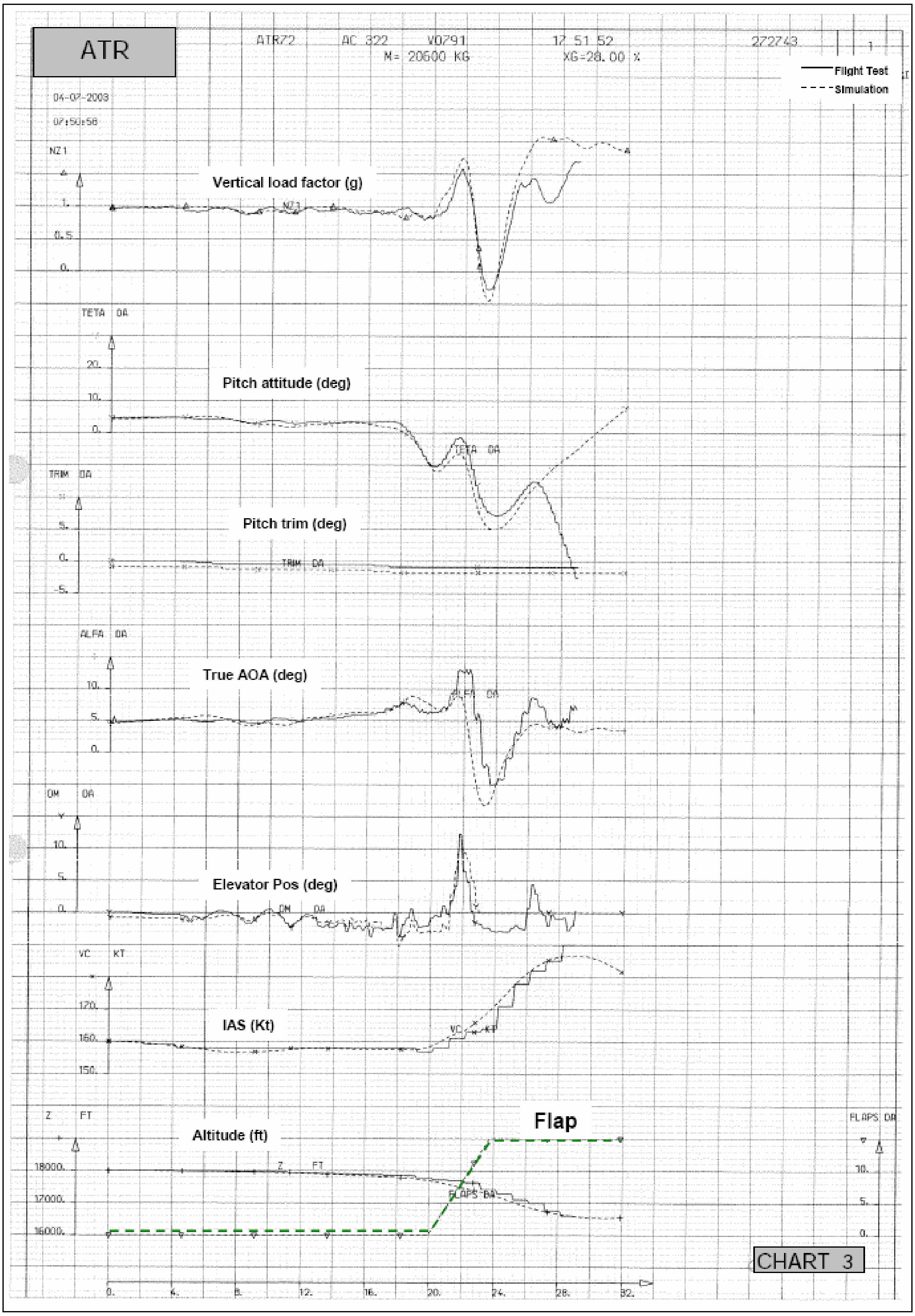

ATR
ATR72
AC 322
V0791
17 51 52
272743
1
M= 20600 KG
XG=28.00 %
Flight Test
Simulation
04-07-2003
07:50:56
NZ1
Vertical load factor (g)
1.
0.5
0.
TETA DA
20.
10.
0.
Pitch attitude (deg)
TRIM DA
5.
0.
-5.
Pitch trim (deg)
ALFA DA
True AOA (deg)
10.
5.
0.
DM DA
10.
5.
0.
Elevator Pos (deg)
VC KT
170.
160.
150.
IAS (Kt)
Z FT
18000.
17000.
16000.
Altitude (ft)
Flap
FLAPS DA
10.
5.
0.
CHART 3
0.
4.
8.
12.
16.
20.
24.
28.
32.

Fig. 3

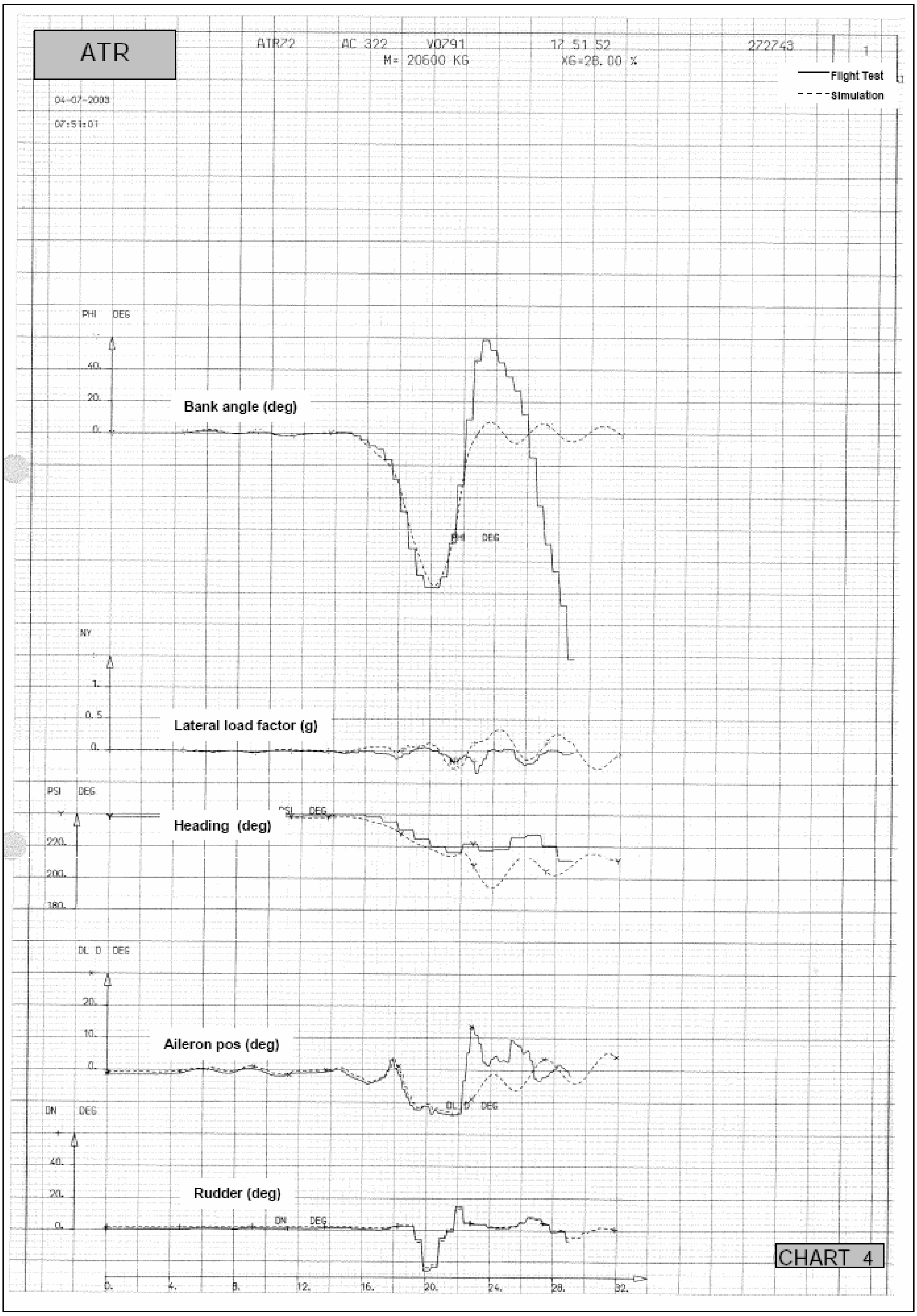

ATR
ATR72
AC 322
V0791
17 51 52
272743
1
M= 20600 KG
XG=28.00 %
Flight Test
Simulation
04-07-2003
07:51:01
PHI DEG
40.
20.
0.
Bank angle (deg)
PHI DEG
NY
1.
0.5
0.
Lateral load factor (g)
PSI DEG
220.
200.
180.
Heading (deg)
PSI DEG
DL D DEG
20.
10.
0.
Aileron pos (deg)
DL D DEG
DN DEG
40.
20.
0.
Rudder (deg)
DN DEG
0.
4.
8.
12.
16.
20.
24.
28.
32.
CHART 4

Fig. 4

Appendix 23 Performance and Stability Analysis of Flight GE791 Accident

Report to

Aviation Safety Council

On

Analysis of Flight GE791 Accident

[redacted]

J. L. Constant Distinguished Professor
Department of Aerospace Engineering
The University of Kansas
Lawrence, Kansas 66045

March 22, 2004

Revised on August 12, 2004

Abstract

Data from the Digital Flight Data Recorder of an ATR-72 involved in a mishap in Flight GE 791 are analyzed over the last 283 seconds. All stability and control derivatives are predicted to be either small in magnitude, or basically unstable. As a result, the roll excursion that precedes the accident is interpreted being caused by wing rock mechanism, that is unstable roll damping. The latter is caused by wing flow separation. Based on the concept of data correlation, it is also shown that it is possible to predict approximately when significant icing may start.

Introduction

The Transasia Aiways Flight GE-791 mishap occurred on December 21, 2002 in icing condition. The icing condition was confirmed by the visual contact of co-pilot (ref. 1). This report is to focus on the aerodynamic analysis based on the available data recorded on the Flight Data Recorder (FDR).

Since the aircraft involved in the accident was an ATR 72-200 turboprop, it is of interest to examine and compare the scenario of accidents involving aircraft of a similar type. A particular one was the American Eagle Flight 4184 that crashed on Oct. 31, 1994 at Roselawn, IN in freezing drizzle (refs. 2 and 3) (to be called the "Roselawn" case). There were several more icing accidents; but they involved either ATR 42 or other aircraft (ref. 3). After extensive investigation, the U. S. National Transportation Safety Board (NTSB) attributed the Roselawn accident to roll excursion after autopilot disengage. Because it happened at a relatively low angle of attack (=6 deg.), roll excursion was determined to be caused by "aileron hinge moment reversal", not by wing stall. That is, wing flow separation due to ice would induce a suction force on the unpowered aileron to force it to deflect in a different manner than on a clean wing. It was possible to demonstrate the concept in the wind tunnel only with an arbitrary "triangular" ice shape. At any rate, whether "aileron hinge moment reversal" is possible for GE 791 will be examined.

In addition, the NTSB revealed several important facts involving ATR-72 in certification and design. These are summarized in the following.

(1) In certification flights, the conditions with double horn ices were the main focus, because they were the most critical ice shapes.
(2) In certification flight testing in freezing drizzle, only performance degradation was noticed. No detrimental handling qualities were experienced.
(3) Effects of freezing drizzles or rains were not well documented.
(4) FAA regulations did not refer to any handling qualities problems in icing conditions.
(5) ATR's warnings to pilots included (a) disengaging autopilot, (2) increasing speed, (3) no "excessive" maneuvering, and (4) exiting freezing rain conditions as soon as possible.
(6) In simulator training, an abrupt asymmetrical stall with roll upset was instituted.

Preparation of GE 791 Flight Data

The present study will emphasize the flying and handling quality issues. Although thrust will not affect these issues too much, and it cannot be estimated accurately anyway, for completeness it is estimated in the following manner. The maximum available power from each engine is taken to be 2400 HP. Therefore, total power available is

Power = (average percent torque in FDR)*max. power*2*550, ft-lb/sec.

Thrust = power*0.85/V

That is, the propeller efficiency is assumed to be 0.85.

The aileron deflection angle is given by the left aileron position reading:$\delta_{a,\ left}$. A positive deflection of aileron would produce a positive rolling moment and a bank angle to the right.

The geometric data are taken as:

W = 45320 lbs S= 656.6 ft^2, mean chord = 7.4 ft. span = 88.75 ft.
I_x = 213800 slug-ft^2, I_y = 220120 slug-ft^2 , I_z = 423050 slug-ft^2
Thrust line at 2.2 ft. above C.G. (measured from a 3-D view)

The moments of inertia are all estimated by using statistical data.

Most of the plots are from t =2550 sec. in the present notation, which is equivalent to UTC time = 17:48:05.

Results and Discussions

Normal Climbing Flight

To demonstrate the model estimation of aerodynamics in normal flight, the data in climbing flight are first used to set up the aerodynamic models for the normal force (C_N), pitching moment coefficient (C_m), rolling moment coefficient (C_l) and yawing moment coefficient (C_n). The objectives are to determine $C_{N\alpha}$, $C_{m\alpha}$, and some lateral-directional dynamic derivatives. It should be noted that to estimate these derivatives, flight conditions exhibited in the flight data must be specified. For the longitudinal aerodynamics, the estimated C_N and C_m are compared with data in Figure1 with good agreement. For the longitudinal derivatives, the following conditions are chosen:

M=0.33, V=350 ft/sec, α = 4.0 deg., k = 0. (static), δ_s (trim elevator position) = -0.3 deg., δ_e = 0.3 deg.

The angle of attack is varied over $\Delta\alpha = 0.5$ degree. The results are presented in Figure 2.

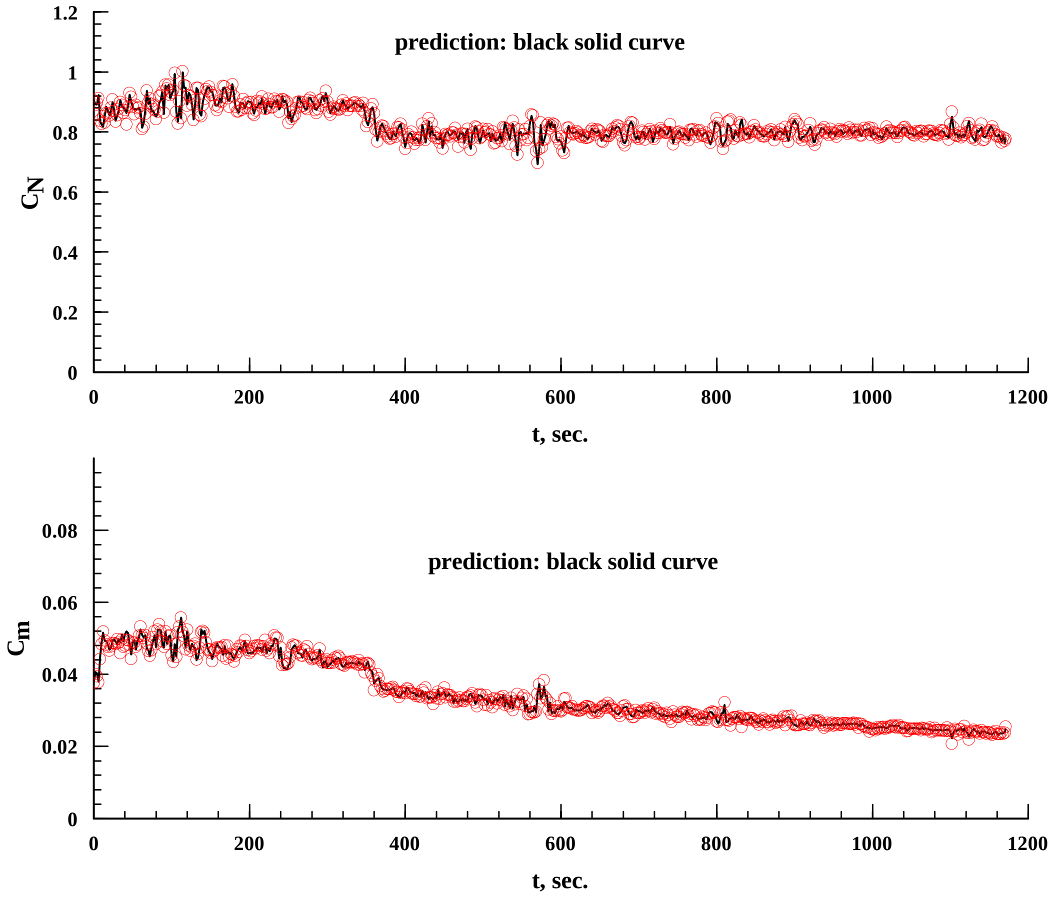


Figure 1. Longitudinal aerodynamics in climbing flight

At α = 4 degrees, $C_{N\alpha}$ = 3.644 per radian, and $C_{m\alpha}$ = -0.1455 per radian. For the lateral-directional aerodynamics, only a slow banking motion was present during the period of 84 – 210 seconds. Since parameters are identifiable only if the related motions are excited, only the flight data in the aforementioned time period plus some records before and after this period are used in modeling. To extract the dynamic derivatives, the following oscillatory flight conditions are specified:

k= 0.01, M = 0.24, V=260. ft/sec., δ_a = 2.7 deg. (rolling), = 2.4 deg. (yawing), δ_r = 0. α = 6 deg.

The roll deflection is chosen to coincide with the maximum aileron deflection to recover from the bank; while the aileron deflection for yawing derivatives is that at maximum yaw rate. To obtain yaw derivatives, a yawing motion of 0.5 degree in amplitude is specified. The results are presented in Figure 3a and b. To obtain the roll damping derivative, a roll amplitude of 16 degrees is specified. This is because k (the reduced frequency) is small, so that a large amplitude is needed to generate enough roll rate. The results are presented in Figure 3c. Based on these results, we can determine that at $\psi = 0$, $C_{nr} = -0.258$ and $C_{n\beta} = 0.197$ per radian; and at $\phi = 0.$, $C_{lp} = -0.334$. These lateral-directional derivatives are comparable to those given in reference 4 for a different turboprop transport ($C_{n\beta} = 0.155$ per radian, $C_{nr} = -0.25$, $C_{lp} = -0.52$ at $\alpha = 0$ deg.), except the present roll damping is much lower.

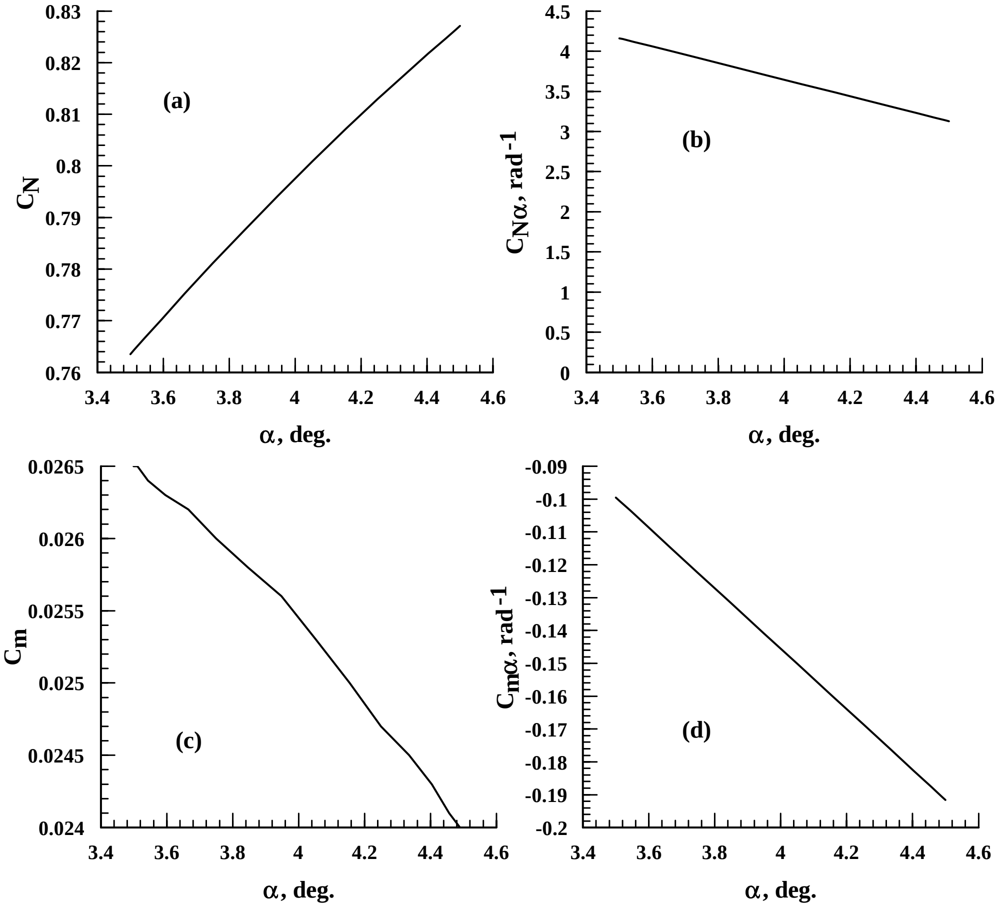


Figure 2 Static longitudinal aerodynamics. M =0.33, δ_s (trim elevator position) = - 0.3 deg., δ_e = 0.3 deg.

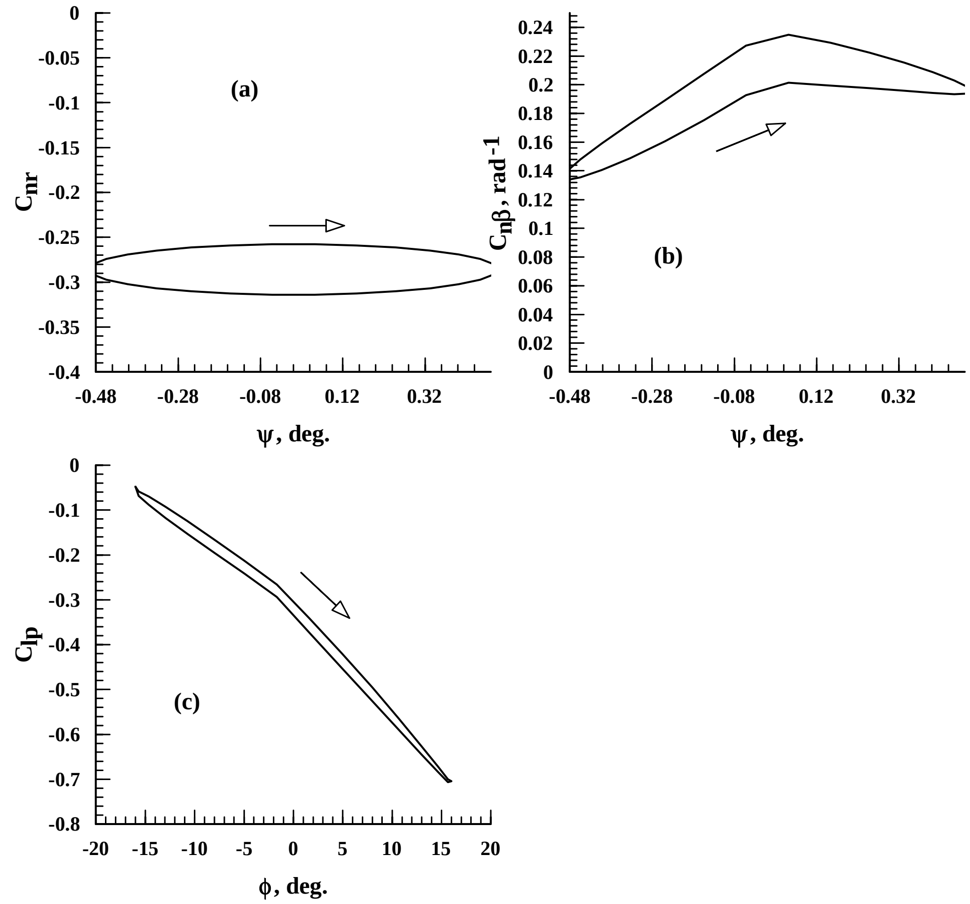


Figure 3 Lateral-directional derivatives. M = 0.24, k=0.01, δ_a = 2.7 deg. (rolling), = 2.4 deg. (yawing), δ_r = 0. α = 6 deg.

Accident Flight

The aircraft attitudes and trajectory in the last 283 seconds are re-created in figure 4. As can be seen, the accident scenario started in rolling motion. This will be verified further with engineering plots. Therefore, only three (3) aerodynamic models for the normal force, pitching moment and rolling moment coefficients will be generated.

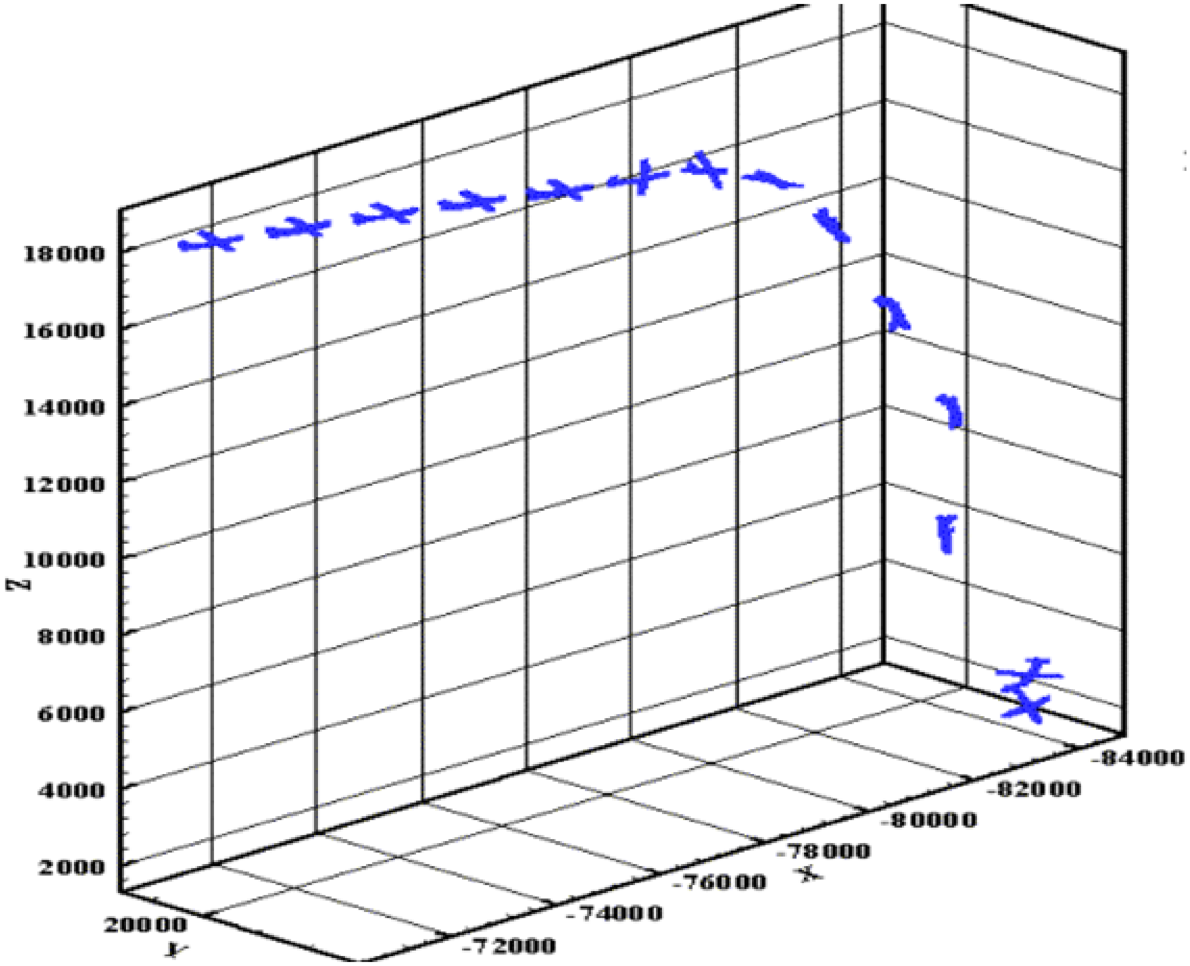


Figure 4 Schematic of GE 791 during the last 288 seconds

The variation along the flight trajectory for these three coefficients are presented in figure 5. It is seen that the model-predicted results match data very well. In fact, all correlation coefficients exceed 0.999. The yawing moment coefficient model is not established, because the yaw rate and sideslip angle were not significant. And if a specific flight variable is not excited in a motion, flying quality parameter corresponding to that variable cannot be identified or calculated.

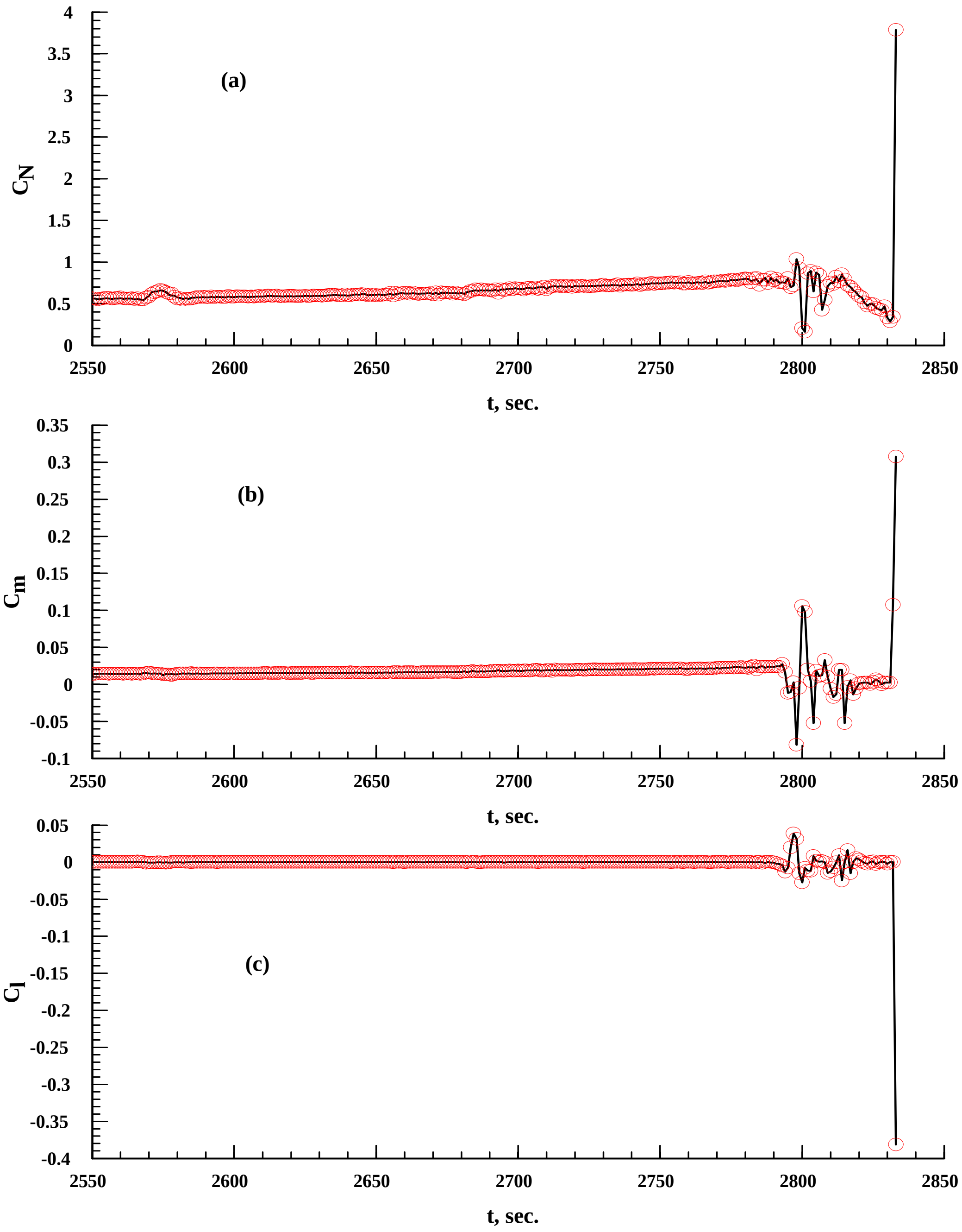


Figure 5 Comparison of predicted aerodynamic coefficients with data along the trajectory

Actually, data of the last 533 seconds are employed in the fuzzy logic modeling technique. In this time period, it was certain that icing on the aircraft would be significant throughout. If the analysis covers a larger time period, an observable flight variable would be needed to distinguish icing level and non-icing conditions. Currently, there is no such variable available in the FDR. Time histories of some primary flight variables are shown in figure 6.

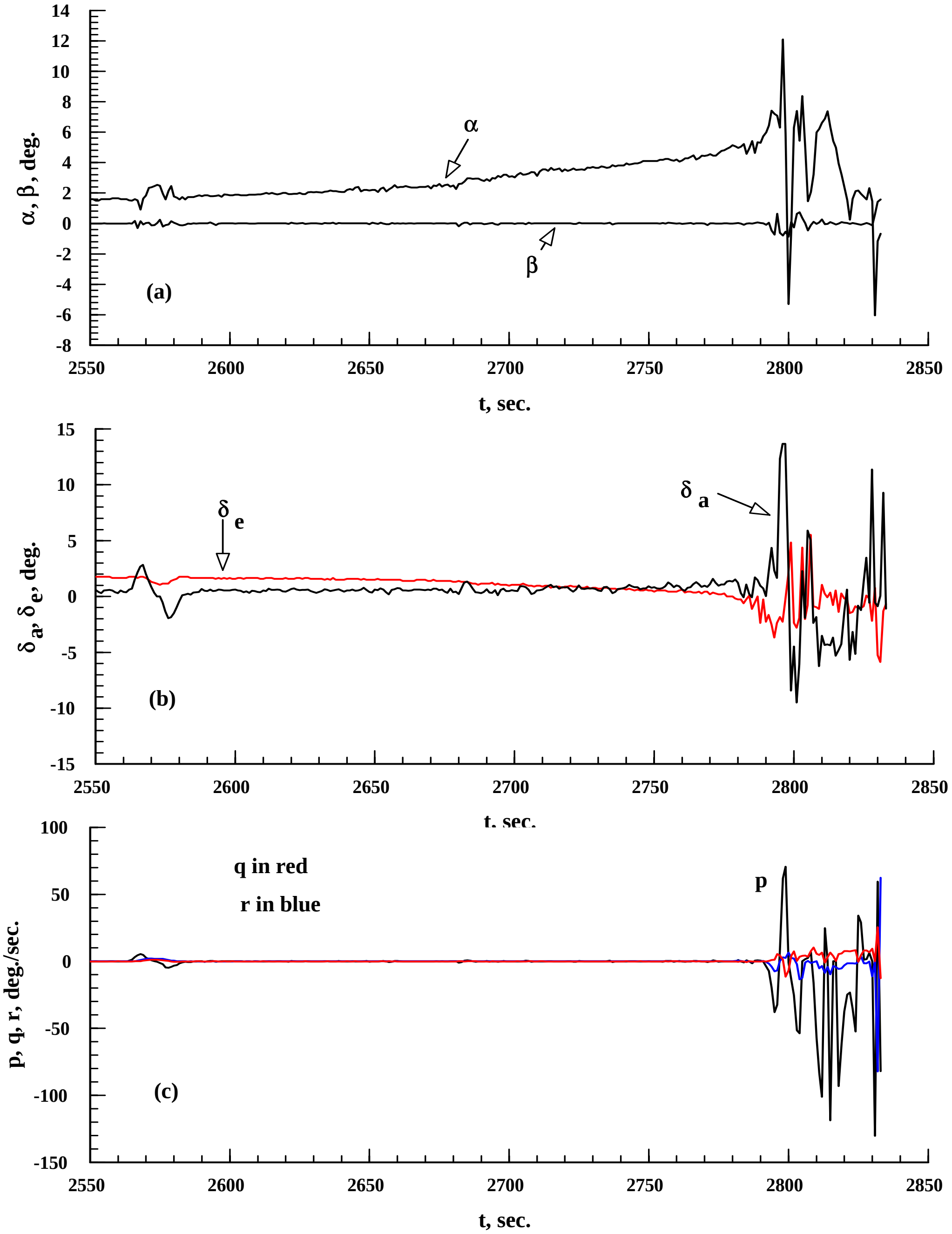


Figure 6 Variation of flight variables of GE 791 along the trajectory

It is seen that large roll rates started at about $\alpha = 6$ deg. (fig. 6a), and the aileron was active (fig. 6b). In figure 6c, it is shown that roll rate is the primary angular rate affecting the motion. In figure 7, the normal force coefficient slope with α before roll excursion is estimated to be about 2.2 per radian. Since the effectiveness of both the elevator and stabilizer before the roll excursion appeared to be small (fig. 7b and fig. 8b), tail icing might have started before wing ice accretion.

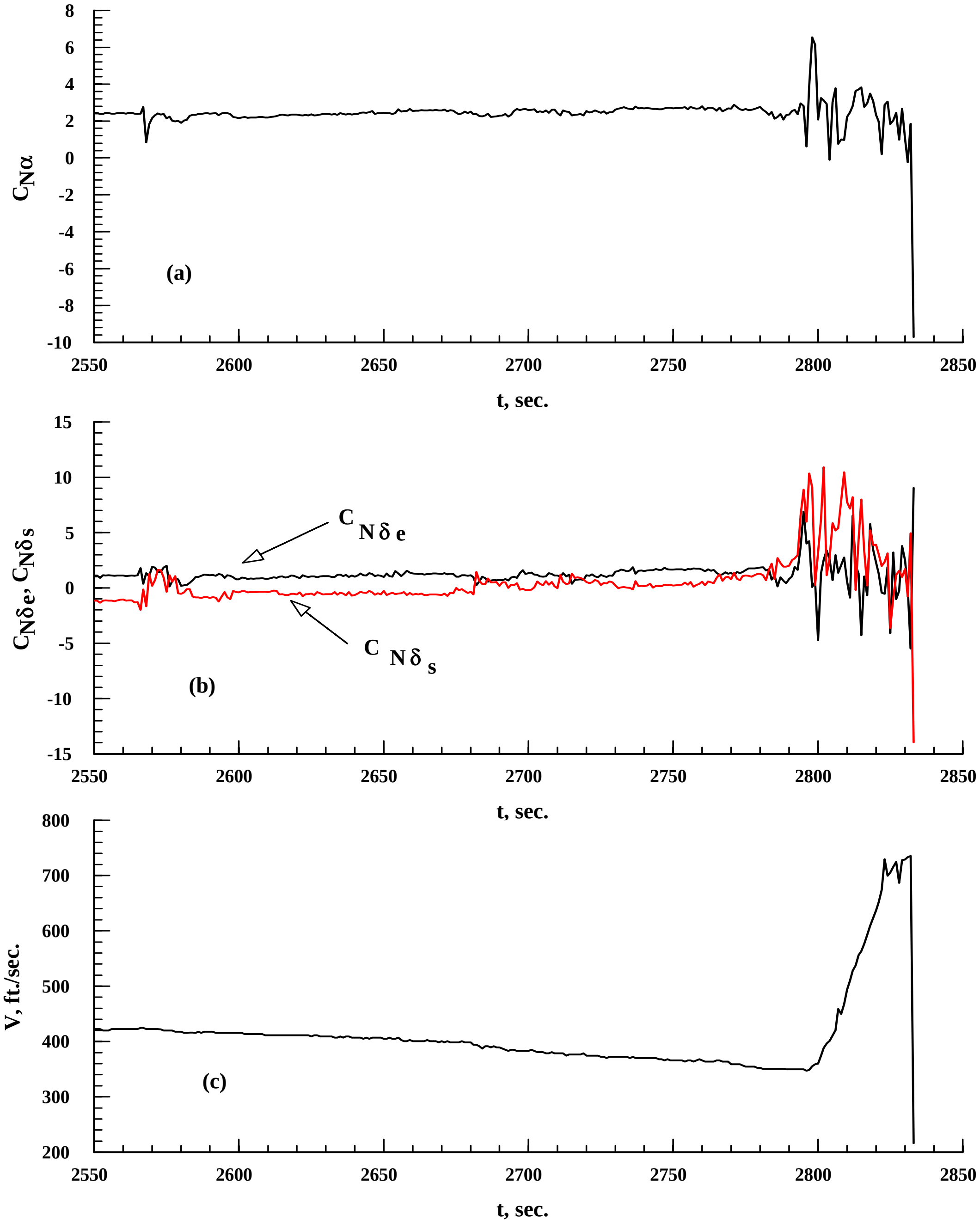


Figure 7 Calculated derivatives for the normal force coefficient along the trajectory

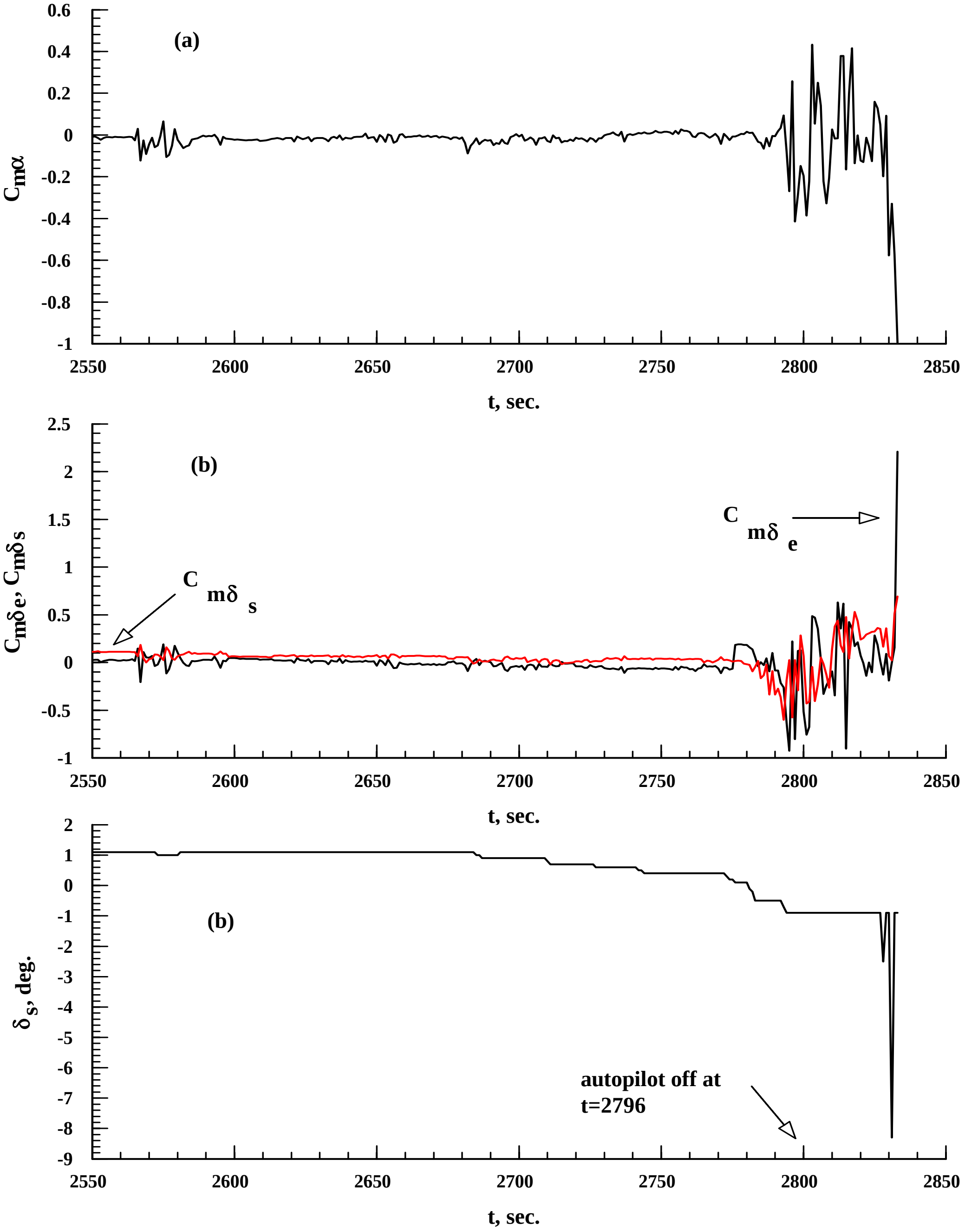


Figure 8 Calculated derivatives for the pitching moment coefficient along the trajectory

The speed decrease at a rate of 0.28 ft./sec per second means that wing ice has increased the aerodynamic drag slightly. In figure 8a, it is seen that longitudinally it was almost neutrally stable (i.e. small negative $C_{m\alpha}$). But the stabilizer angle, although small, moved toward the negative side slowly to produce the nose-up pitching moment probably to counteract the nose-down pitching moment due to ice. Of course, reduced effectiveness of the stabilizer also means it required adjustment continuously.

The main interest in the present case is in the behavior of rolling moment. Figure 9a shows that the dihedral effect is unstable ($C_{l\beta} > 0$) and the roll damping is also slightly unstable ($C_{lp} > 0$, see fig. 9b).

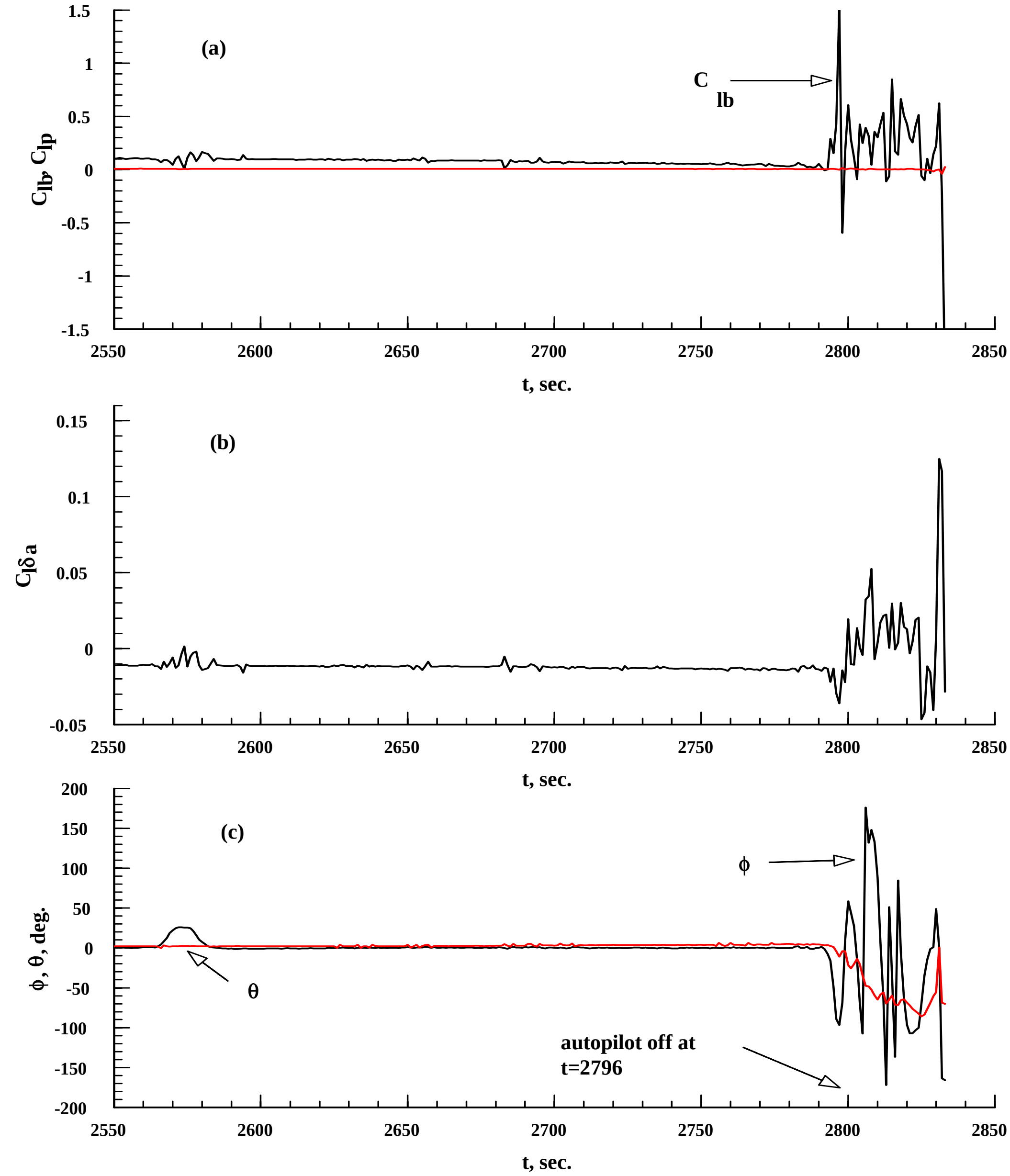


Figure 9 Calculated derivatives for the rolling moment coefficient along the trajectory

And the roll control effectiveness is negative ($C_{l\delta a} < 0$) before roll excursion. According to the conventional sign, if the roll control is effective, $C_{l\delta a}$ should be positive. Before the scale in figure 6a for C_{lp} is too small, it is re-plotted in figure 7b to show that it is positive.

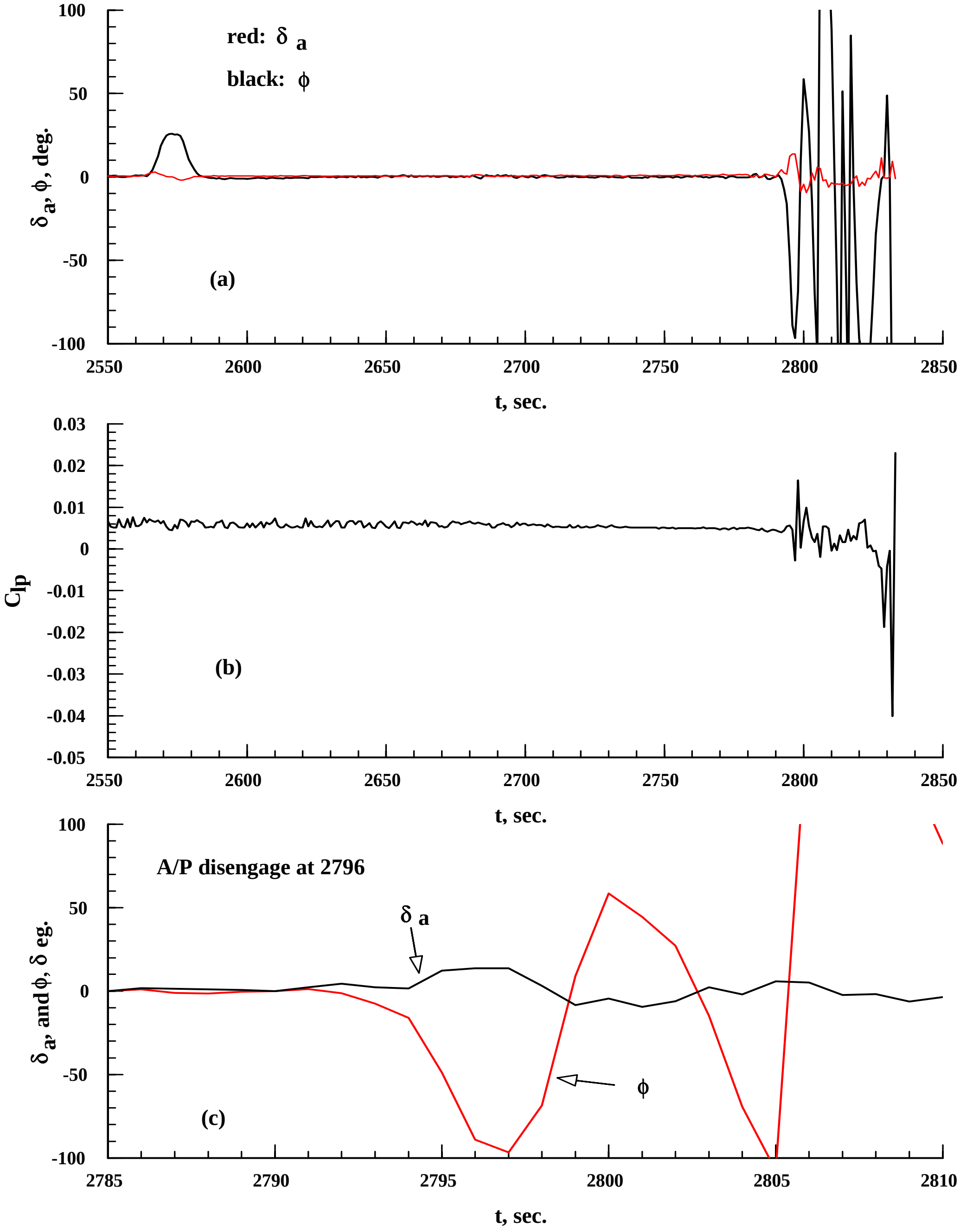


Figure 10 Enlarged plotting of rolling characteristics along the trajectory

In figure 10a with the roll angle and aileron deflection superposed, it is seen that initially the aileron deflection is opposite that of the bank angle before the autopilot disengage. This plot (fig. 10a) is further enlarged in figure 10c. Furthermore, during the roll excursion, there was a divergent roll oscillation. In the first 10 seconds, the rolling motion looks like a wing rock that is a limit-cycle oscillation. But because of increasing angle of attack and the dihedral effect being unstable, the rolling motion became divergent.

For a wing rock to occur, the necessary condition is that the roll damping must be unstable (i.e. C_{lp} >0. But to develop and maintained a limit-cycle oscillation, the dihedral effect must be stable (ref. 5). To examine these conditions from another viewpoint, response in rolling moment to a roll oscillation is calculated by using the established rolling moment aerodynamic model. The conditions of the roll oscillation are specified to be:

Amplitude =40 deg., k=0.03, M=0.4, V = 400 ft./sec.
α = 6 deg., δ_r =0.

The results are extracted from the aerodynamic model and presented in figures 11a with β effect and 11b without β effect.

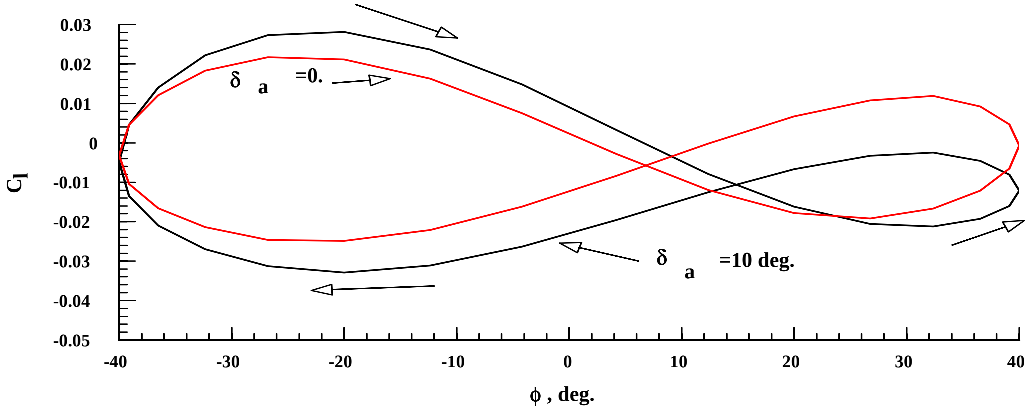


Figure 11a Response in rolling moment with β effect to a rolling oscillation input at k=0.03, M = 0.4, V=400 ft./sec., α = 6 deg.

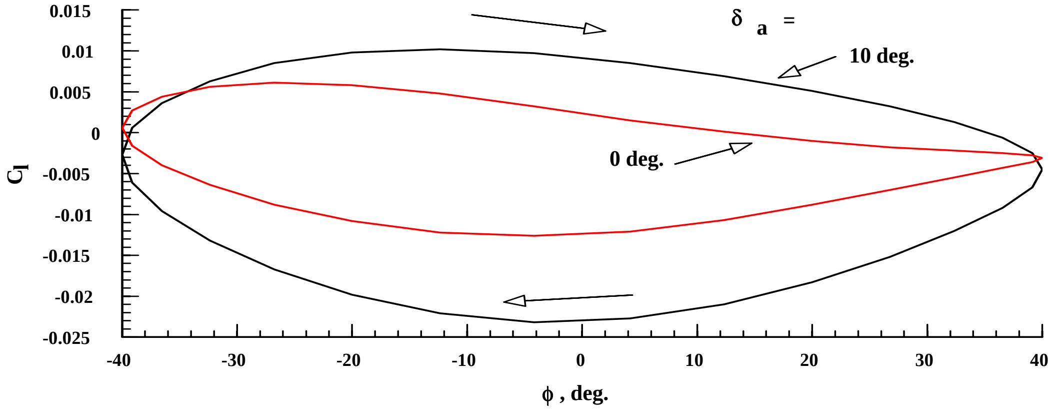


Figure 11b Response in rolling moment without β effect

The β effect is present when rolling about the body axis at an angle of attack is performed. On the other hand, if the rolling is about the stability axis, no β would be generated. Figure 6a indicates that β is small; but not zero. Both figures show interesting hysteretic characteristics. It is well known that if hysteretic loop is clockwise, the oscillatory roll damping derivative $(C_{lp})_{osc}$ is positive, implying dynamic instability. On the other hand, a counterclockwise hysteretic loop implies a negative $(C_{lp})_{osc}$, and hence, dynamic stability. Figure 11a shows that left roll is unstable, so that the aircraft will roll to the left under any disturbance, not necessarily due to aileron deflection. Besides, the aileron has lost its effectiveness already (fig. 9b). As the left roll angle became large, $C_{l\beta}$ changed its sign to negative (stable), and the aircraft would roll back. Note that all rolling moment derivatives are primarily contributed from the wing. If wing rock was the cause, it would not be possible to control the aircraft and recover from the disaster, not only because of the issue of control effectiveness, but also a human pilot just can not provide timely roll control input for stability augmentation. To damp wing rock, the only way is to generate artificial damping moment (ref. 6).

Based on these results, we can now compare the roll excursion scenario between the Roselawn case (fig. 12) and GE 791:

Roselawn case	GE 791
No roll oscillation	roll oscillation
In descent and holding pattern	in cruise
No stall warning sounded	stall warning sounded
Propeller RPM=77%	Propeller RPM=86%
Speed decreased faster	speed decrease was slight and eventually it was increased fast
autopilot disengaged	autopilot disengaged
$\alpha \cong 6$ deg.	$\alpha \cong 6$ deg.

Note that roll oscillation was also present in the Antonov AN-12 icing accident on January 31, 1971, as mentioned in ref. 3.

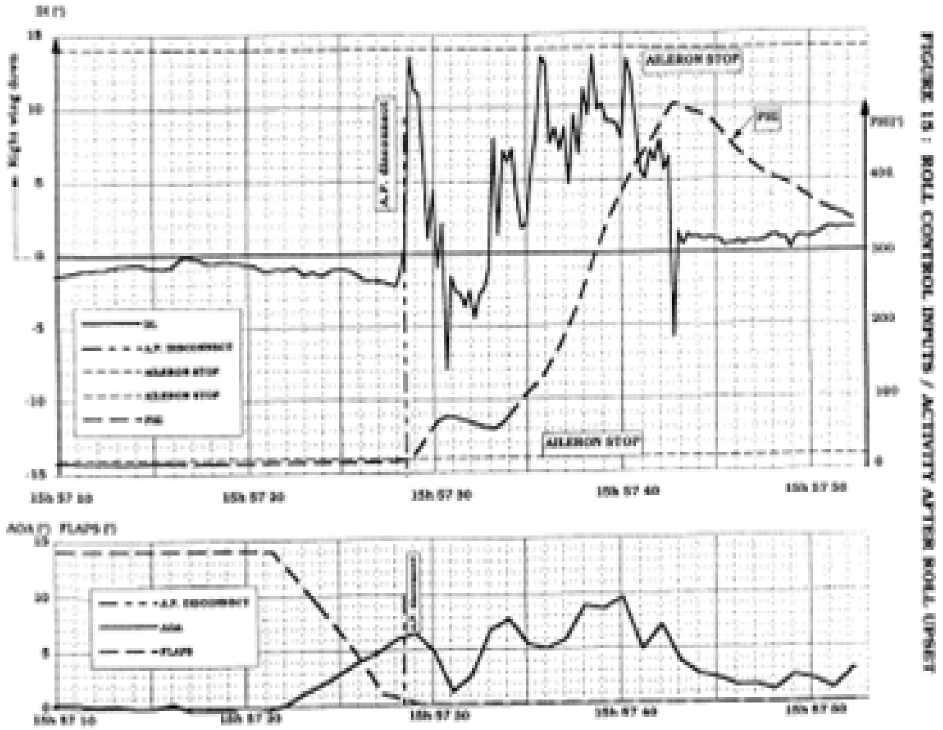


Figure 12 Roll characteristics of an ATR-72 in Roselawn, IN accident

Finally, we will examine the possibility of early ice detection. One proposed scheme of ice detection was based on change in short period mode. However, to detect the short period motion, the aircraft must be intentionally disturbed, by a doublet input for example. This would be too risky. In the case of GE 791, although the first visual contact of icing was established at UTC 17:32:35 (the present time = 1620), significant icing might have developed much earlier. To check if it is possible to determine more accurately possible starting time for "significant" icing built-up, we will use the concept of data correlation. Data between 1450 to 1550 seconds (the present time) in the normal force coefficient are employed to set up the aerodynamic model. The results are plotted in figure 13. It is seen that the correlation is poor because of large errors at some data points. After the model stops changing, those data points with large errors are removed and model training is continued. The process continued until the correlation coefficient reached a high value (>0.95). Based on this process, the following results are obtained:

(1) Initial $R^2 = 0.918$
(2) After points at 1487, 1490, 1498 are removed, $R^2 = 0.935$.
(3) After additional points at 1484, 1542 and 1544 are removed, $R^2 = 0.9479$.
(4) After additional points at 1489 and 1481 are removed, $R^2 = 0.972$.

It appears that change in stabilizer angle could represent another scheme of ice detection. But the change may be too small to avoid false alarm.

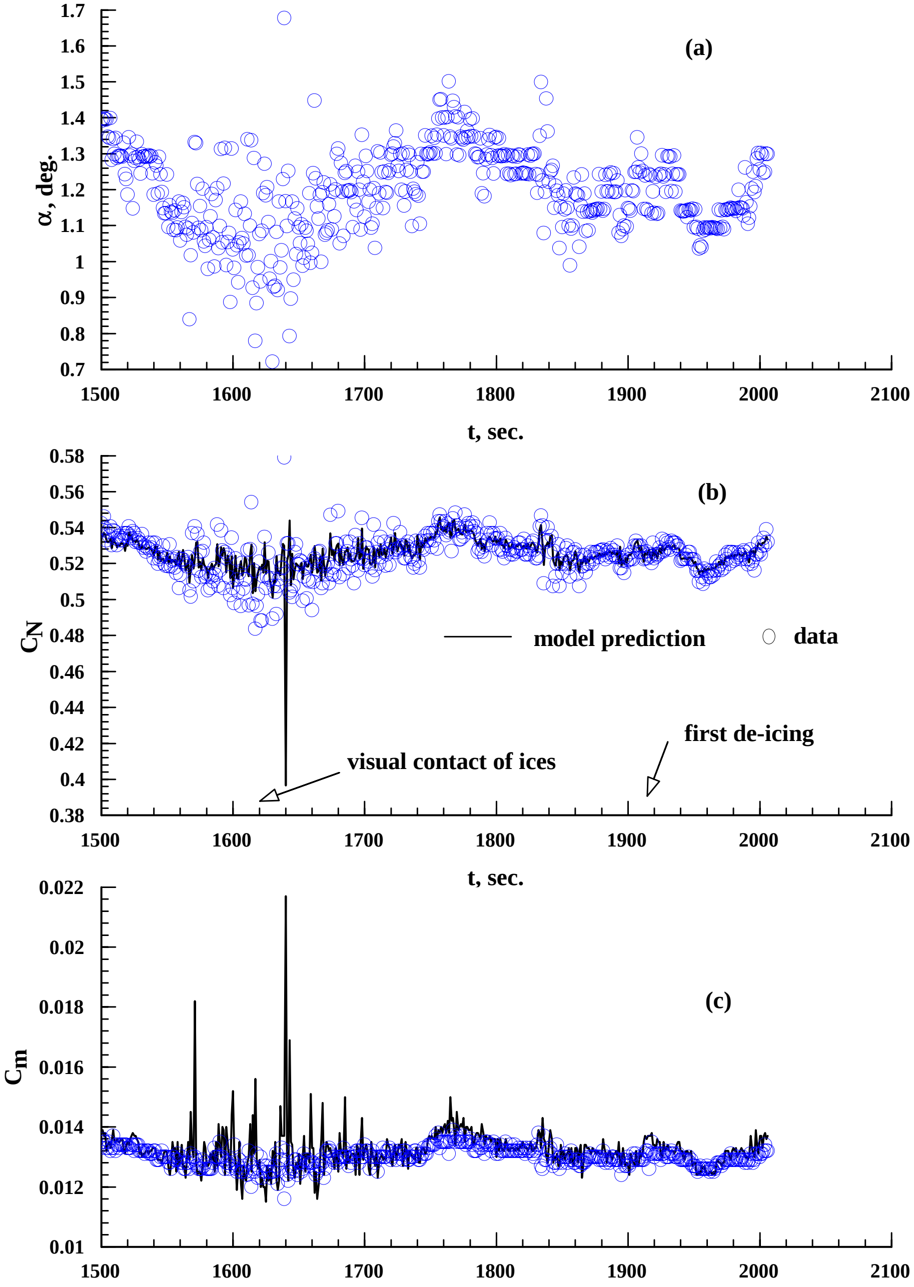


Figure 13 Normal force and pitching moment coefficients for GE 791 in the period of ice built-up

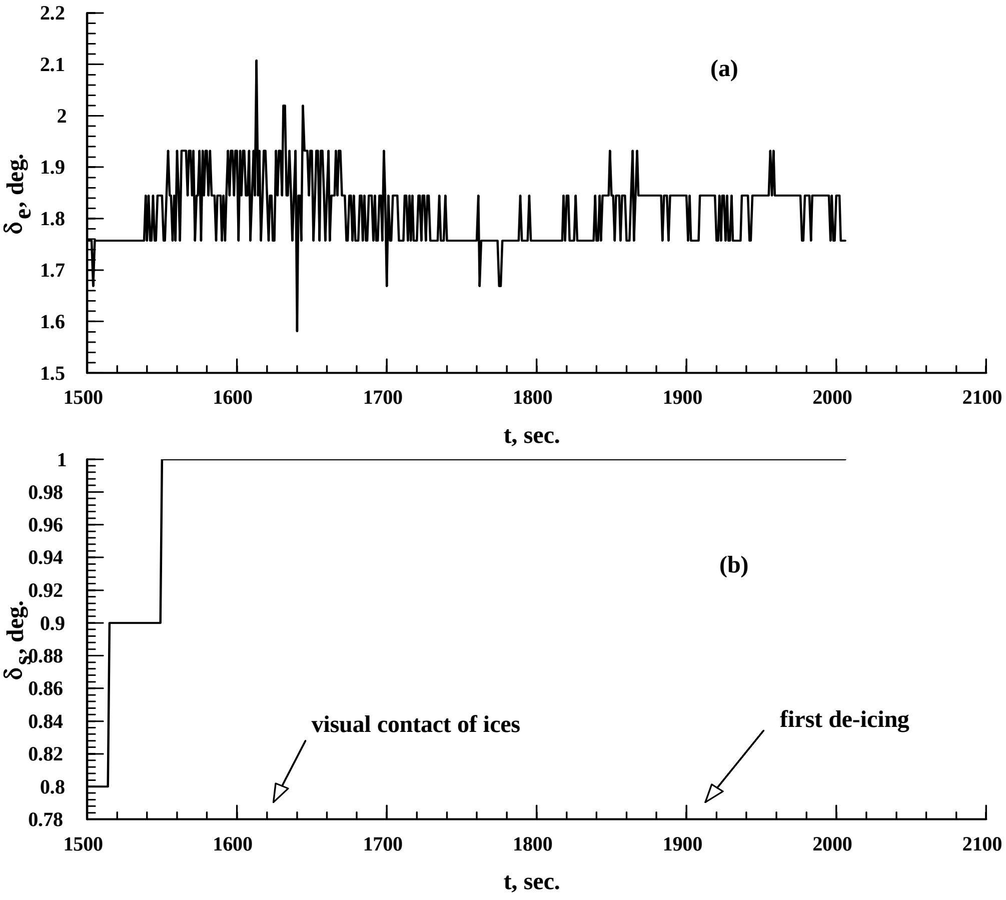


Figure 13. Concluded

Based on these results, it may be concluded that significant icing occurred after 1480 (UTC 17:30:15) and it can be detected by using data correlation.

Concluding Remarks

Based on the FDR data, aerodynamic models for the normal force, pitching moment and rolling moment coefficients were set up with a fuzzy logic algorithm. By calculating the stability and control derivatives from the established aerodynamic models, it could be concluded that:

(1) All stability and control derivatives became unstable before roll excursion;
(2) Flight departure occurred only at a high enough angle of attack, such as 6 degrees;
(3) The mode of departure was divergent wing rock.

Finally, based on data correlation concept, it was shown that it could be possible to detect the occurrence of significant icing.

References

(1)“GE 791 Accident Investigation, Factual Data Collection Group Report”, ASC-GRP-03-10-001, Oct. 28, 2003.

(2)“In-Flight Icing Encounter and Loss of Control, Simmons Airlines, d.b.a. American Eagle Flight 4148 Avions de Transport Regional (ATR) Model 72-212, Roselawn, Indiana, Oct. 31, 1994,” NTSB/AAR-96-01, July 9, 1996.

(3)“In-Flight Icing Encounter and Loss of Control, Simmons Airlines, d.b.a. American Eagle Flight 4148 Avions de Transport Regional (ATR) Model 72-212, Roselawn, Indiana, Oct. 31, 1994,” NTSB/AAR-96-02, July 9, 1996.

(4) Coe, P. L.; Turner, S. G. and Owens, D. B., “Low-speed wind-tunnel investigation of the flight dynamic characteristics of an advanced turboprop business/commuter aircraft configuration,” NASA TP 2982, 1990.

(5) Hsu, C. H. and Lan, C. E., “Theory of Wing Rock,” *Journal of Aircraft*, Vol. 22, Oct. 1985, pp. 920-924.

(6) Luo, J., and Lan, C. E., "Control of Wing-Rock Motion of Slender Delta Wings," *Journal of Guidance, Control and Dynamics*, Vol. 16, March-April 1993, pp.225-231.

Appendix 24 Comments on the Report to ASC on Performance and Stability Analysis of Flight GE791 Accident

Comments

on the Report to ASC

On

Performance and Stability Analysis of Flight GE791 Accident

[redacted]

ATR Flight Physics Director

and

EADS Flight mechanic Expert

Introduction:

The aim of this note is to produce relevant comments on the report" Performance and stability Analysis of flight GE 791 Accident", in particular during the 4mn before autopilot disconnection.

Comments:

Page 2: *Because it happened at a relatively low angle of attack (=6 deg)*

It is worth to specify that the following relation between true AOA and Vane AOA is:

True AOA = Vane AOA*0.6262 + 0.98

> -The Roselawn accident occurs at Vc= 187Kt and AOA (Right vane+ Left vane)/2 = 5.5°) True AOA = 4.4°
>
> - The GE 791 Accident occurs (beginning of roll departure) Vc= 158Kt and AOA (Right vane+ Left vane)/2 = 8°
>
> True AOA = 6°

Page 3: *Power = (average percent Torque in FDR) * max.power*2*550,ft-lb/sec*

This approximate formula must take into account the RPM of the propeller Aircraft.

> - Power = (average percent Torque in FDR) *(average percent RPM in FDR) * max.power*2*550,ft-lb/sec

Page:3 *The aileron deflection angle is given by the left aileron position reading :* $\delta_{a,left}$ *. A positive deflection of aileron would produce a positive rolling moment and a bank angle to the right.*

Unfortunately the left aileron data is recorded with a wrong sign. The proof is given on Chart 14 of performance analysis.

In this case, either we consider that it is the right aileron($\delta_{a,right}$):

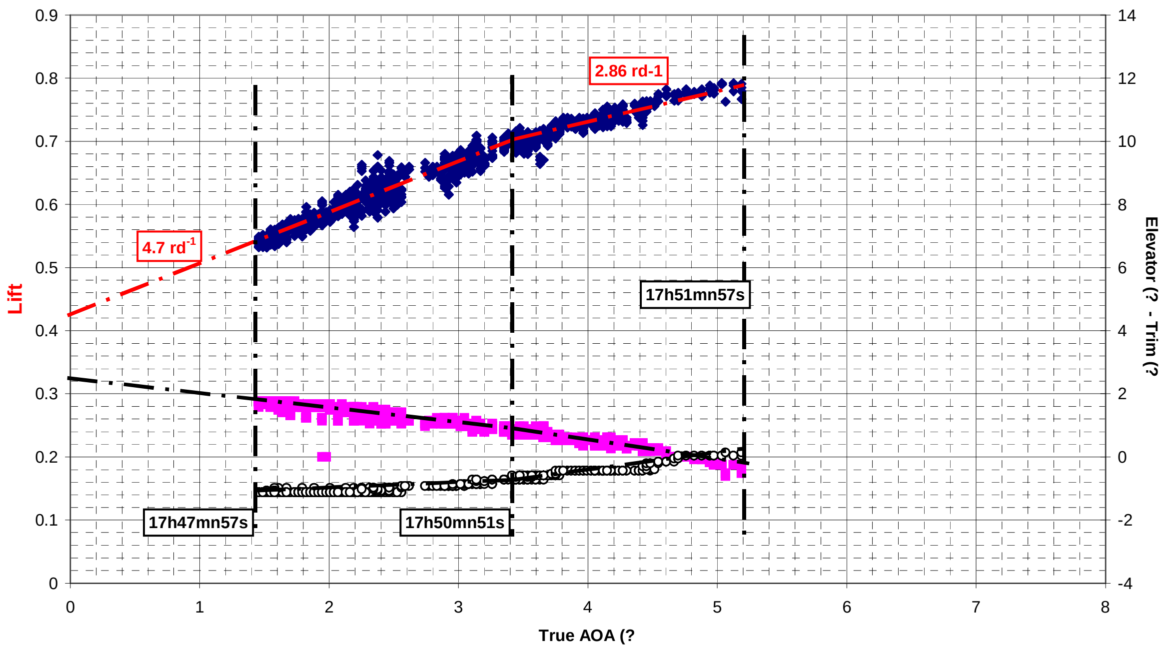
> - A positive deflection of aileron would produce a negative rolling moment and a bank angle to the left.

Or, we consider that it is the left aileron ($\delta_{a,left}$) and it is necessary to change the sign of the left aileron recorded:

- A positive deflection of aileron would produce a positive rolling moment and a bank angle to the right.

Page 4 *In figure 4, the normal force coefficient slope with* α *before roll excursion is estimated to be about 2.2 per radian.*

Figure: 1 - AC 322 LONGITUDINAL STABILITY



The figure 1 shows that between 17h 47mn 57s to 17h 50mn 51s the lift coefficient is 4.7^{rd-1} **and not 2.2** $^{rd-1}$**.**

Page 4: *Since the effectiveness of both elevator and stabilizer angle before the roll excursion appeared to be small (fig 4b and 5b), tail icing might have stuttered before wing ice accretion.*
Remember: All ATR and in particular ATR 72 200 is fitted with a fixed Tail plane and the longitudinal stability of the aircraft is realised by the elevator. As the ATR 72 200 has all controls unpowered, a little surface called "trim tab" reduces and cancels the pilots or auto pilot stick forces.

The sign of these surfaces are:

- Elevator deflection : Positive value gives pitch down (trailing edge down)
- Elevator trim deflection: Positive value gives pitch up (trailing edge up)

The efficiencies of these surfaces are:

- Elevator lift gradient : $Cz_{\delta e} = 0.405^{rd-1}$
- Elevator trim lift gradient: $Cz_{\delta trim} = 0.0635^{rd-1}$
- Elevator pitching moment efficiency: $Cm_{\delta e} = -2.25^{rd-1}$

- Elevator trim pitching moment efficiency: $Cm_{\delta trim} = -0.389 \quad ^{rd-1}$

In the report to ASC the value in figure 4 are about:

- Elevator lift gradient :$Cz_{\delta e} = -1^{rd-1}$
- Elevator trim lift gradient : $Cz_{\delta trim} = 1 \quad ^{rd-1}$
- Elevator pitching moment efficiency : $Cm_{\delta e} = \quad 0^{rd-1}$
- Elevator trim pitching moment efficiency :$Cm_{\delta trim} = -1 \quad ^{rd-1}$

The values produced in the report to ASC are not correct and do not permit to evaluate correctly the longitudinal stability of this aircraft.

Longitudinal stability:

As that the tail plane works at lower AOA than the wing (-3 to -5°) it is possible to use ATR clean aircraft coefficient associated at the FDR coefficients (lift) and parameters (elevator).

Notice: In severe icing conditions and at positive AOA the flow separation appears always on the wing and never on the tail plane. On the other hand, at negative AOA the flow separation occurs always on tail plane.

In body axis the pitching moment is written:

$$Cm = Cm_{\alpha}*\alpha + Cm_{\delta e}*\delta e \quad + Cm_{\delta trim} * \delta trim + Cm_{\beta}*\beta \quad + Cmq_1*q_1*l/v \quad + Cm_{d\alpha/\delta\tau} *d\alpha/dt* l/v$$

As during this period the term in β, $q_{1,}$ $d\alpha/dt$, are negligible the equation is written:

$$Cm = Cm_{\alpha}*\alpha + Cm_{\delta e}*\delta e + Cm_{\delta trim} * \delta trim = 0.$$

$$Cm_{\alpha}*\alpha = - Cm_{\delta e}*\delta e - Cm_{\delta trim} * \delta trim$$

$$Cm_{\alpha =} \; - Cm_{\delta e\,*} \frac{\delta e}{\alpha} \; - Cm_{\delta trim} * \frac{\delta trim}{\alpha}$$

To compute the longitudinal stability of an aircraft it is necessary:

To take the lift and pitching moment values on a time interval and not on a single point because we have to compute differentials,

In this way we take a linear segment on lift and pitching moment and we calculate the differentials.

Note: In the Figure 1:

- All the points recorded in the DFDR have been used for calculations: the lift, (blue) elevator (pink) and trim (black areas).
- The lines in red (lift) black (elevator) and circled black (trim) are the averaged (smoothed) values.

- The trim sign is reported with the following convention: trailing edge down positive

Application at the GE 791 accident:

The Figure 1 shows three break points:

1) At 17h 47mn 57 the corresponding linear values are:
   - Alpha 1.4
   - Elevator 1.9
   - Tim -1.1°
   - Lift 0.535
2) At 17h 50mn 51s the corresponding linear values are:
   - Alpha 3.4
   - Elevator 1.
   - Tim -0.8°
   - Lift 0.7
3) At 17h 51mn 57s the corresponding linear values are:
   - Alpha 5.2
   - Elevator -0.2
   - Tim 0.1°
   - Lift 0.79

According the figure 1 the first linear segment is 17h 47mn 57s to 17h 50mn 51s:

In the note " comments to ASC the trim effect have been voluntary missed and the result were:

$$\mathrm{Cm}_{\alpha} = 2.25 * \frac{-0.9}{2} = -1.01\ ^{\mathrm{rd\text{-}1}}$$

With trim

$$\mathrm{Cm}_{\alpha} = 2.25 * \frac{1-1.9}{3.4-1.4} + 0.39 * \frac{-0.8+1.1}{3.4-1.4} = -1.07\ ^{\mathrm{rd\text{-}1}}$$

and

$$\mathrm{Cz}_{\alpha} = 57.3 * \frac{0.7-0.535}{3.4-1.4} = 4.727\ ^{\mathrm{rd\text{-}1}}$$

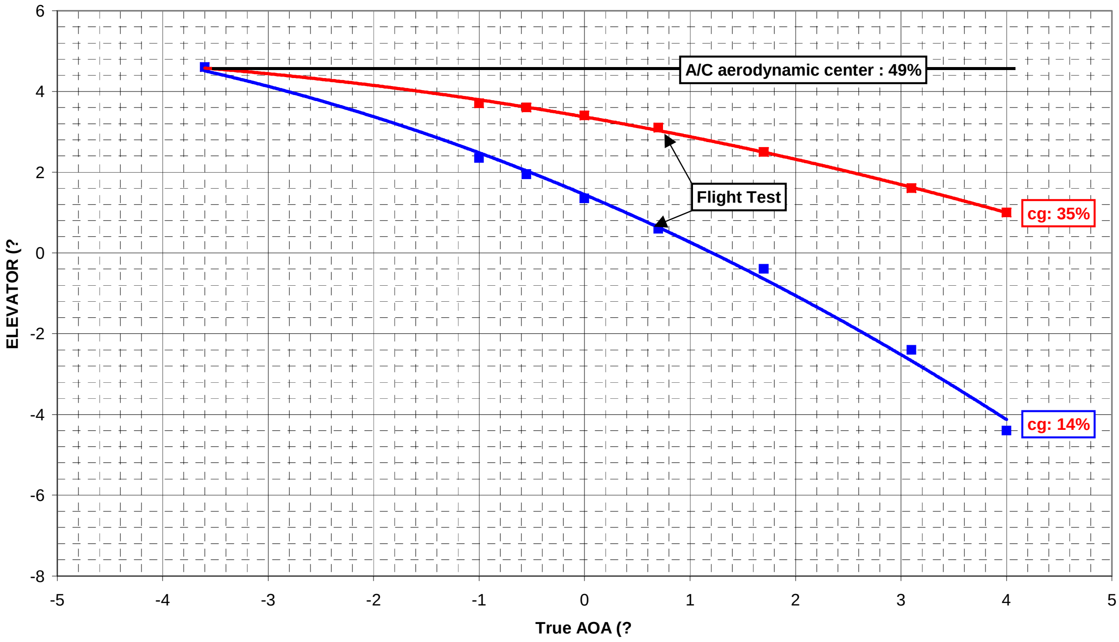
We obtain:

$$(0.28 - \frac{\mathrm{XF}}{mean\,Chord}) = \frac{-1.0T}{4.727}$$

The aerodynamic center of this aircraft is situated at $\frac{\mathrm{XF}}{mean\,Chord} = 0.506$.

Flight test conducted on ATR 72 200 A/C 98 shows that the aerodynamic center with the same configuration is situated at 49% of the Mean Chord. The small differences in the results are normal and come from: recording equipment and pick up installation, sampling, flight tests acquisition units, storage of data, conversion of recorded parameters into physics data, reading of curves made by specialists. For this reasons 1% of variation is largely tolerable and a closer look could reduce it, but in our case the margin is so huge and we accept the result.

Figure: 2 - ATR 72-200 - LONGITUDINAL STABILITY
CLEAN A/C - FLAPS 0 - POWERED



Longitudinal stability of A/C 322 (flight 791) is nominal in this period

During the second segment 17h 50mn 51s to 17h 51mn 57s:

$$Cm_{\alpha} = 2.25 * \frac{-0.2-1}{5.2-3.4} + 0.39 * \frac{0.1+0.8}{5.2-3.4} = -1.305$$

and

$$Cz_{\alpha} = 57.3 * \frac{0.79-0.7}{5.2-3.4} = 2.865 \ ^{\text{rd-1}}$$

We obtain:

$$(0.28 - \frac{XF}{mean\,Chord}) = \frac{-1.305}{2.865}$$

The aerodynamic center of this aircraft is situated at $\frac{XF}{mean\,Chord} = 0.735$

This period confirms that the tail plane is nominal because the aerodynamic center

moves back (generally a loss of efficiency of tail plane moves forward the aerodynamic center and reduces the longitudinal stability).

In fact the flow separation on the wing due to severe ice produces a loss of lift, which reduce the pitch up due to the wing and also reduce the downwash. These effects increase the Cm_{α} due to tail plane.

Remember:

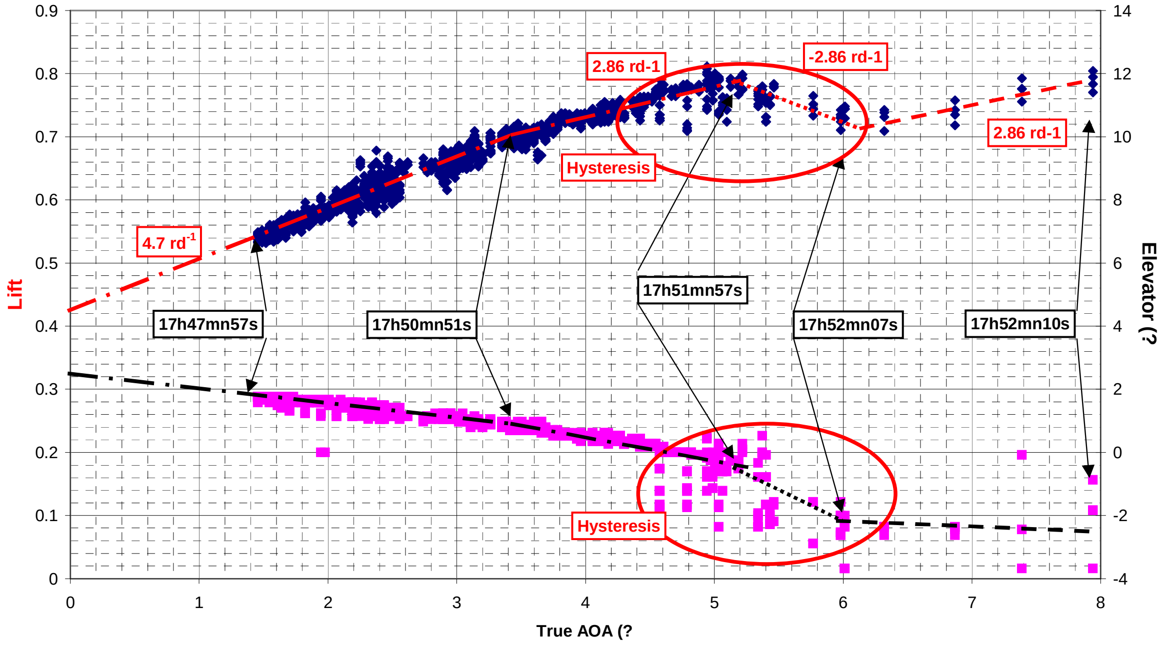
$$\Delta Cm_{\alpha \text{ (Tail plane)}} = Cz_{\alpha \text{ (Tail plane)}} * \frac{Arm\ between\ tail\ and\ wing}{mean\ chord} * (1 - \frac{d\varepsilon}{d\alpha})$$

In configuration flaps 0° , $\frac{d\varepsilon}{d\alpha}$ = 0.27 when the A/C is not polluted in this case the downwash is estimated to $\frac{d\varepsilon}{d\alpha}$ = 0.2

This proof that the loss of lift gradient is due only at the wing

3) 17h 51mn 57s to stall warning:

Figure: 3 - AC 322 LONGITUDINAL STABILITY



When the autopilot initiated the descent a flow separation occurs simultaneous on the two wings (no roll) up to AOA=6°, then an asymmetrical left roll appears.

During this period it is difficult to check correctly the longitudinal stability due to the aerodynamic hysteresis phenomenon on the lift (See figure:3). However the elevator efficiency is not affected and after the roll departure (17h52mn07s). The longitudinal stability after stall is reduced (but Aerodynamic center > 28%) and the recovery from stall can be performed because elevator remains always effective.

Page 4: *Figure 6a shows that the dihedral effect is unstable ($Cl\beta>0$) and the roll damping also slightly unstable (Clp >0 See figure 6b). and the roll control effectiveness is negative ($Cl_{\delta a}<0$) before roll excursion.* *<u>According to the conventional sign, if the roll control is effective, $Cl_{\delta a}$ should be positive.</u>*

The roll control effectiveness without spoiler is $Cl_{\delta a}= -2^{rd-1}$ when the following conventional sign is used: Aileron = (Right aileron - Left aileron)/2

And

$Cl_{aileron} = Cl_{\delta a}$ * Aileron /57.3

With this formula and after correction of the sign of FDR left aileron (see page 2) the roll control of the ATR 72 200 A/C 322 is nominal before the roll excursion.

The roll due to roll rate (p) is written:

Cl = Clp * p * C/V

With: Clp (rd^{-1}); p (rd/s); C aerodynamic chord (m); V aircraft speed (m/s)

The nominal value for an ATR 72-200 clean aircraft is : Clp = -34.9 $^{rd-1}$

The following approach allows knowing the Clp before autopilot disconnection.

Total Lift = Right wing Lift + Left wing lift

Right wing Lift = f(Alpha $_{right\ wing}$)

Left wing Lift = f(Alpha $_{left\ wing}$)

Alpha $_{right\ wing}$ (rd) = $AOA_{(true)}$ (rd) + p (rd/s) * Y (m) / V (m/s)

Alpha $_{left\ wing}$ (rd) = $AOA_{(true)}$ (rd) - p (rd/s) * Y (m) / V (m/s)

Total Roll = (Left wing Lift - Right wing Lift) * Y (m) / C(m)

C : Aerodynamic mean chord; Y : Lift application point along Y axis

According to the figure:1 $Cz_{\alpha} = 4.7^{rd-1}$ then $Cz_{\alpha} = 2.86^{rd-1}$ and according to the figure:3 Cz_{α} = -2.86 few seconds before the roll departure and Cz_{α} = 2.86 between roll departure and stall warning.

1) 17h 47mn 57s to 17h 50mn 51s : $Cz_{\alpha} = 4.7^{rd-1}$

Left wing Lift = 4.7/2 * (α - p*Y/V)

Right wing Lift = $4.7/2 * (\alpha + p*Y/V)$

Total Roll = $(4.7/2 * (\alpha - p*Y/V) - 4.7/2 * (\alpha + p*Y/V)) * Y/C$

$$\text{Total Roll} = -4.7*p*\frac{Y*Y}{V*C} = -4.7*p*\frac{Y*Y*C}{V*C*C}$$

As Cl = Clp * p * C/V

$$Clp * p * C/V = -4.7*p*\frac{Y*Y*C}{V*C*C}$$

$$Clp = -4.7*\frac{Y*Y}{C*C}$$

With Y= 6.2m and C= 2.3m Clp = -34 $^{rd-1}$

During this period the Clp is nominal

2) 17h 50mn 51s to 17h 51mn 57s : $Cz_{\alpha} = 2.86^{rd-1}$

Clp = - 20.7

During this period the Clp is not nominal but it is effective

3) 17h 51mn 57s to 17h 52mn 07s : $Cz_{\alpha} = -2.86^{rd-1}$

Clp = 20.7

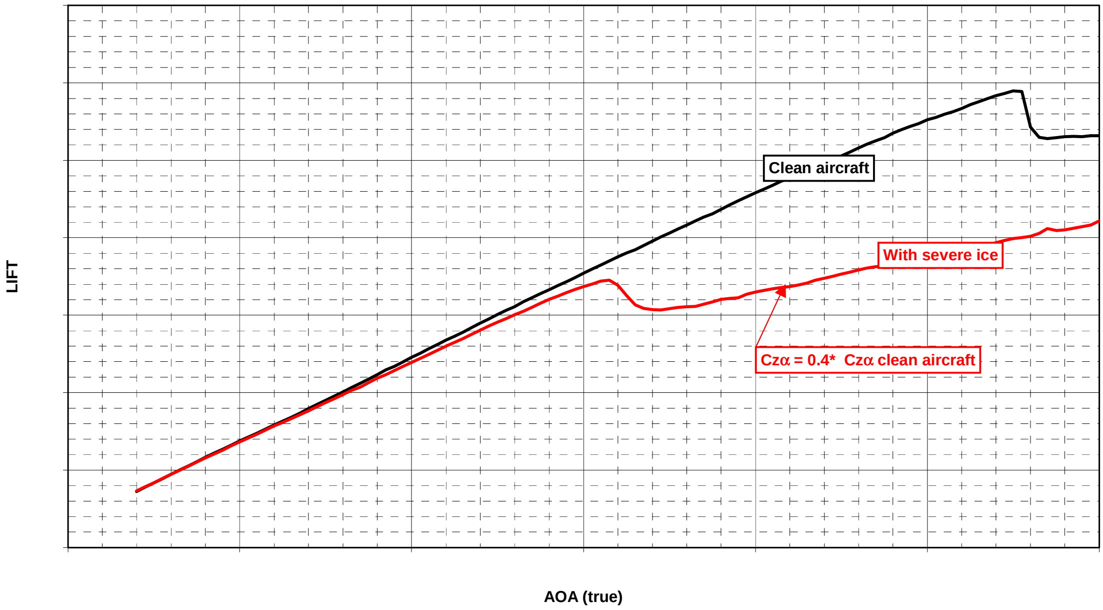
During this period flows separations occur on the wings, inducing a loss of lift (negative gradient) without roll.

4) 17h 52mn 07s to 17h 52mn 10s $Cz_{\alpha} = 2.86^{rd-1}$

Clp = - 20.7

After the roll departure the Clp is again effective but not nominal (50%)

Figure 4 : ATR 72 - WIND TUNNEL TEST



Note:

Wind tunnel tests conducted on a mockup (1/2 span; Scale: 1/8) with and without Severe Ice on the airframe show a same result on lift coefficient (See Figure 4)

When a flow separation occurs, the figures 3 et 4 show that a significant reduction of angle of attack (about 3°) during few seconds, leads the aircraft in a situation where all aerodynamic parameters are nominal.

Conclusions:

In the report "Performance and stability analysis of Flight GE 791 Accident", conclusions are affected by wrong control surface and aerodynamic coefficient assumption. This document qualifies and quantifies the errors and gives the following conclusion.

Except the 10s before the roll excursion (17h 51mn 57s to 17h 52mn 07s) where the longitudinal and lateral stability has been modified by the hysteresis due to flow separation, the longitudinal and lateral stability and the efficiency of the elevator and aileron are enough to recover the aircraft. In particular the application of recovery procedures using a significant reduction of aircraft AOA (3°) by a pitch down elevator input or flaps extension (15°) lead the aircraft in a situation where all aerodynamic parameters are nominal.

Appendix 25 Alert to Pilots for Wing Upper Surface Ice Accumulation

美國國家運輸安全委員會（NTSB）
華盛頓 DC 20594
2004年12月29日
****

敬告飛航組員：上翼面積冰
****

最近一次起飛意外事件引發了對上翼面積冰之影響有了廣泛的討論，美國國家運輸安全委員會（NTSB）對飛航組員發佈了以下的警示：

上翼面積冰警告

美國國家運輸安全委員會對於在機翼上翼面少量的積冰所造成的潛在危險已經有長久的關注，該會在針對2004年11月28日在克羅拉多州Montrose的一架Bombardier Challenger 604飛機意外事件的初步調查中揭露，在事件發生當時有大氣因素造成上翼面積冰的情況發生（飛機性能問題及包括上翼面結冰的可能性正進行調查中）（1）。

多年來飛航組員都瞭解，可見的機翼結冰將導致氣動力及操控上嚴重的破壞，然而很明顯的，許多飛航組員並不認為附著在機翼上微量的結冰也同樣會造成相同的破壞。研究結果顯示，若在上翼面每一平方公分面積內有一粒細如鹽粒大小的冰粒或霜粒存在，將足以破壞昇力以阻礙起飛，該會早已在過去多次飛機意外事件調查報告中論及上翼面積冰的危險，這些報告中部分的摘要如下：

---依據風洞實驗資料，密度在每一平方公分內僅僅有1-2厘米直徑大小的顆粒（食用鹽粒大小）所形成上翼面粗糙的程度，將分別造成地面效應與空中昇力22% 及33 % 的損失。(2)

---研究顯示，在起飛期間飛機上翼面幾乎無法察覺的積冰量將明顯的降低飛機性能，因此，美國國家運輸安全委員會在歷次的飛安建議中（包括2004年12月15日發給FAA的A-04-66安全建議）多次勸導飛航組員在執行上翼面檢查時要以目視與觸摸方式(3)。

---在上翼面的積冰，由於其為透明或白色所以可能難以從座艙內或自機翼前後目視察覺，美國國家運輸安全委員會強烈的相信，若要確定機翼沒有積冰唯有用手觸摸。(4)

---歷年意外事件檔案顯示：渦輪噴射、無緣縫翼（nonslatted）之運輸類型飛機在起飛意外事件中，有極高的數字是可能由於（或已證實）上翼面結冰的緣故所導致。(5)

---航空業界也承認，由觀察來判定機翼是濕的或是有冰膜產生近乎不可能，非常薄的冰膜或霜，對任何機種均會降低其氣動力性能。(6)

---美國國家運輸安全委員會認為，即使使用機翼檢查燈從約 30-40 呎外透過可能已經被淋濕了的窗戶去觀察，也不能算是仔細檢查，而足以造成氣動力性能問題的微量積冰，是難以不用觸摸檢查而察覺。(7)

---FAA 的「環境結冰 Environmental Icing」國家資源專家（NRS）指出，他擔心大多數的飛航組員根本不瞭解，微量的霜或積冰會大大的降低飛機的性能。飛航組員或許會觀察到他們認為不太大量的機翼表面結冰，但卻不瞭解將面臨因結冰而飛機性能降低的風險。(8)

---從氣動力的觀點而言並沒有「些微結冰（a little ice)」這回事，但確保起飛前重要之飛機表面無任何結冰的議題則應嚴肅看待。(9)

---很奇怪的是，一層非常薄，薄到難以看出來的雪或冰，將嚴重降低現代飛機的性能（Jerome Lederer, M.E., 1939)。(10)

---儘管意外事件及研究證據顯示，小到無法以目視察覺到的上翼面積冰將與大量積冰（較能目視的）對氣動力的損失造成相同結果。但最近的幾起意外事件顯示，飛航組員仍然不重視微量積冰所潛存的後果。諸如，參閱 2001 年 10 月 10 日在阿拉斯加 Dillingham 一架 Cesssna 208 N9530F 意外事件終結報告。(11) 及參閱 2002 年 1 月 4 日在英格蘭 Birmingham 一架 Bombardier Challenger 604, N90AG 意外事件終結報告。(12)

顯然飛航組員認為，若從遠處或從機艙或客艙內看不到機翼上有冰或霜，就是沒有結冰，而即使有結冰但也看不出來的話，這些積冰量也就太少而不會有任何後續的影響。縱然證據顯示與想法相左，但飛航組員的這些想法可能仍然存在，因為許多飛航組員在飛行中都見過大量的冰附著在翼前緣上（包括大量的尖角狀積冰)，更認為在上翼面一層薄薄的冰或霜將不會有任何的影響。然如前述研究顯示，上翼面微量積冰與大量積冰（較能目視的）同樣將造成氣動力嚴重的降低。

可能許多飛航組員相信，只要有足夠的引擎動力，就可以輕易的以動力來克服在上翼面微量而看不出來的積冰所造成性能降低之問題，然而當飛機離地通常攻角達到最大時，引擎的動力將無法克服其導致的失速及失控。此外，小區塊無法察覺的冰或霜將在機翼上造成區域性的不對稱失速，也將導致離地時的側滾操控問題。

美國國家運輸安全委員會指出，有一些上翼面積冰的情況是難以用目視察覺的，如依飛機設計之不同（大小、高翼、低翼等）及環境與燈光情況（濕翼、暗夜、燈光黯淡等），使飛航組員難以從地面或由座艙及其他窗口以目視發現上翼面結冰，其他如霜、雪及霜淞冰，在白色的上翼面也很難被察覺，而明冰在任何顏色的上翼面均難以被辨認。然而，不論以任何方法在起飛前確認上翼面無積冰的情形是極為重要的。這也是為何安全委員會最近發佈的 A-04-66 飛安建議的原因，以督促飛航組員用目視及觸摸去檢查飛機之上翼面。

至少要讓飛航組員瞭解，上翼面沒有任何的積冰才能視為可以安全的起飛。然而，歷次資料顯示，唯有謹慎周密的飛行前檢查，包括觸摸檢查與適時執行除冰程序，儘管在冬季時不幸遭遇狀況，也能安全的操控飛機。

（1）其他有關此次意外事件之資訊可至美國國家運輸安全委員會網站 http://www.ntsb.gov, accident number DEN05MA028 查詢。

（2）此資訊取自 1992 年 3 月 22 日美國航空 405 航班於紐約 Flushing 意外事件之美國國家運輸安全委員會終結報告。其他相關資訊請參閱該委員會 1993 年美國航空 405 班機 Fokker F-28, N485US, 1992.03.22 在紐約 Flushing 之 Laguardia 機場在結冰情況下起飛失速，飛機意外事件報告 NTSB/AAR-93/02。

（本篇所討論的上翼面積冰問題外，更廣泛的飛機結冰議題從 1997 年起已經成為 NTSB 飛安改善的首要議題，有關此議題美國國家安全委員會的具體行動與建議結論可查閱其網站 www.ntsb.gov/Recs/mostwantd/air_ice.htm.）

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NTSB ADVISORY

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National Transportation Safety Board
Washington, DC 20594

December 29, 2004

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ALERT TO PILOTS: WING UPPER SURFACE ICE ACCUMULATION

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As a result of a recent takeoff accident that has generated much discussion about the effects of wing upper surface ice accumulations, the National Transportation Safety Board is issuing the following alert letter to pilots:

Wing Upper Surface Ice Accumulation Alert

The National Transportation Safety Board has long been concerned about the insidious nature of the effects of small amounts of ice accumulated on an airplane's upper wing surface. The Safety Board's preliminary investigation of the November 28, 2004 accident involving a Bombardier Challenger 604 in Montrose, Colorado,(1) has revealed that atmospheric conditions conducive to upper wing surface ice accumulation existed at the time of the accident (airplane performance issues, including the possibility of upper wing ice contamination, are being investigated).

For years most pilots have understood that visible ice contamination on a wing can cause severe aerodynamic and control penalties; however, it has become apparent that many pilots do not recognize that minute amounts of ice adhering to a wing can result in similar penalties. Research results have shown that fine particles of frost or ice, the size of a grain of table salt and distributed as sparsely as one per square centimeter over an airplane wing's upper surface can destroy enough lift to prevent that airplane from taking off. The Safety Board has commented on the hazards of upper wing ice accumulation in several previous aircraft accident reports; some excerpts from these reports follow:

-- According to.wind tunnel data, a wing upper surface roughness caused by particles of only 1-2 mm [millimeter] diameter [the size of a grain of table salt], at a density of about one particle per square centimeter, can cause lift losses.of about 22 and 33 percent, in ground effect and free air, respectively.(2)

-- Research has shown that almost imperceptible amounts of ice on an airplane's wing upper surface during takeoff can result in significant performance degradation. Therefore, the Safety Board has urged pilots to conduct visual and tactile inspections of airplane wing upper surfaces in past safety recommendations (including Safety Recommendation A-04-66, which was issued to the FAA on December 15, 2004).(3)

-- Ice accumulation on the wing upper surface is very difficult to detect..It may not be seen from the cabin because it is lear/white.and it is very difficult to see from the front or back of the wing..The Safety Board believes strongly that the only way to ensure that the.wing is free from critical contamination is to touch it.(4)

-- Accident history shows that nonslatted, turbojet, transport-category airplanes have been involved in a disproportionate number of takeoff accidents where undetected upper wing ice contamination has been cited as the probable cause or sole contributing factor.(5)

-- The industry acknowledges that it is nearly impossible to determine by observation whether a wing is wet or has a thin film of ice..a very thin film of ice or frost will degrade the aerodynamic performance of any airplane.(6)

-- The Safety Board believes that even with the wing inspection light, the observation of a wing from a 30-to 40-foot distance, through a window that was probably wet from precipitation, does not constitute a careful examination..the Safety Board acknowledges that the detection of minimal amounts of contamination, sufficient to cause aerodynamic performance problems, is difficult and may not be possible without a tactile inspection.(7)

-- The Federal Aviation Administration's (FAA) Environmental Icing National Resource Specialist (NRS) indicated that he was concerned that most pilots were not aware that a slight amount of frost or ice accumulation could result in a significant degradation of airplane performance. The Icing NRS stated, 'pilots may observe what they perceive to be an insignificant amount of ice on the airplane's surface and be unaware that they may still be at risk because of reduced stall margins resulting from icing-related degraded airplane performance.'(8)

-- From an aerodynamic viewpoint, there is no such thing as "a little ice." Strict attention should be focused on ensuring that critical aircraft surfaces are free of ice contamination at the initiation of takeoff.(9)

-- Strange as it may seem, a very light coating of snow or ice, light enough to be hardly visible, will have a tremendous effect on reducing the performance of a modern airplane. (Jerome Lederer, M.E., 1939) (10)

Despite the accident and research evidence indicating that small, almost visually imperceptible amounts of ice accumulation on the upper surface of a wing can cause the same aerodynamic penalties as much larger (and more visible) ice accumulations, recent accidents indicate that the pilot community still may not appreciate the potential consequences of small amounts of ice. For example, see the final report on the October 10, 2001, accident involving the Cessna 208, N9530F that occurred in Dillingham, Alaska; (11) also see the final report on the January 4, 2002, accident involving the Bombardier Challenger 604, N90AG, which occurred in Birmingham, England.(12)

It appears that some pilots believe that if they cannot see ice or frost on the wing from a distance, or maybe through a cockpit or cabin window, it must not be there - or if it is there and they cannot see it under those circumstances, then the accumulation must be too minute to be of any consequence. Despite evidence to the contrary, these beliefs may still exist because many pilots have seen their aircraft operate with large amounts of ice adhering to the leading edges (including the dramatic double horn accretion) and consider a thin layer of ice or frost on the wing upper surface to be more benign. However, as noted, research has shown that small amounts of ice accumulation on the upper surface of a wing can result in aerodynamic degradation as severe as that caused by much larger (and more visible) ice accumulations.

It is also possible that many pilots believe that if they have sufficient engine power available, they can simply "power through" any performance degradation that might result from almost imperceptible amounts of upper wing surface ice accumulation. However, engine power will not prevent a stall and loss of control at lift off, where the highest angles of attack are normally achieved. Further, small patches of almost imperceptible ice or frost can result in localized, asymmetrical stalls on the wing, which can result in roll control problems during lift off.

The Safety Board notes that there are circumstances in which upper wing surface ice accumulation can be difficult to perceive visually. For example, depending on the airplane's design (size, high wing, low wing, etc.) and the environmental and lighting conditions (wet wings, dark night, dim lights, etc.) it may be difficult for a pilot to see ice on the upper wing surface from the ground or through the cockpit or other windows. Further, frost, snow, and rime ice can be very difficult to detect on a white upper wing surface and clear ice can be difficult to detect on an upper wing surface of any color. However, it is critically important to ensure, by any means necessary, that the upper wing surface is clear of contamination before takeoff. That is why the Safety Board recently issued Safety Recommendation A-04-66, urging pilots to conduct visual and tactile inspections of airplane wing upper surfaces.

The bottom line is that pilots should be aware that no amount of snow, ice or frost accumulation on the wing upper surface can be considered safe for takeoff. However, history has shown that with a careful and thorough preflight inspection, including tactile inspections and proper and liberal use of deicing processes and techniques, airplanes can be operated safely in spite of the adversities encountered during winter months.

(1) Additional information regarding this accident can be found on the Safety Board's Web site at http://www.ntsb.gov, accident number DEN05MA028.
(2) This information is from the Safety Board's final report on the March 22, 1992, accident involving USAir flight 405, at Flushing, New York. For additional information, see National Transportation Safety Board. 1993. Takeoff Stall in Icing Conditions, USAir flight 405, Fokker F-28, N485US, LaGuardia Airport, Flushing, New York, March 22, 1992. Aircraft Accident Report NTSB/AAR-93/02. Washington, D.C.
(3) For additional information, see http://www.ntsb.gov/recs/letters/2004/A04_64_67.pdf.

(4) This information is from the Safety Board's final report on the February 17, 1991, accident involving Ryan International Airlines, at Cleveland, Ohio. For additional information, see National Transportation Safety Board. 1991. Ryan International Airlines, DC-9-15, N565PC, Loss of Control on Takeoff, Cleveland-Hopkins International Airport, Cleveland, Ohio, February 17, 1991. Aircraft Accident Report NTSB/AAR-91/09. Washington, D.C.

(5) See Aircraft Accident Report NTSB/AAR-93/02. Washington, D.C., cited above.

(6) See Aircraft Accident Report NTSB/AAR-93/02. Washington, D.C., cited above.

(7) See Aircraft Accident Report NTSB/AAR-93/02. Washington, D.C., cited above.

(8) This is information contained in the Safety Board's final report on the January 9, 1997, accident involving Comair flight 3272 at Monroe, Michigan. For additional information, see National Transportation Safety Board. 1998. In-flight Icing Encounter and Uncontrolled Collision with Terrain, Comair flight 3272, Embraer EMB-120RT, N265CA, Monroe, Michigan, January 9, 1997. Aircraft Accident Report NTSB/AAR-98/04. Washington, D.C.

(9) This statement is a quote from a technical paper, titled, The Effect of Wing Ice Contamination on Essential Flight Characteristics, by Douglas Aircraft Company's deputy chief design engineer for the MD-80/DC-9 program (presented in 1988 and again in 1991). See appendix E of the previously cited Aircraft Accident Report NTSB/AAR-91/09.

(10) This quote is from Safety in the Operation of Air Transportation, a lecture presented by Jerome Lederer, M.E., at Norwich University, in 1939, and cited in the Safety Board's final report on the March 22, 1992, accident involving USAir flight 405 at Flushing, New York. See Aircraft Accident Report NTSB/AAR-93/02. Washington, D.C., cited above.

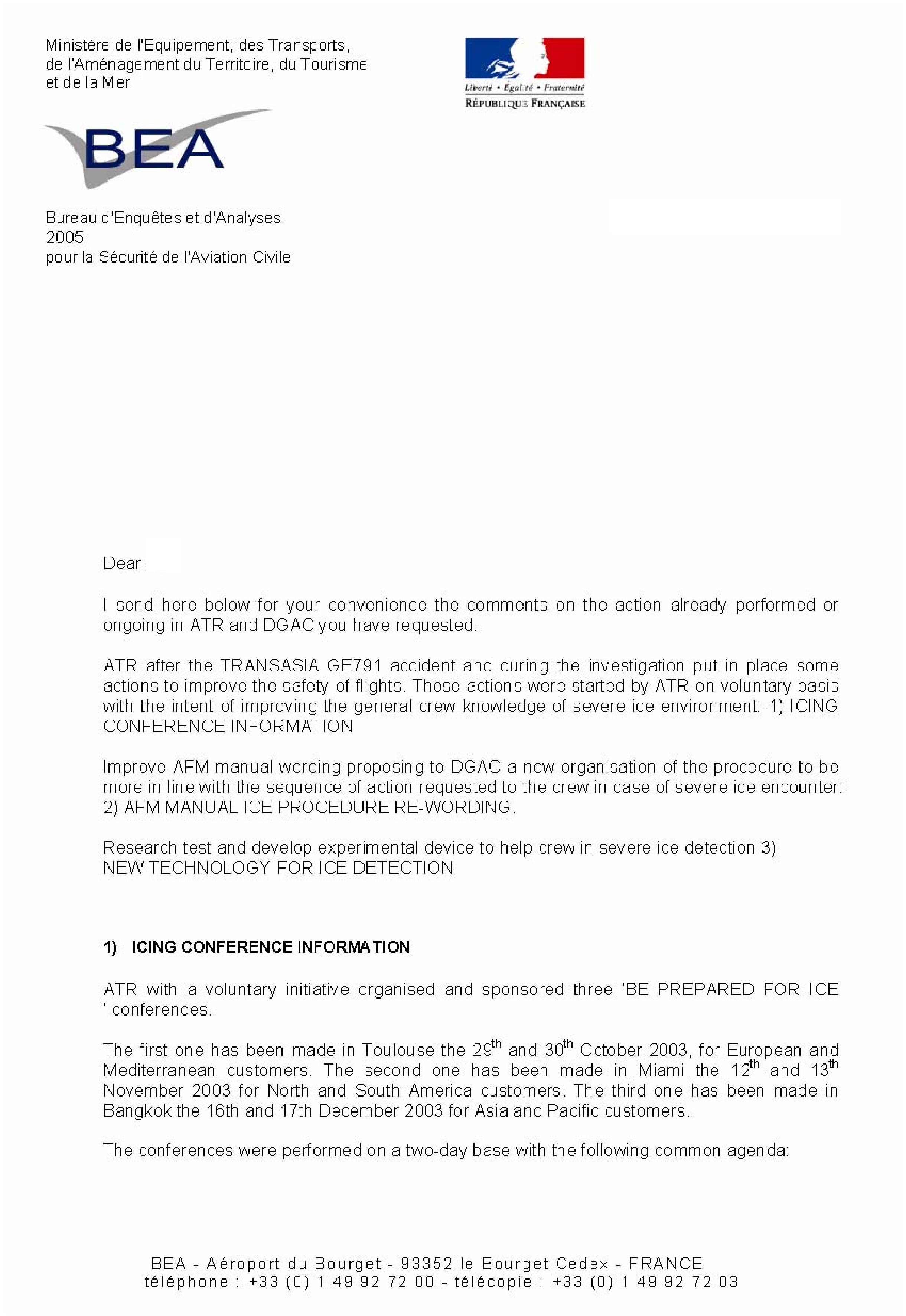
(11) As a result of this and other icing-related accidents involving Cessna 208 series airplanes, on December 15, 2004, the Safety Board issued Safety Recommendations A-04-64 through-67. Additional information on the Dillingham, Alaska accident (DCA02MA003) and on Safety Recommendations A-04-64 through -67 can be found on the Safety Board's Web site at http://www.ntsb.gov.

(12) This accident was investigated by the Air Accidents Investigation Branch (AAIB), Department for Transport, Great Britain. Additional information on this accident can be found at www.dft.gov.uk/stellent/groups.dft_avsafety/documents/page/dft_avsafety_030576.hcsp.

(Although broader than the issue of wing upper surface ice accumulation discussed in this alert notice, aircraft icing has been an issue on the NTSB's Most Wanted List of Safety Improvements since 1997. A summary of the Board's actions and recommendations in this area may be found on its website, at www.ntsb.gov/Recs/mostwanted/air_ice.htm.)

NTSB Media Contact:
(202) 314-6100
lopatt@ntsb.gov

Appendix 26 The safety Actions Accomplished or Being Accomplished of ATR and DGAC



Ministère de l'Equipement, des Transports,
de l'Aménagement du Territoire, du Tourisme
et de la Mer

Bureau d'Enquêtes et d'Analyses
2005
pour la Sécurité de l'Aviation Civile

Dear

I send here below for your convenience the comments on the action already performed or ongoing in ATR and DGAC you have requested.

ATR after the TRANSASIA GE791 accident and during the investigation put in place some actions to improve the safety of flights. Those actions were started by ATR on voluntary basis with the intent of improving the general crew knowledge of severe ice environment: 1) ICING CONFERENCE INFORMATION

Improve AFM manual wording proposing to DGAC a new organisation of the procedure to be more in line with the sequence of action requested to the crew in case of severe ice encounter: 2) AFM MANUAL ICE PROCEDURE RE-WORDING.

Research test and develop experimental device to help crew in severe ice detection 3)
NEW TECHNOLOGY FOR ICE DETECTION

1) ICING CONFERENCE INFORMATION

ATR with a voluntary initiative organised and sponsored three 'BE PREPARED FOR ICE ' conferences.

The first one has been made in Toulouse the 29th and 30th October 2003, for European and Mediterranean customers. The second one has been made in Miami the 12th and 13th November 2003 for North and South America customers. The third one has been made in Bangkok the 16th and 17th December 2003 for Asia and Pacific customers.

The conferences were performed on a two-day base with the following common agenda:

First day	2:30 pm to 5:30 pm	**Conference Introduction**	J.M. Bigarre and Carmine Orsi
		Icing Mechanism	**Didier Cailhol**
		Review of icing related incidents	**Giuseppe Caldarelli**
		Severe Icing procedure	**Eric Delesalle**
Second day	9:30 am to 12:30 am	**CRM Aspects**	**Sammy Szpic**
		Weather Reminder	**Véronique Elaphos**
		Flight Preparation	**Eric Delesalle**
	2:30 pm to 3:30 pm	**Flight Operation**	**Eric Delesalle**
	3:45 pm	**Open Forum**	
	1630	**Conference Conclusion**	**J-M Bigarré** Carmine Orsi

Carmine Orsi Head of ATR Engineering
J-M Bigarré Head of ATR Training Center in Toulouse
Didier Cailhol ATR expert of ice.
Giuseppe Caldarelli ATR Product Safety
Eric Delesalle ATR Chief test pilot
Sammy Szpic working for French research center GIFAS and expert of Cockpit Resource Management
Véronique Elaphos responsible for ATR operational training

This conference addressed the issues we sorted out during last years of ATR and world turboprop fleet operation. The presentation was mainly focused on:

- Icing meteorological aspect,
- Training and procedures application,
- icing phenomena recognition evaluation
- CRM and decision-making processes,
- aerodynamic and cases study

The participants were mainly ATR chief pilots, Instructor pilots, Safety officers.
There were around 100 person in Toulouse, including (DGAC) French Certification Authority Experts, (BEA) French Bureau of Investigation representatives and Transasia People from Taiwan.
In Miami (USA) there were 50 people including Experts from FAA.
In Bangkok there were 35 participants.
We gathered very positive comments from DGAC, BEA and FAA. They encouraged us to continue on this approach.
Many of the Operators expressed the wish that other manufacturers would follow the same ATR approach.
Each participant received a copy of the 'Be prepared for ice ' brochure and a copy of a CD-ROM both containing the content of the conference. (I already sent them to ASC).

Those brochures and CD's as the entire conference organisation has been paid by ATR.

The part regarding the icing meteorological aspect and the training has been reported into the Brochure and CD-ROM.

The part related to the CRM and decision-making process has been only presented.

The part regarding the Aerodynamic explication of icing effect on the wing and the analysis of ATR incident of bad de-icing and severe icing encounter with non application of AFM flight procedure DFDR analysis of previous incident was presented in detail and the slide content was not provided.

The people present have very well perceived the Conference content and the interest showed during the presentation and the comments collected during coffee breaks and at the end of conference have been enthusiastic.
This has well compensated the effort of ATR in general and of the people involved in the preparation of the conference in particular.

Most of the people have been very interested and impressed into the aerodynamic explication of the performance degradation in severe icing condition which has been made presenting a CL/CD plot with clean and polluted aircraft values.
This is a simplified CL/CD plot relative to a severe icing encounter similar to what you can find in the DO/TF-2524/03 technical note.

Other positive comments went for the presentation of the DFDR regarding consequence in flight as consequence of bad de-icing. This is an action normally performed on airport by ground de-icing team and shall be monitored by pilots.

The pilots appreciated the conference and confirmed that the presentation content, which has to be used for flight in severe ice condition, should be part of their professional background, disregarding the kind of aeroplane they are going to fly.
This is true because when there is a big deposit of ice on a wing either jet or turboprop always gives performance penalties.

2) AFM MANUAL ICE PROCEDURE RE-WORDING

The AFM manual is known to be a document approved by certification and airworthiness authority, for ATR is the French DGAC. The AFM chapter Limitation treating the Icing condition has been approved and published for the ATR 72-200 and last update is February 1999.

Since the first certification of the ATR 72 this chapter has been reworded to include all the possible information available to the crew.

During initial discussion with ASC investigators after the accident of the Transasia ATR72 msn 322 it was noted that the AFM procedure which were the result of years of data collection and information gathering were not optimised due to the large amount of information included as the knowledge were progressing.

Therefore ATR, thinking that a new procedure presentation could have been beneficial to the crews, took the lead proposing to DGAC a new organisation of the procedure to be more in line with the sequence of action requested to the crew in case of severe ice encounter. This was done without waiting for the final action issuance from ASC therefore bearing in mind that if everybody agrees it is beneficial for the flight there is no need to wait the official issuance.

The general commitment of this update was to improve and optimise the action and reading straightforwardness of the procedure keeping the same meaning.

The new revision has now the changes here below detailed:

- Limitation Section: the definition of the severe icing cues was surrounded (Attachment. 1). We changed it considering that the surrounded words should be limited to procedure task and the surrounding has been removed (Attachment 2).

- Limitation Section: The definition of the severe icing cues included "water splashing and streaming on the windshield" (Attachment 1). This cue has been removed from the primary cues and transferred as secondary indications (Attachment 2).

- Limitation Section: A note describing conditions conducive to severe icing has been added (Attachment 2).

- Emergency Procedures Section. ATR considered that when a crew reads this section it is to find first the emergency procedure to be applied. The previous AFM revision (Attachment 3.1 and 3.2) reminded first the means to detect severe icing then described the emergency procedure to be applied.

Furthermore there were too many words to describe the emergency procedures. The actual revision (Attachment 4.1 and 4.2) details first the emergency procedure to be applied step by step as for a check list and then reminds the description of the severe icing cues using the same wording as within the limitation section.

DGAC and FAA now approve the version attached and are now published and in use in all ATR models of the ATR family.

3) NEW TECHNOLOGY FOR ICE DETECTION

Some modern aircraft are equipped with ice detectors that tell the crew when icing conditions are encountered or when to switch 'ON' ice protections system. There are two kinds of ice detection system either advisory (signal provided for information) or primary (signal provided for action). Some recent incidents or accidents have shown that these current ice detection systems may not work for some specific icing conditions, such as severe ice condition, which are outside the current icing certification envelope (JAR/FAR25 Appendix C). For this reason, Authorities are now downgrading some originally certificated primary systems to advisory system. ATR aircraft are equipped with an advisory ice detection system as supplement of the primary detection means described within the operational manuals.

Several working groups have been created (and ATR participates in most of them) to address icing conditions (called severe icing conditions) beyond the current certification envelope.
The regulatory authorities have tasked these working groups to define : a new icing envelope, and associated regulatory materials (including the development of new means of compliance to certification) and to investigate into new technologies for ice detection.

New ice detection principles are based on
- droplet diameter or Liquid Water Content measurements, or
- aerodynamic performance monitoring, or
- detection of ice on aircraft parts not usually accreting ice.

Some of them seem to offer promising performance but they still require a lot a development work to reach a mature status. The application of that new reliable equipment needs a parallel development of new certification regulations and certification standard evolution.

The simple low speed indicator in the cockpit, which give a warning when a fixed speed is attained, is not welcome by pilots because it presents a lot of untimely activation during flight therefore it looses credibility for the crew.

ATR determined that several visual cues, which may be present upon severe icing condition encounters, are adequate. These visual cues have been documented and detailed within our operational manuals as well as the exit procedures to be applied by the crew in case of inadvertent encounters.

Nevertheless ATR is always active and continuously research and test equipment capable to help crews in ice detection.

This continuous activity at present is focused on an onboard real time calculation of aircraft performance, comparison with expected performance. If the system finds differences the crew is alerted. The specified goals of the system are: easy to retrofit, easy to install, low rate of false alarm, alert given when degraded performance are present.

At present a prototype is in flight test, the evaluation is undergoing through normal operational flight, the scope is to gather as much flight we can to examine them before to decide its launch in production.

ATR presented the content and to scope of this activity has been to French Airworthiness Authority (DGAC) and in case of compliance of the system with technical requirements they will grant the certification.

Taking into account the ASC recommendations we believe that our willingness in developing such is proven, it remains to assess the proof of the concept with the operational tests and the industrial application.