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.

[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	1^{st} 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).

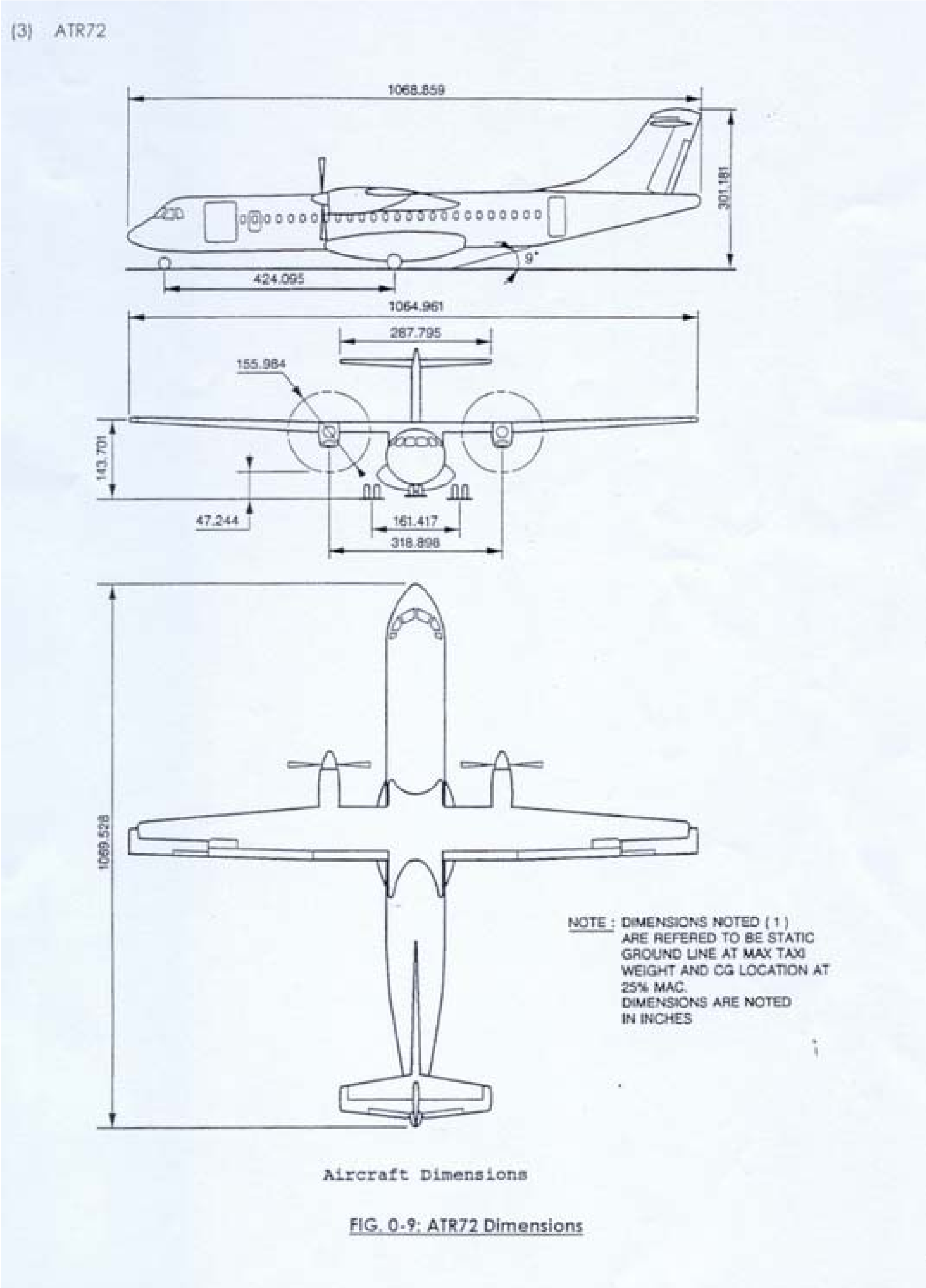

Figure 1.6-1 ATR72 dimensions

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.

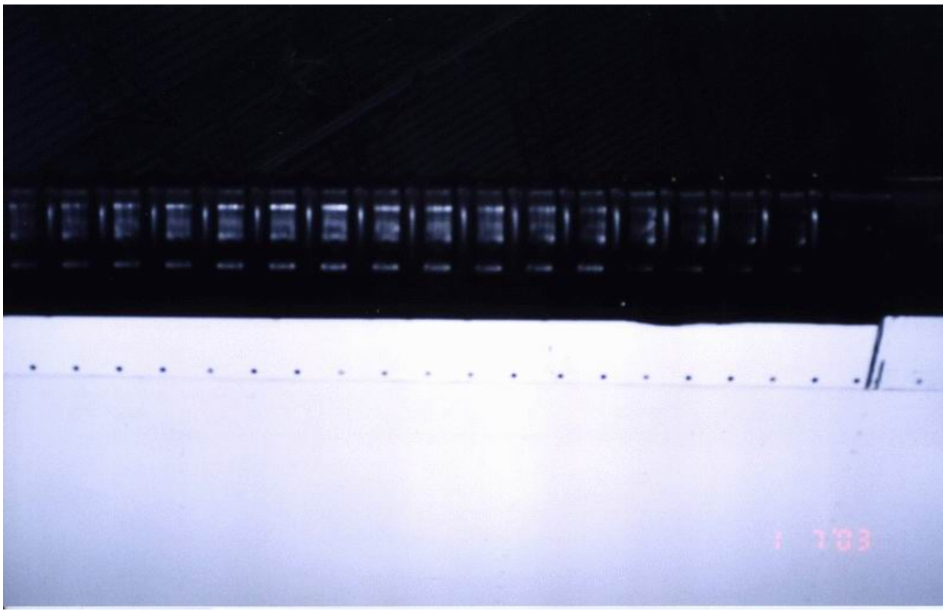

Figure 1.6-2 The inflating Deicing boot (wing and empennage)

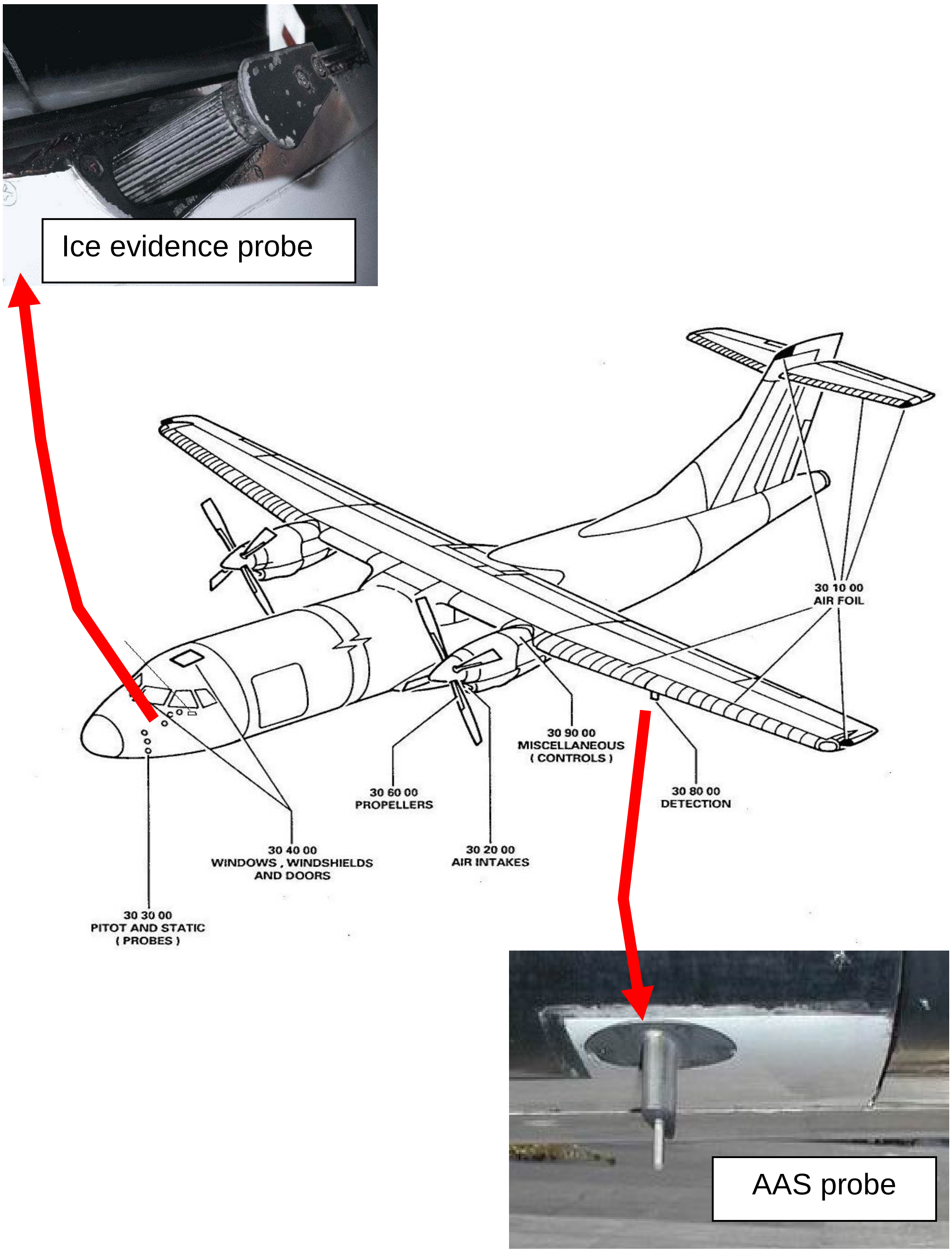

Figure 1.6-3 The Ice evidence probe & The Anti-Icing Advisory System (AAS) probe

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.

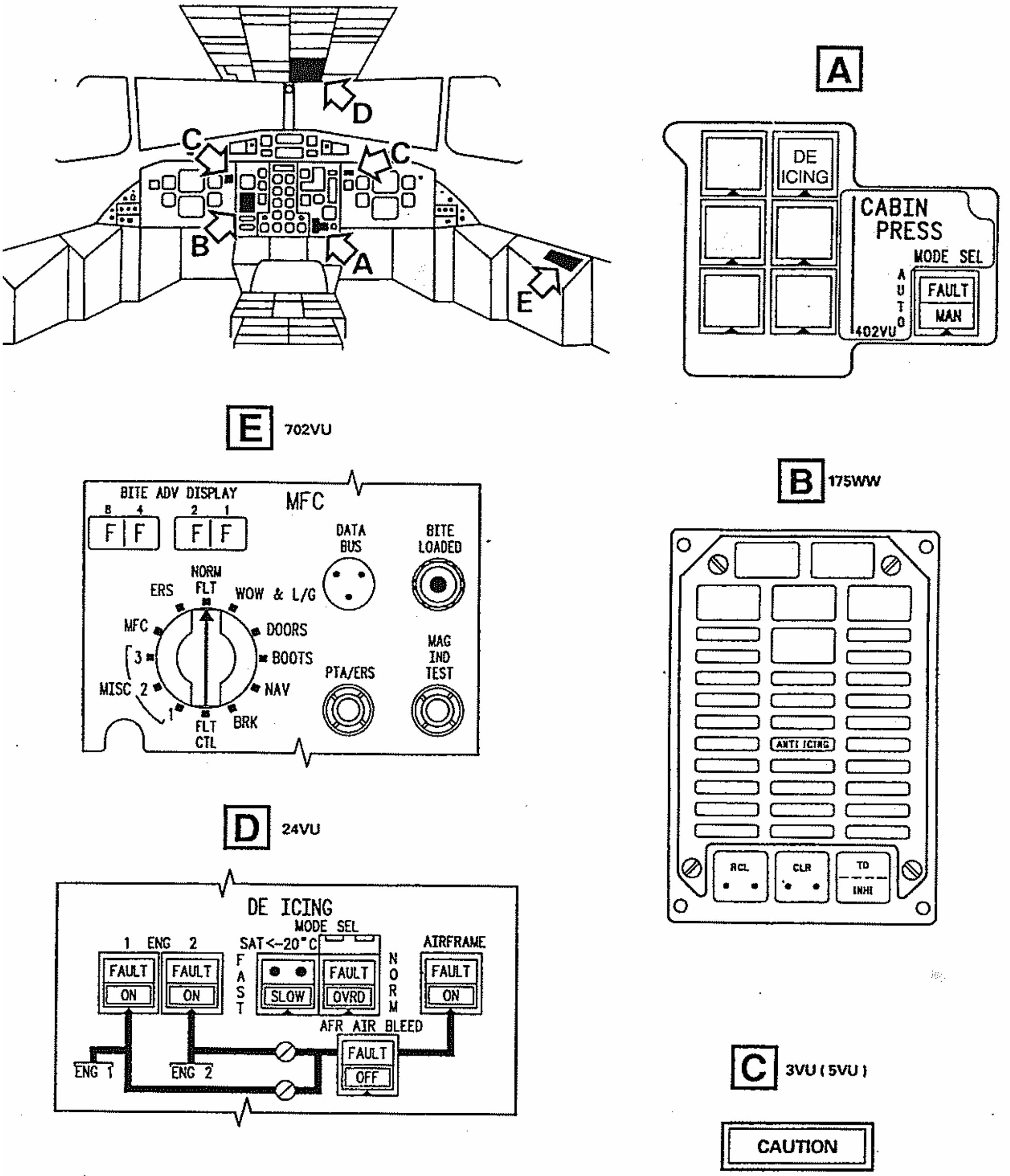

Figure 1.6-4 The location of airframe ice protection system instrument panels in the cockpit

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

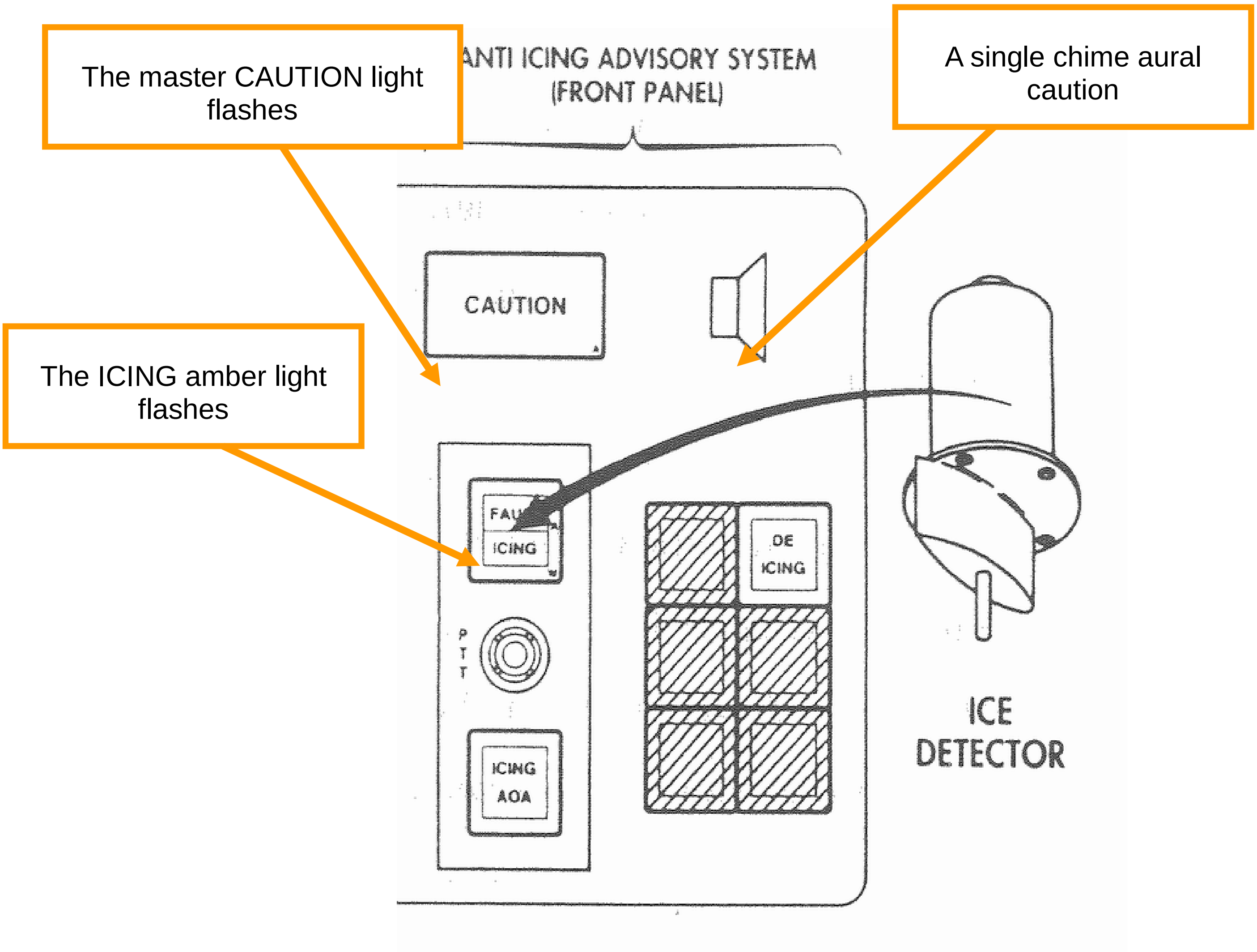

Figure 1.6-5 AAS visual and aural alert signals

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)

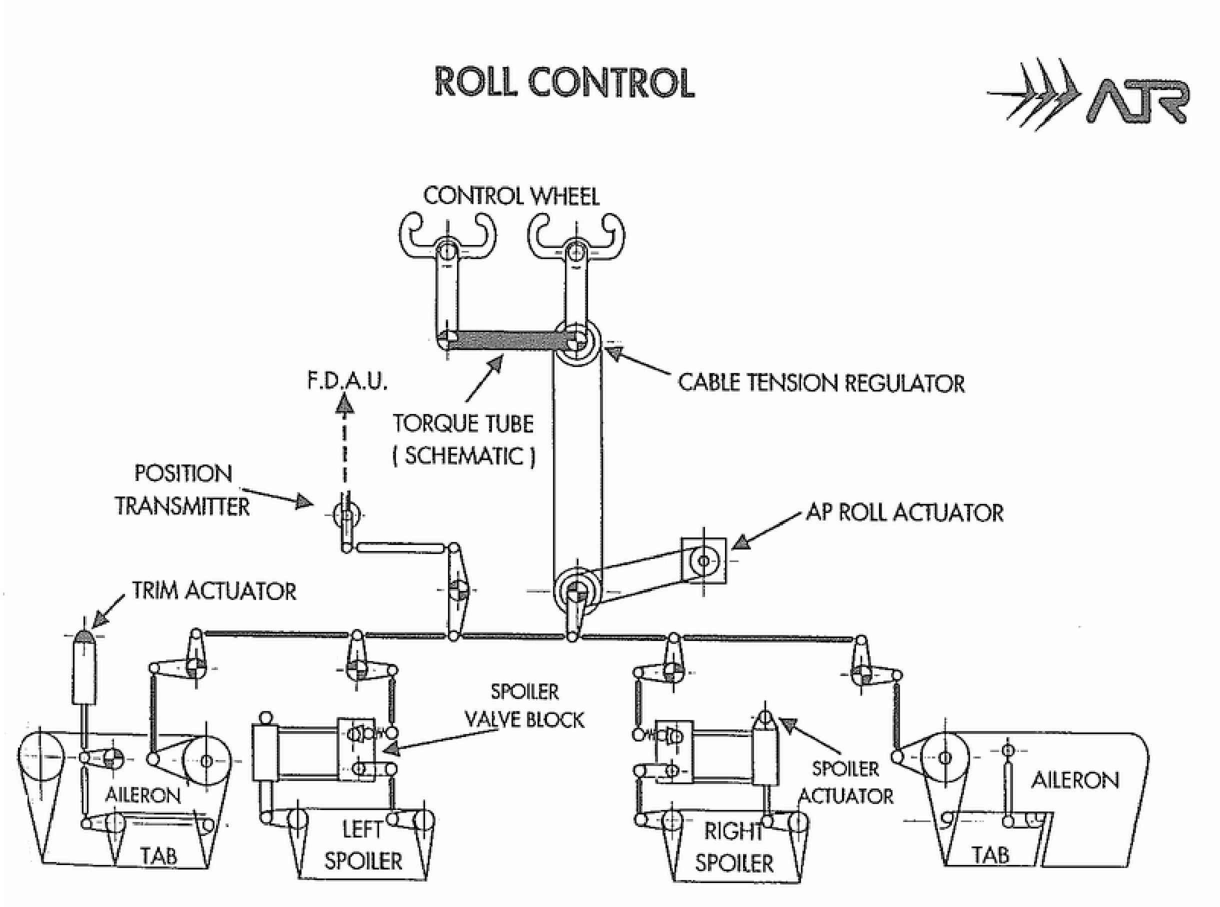

Figure 1.6-6 Roll control system diagram

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.

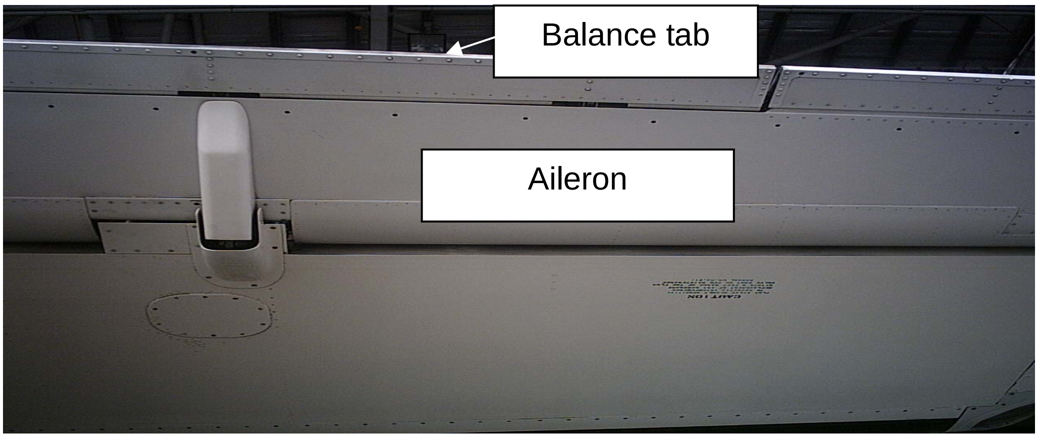

Figure 1.6-7 ATR72 aileron and balance tab

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

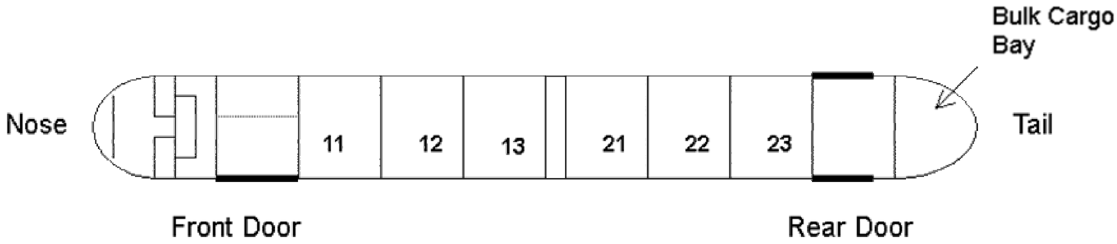

Figure 1.6-9 Schematics of ATR72 Cargo Bays

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:

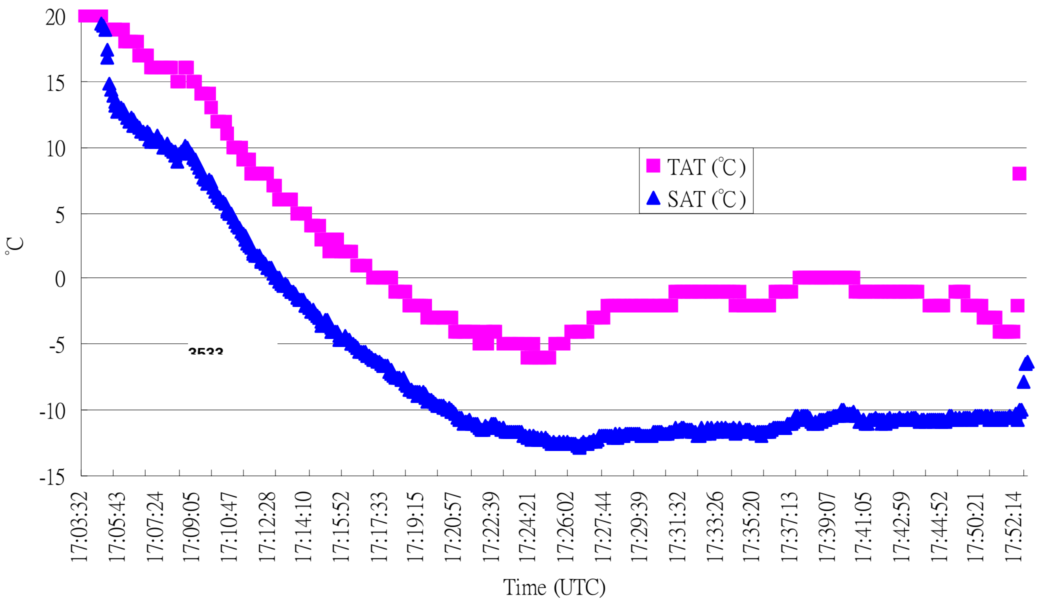

Figure 1.7-1 TAT and SAT along the track of FDR.

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.

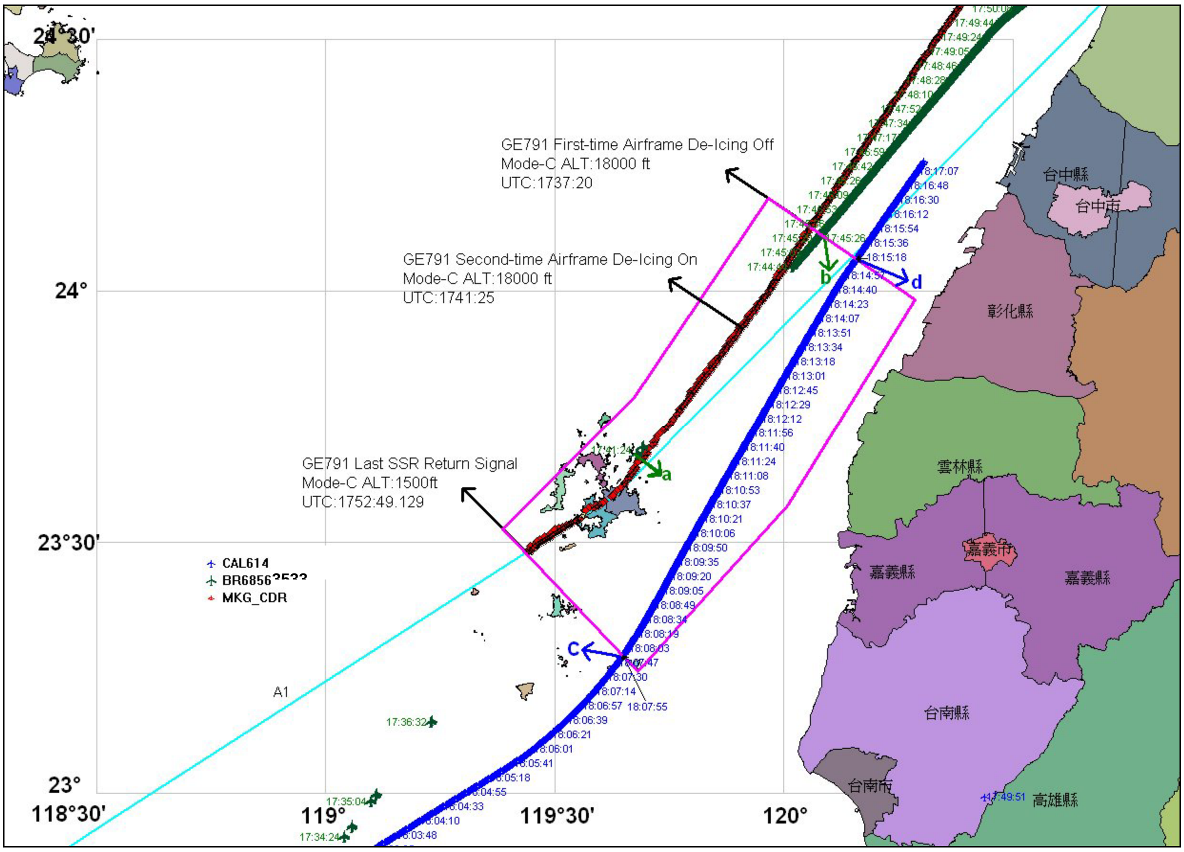

Figure 1.7-2 Superposition of the flight tracks of beacon code 3533 and 3563 aircraft near the accident site of GE791.

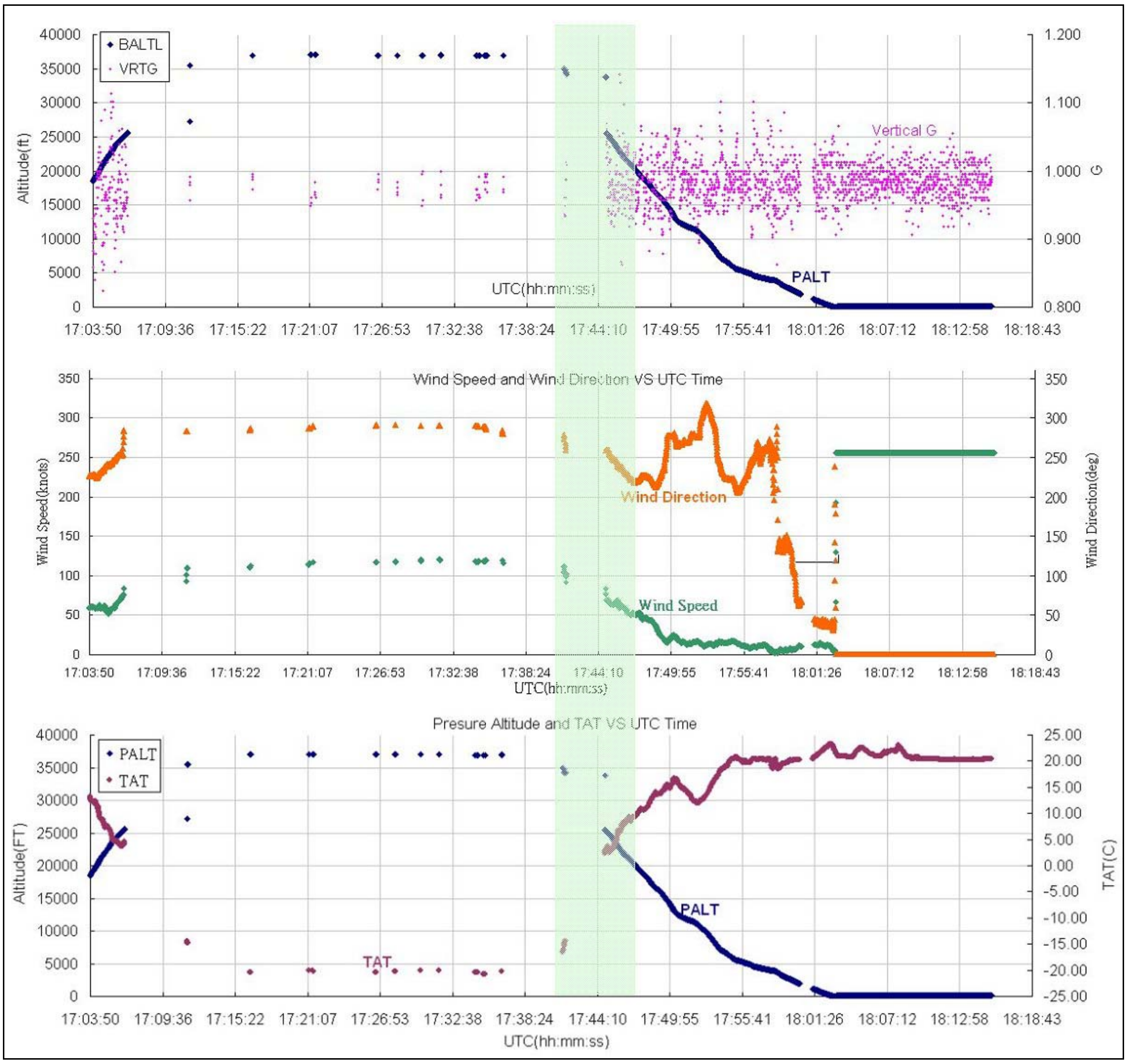

Figure 1.7-3 The wind condition and TAT of the beacon code 3563 aircraft
（The green area was flown pass by the accident site.）

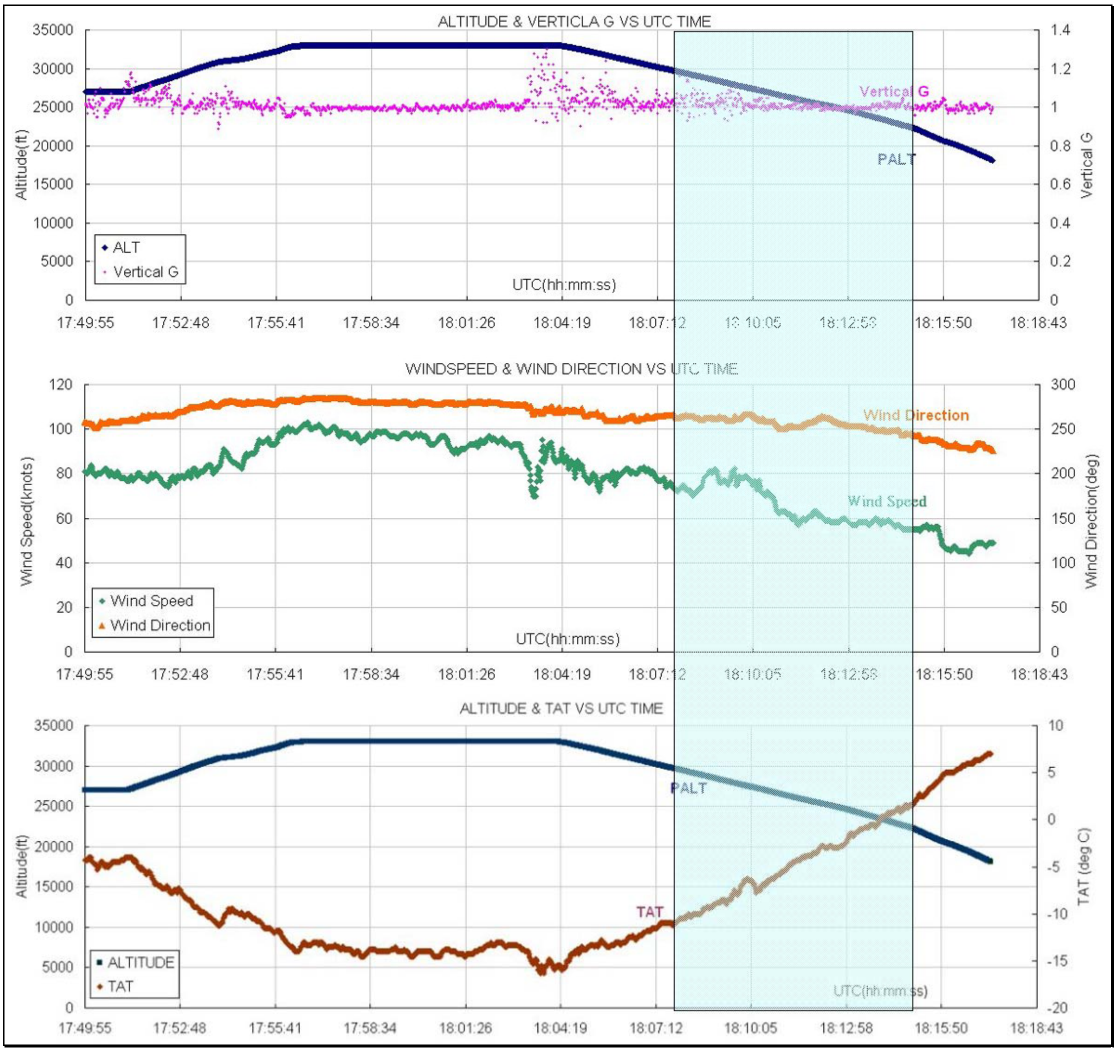

Figure 1.7-4 The wind condition and TAT of the beacon code 3563 aircraft
（The blue area was flown pass by the accident site.）

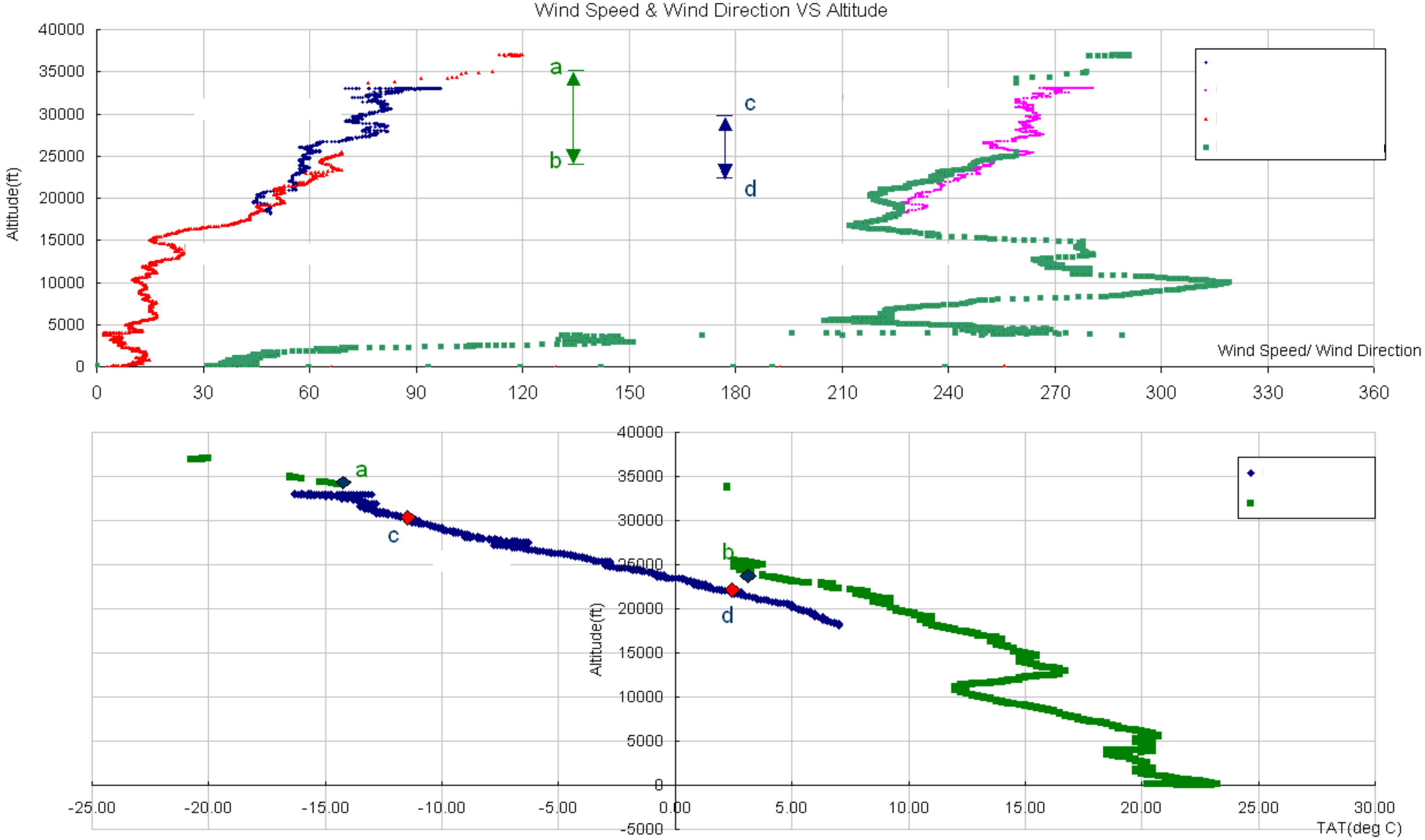

Figure 1.7-5 The variation of wind condition and TAT with altitude of the beacon code 3533 and 3563 aircraft.

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)

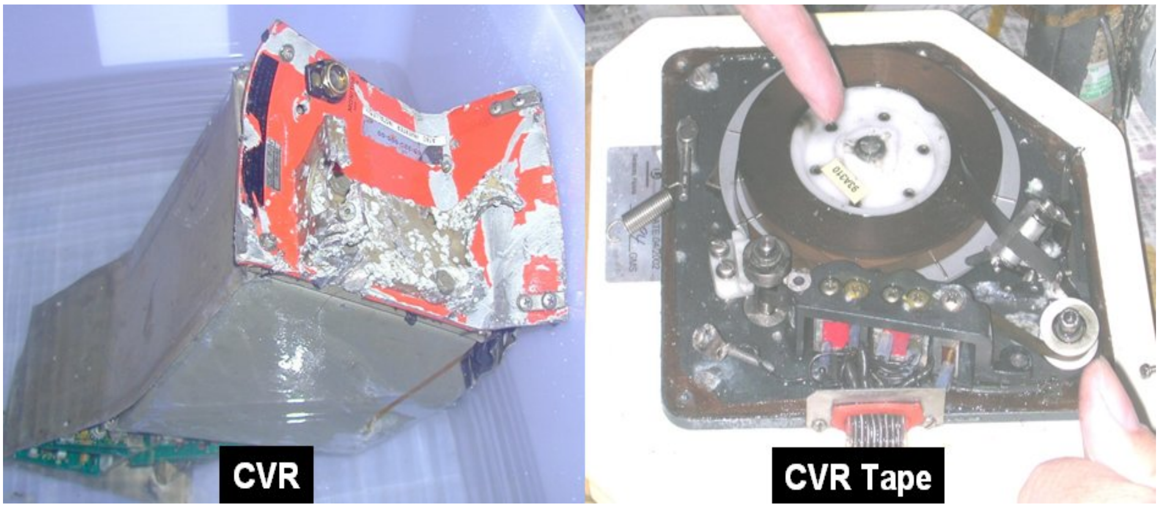

Figure 1.11-1 CVR physical damage and the CVR tape

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）

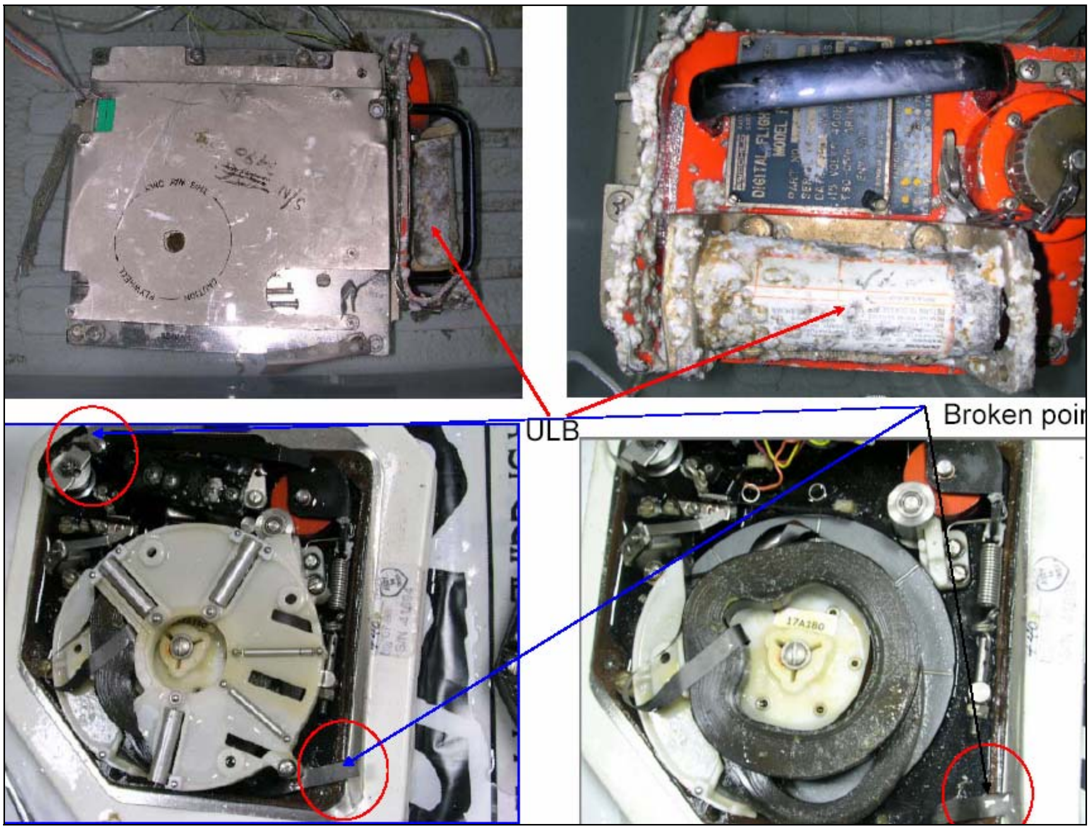

Figure 1.11-2 FDR physical damage and FDR tape

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

[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:

$$\alpha_{True} = 0.6262 * \alpha_{Local} + 0.98 \text{ (degree), with flap } = 0$$

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).

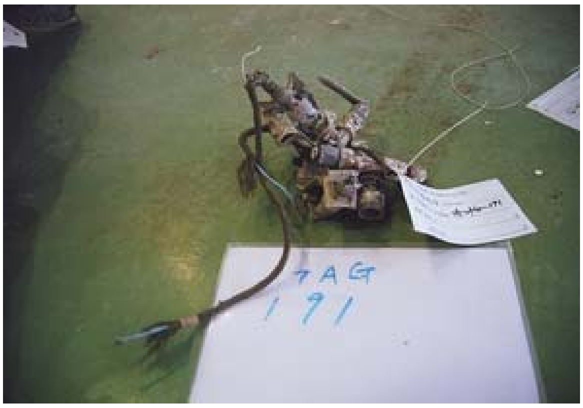

Figure 1.12-27 Wing de-icing regulator

● 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 icin 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	

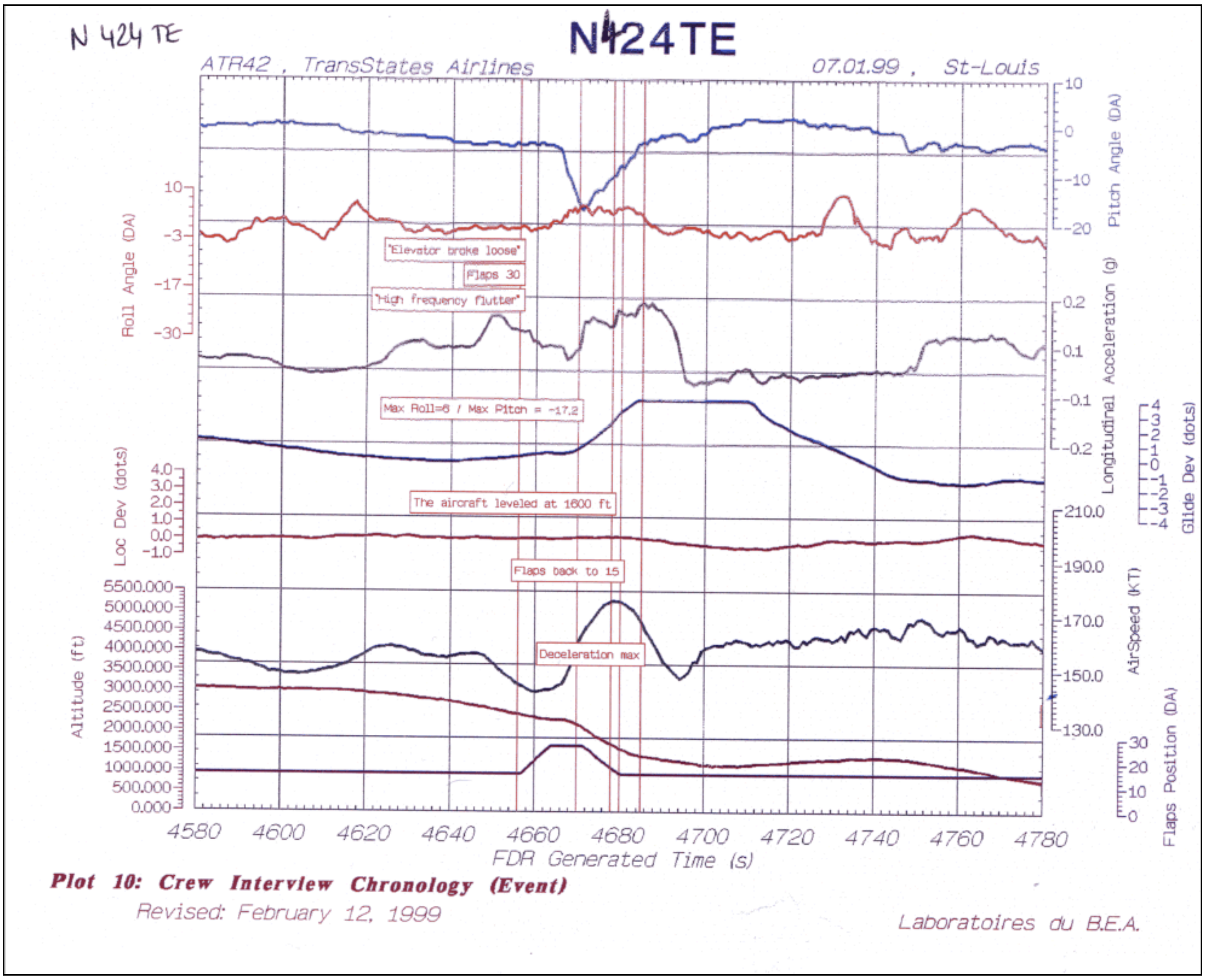

Figure 1.16-1 Trans States Airlines ATR42FDR Data (BEA)

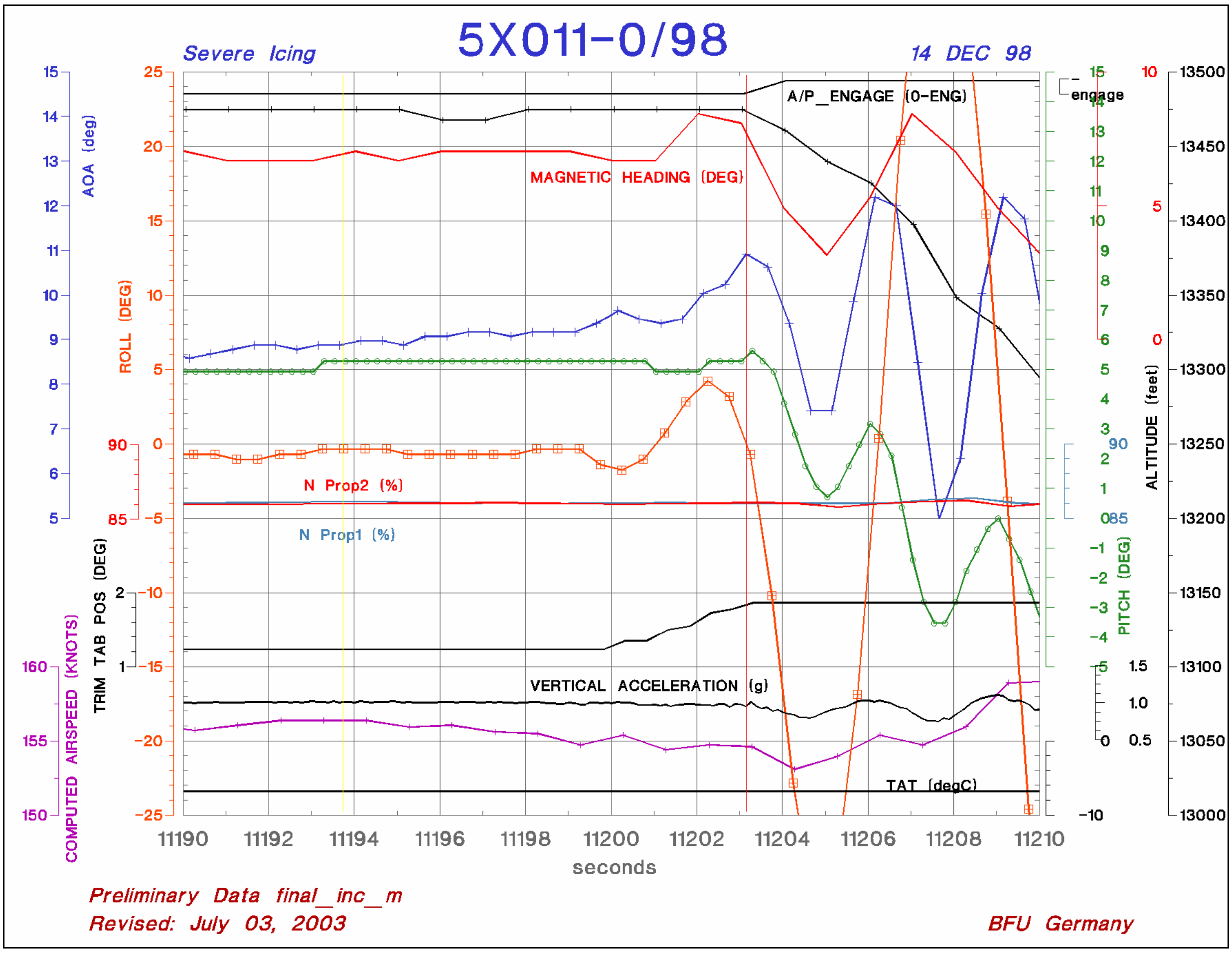

Figure 1.16-2 Cottbus, Germany, ATR42 FDR Data (BFU, Report No.:5x011-0/98)

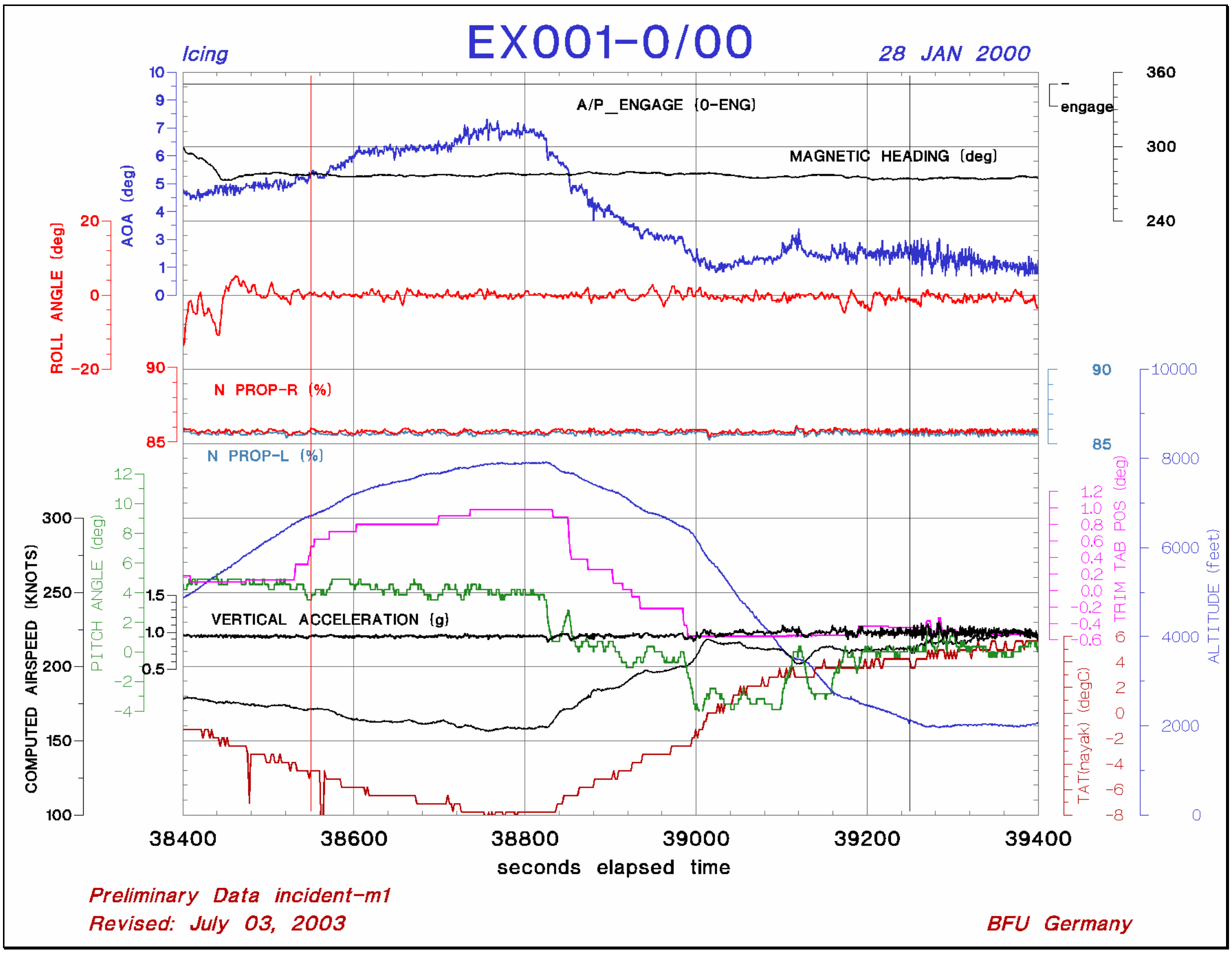

Figure 1.16-3 Near Berlin-Tegel, Germany, ATR42 FDR Data (BFU, Report No.: EX001-0/00)

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）

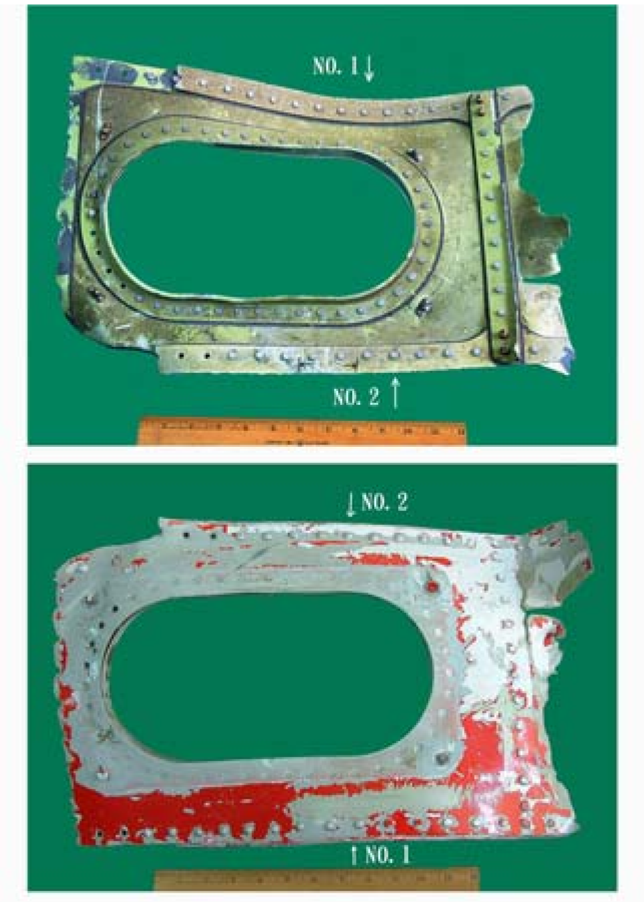

Figure 1.16-4 Wreckage with suspected fatigue crack

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).

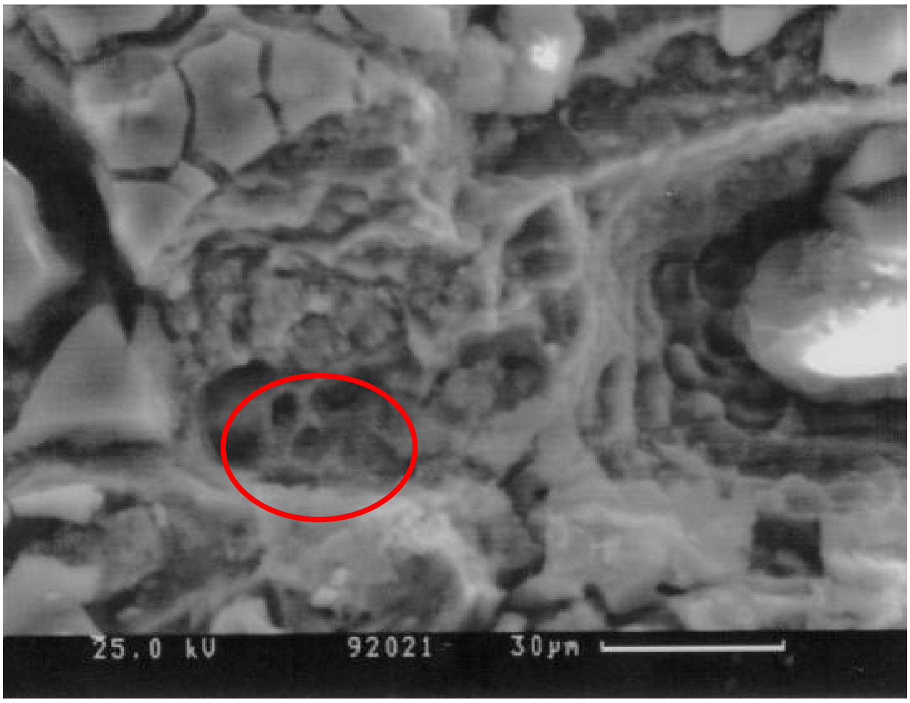

Figure 1.16-5   SEM examination showing the dimple structure (790X)。

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.

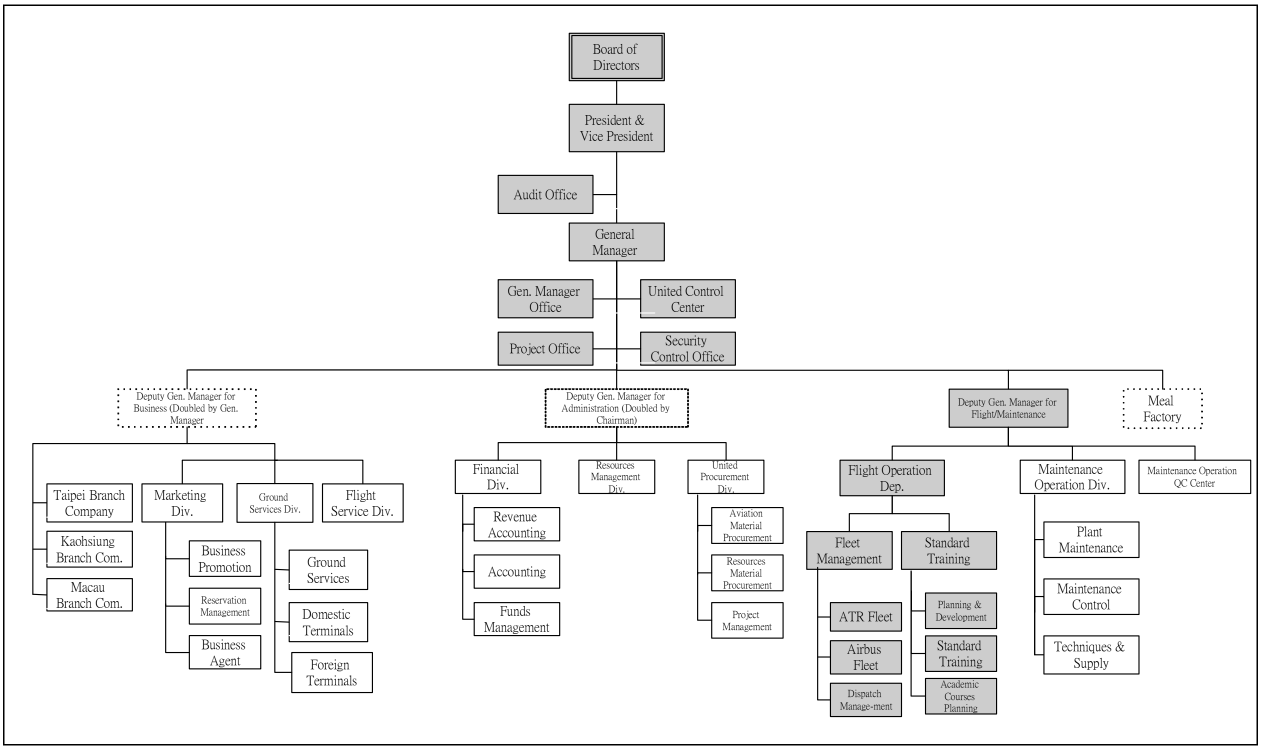

Figure 1.17-1 TNA Organizational Chart

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.

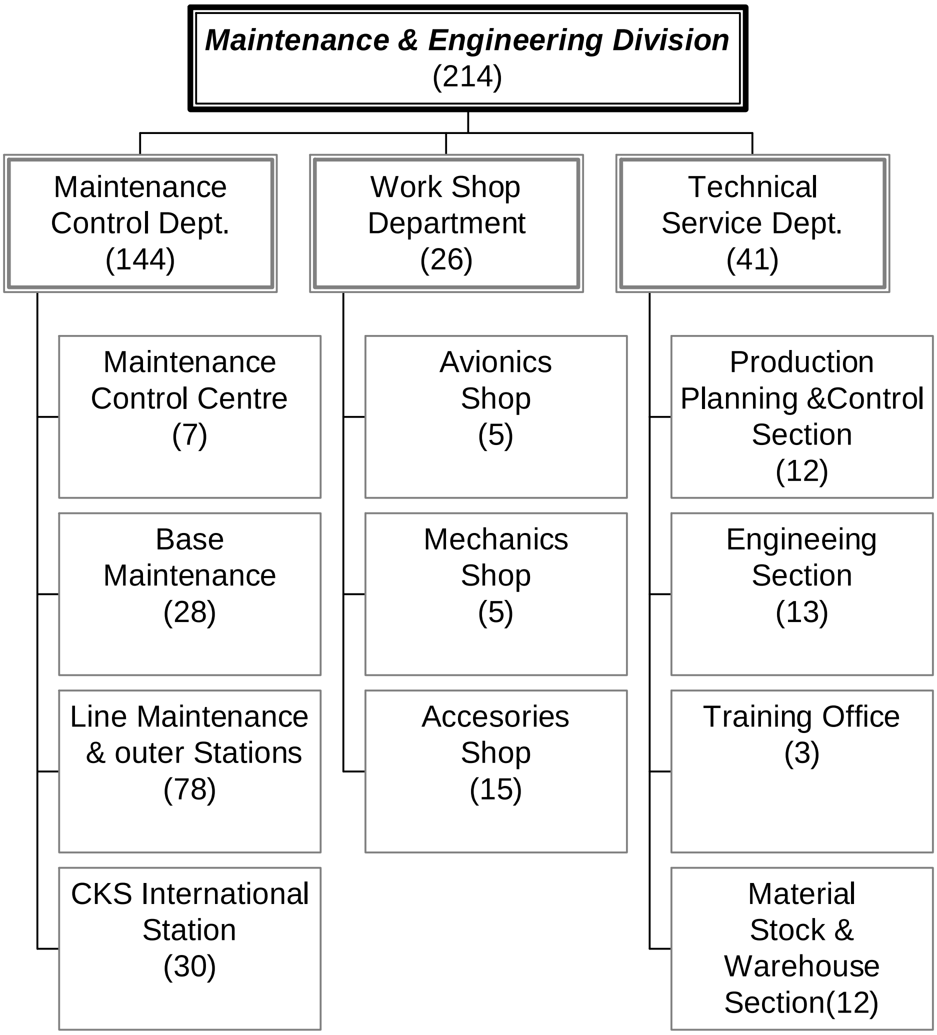

Figure 1.17-2 The Organization Chart of TNA Maintenance and Engineering Division

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

[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 Mode-C Altitude（Ft）	Ending Time Mode-C Altitude（Ft）	Time difference between MKR Radar Site (sec)
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)	

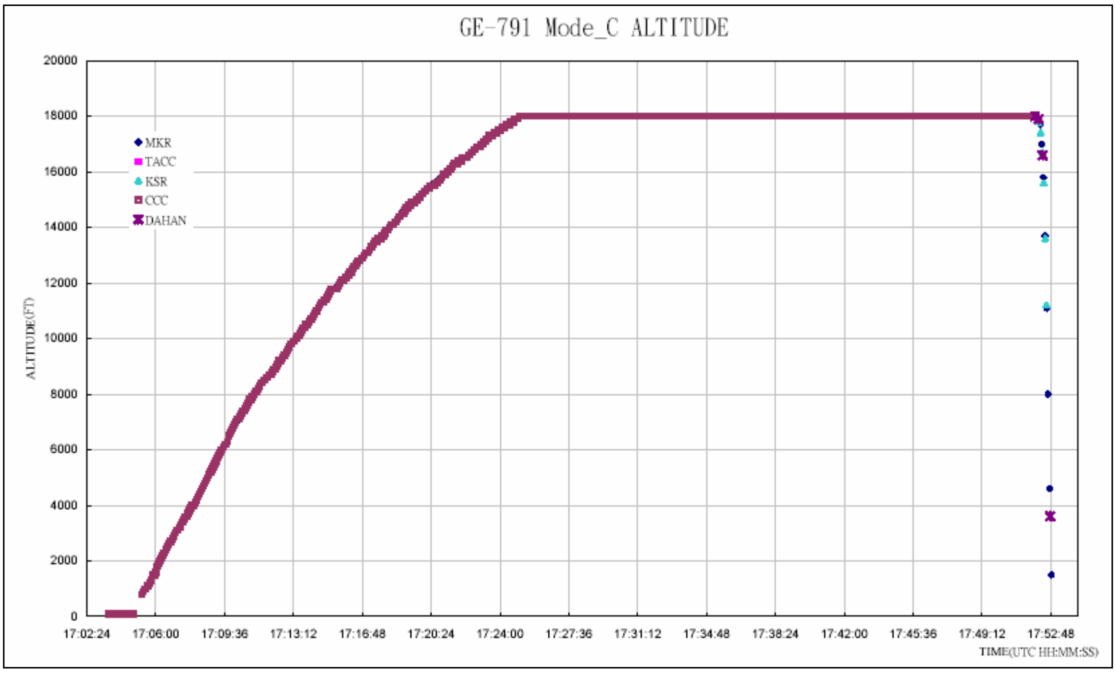

Figure 1.18-1 Mode-C altitude of GE791 (01:03: 31~01:52:56)

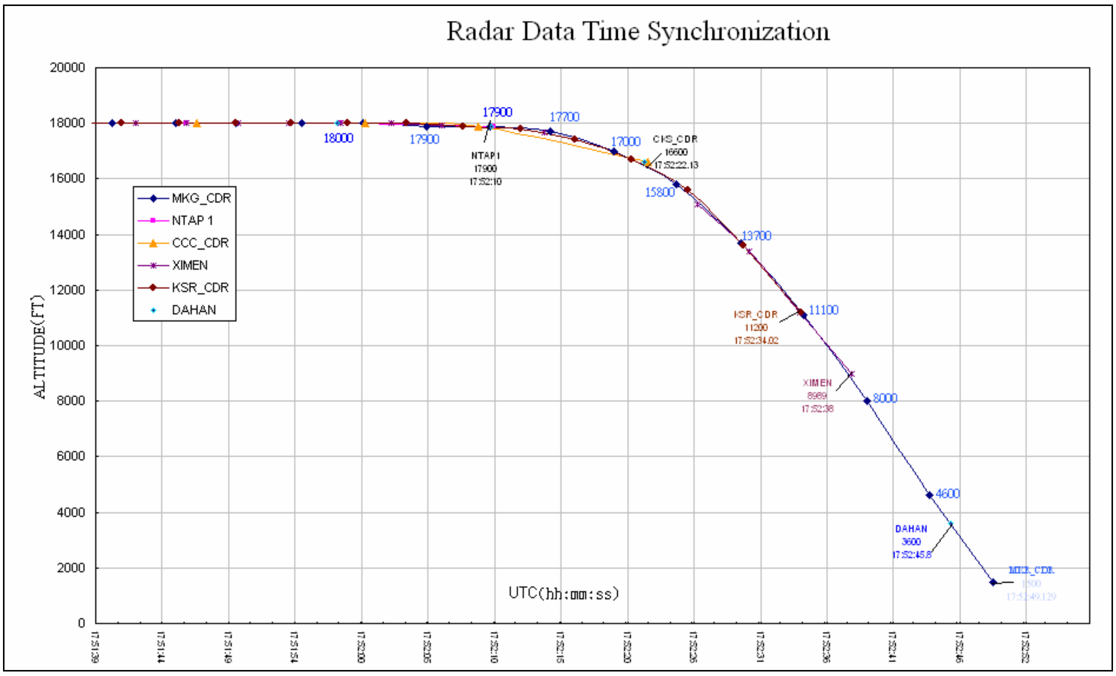

Figure 1.18-2 Mode-C altitude of GE791 (01:51:38~01:52:48)

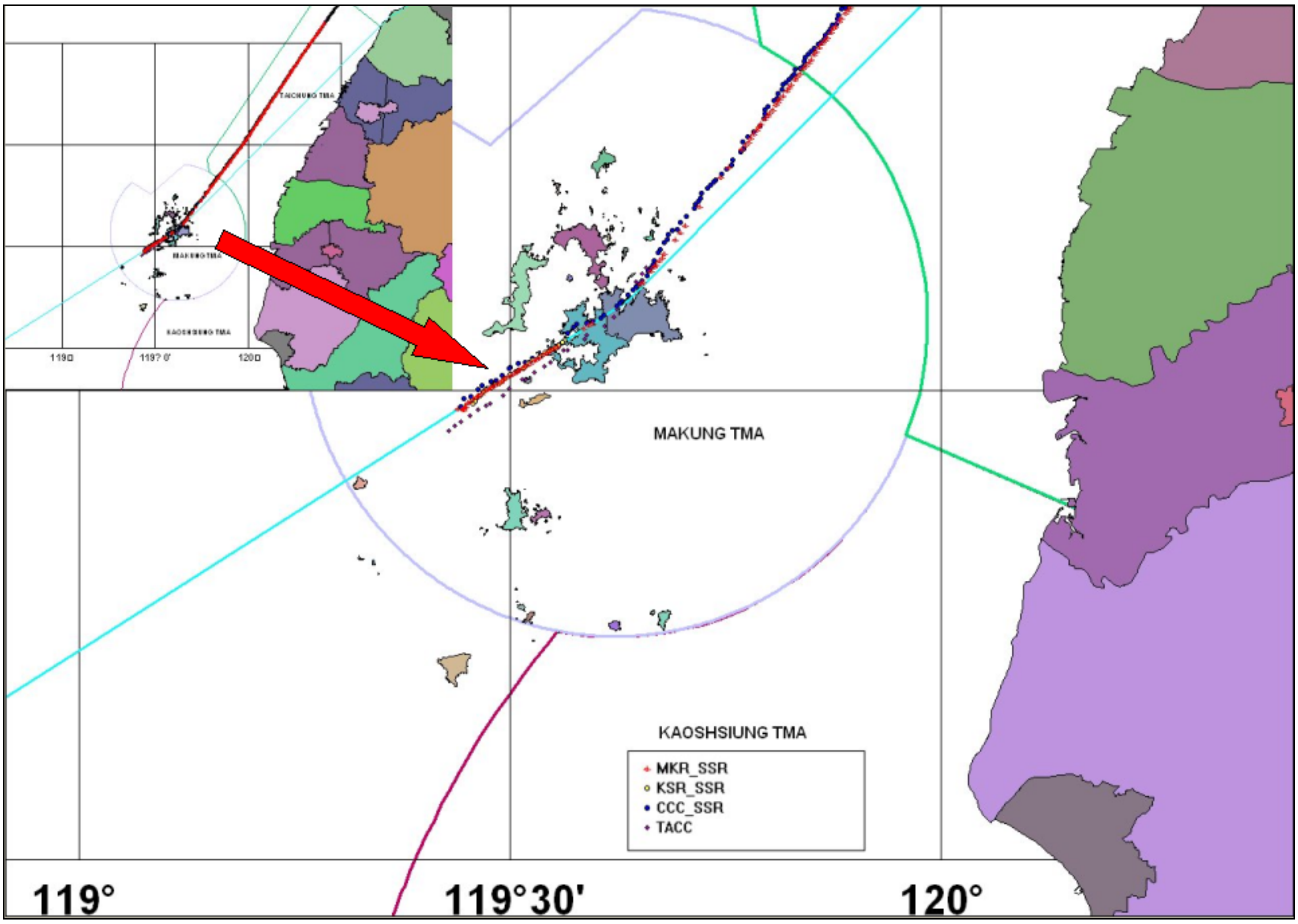

Figure 1.18-3 Superposition of the GE791 radar track, which were detected by the MKR, CCC, and KSR.

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

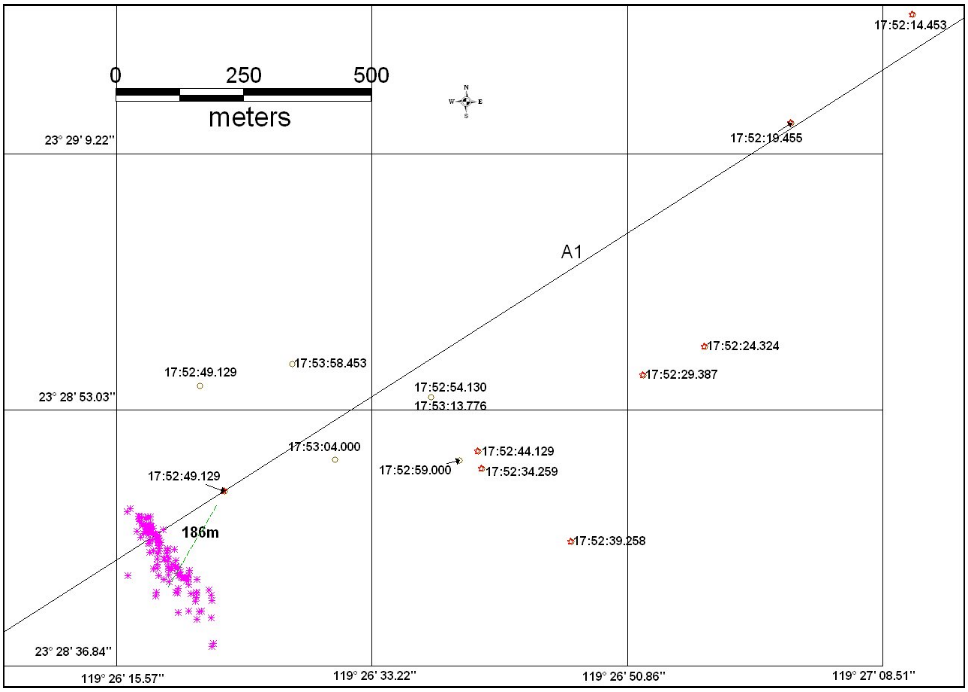

Figure 1.18-4　Primary and Secondary radar return of MKR and sonar targets

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.

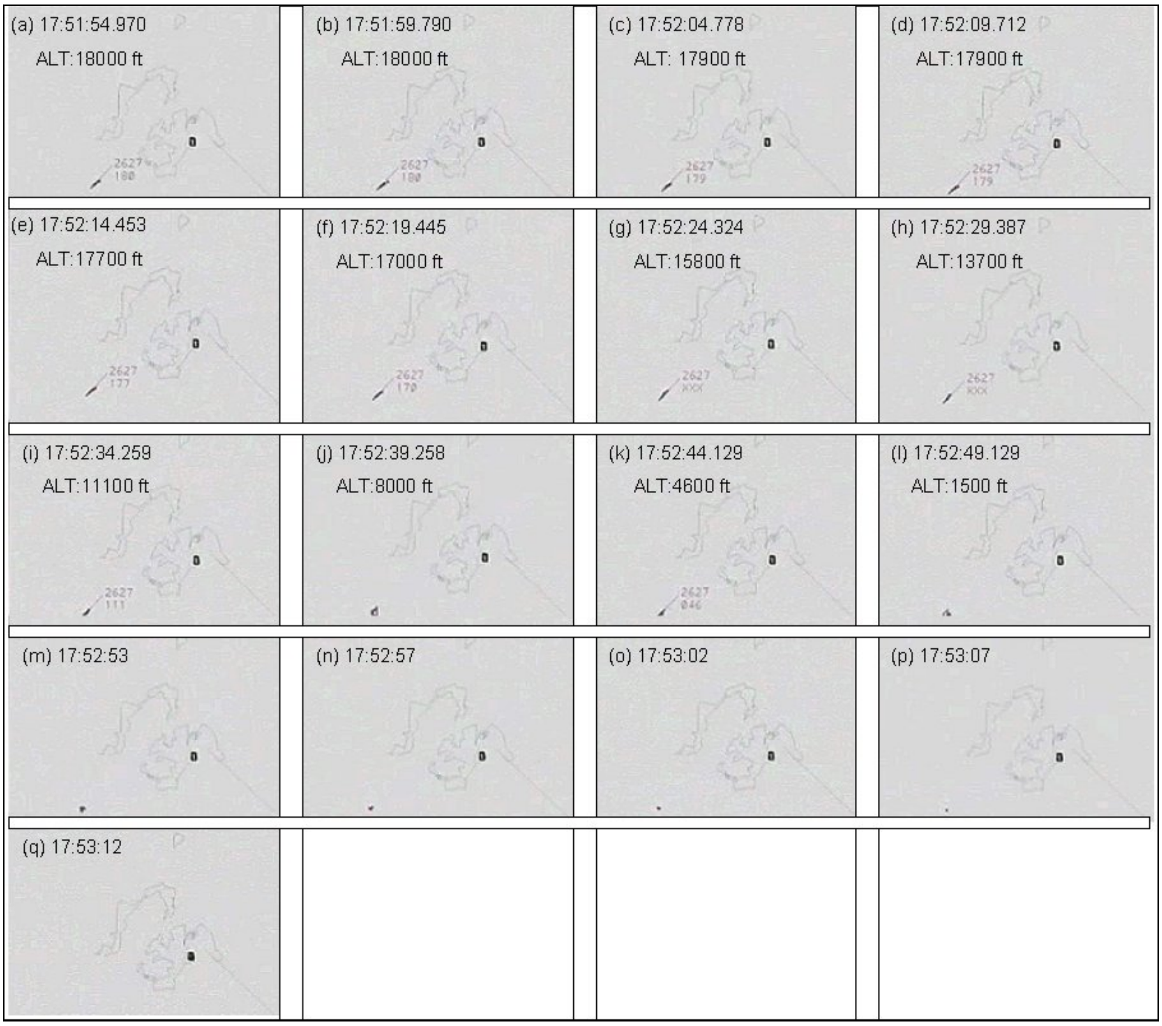

Figure 1.18-5 Secondary and primary radar returns recorded by the ATAS （from TACC）

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

[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.

[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.

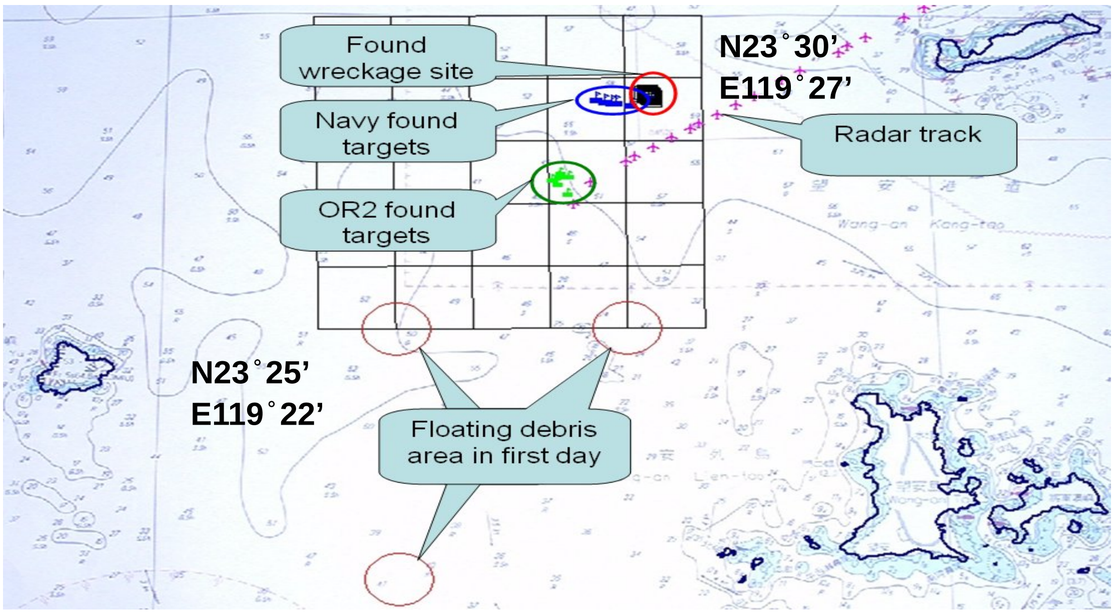

Figure 1.18-6 Shows the floating wreckage distribution, suspected targets areas and radar track.

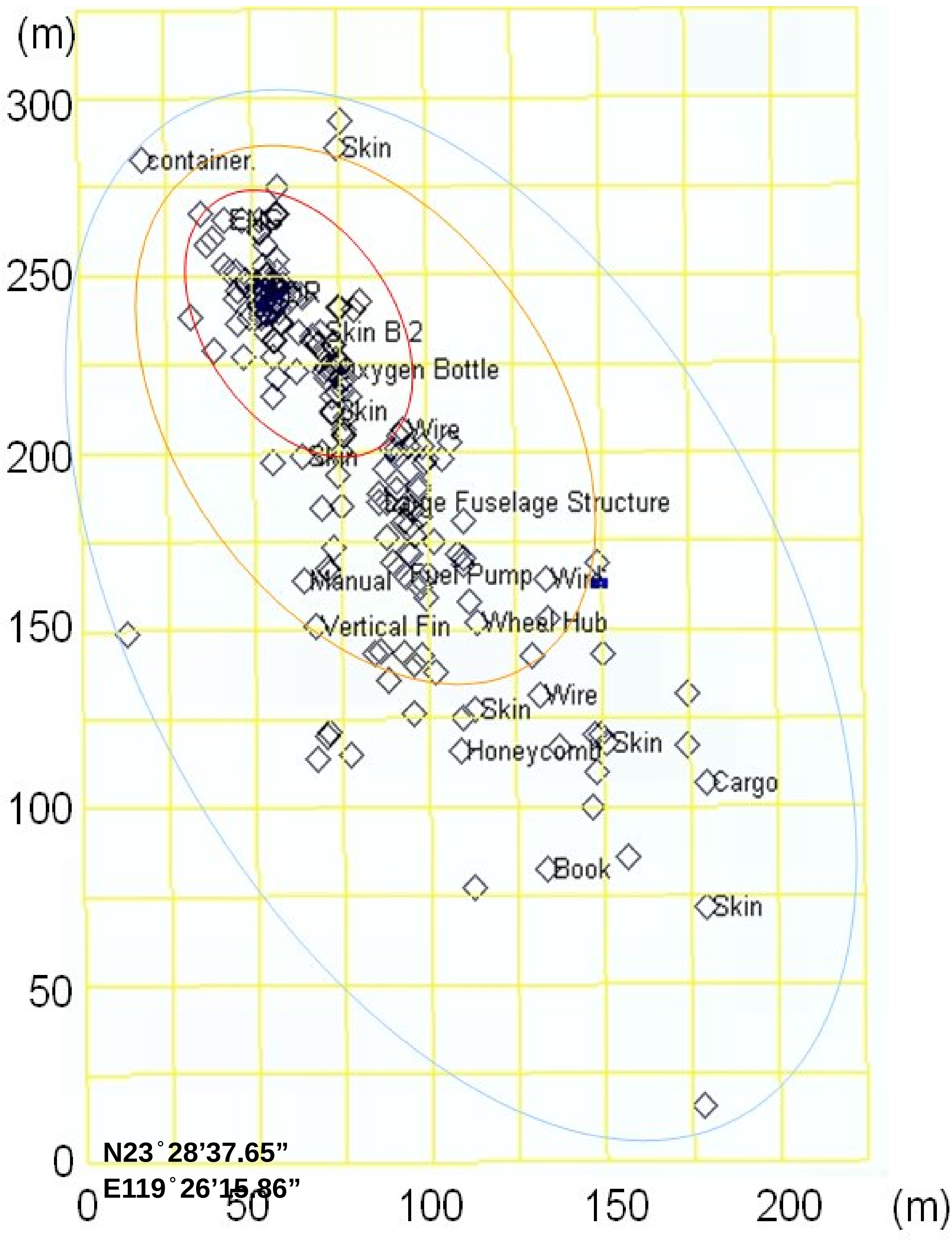

Figure 1.18-7 Wreckage distribution pattern

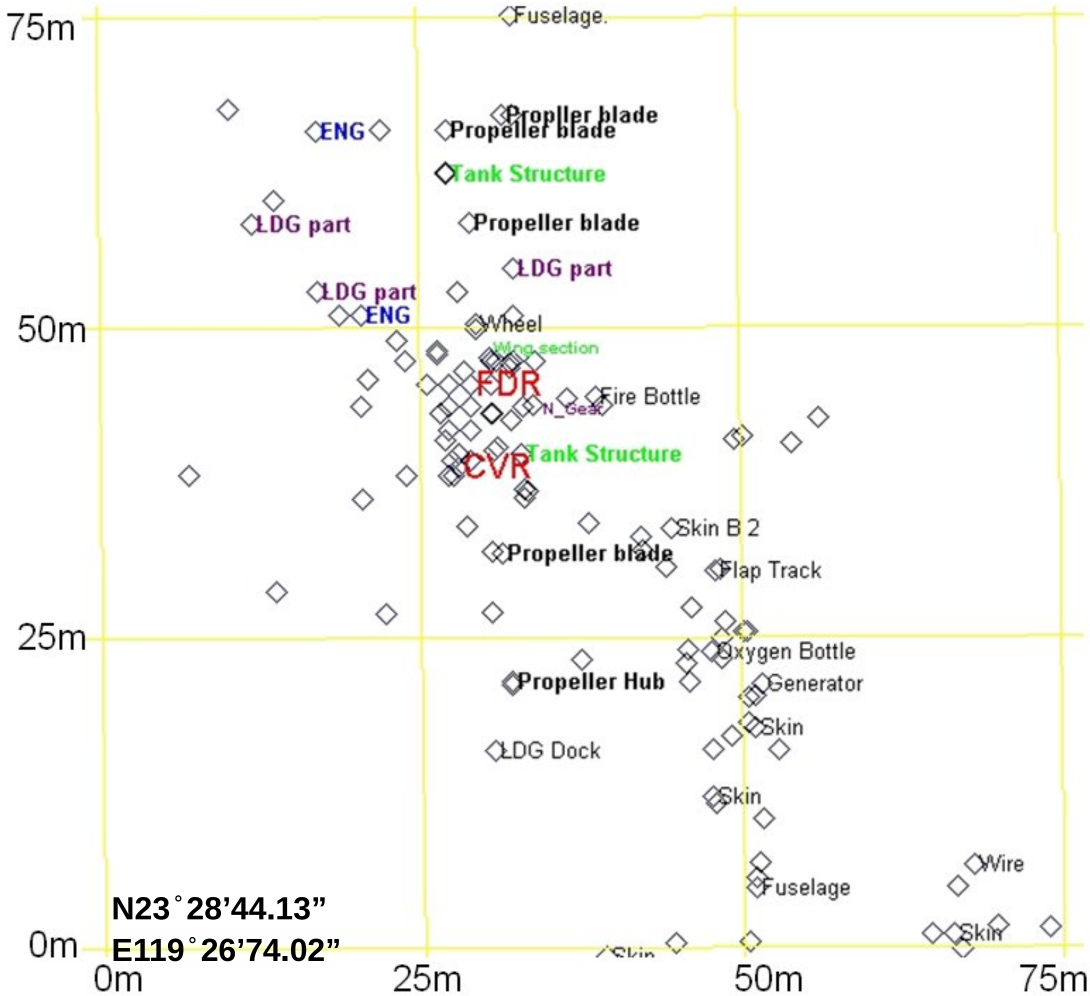

Figure 1.18-8 Wreckage distribution in dense area

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.

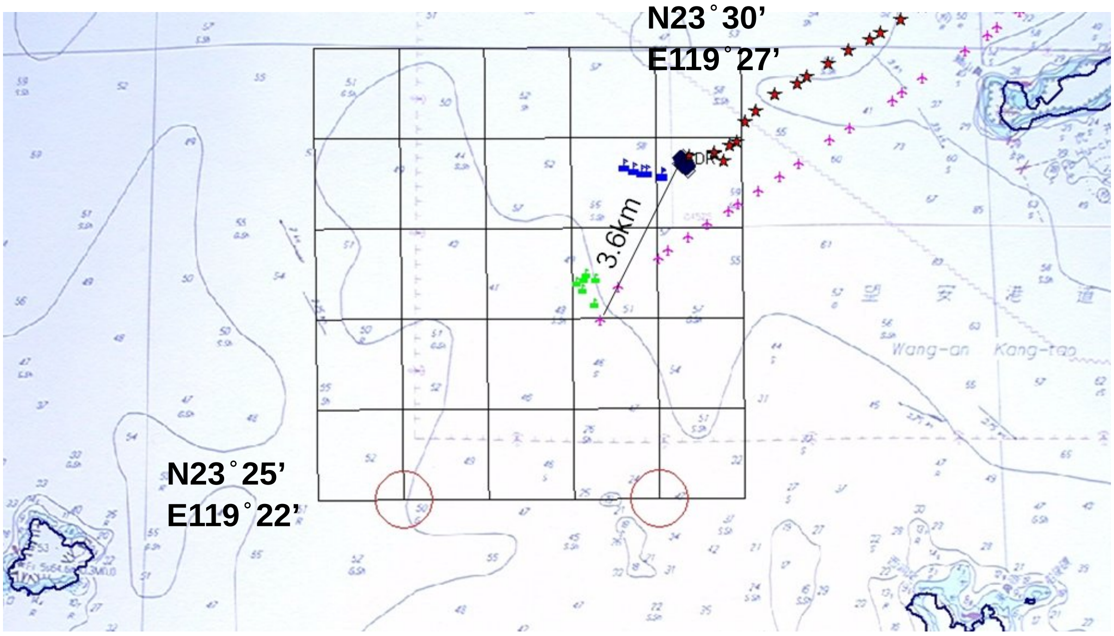

Figure 1.18-9 Comparison between radar tracks and main wreckage site

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.

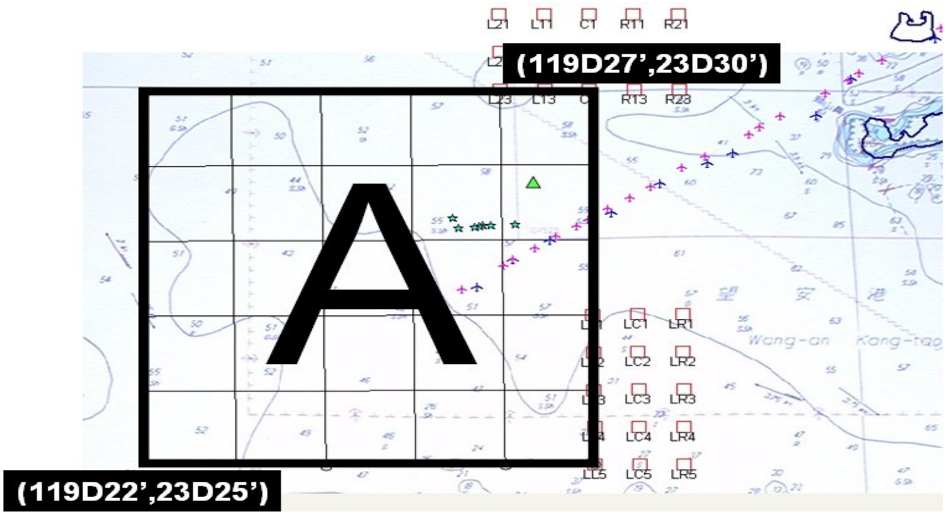

Figure 1.18-16 Initial search and survey area

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).

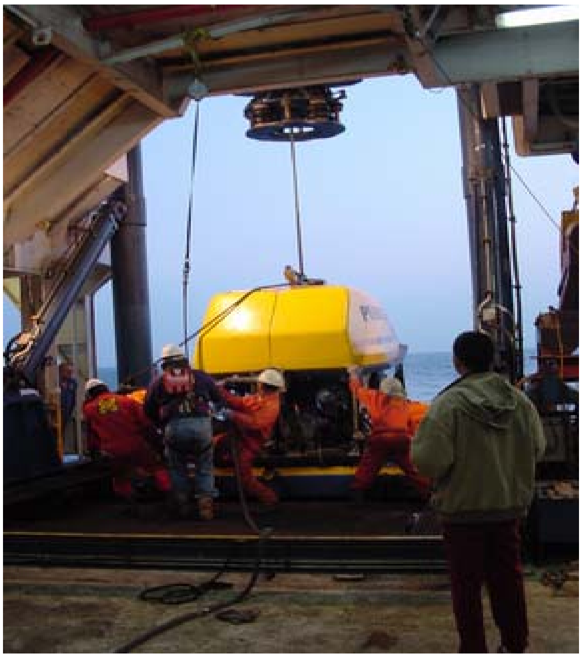

Figure 1.18-22 ROV operation on Ocean Hercules

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.

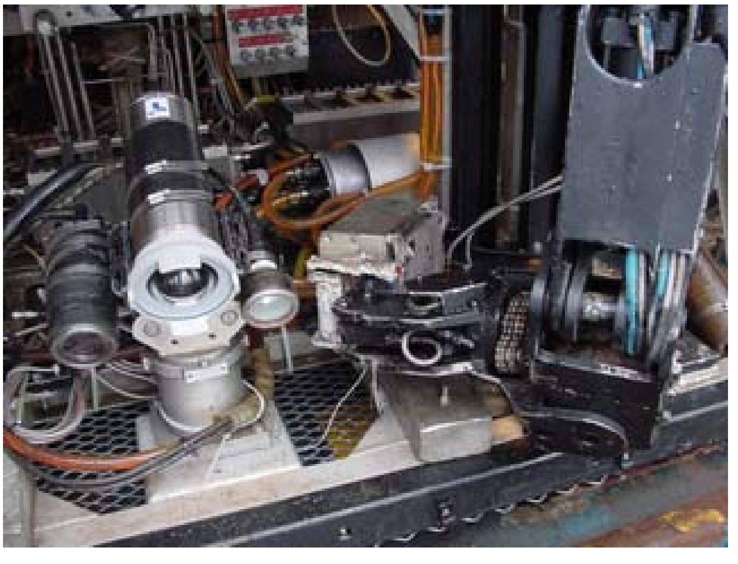

Figure 1.18-25 FDR recovered by ROV

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.*

[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)

<table>
<tr><th colspan="2">Icing Intensity Scale for forecasters</th><th colspan="4">Icing Severity Scale used by the U.S. Air Force in 1956</th></tr>
<tr><th rowspan="2">Icing Intensity</th><th rowspan="2">LWC (g/m3)</th><th rowspan="2">Icing Intensity</th><th rowspan="2">LWC (g/m3)</th><th>Ice collection rates</th><th rowspan="2">Aircraft Performance Criteria</th></tr>
<tr><th>Inches per 10 miles</th></tr>
<tr><td>Trace</td><td>0.0 - 0.1</td><td rowspan="2">Trace</td><td rowspan="2">0.0 – 0.125</td><td rowspan="2">0.0 – 0.09</td><td rowspan="2">Barely perceptible ice formations on unheated aircraft components</td></tr>
<tr><td rowspan="3">Light</td><td rowspan="3">0.1 – 0.6</td></tr>
<tr><td>Light</td><td>0.125 – 0.25</td><td>0.09 – 0.18</td><td>Evasive action unnecessary. (No perceptible effects on performance)</td></tr>
<tr><td>Moderate</td><td>0.25 – 0.60</td><td>0.18 – 0.36</td><td>Evasive action desirable. (Noticeable effects on performance)</td></tr>
<tr><td rowspan="2">Moderate</td><td rowspan="2">0.6 – 1.2</td><td>Heavy</td><td>0.6 – 1.0</td><td>0.36 -0.72</td><td>Eventual, evasive action necessary. (Aircraft is unable to cope with icing situation and extended operation is not possible)</td></tr>
<tr><td rowspan="2">Severe</td><td rowspan="2">> 1.0</td><td rowspan="2">> 0.72</td><td rowspan="2">Immediate evasive action is required. (Aircraft uses climb power to hold altitude, and continued operation is limited to a few minutes.)</td></tr>
<tr><td>Severe</td><td>> 1.2</td></tr>
</table>

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

[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:

> *<u>Note</u> : 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:

> ***<u>WARNING</u>:***
> *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.

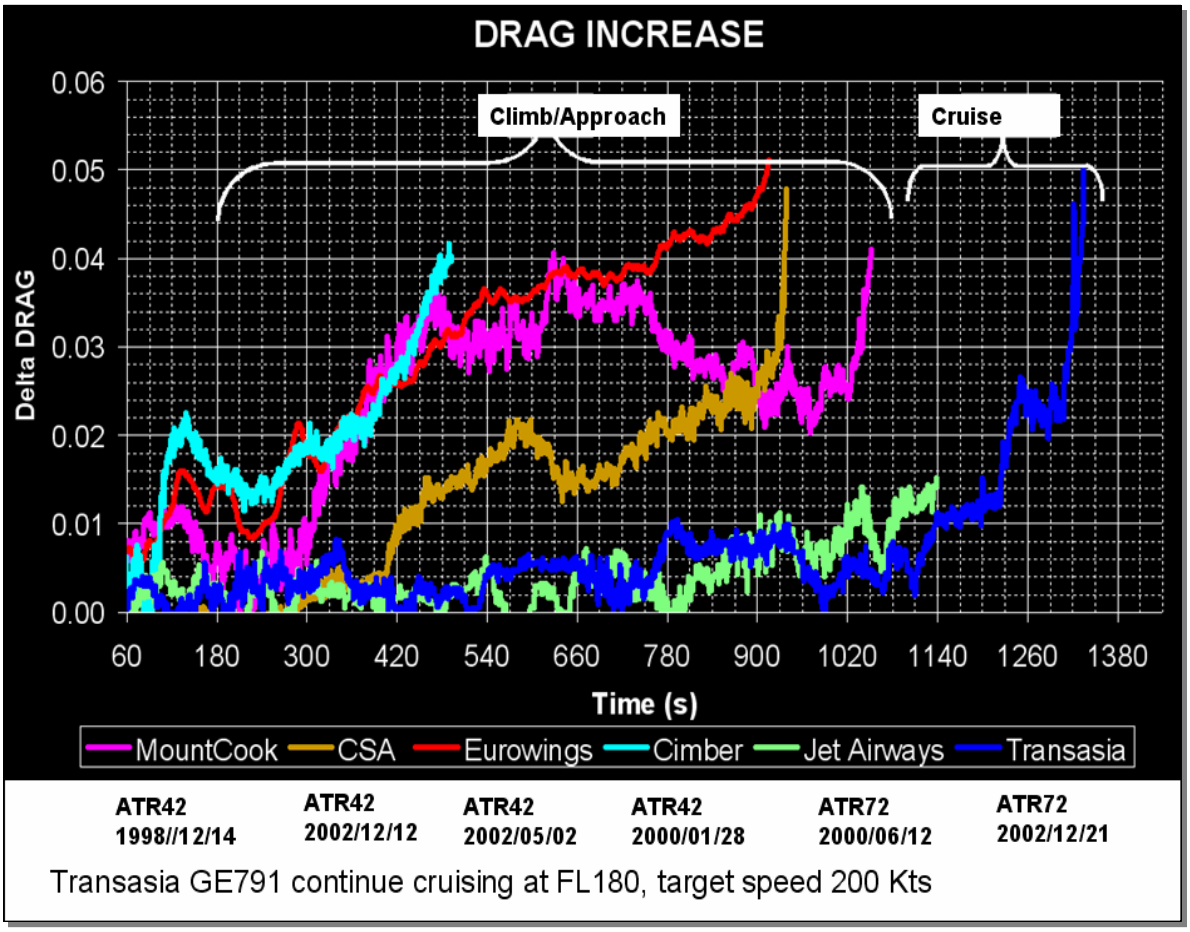

Figure 2.4-1 Aircraft extra drag due to ice versus time after Roselawn (1998~2002)

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.

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

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

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".

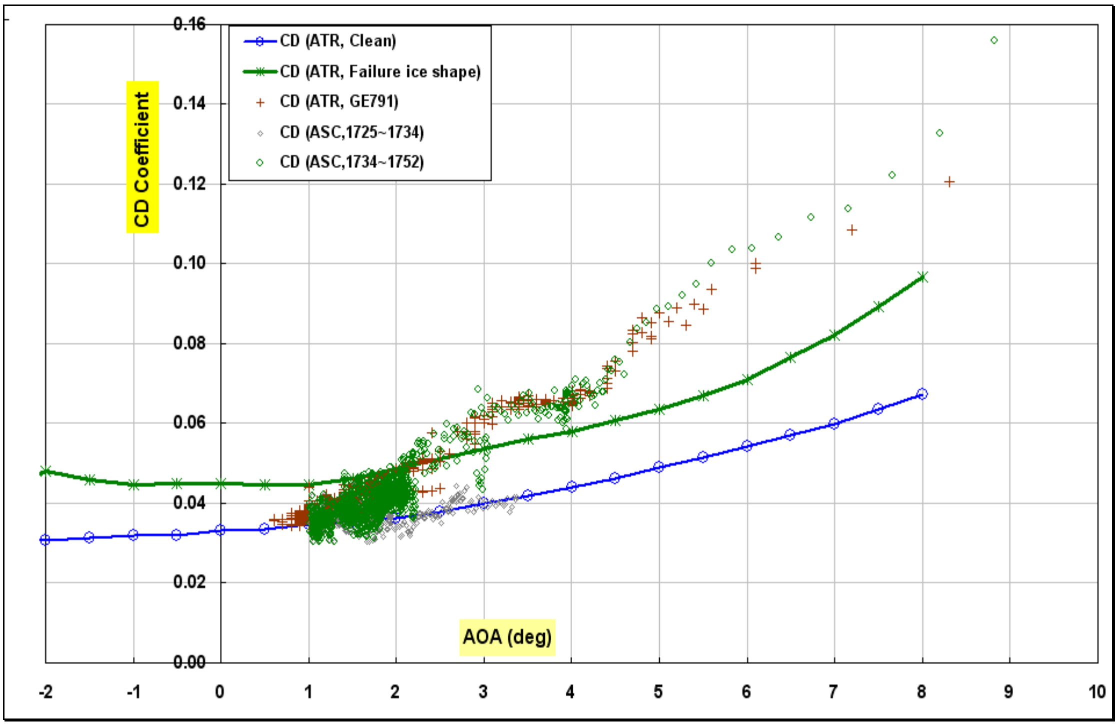

Figure 2.4-2 The extra drag of GE791 due to ice versus time (blue: clean configuration; green: de-icing boots inoperative; red: GE791 ice accretion)

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 $\pm$ 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$\pm$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.

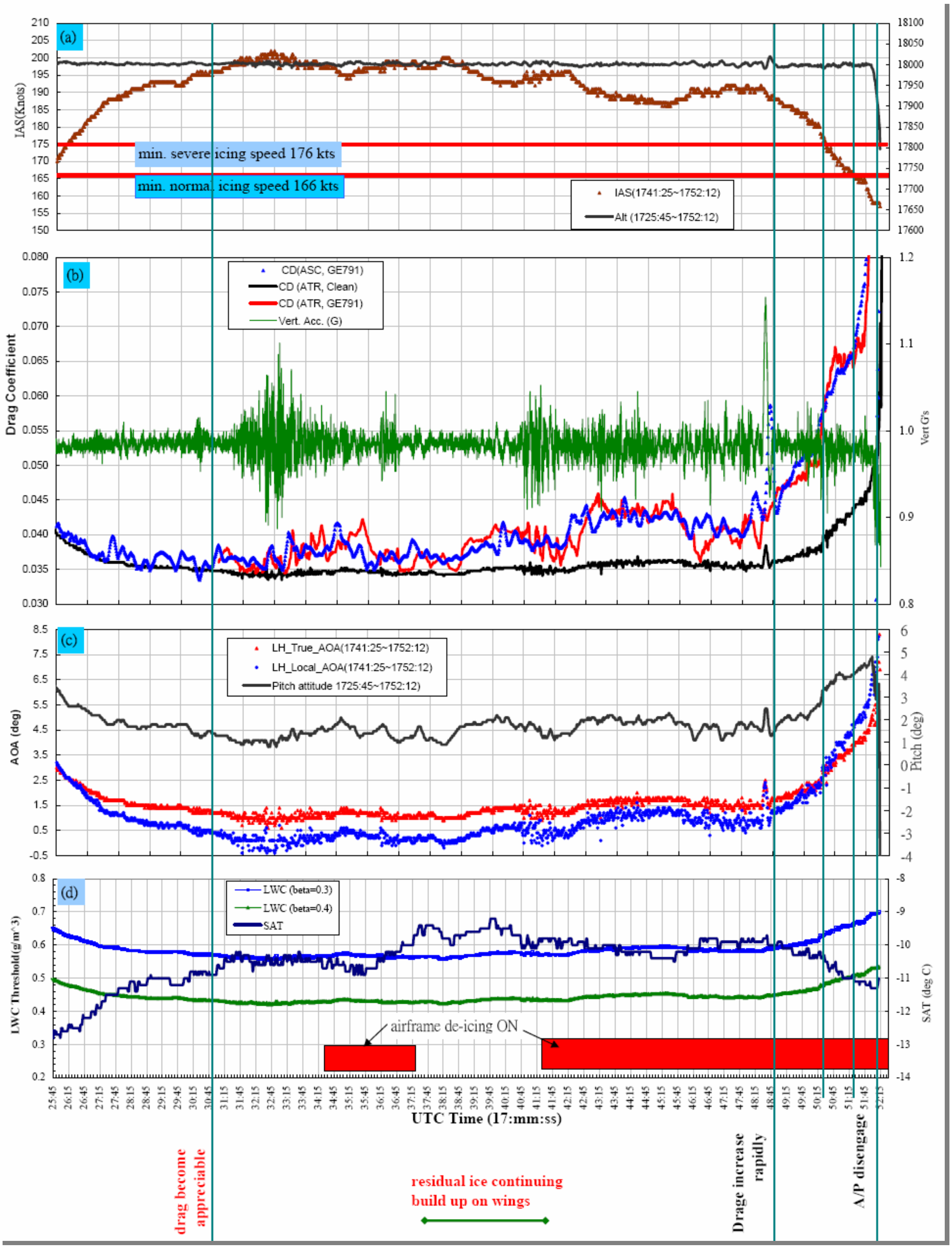

Figure 2.4-3 GE791 performance data plot due to ice accretion versus time (airspeed, altitude, OAT, drag, and severe icing threshold value of LWC)

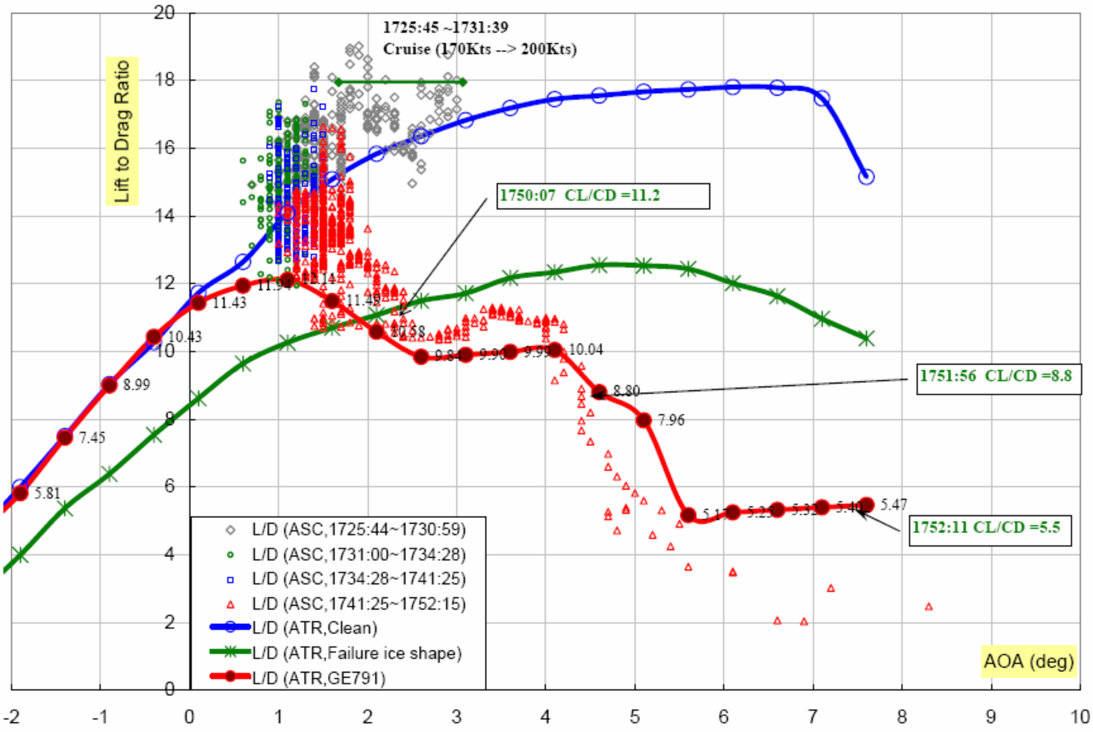

Figure 2.4-4 The lift-drag ratio of the GE791 due to ice accretion versus true AOA

<u>Performances during roll excursion</u>

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.

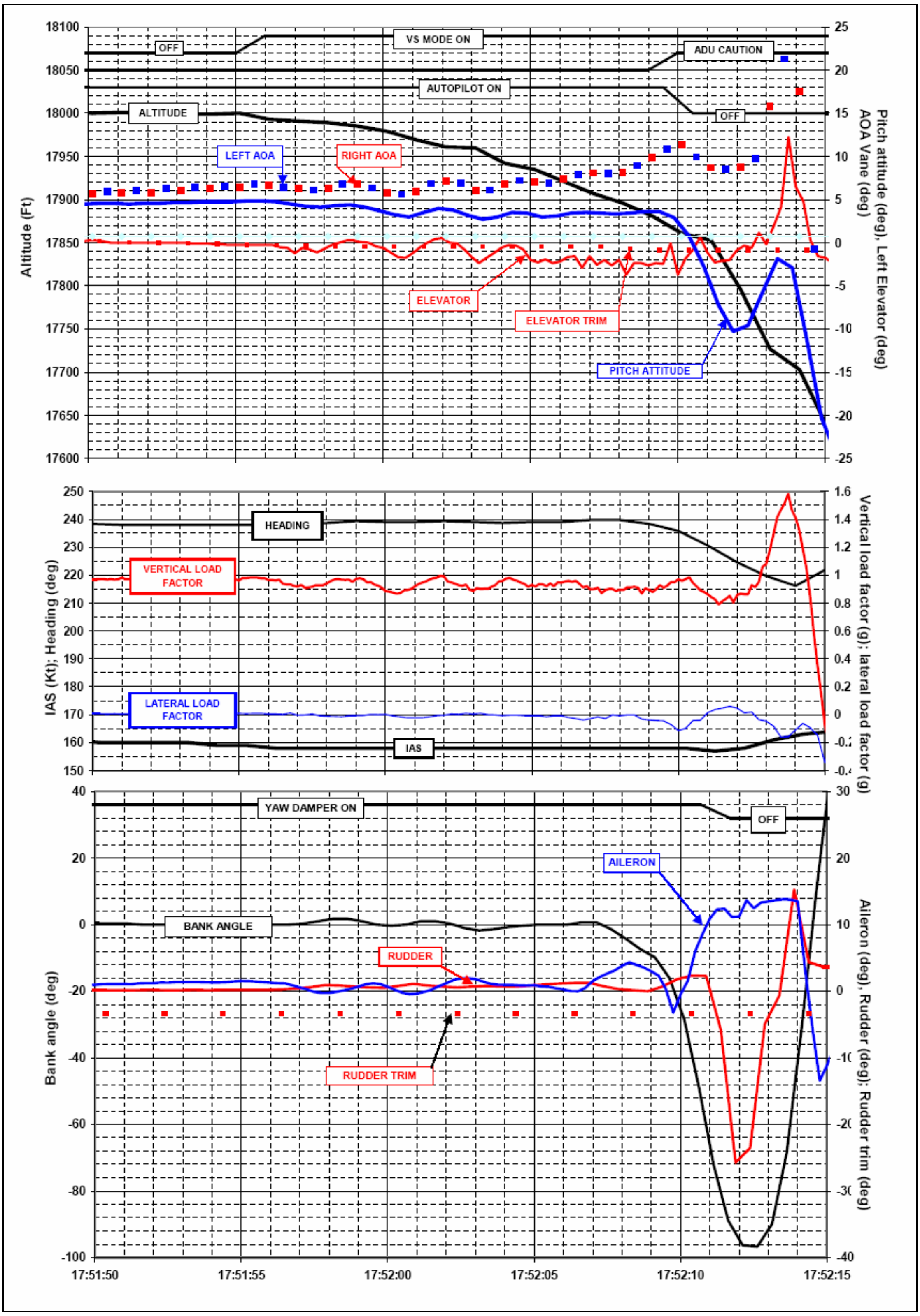

Figure 2.4-5 GE791 FDR data plot during the roll upset

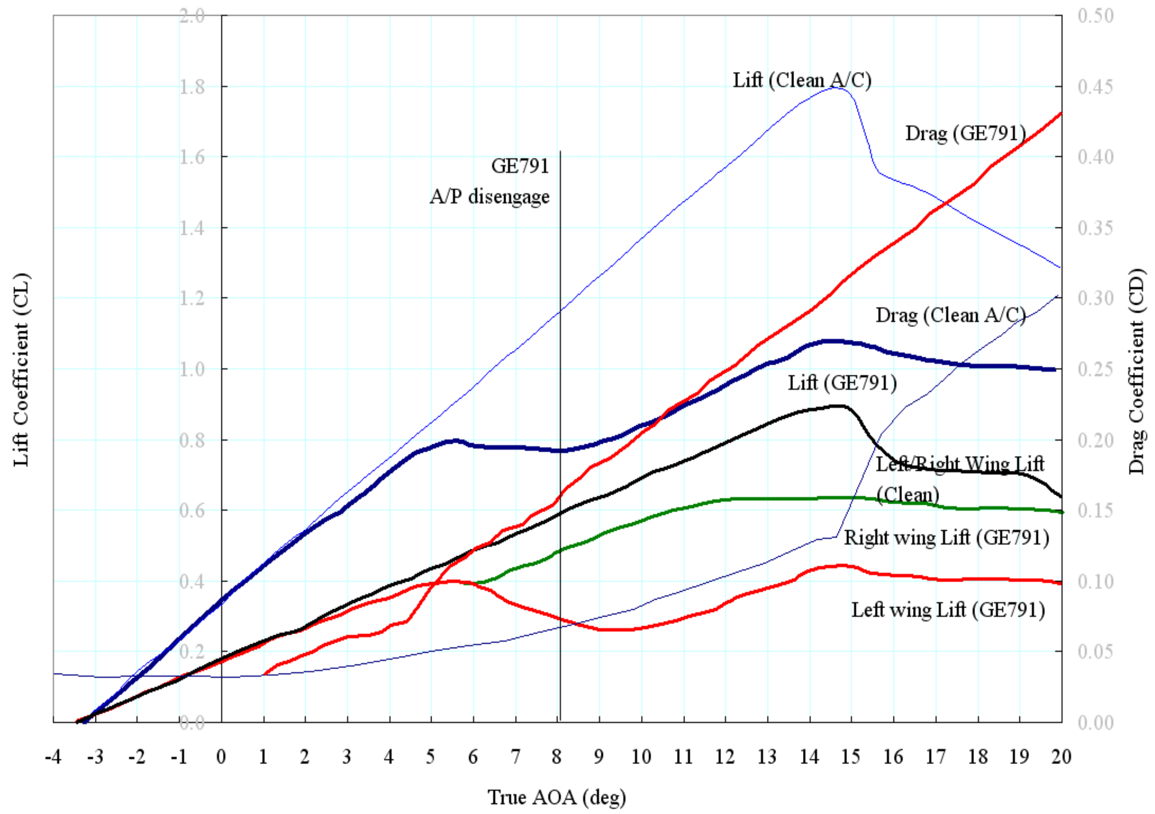

Figure 2.4-6 The lift and drag coefficients versus true AOA (ATR72 clean and GE791 ice polluted)

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

[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 conducted[31] 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.”

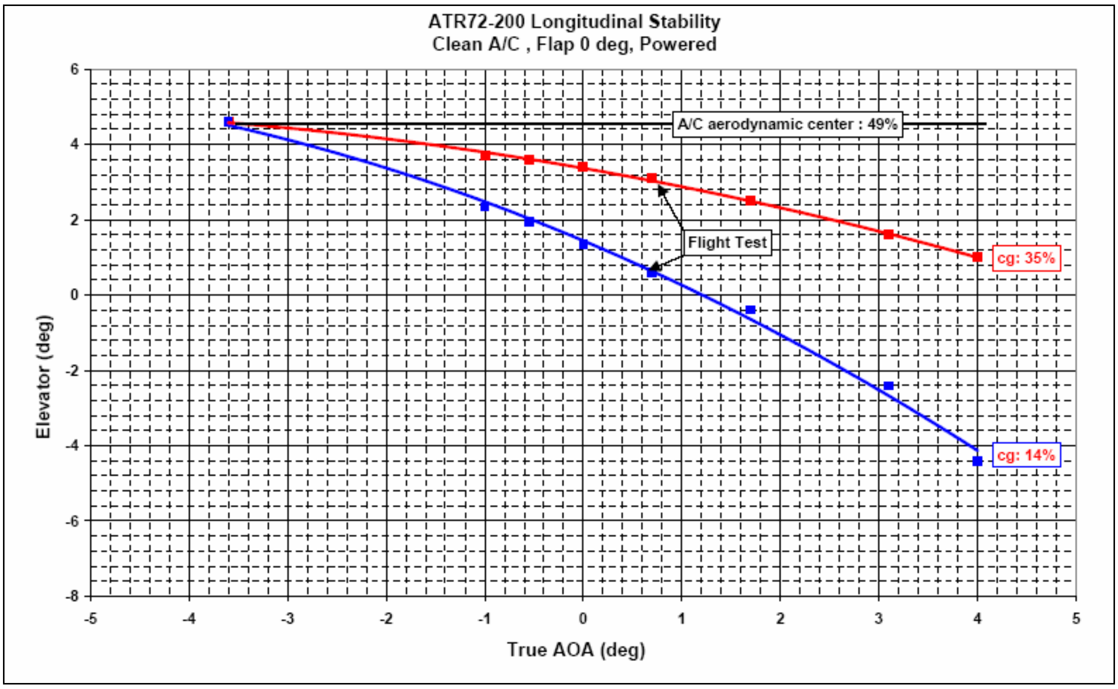

Figure 2.4-7 ATR 72-200 longitudinal stability

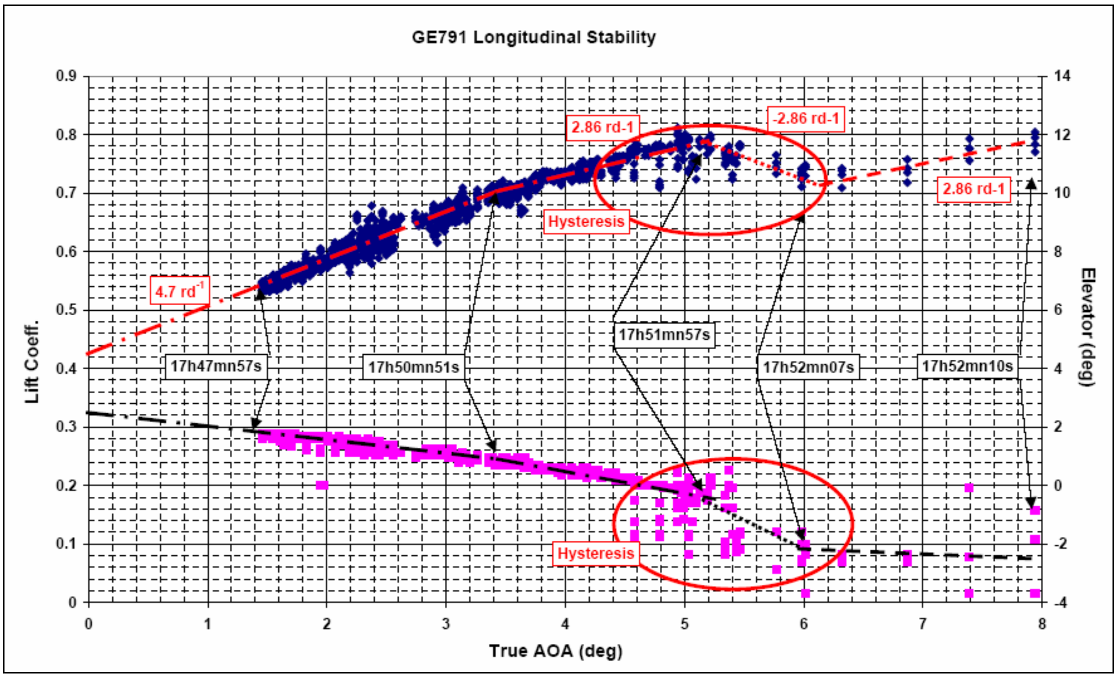

Figure 2.4-8   GE791 longitudinal stability (derived from FDR data)

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

[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

[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.

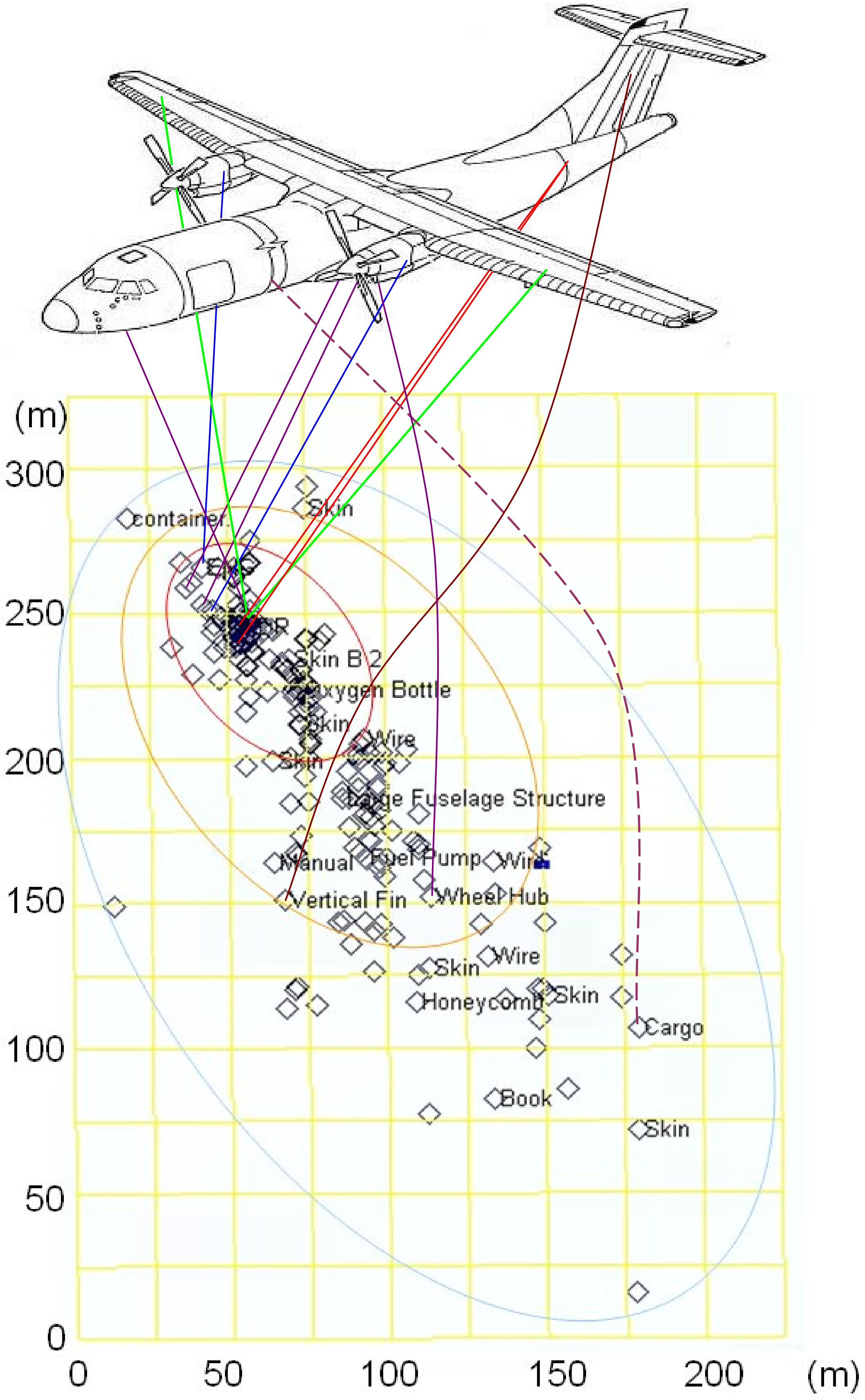

Figure 2.6-1 Wreckage scattering observed from ROV

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）

本公司看法為此條文中「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，氣溫為零下 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）

以上兩項條文為相互關聯之事件，於此合併提報。此二項條文我們看法為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。

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) 本公司為瞭解所屬 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，為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。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為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，氣溫為零下 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為結論依據如（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為：

1、該條文為附件，其目的係規範及提醒人員作業項目，非為僅

3

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為：

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，為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，天氣提示為固定及必要之程序，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為**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』，此為重要之飛航資訊，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為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 有效時間為 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 <u>20 日</u>1700 UTC	同上
10	（P34）	時間 1800 UTC	時間 <u>20 日</u>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 <u>20 日</u>1700 UTC	同上
12	（P34）	時間 1800 UTC	時間 <u>20 日</u>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 <u>20 日</u>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 <u>20 日</u>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<u>低（SFC-10,000 呎）、中（FL100-250）、高（FL250 以上）層</u>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 <u>0600 UTC</u> 至 <u>1000 UTC</u>，以及 <u>20 日 2030 UTC</u> 至 21 日 <u>0030 UTC</u>	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 <u>20 日</u>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。