Registration No.	
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Handling Agency	

Aircraft Accident Report

Hail Encounter During Approach
Asiana Airlines Flight 8942
A321-100, HL7594
20 miles South East of Anyang VOR
June 9, 2006

Aviation and Railway Accident Investigation Board
Korea Ministry of Construction and Transportation

ARAIB ARAIB/AAR0603

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January, 2008

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According to the Aviation and Railway Accident Investigation Act of the Republic of Korea, Chapter 4, Article 30, it is stipulated;

「Accident investigations shall be conducted separately from any judicial, administrative disposition, administrative lawsuit proceedings associated with civil or criminal liability.」

And in Annex 13 to the Convention on International Civil Aviation, Chapter 3, Paragraph 3.1 and Chapter 5, Paragraph 5.4.1, it is stipulated and recommended as follows;

「The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.」

「Any judicial or administrative proceedings to apportion blame or liability should be separate from any investigation conducted under the provisions of this Annex.」

Thus, based on the Aviation and Railway Accident Investigation Act of the Republic of Korea and Annex 13, this accident investigation report, including findings herein, as the result of the investigation effort of Asiana Airlines Flight 8942, shall not be used for any other purpose than to improve aviation safety.

If conflicts occur on the interpretation of this accident investigation report between the Korean version and English version, the Korean version takes priority over English version.

Aircraft Accident Report

Korea Aviation and Railway Accident Investigation Board. Hail Encounter during Approach, Asiana Airlines Flight 8942, A321-100, HL7594, 20 NM South East of Anyang VOR, June 09, 2006. Aircraft Accident Report ARAIB/AAR 0603, Seoul, Republic of Korea

Korea Aviation and Railway Accident Investigation Board (ARAIB) is an independent government agency, established on August 12, 2002. The Board conducts accident investigations in accordance with the provisions of the Aviation and Railway Accident Investigation Act of the Republic of Korea and Annex 13 to the Convention on International Civil Aviation.

The sole objective of the Board's investigation of an accident or incident shall be the prevention of accidents and incidents, and it is not the purpose of the activity to apportion blame or liability.

The main office is located near Gimpo International Airport, and the flight recorder analysis and wreckage laboratories are located inside the airport.

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Contents

Ⅰ. Title

- Aircraft Operator: Asiana Airlines
- Aircraft Manufacturer: Airbus Industry, France
- Aircraft Type: A321-100
- Nationality of Aircraft: The Republic of Korea
- Registration: HL7594
- Date and Time: June 9, 2006, 17:40 (Korea Standard Time[1])
- Place of Accident: 20 miles South East of Anyang VOR

  N37°05'26.7" E127°25'21.0"

Ⅱ. Executive Summary

On June 9, 2006, about 17:40, Asiana flight 8942(flight 8942 hereinafter), an Airbus 321-100 (Registration HL7594), operated by Asiana Airlines, en route from Jeju International Airport (Jeju Airport hereinafter) to Gimpo International Airport (Gimpo Airport hereinafter), encountered a thunderstorm accompanied by hailstones around 20 miles southeast of Anyang VOR at an altitude of 11,500 ft during descending to approach Gimpo Airport, and the radome in the nose section of the aircraft was detached and the cockpit windshield was cracked due to impact with ice stone carried by the thunderstorm .

Flight 8942 was a regularly scheduled domestic passenger service flight operating under instrument flight rules (IFR). At the time of the accident, one captain, one first officer, 4 cabin crew and 200 passengers were on board, and no one sustained injuries in this accident.

Upon notification of the accident, the Korea Aviation and Railway Accident Investigation Board (ARAIB hereinafter) initiated an independent investigation in accordance with Korean Aviation Act, and the International Civil Aviation Organization (ICAO) and the BEA, the investigation authority of France (State of Design and Manufacture), were notified of the accident pursuant to the provisions of Annex 13 to the Convention on International Civil Aviation.

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[1] Unless otherwise indicated, all times herein are Korea Standard Time, based on 24-hour clock.

After the on-site investigation, the ARAIB issued an immediate safety recommendation to the Civil Aviation Safety Authority to execute radome inspection of all Korea registered Airbus series aircraft, and there were no failures in latches found. And a technical meeting was held between the ARAIB, the BEA and the EASA (European Aviation Safety Agency), and details on the radome detachment, damage to cockpit windshield, disconnection of auto pilot system, etc. were discussed.

The analysis of the accident included examinations of issues related to the accident sequence, SIGMET information, air traffic control services, damage to aircraft by hail encounter, etc.

As a result of the investigation, the ARAIB developed findings derived from the factual information and the analysis of the flight 8942 accident. There are three different categories of findings: findings related to probable causes, findings related to risk, and other findings.

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

The ***Findings related to risk*** identify elements that have the potential to degrade aviation safety. Some of the findings in this category identify unsafe acts, unsafe conditions, and safety deficiencies, including organizational and system risks, that have the potential to degrade aviation safety; however, they cannot be clearly shown to have operated in the incident. Further, some of the findings in this category identify risks that are unrelated to this incident, 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 unsolved ambiguity. Some of these findings are of general interest and are not necessarily analytical, but are often included in the ICAO format of incident/accident reports for informational, safety awareness, education, and improvement purposes.

Note: Findings are a key part of this report and published solely to identify safety deficiencies and risk for the prevention of future incidents/accidents. Any use of the findings to assign blame or liability would be a violation of international aviation law and international best practices, including those contained in Annex 13, Chapter 3, Paragraph 3.1, and Chapter 5, Paragraph 5.4.1, to the Convention on International Civil Aviation.

Findings Related to Probable Causes

The flight route selected by the flight 8942 crew in order to avoid the thunderstorm was not separated enough by distance from the thunderstorm, and the alertness to the thunderstorm paid by the flight crew during descending was not sufficient, and the flight direction chosen when in close proximity to the thunderstorm was not appropriate to avoid the thunderstorm.

Findings Related to Risk

1. Flight 8942 was maintaining high descending speed when encountered with the thunderstorm.

2. The speed of flight 8942 was increased to 346.4 knots almost close to the maximum operating speed (350 knots) after disconnection of auto thrust and auto pilot systems.

3. The noise generated after the detachment of radome seriously hindered conversations between the flight crew and the communications between the flight crew and the approach control. .

4. The cracked cockpit windshield seriously impeded the flight crew from having visual contact with the runway and making a landing.

5. The disconnection of auto thrust, auto pilot and fight director systems seriously impeded the flight crew from making a stable landing.

6. Asiana Airlines did not use the weather forecast or SIGMET information officially dispatched by Aviation Meteorological Office through AFTN by means of having them input in the FMC, instead obtained the necessary weather information including weather forecast by means of logging into the weather information system provided additionally by Aviation Meteorological Office.

7. SIGMET information was not announced by Aviation Meteorological Office although it existed between 16:30 and 18:30 on the day of accident.

8. It is stipulated in a relevant agreement that the weather forecaster of Aviation Meteorological Office should conduct a weather briefing to the Air Traffic Center controllers, however, on the day of accident, the briefing was not conducted to the group of the controllers on duty who provided the ATC services to flight 8942.

9. The controllers of Seoul Approach Control could not receive directly in their control seats SIGMET information officially provided by Aviation Meteorological Office, instead, they used a system of obtaining weather information by logging into the weather information system provided additionally by Aviation Meteorological Office, which was insufficient to receive on time the weather forecast or SIGMET information announced at irregular hours.

10. Under the weather condition of visibility of 5 miles or less in Gimpo Airport, the airport lightings were switched on by the Gimpo Tower controller 14 minutes after the controller was aware of the emergency landing declared by flight 8942, the timing of which was inappropriate.

11. Air traffic control and Seoul approach control were not operation the broadcasting system on the SIGMET information for the aircraft flying in their control areas.

Other Findings

1. The flight crew of flight 8942 were certified and qualified for this flight, and airworthiness certificate of the aircraft was valid.

2. The regulated maintenance was performed on flight 8942, and no defects were found in its structure or systems prior to the accident.

3. The weight and balance of flight 8942 were within the specified limits, and the fuel loaded was appropriate for a flight between Jeju Airport and Gimpo Airport.

4. Asiana Airlines selected the weather related training for flight crew as an annual based regular training subject, and was in possession of training materials on the thunderstorm characteristics and avoidance, and the training on aircraft radar was included in flight crew initial and transition/upgrade training syllabuses.

5. When the Seoul Approach controller, as deemed necessary, selects radar detected altitude and distance on the terminal doppler weather radar monitor located next to the control seat, the monitor displays the intensity and range of echoes in colors, however, SIGMET can't be detected on the monitor.

6. The echo area was shown in black color on the control radar display in Seoul Approach Control while flight 8942 was flying in its control area, however, the intensity of the echoes could not be identified by the system.

7. The Air Traffic Center controller gave permission when flight 8942 crew requested heading 030° to avoid clouds about 15 miles south of NUMDA, and also notified it to Seoul Approach Control.

8. Seoul Approach Control received the information from Air Traffic Center in advance that flight 8942 was flying at a heading of 030 ° in order to avoid clouds, and gave permission to maintain heading 030 ° after establishing radio contact with flight 8942.

9. Echoes were displayed on the monitors of the control radar and the terminal doppler weather radar in Seoul Approach Control, however, the controller did not provide advice on the echo positions or did not recommend to avoid echoes since the flight crew had requested heading 030 °.

10. Air Traffic Center was receiving in the controller's seat SIGMET related forecast or SIGMET information announced by Aviation Meteorological Office, and was making reference to cloud distribution or precipitation area by searching for observational images of Aviation Meteorological Office weather radar and weather satellite on the personal computer for weather information.

11. When the flight crew declared an emergency situation and informed of having no foreview, the approach controller tried to reassure the flight crew, saying, "You can depend on the controller for the view," and gave a timely instruction to climb when the aircraft was flying toward mountainous terrain deviated from the final approach course.

12. After flight 8942 executed two missed approaches due to inappropriate handling of speed and altitude, the controller was substituted in a timely manner with a more experienced controller in precision approach radar, and this controller vectored the aircraft to the runway safely in a method of precision approach, providing the appropriate altitude and heading by magnifying the control radar display.

13. Aviation Meteorological Office produces and announces route forecast, area forecast and SIGMET information, and on the day of the accident, the route forecast and area forecast including thunderstorm effective for flight 8942 was announced and dispatched through AFTN.

14. According to the observation records of the weather satellite, weather radars and terminal doppler weather radar, there were isolated rain clouds accompanied by heavy precipitation in the air space where the aircraft encountered with the hailstorm.

15. Due to the unavailability of an aeronautical chart drawn of en-route or location of aerodrome on the display of the weather radar or weather satellite images, it was difficult for the controllers or civil aviation related personnel to accurately identify the en-route associated with SIGMET.

16. According to the FDR recording and the result of precise examination of the airborne weather radar conducted by the weather radar manufacturer, the weather radar transceiver was operating normally.

17. Radar components installed inside the radome and forward pressure bulkhead were damaged by the exposure to the outside due to the radome detachment.

18. The left radome hook latch was in the locked position when the handle was ripped off. .

19. The origin of the loads opposed to the locking loads exerted on the pushbutton.

20. The latch was detached by the huge external force and it penetrated into the engine cowling as it was detached from the radome.

21. The handle was pulled off by the radome body after the latter was damaged.

22. There was no hailstorm certification requirement established on the radome design of A321 type aircraft.

On the basis of these findings, the ARAIB developed safety recommendations to Asiana Airlines, air traffic control facilities (Air Traffic Center [2], Seoul Approach Control), Meteorological Administration (Aviation Meteorological Office), aircraft manufacturer (Air Bus Industry, France) , and the European Aviation Safety Agency (EASA).

[2] As of July 1, 2006, the name has changed from "Air Traffic Control Station" to "Air Traffic Center," which has a control room, and it is called Incheon ACC for its control function.

Ⅲ. BODY

1. Factual Information

1.1 History of Flight

On June 9, 2006, about 17:40, flight 8942, an Airbus 321-100 (Registration HL7594), operated by Asiana Airlines, en route from Jeju Airport to Gimpo Airport, encountered a thunderstorm accompanied by hailstones around 20 miles southeast of Anyang VOR at an altitude of 11,500 ft during descending to approach Gimpo Airport.

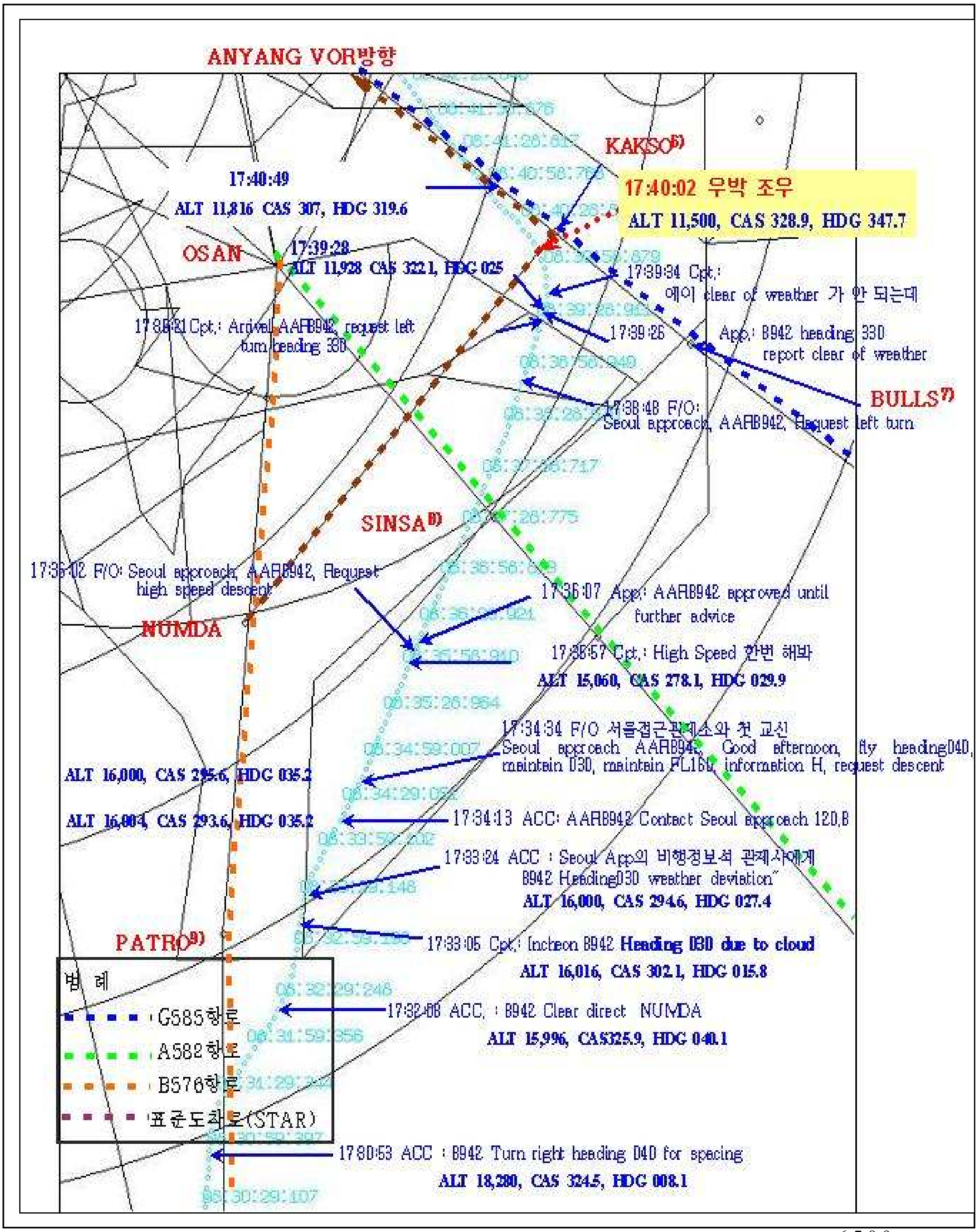
Flight 8942 was a regularly scheduled domestic passenger service flight operating under instrument flight rules (IFR). At the time of the accident, one captain, one first officer, 4 cabin crew and 200 passengers were on board, and no one sustained injuries while the radome in the nose section of the aircraft was detached and the cockpit windshield was cracked.

On the day of the accident, the flight crew were scheduled for two round-trip flights between Gimpo and Jeju Airports departing from Gimpo Airport at 11:50. And at the time of the accident, the aircraft was on the final leg to Gimpo Airport after departing from Jeju Airport about 17:05.

According to the radar track (refer to Figure 1) and Cockpit Voice Recorder recordings, when flight 8942 was flying along route B576[3] to Gimpo Airport after taking off from Jeju Airport, at 17:30:53, the controller in Air Traffic Center instructed flight 8942 to fly heading 040 ° for the separation from the other aircraft around 30 NM south of NUMNDA[4], and at 17:32:08, instructed the flight to fly directly to NUMNDA in order to reenter route B576.

At 17:33:05, the flight crew requested heading 030 ° to avoid[5] clouds during a turn to NUMDA, and the controller gave permission.

3 Route connecting Jeju-Gwangju-Osan VOR.
4 Location on route B576, about 6 km south of Asan, Chungnam province.
5 Captain requested, “Incheon, AAR 8942, heading 030 due to cloud.”



[Figure 1]CVR & ATC Transcript Plotted along the Flight Track from the FDR Data(6,7,8,9)

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6 Location on route G585 (Iljuk IC, Gyeonggi province).
7 Location on route G585 (4.4 km east of Geumwang, Chungbuk province).
8 Location on route A582 (8.6 km west of Jincheon, Chungbuk province).
9 Location on route B576 (14.8 km north of Buyeo, Chungnam province).

At 17:34:04, immediately after the flight crew requested[10] the controller of Air Traffic Center for the further descent from an altitude of 16,000 ft, the Air Traffic Center controller transferred the control of flight 8942 to Seoul Approach Control, and the Seoul Approach Control controller gave permission to descend to an altitude to 11,000 ft.

At 17:36:02, the flight crew requested[11] high speed descent, and the controller permitted it. In the meantime, the speed of flight 8942 reached up to about 325 knots at 17:37:09.

At 17:38:33, flight 8942 started to shake as it was passing through an area at an altitude of about 13,000 ft, and the cabin crew announced to check passenger seat belts fastened.

At 17:38:42, the captain instructed[12] the first officer to request for a left-turn, and at 17:38:48, the first officer requested the left-turn to the controller ("Seoul Approach, AAR8942 request left Turn").

At 17:39:26, flight 8942 was given permission to turn left to 330 °, and during the turn, it encountered with a hailstorm[13] for 36 seconds from 17:40:02 until 17:40:38.

After the encounter with the hailstorm, the radome located in the front section of the aircraft was detached, and the surface of windshield was cracked to the extent that the flight crew were not able to discern the foreview.

In addition, Auto Thrust System, Auto Pilot System and Flight Director System were disconnected. The flight crew manually attempted to approach and land on runway 14R of Gimpo Airport twice following the radar vectoring of the approach controller, but went around due to its difficulty in safe landing. About 18:13, they made a successful and safe landing on the third approach attempt.

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[10] First officer requested, "Incheon Control, AAR 8942, request further descent."
[11] At 17:36:02, flight 8942 requested while passing through an area at an altitude of 15,000 ft. Even though the flight speed within Seoul Approach Control area is limited to less than 250 knots, with the controller's permission, the speed can be more than 250 knots.
[12] Requested left-turn without desired heading.
[13] Encounter with hailstorm: At 17:40:02, Location N37°05'26.7"/ E127°25'21.0", Altitude 11,500 ft, Speed 328.9 knots, Heading 344.7 °, Bank 25.3 °.

1.2 Injuries to Persons

Injuries	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	0	0	0	0	0
Severe	0	0	0	0	0
Minor	0	0	0	0	0
No Injury	2	4	200	0	**206**
Total	**2**	**4**	**200**	**0**	**206**

1.3 Damage to Aircraft

In accordance with Chapter 1, General, 1.2.1(Definitions), Aircraft Accident Investigation Policy and Procedures Manual[14] of the Korea Aviation and Railway Accident Investigation Board, flight 8942 sustained substantial[15] damage by the encounter with the hailstorm, and the damage was estimated to be about 3.5 million U.S. dollars.

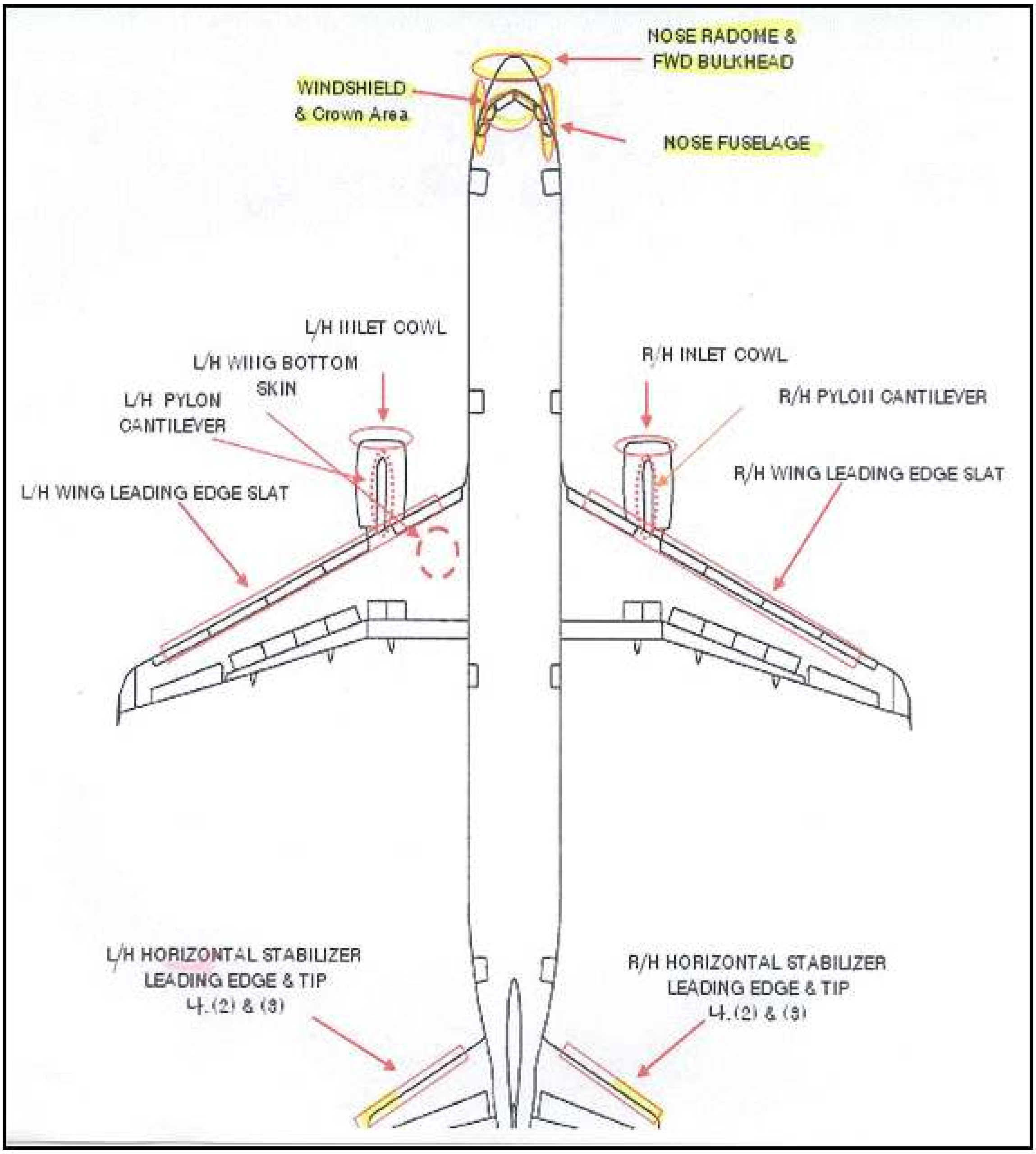
The airframe of flight 8942 was damaged overall, and the radome in the front section of the aircraft was torn away, and there were about 40 marks found in the forward pressure bulkhead and in the rivets of the inlet cowling. Some of the rivet heads were broken off in a serious case.

Some parts of the engine mounted area were damaged by debris from the radome, and the hail marks were found in wing leading edges.

Horizontal stabilizer leading edges and both tips were also damaged by the hailstorm, and the locations of damage are shown in [Figure 2].

14 Established on March 22 of 2006.

15 Substantial Damage: Damage of an aircraft which seriously affects the aircraft performance or structural strength while airworthiness can be maintained by means of the repair or modification inspection of the Minister of Construction and Transportation after repairing the damaged part or replacing equipment, etc



[Figure 2] Damaged Areas (Shown In Red Color)

1.4 Other Damage

There was no other damage caused by the detached radome from the aircraft.

1.5 Personnel Information

1.5.1 The Captain

The captain (age 45) with military career was hired by the company in March 1997, had worked as a first officer for B747-400 and A321 until January of 2005, and was promoted to a captain of A321 in March 2005.

The captain held a valid airline transport pilot license, a first class airman medical certificate (valid through November 30, 2006) and a radiotelephone operator's certificate. His total flight time was 6,950 hours including 2,024 hours in the A321 aircraft type with 917 hours as a pilot in command on the type.

The flight hours for the recent three months were 154 hours including 54 hours for recent one month, and he completed recurrent training and passed proficiency check in April 2006.

He stated that he was off-duty the day before the flight, and had enough sleep after exercise. In addition, he testified not to have taken any unauthorized medicine and health status was normal.

1.5.2 The First Officer

The first officer (age 40) with military career was hired by the company in July 2005, and was promoted to a first officer for A321 in May 2006 after completing the initial training course.

The first officer held a valid commercial pilot license, a first class airman medical certificate (valid through February 8, 2007) and a radiotelephone operator's certificate. His total flight time was 3,876 hours including 198 hours in the A321 aircraft type.

The flight hours for the recent three months were 171 hours including 73 hours for recent one month, and he was promoted to a first officer in May, 2006 after passing the line check, having succeeded in proficiency check in January 2006.

He stated that he had a roundtrip flight between Jeju and Gimpo Airports from 13:15 to 15:05 in the previous day, had enough sleep, and did not take any unauthorized medicine, and his health status was normal.

1.6 Aircraft Information

1.6.1 History of Aircraft

Flight 8942 was A321-100 manufactured by Airbus Industry, France on November 2, 2000, and was being in operation since introduced to Asiana Airline as of November 15, 2000.

The total flight hours of the aircraft were 11,427:23 hours and number of landing / takeoff was 16,008 until June 9 of 2006.

Flight 8942 was equipped with dual V2500-A5 engines manufactured by International Aero Engine and the total operational hours since installation were 2,333:23 hours for the left engine and 4,962:57 hours for the right one.

1.6.2 Aircraft Maintenance Discrepancies

The aircraft had six flight operations on the day of accident, had nothing found to be abnormal in the examinations before and after the flights, and had no defects recorded on the flight / maintenance logs until the day of accident.

1.6.3 Weight and Balance

The Takeoff Weight Center of Gravity Percentage Mean Aerodynamic Chord (TOW C.G % MAC) of flight 8942 was 25.36, which was within the allowable limit. Based on the comparison between the maximum and actual takeoff weights, there was margin for takeoff, and the followings are the information in detail.

- Zero fuel weight (ZFW)………………109,932 LBS (Max. 155,426 LBS)
- Take-off fuel (TOF)…………………… 12,900 LBS
- Trip fuel (TIF)……………………………5,699 LBS
- Take-off weight (TOW)……………….152,832 LBS (Max. 171,961 LBS)
- Landing weight (LDW)………………..147,132 LBS (Max. 164,245 LBS)
- Pay load……………………………….. 33,577 LBS

Flight 8942 was carrying authorized fuel required for trip from Jeju to Gimpo Airport, and the information about loaded fuel is shown in the followings:

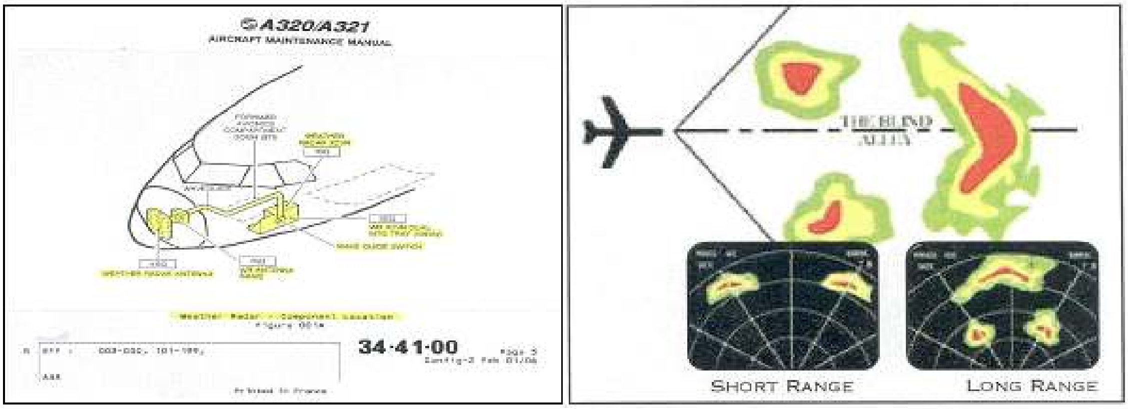
- TIF (Trip fuel)………………………………………5,700 LBS
- CONT (Contingency fuel, 10 % extra)………………...1,400 LBS
- ALTN (Alternate fuel)…………………………………2,600 LBS
- HOLD (Holding fuel)…………………………………..3,200 LBS
- RQRD (Required fuel)……………………………......12,900 LBS
- TOF (Take-off fuel)…………………………………..12,900 LBS
- TAXI (Taxi fuel)………………………………………300 LBS
- RAMP (Ramp fuel)…………………………………..13,200 LBS

1.6.4 Weather Radar

1.6.4.1 Composition

The weather radar of flight 8942 is consisted of major parts such as Transceiver, Control Unit, Antenna Drive Unit, and Flat-plat Array Antenna, etc., and all of them were manufactured by Honeywell, USA.

The left of [Figure 3] is showing the location of parts for weather radar. The location and shape of obstacles in the atmosphere can be detected and displayed as an image while the radar antenna scans the area up to ±90 degrees in right and left direction and 320 NM in forward area by motion device. In addition, it can detect the existence of precipitation and location of cloud when adjusted.



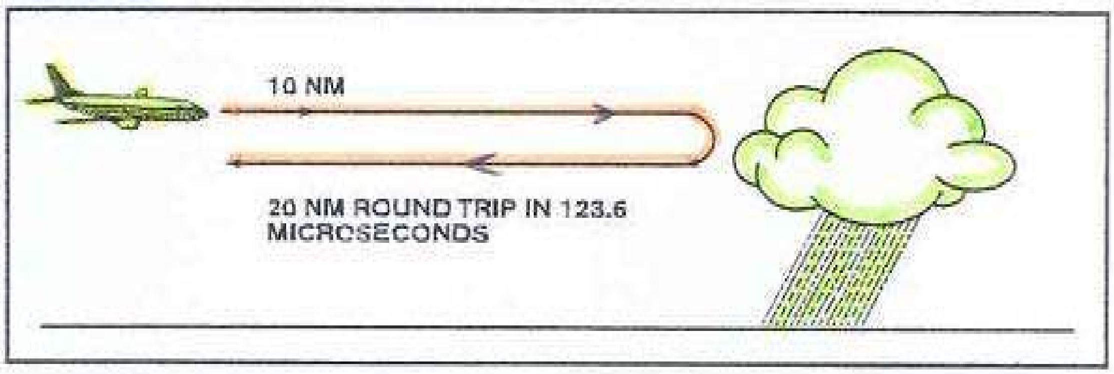
[Figure 3] Parts for Weather Radar (Left) and Precipitation Image on Display (Right)

1.6.4.2 Function

The major function of built-in weather radar is to show the weather status in real time to crew members to recognize and avoid bad weather during flight.

The function of built-in weather radar is that the antenna inside radome sends out cone-type microwave in 3° angle moving left and right ±90° from center line, and it transforms the strength of wave into the energy and makes it reflected from obstacle onto the images of weather status.

The speed of microwave sent from the built-in weather radar is close to the speed of light and the strength of reflected wave can be shown in colors on the navigation display of cockpit as shown in bottom, right corner of [Figure 3], and the relationship between response time and distance to obstacle is shown in [Figure 4].

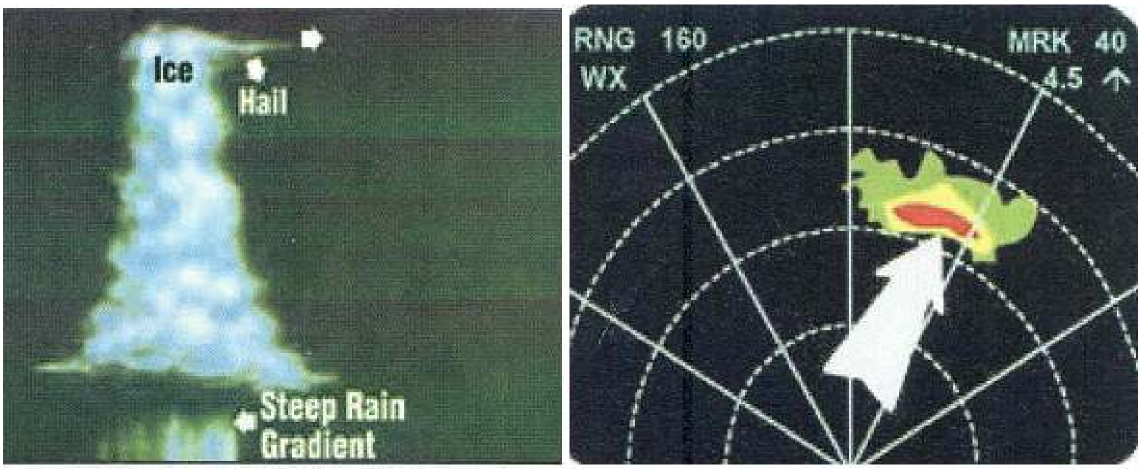


[Figure 4] Radar Microwave Response Time/Distance Relationship

1.6.4.3 Operation

It is necessary for flight crew to operate the weather radar system during flight. This ensures the safe flight by detecting thunderstorm in advance. In order to precisely detect the weather status in air path, the selection of distance should be changed periodically and the tilting of antenna up and down is also required.

When a cliff-like rain cloud is ahead of the flight as shown in [Figure 5] on the left side, periodic adjustment of antenna's tilt and distance is necessary to figure out the accurate shape for detection.



[Figure 5] Normal Image When Thunderstorm is Scanned in Overall

Since the echo from large wet hails displayed like a large water droplet, it creates good reflection of radar wave. The amount of precipitation is shown in colors on the display of cockpit.

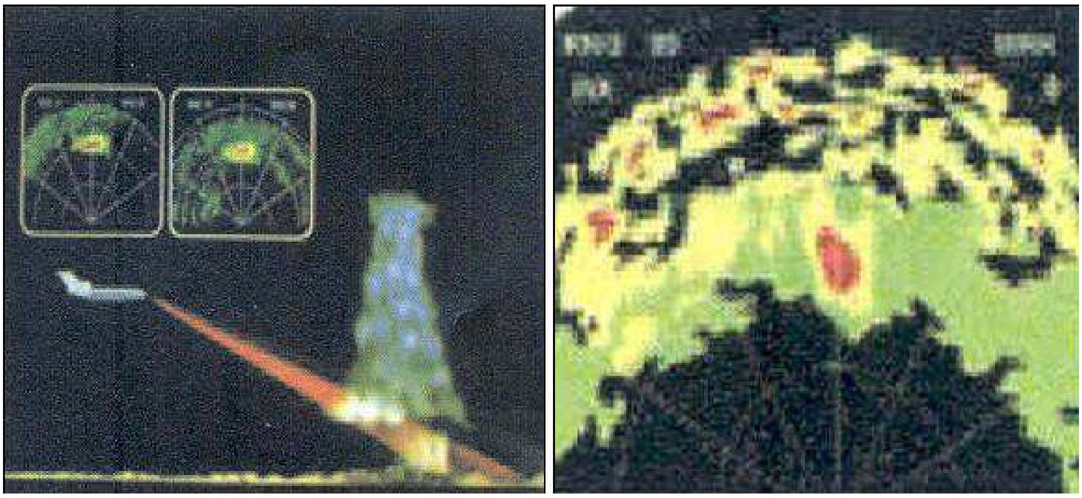
Therefore, the manufacturer clearly states that the crew should manually change the tilt of antenna when passing the bad weather expected area.[16] The center of radar beam should be adjusted to scan up and down in the direction of aircraft.

16 Radar Manufacturer (Honeywell) Weather Radar System User's Manual with Radar Operating Guidelines, Page 56, 61, 68, 71.

Since the hail is generally coated with water, it is working as a large water droplet creating the strongest echo among all kinds[17].

The crew adjusts the tilt of antenna a little upward during flight or landing. In this way, the echo from bad weather can be discerned from the one reflected from the ground[18].

When flying with the antenna angle downward, the overall shape of thunderstorm can not be shown from time to time and radar beam reflected from the ground may be displayed as shown in [Figure 6].



[Figure 6] Image Scanning Bottom Part of Thunderstorm

1.6.4.4 Precipitation Display

Flight 8942 was carrying weather radar manufactured by Honeywell, and, when bad weather was detected during the flight, the amount of precipitation could be displayed in high resolution and by colors on the screen in the cockpit. In addition, the MWO in Incheon Airport is also equipped with the system to transfer weather information to airlines by utilizing radar displaying the precipitation.

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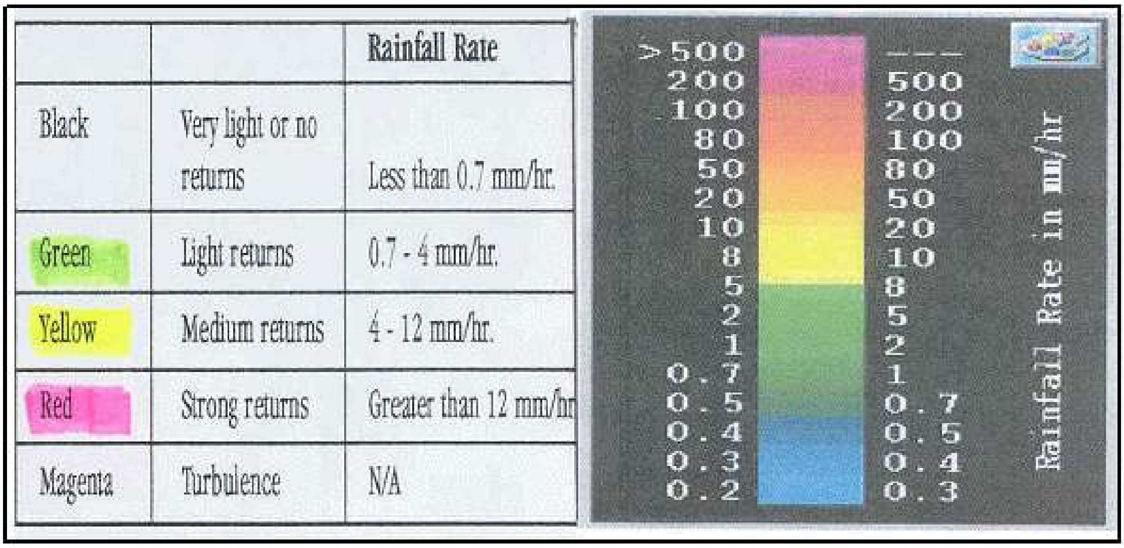
17 Radar Manufacturer (Honeywell) Weather Radar System User's Manual with Radar Operating Guidelines, Page 47 (Hailstones usually are covered with a film of water and acts as huge water droplets giving the strongest of all echoes.)

18 Ground Clutter

The amount of precipitation is shown in colors such as black, green, yellow, and red on the display as shown in [Figure 7] as per user's manual by Honeywell. Black color indicates no precipitation while red color shows the heaviest precipitation, which is more than 12mm per hour, and magenta color means turbulence.

In the meantime, Terminal Doppler Weather Radar in Incheon Airport shows the precipitation more than about 100mm per hour in red as shown in the right side of [Figure 7]. Therefore, the weather radar shows red colors for less precipitation compared to Terminal Doppler Weather Radar in Incheon Airport.



		Rainfall Rate
Black	Very light or no returns	Less than 0.7 mm/hr.
Green	Light returns	0.7 - 4 mm/hr.
Yellow	Medium returns	4 - 12 mm/hr.
Red	Strong returns	Greater than 12 mm/hr
Magenta	Turbulence	N/A

[Figure 7] Indication of Precipitation in Built-in Weather Radar (Left) and Terminal Doppler Weather Radar (Right)

1.6.4.5 User's Manual

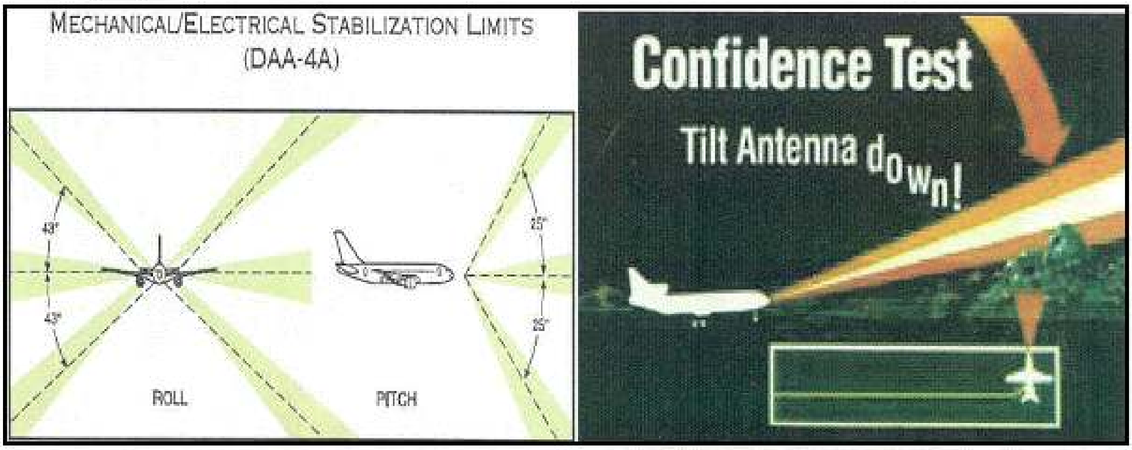
User's manual states that "When there are indistinguishable layers of precipitation or cliff-like precipitations layer at both sides, it is a very dangerous situation. In observing of short range, the distance should be set to long range to verify the distance to an obstacle in front."[19]

19 RDR-4B Forward Looking Windshear Detection / Weather Radar System User's Manual with Radar Operating Guidance, P66

As shown in [Figure 3] (right), only small obstacles are displayed in both sides when short range is set, whereas large ones shown when long rage is selected.

According to the user's manual[20] by the manufacturer, Honeywell, the captain must examine the condition of radar prior to operation. The same statement can be found in the operation manual for A321-100.

The antenna is designed to detect any change in weather within ±90° in left and right, ±25° in pitching, and ±40° in rolling, and within the range of ±43° in case of tri-axial movement.



[Figure 8] Detection Range for Positions of Aircraft and Examination of Radar System Prior to Operation

1.6.4.6 Control and Indication

The navigation display in the cockpit simulates navigation information and weather image information in real time as shown in [Figure 9]. There are five modes to simulate. At each mode except PLAN[21], weather radar image is displayed[22].

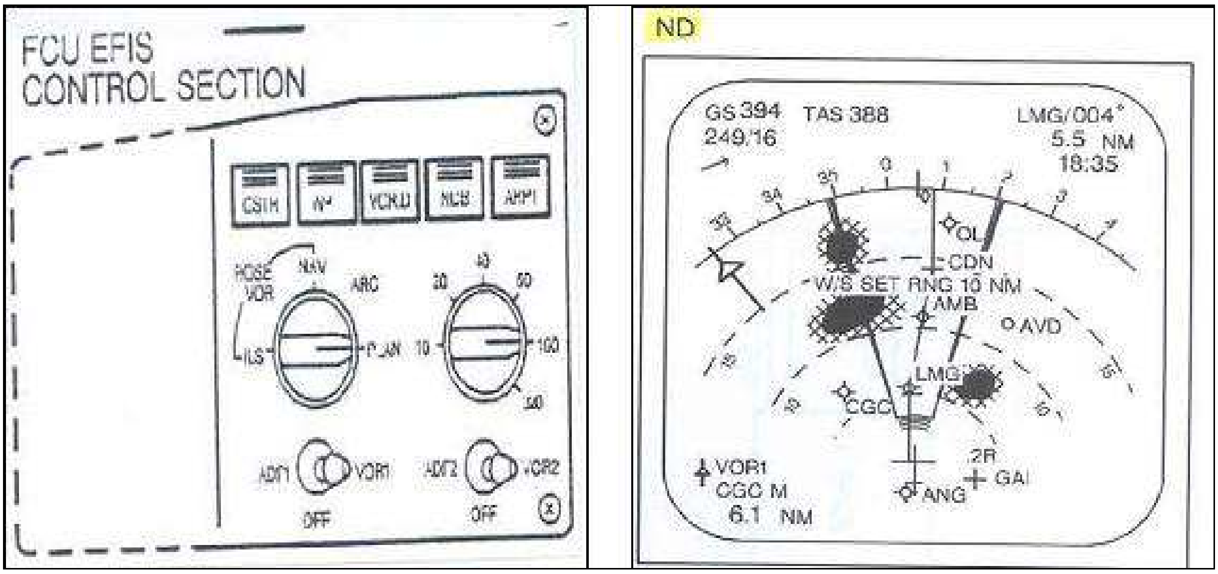
20 RDR-4 Forward Looking Windshear Detection / Weather Radar System User's Manual with Radar Operating Guidances, P53

21 There are modes of ROSE ILS, ROSE VOR, ROSE NAV, ARC, PLAN and the flight crews used ARC mode at the time of accident.

22 Use for input of flight data and its verification

The scanning range of 10~320 NM in weather radar can be set by a switch. In the concerned aircraft, there is no Automatic Tilt Function.

According to FDR, the crews selected ARC mode in the air path, and set the scanning range of weather radar to 10~160NM and selected 40NM until they encountered with the thunderstorm at 17:35:32. The crew stated that "The tilt of antenna was set to +0.25°."



[Figure 9] Selection of Distance in Weather Radar and Image Displayed

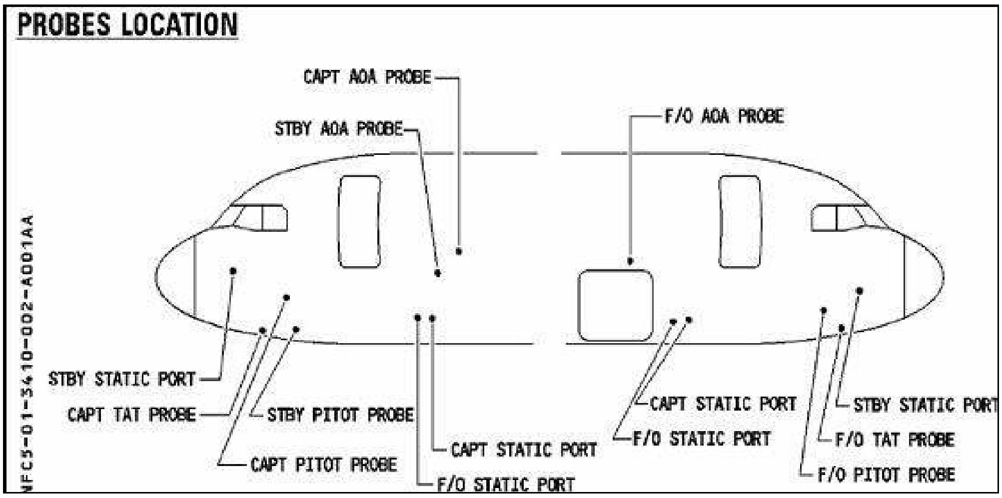
1.6.5 Aircraft System Operation

According to FDR and CVR, the operation status was normal until they encountered with the thunderstorm. However, the operation system including Auto Pilot System, Auto Thrust System, Flight Director, etc. were in deficient condition since encountered with the thunderstorm.

1.6.6 Airflow Sensing Probes

The locations for sensing probes of the concerned aircraft are shown in [Figure 10]. Since the probes are mounted in the side of airframe at the rear face of streamlined radome, they detect static/dynamic pressure and moving direction generated by the air flow.

When the radome was detached from the aircraft, the air flow became abnormal and static/dynamic pressures were not detected.



[Figure 10] Locations of Probes Installed in the Aircraft

1.7 Meteorological Information

1.7.1 Weather Condition

According to the regulations in the Annex 3, Article 3.4 of Convention on International Civil Aviation, Meteorological Watch Offices continuously watch meteorological condition which may affect to aircraft operation within the concerned area[23], and provides SIGMET information and other information to air traffic control facility. The Aviation Meteorological Office (AMO) performs those services as specified in the Article 16 of forecast service regulation of Korea Meteorological Administration.

[23] In case of Korea, Incheon Flight Information Region (FIR)

The AMO of Korea Meteorological Administration(located in Incheon Airport) announced en-route forecast and area forecast including SIGMET thunderstorm at 15:20(local time) on the day of accident.

```
ROFOR AMD 090620Z 090719 KT
RKSS RKPC TS FEW020CB 7250110 BKN025 7080/// OVC100 7150///
4180M17 23035
```

(En-route forecast between Gimpo airport and Jeju Airport announced at 15:20 on June 9. Thunderstorm is expected from 16:00 of June 9 to 04:00 of June 10, slight cumulonimbus cloud from 2,000 ft to 25,000 ft, thick cloud from 2,500 ft to 8,000 ft, and totally covered with cloud from 10,000 ft to 15,000 ft, while temperature at 18,000 ft is -17° and wind is 35 knots southwest.

```
ARFOR AMD 090620Z 090715 KT
NORTH SECTOR TS FEW020CB 7250110 SCT030 7080/// BKN120
7200///91995=
```

(The area forecast of northern sector announced at 15:20 on June 9. Thunderstorm is expected with slight cumulonimbus cloud from 2,000 ft to 25,000 ft and thick cloud from 12,000 ft to 20,000 ft.)

When the flight 8942 was making final approach to the Runway 14R in Gimpo Airport, the surface wind in the direction of Runway 14 was 280° at 7 knots notified to flight 8942 by the arrival controller on the issuance of the landing clearance.

METAR and Aerodrome Advisory at 17:00(local time) and at 18:00 on the day of accident observed by Meteorological Station in Gimpo Airport are as follows:

METAR RKSS 090800Z 21008KT 7000 BKN025 OVC080 22/17 Q0995 NOSIG (Wind direction 210°, wind speed 8 knots, cloud height 2,500 ft, temperature 22°, and no significant change in weather)
METAR RKSS 090900Z 24006KT 200V270 7000 SCT030 OVC080 22/17 Q0995 NOSIG (Wind direction 240°, wind speed 6 knots, wind direction variable from 200° to 270°, cloud height 8,000 ft, temperature 22°, and no significant change in weather)
AERODROME ADVISORY NO. 28 ISSUED AT 090700 V.T 090700/090800 MOD TS FCST WITH SHRA FOR GIMPO AP (Effective weather forecast in airport between 16:00~17:00. Moderate thunderstorm is expected with shower in Gimpo Airport.)

The following is the SIGMET announced by AMO on the day of accident and no SIGMET information was officially forecasted between16:30 and 18:30[24].

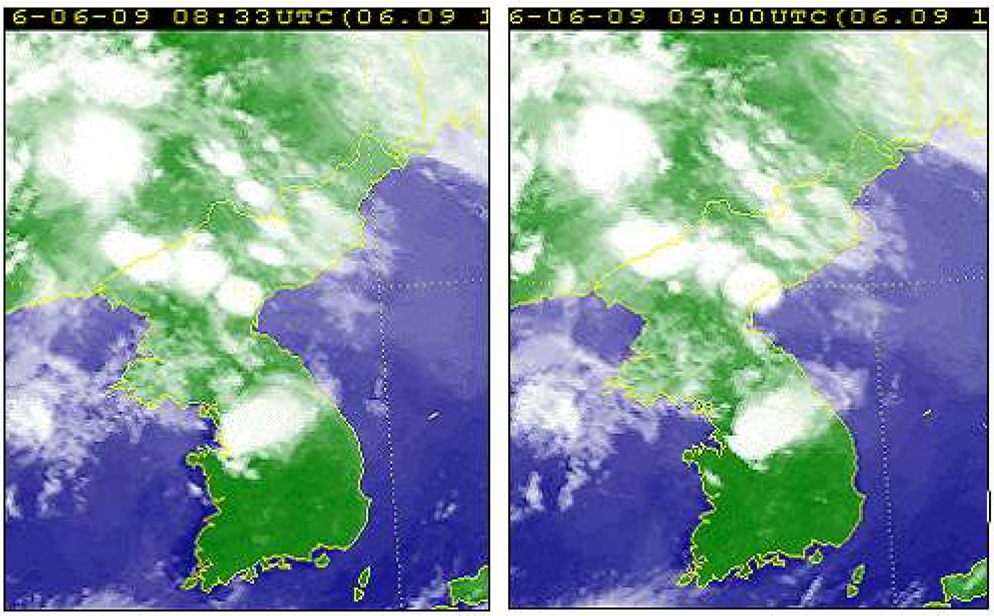
```
<STX> WSKO31 RKSI 090620
RKRR SIGMET 01 VALID 090630/090730 RKSI-
INCHEON FIR ISOL TS OBS
AT 06Z TOP FL300 BOUNDED
BY 38N125E 38N127E 37N127E 37N125E
AND 38N125E
MOV W 07KT WKN=
<VT><ETX>
```

```
<STX> WSKO31 RKSI 090925
RKRR SIGMET 02 VALID 090930/091230 RKSI-
INCHEON FIR ISOL TS FCST
TOP FL300 IN AREA BOUNDED
BY 38N127E 38N129E 36N129E 36N127E
AND 38N127E
MOV E 07KT INTSF=
<VT><ETX>
```

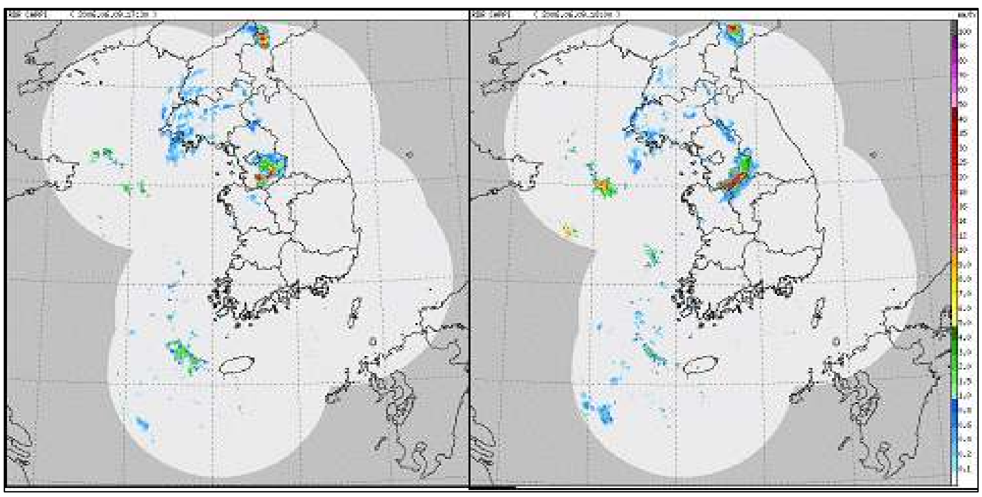
24 Including flight hours exposed to the hail while flying from Jeju to Gimpo Airport

The cloud image observed at about 17:33 and 18:00 on the day of accident is shown in [Picture 1] and there was thick cloud in the capital area and Gyeonggi-do.

The meteorological condition observed by 10 weather radars of Korea meteorological administration at 17:30 and at 18:00 on the day of accident is shown in [Picture 2], and there was cloud with strong precipitation in the metropolitan area and southeast area of Gyeonggi-do.

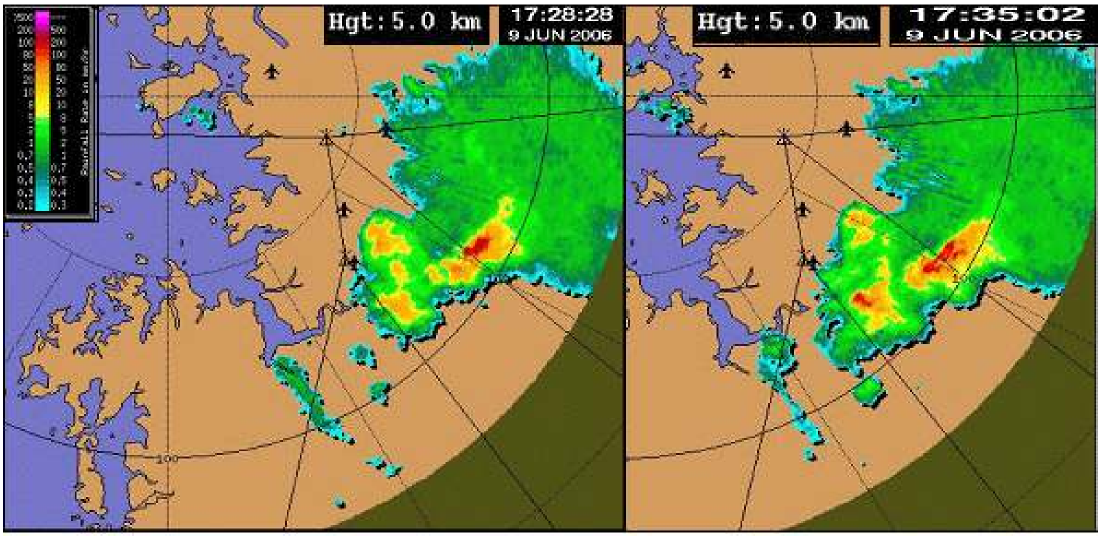


[Picture 1] Cloud Observed by Weather Satellite at 17:33 and 18:00 on the Day of Accident

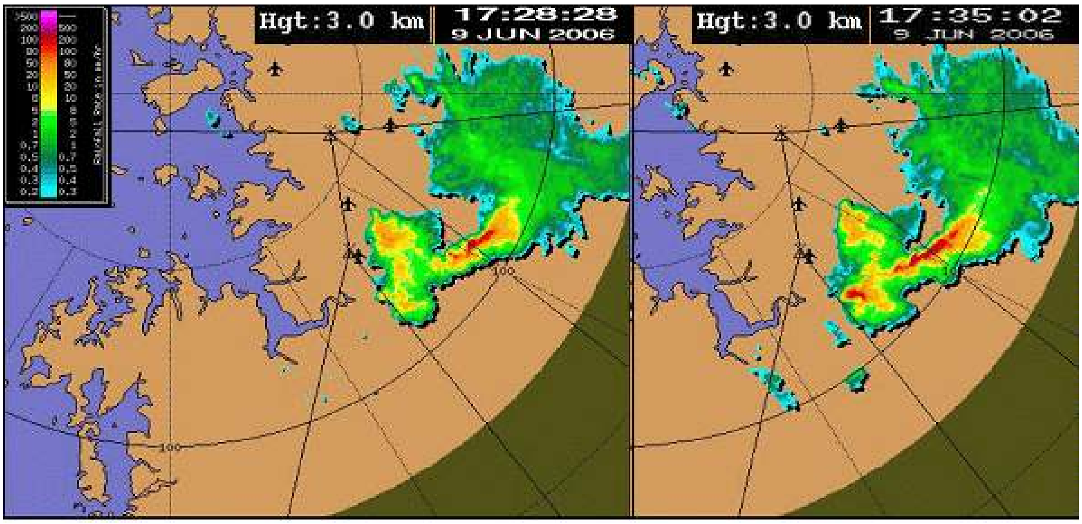


[Picture 2] Weather Condition Observed by Nationwide Weather Radar

The weather condition observed with Terminal Doppler Weather Radar (TDWR)[25] in Incheon Airport from 17:28:28 to 17:41:35 at 5km height when flight 8942 was flying at an altitude of about 16,000 ft and 11,000 ft are shown in [Picture 3], and weather condition from 17:28:28 to 17:41:35 at 3km height are shown in [Picture 4] and [Picture 5].



[Picture 3] Cloud Images of 5km Height at 17:28:28~17:35:02 and 17:35:02~17:41:35



[Picture 4] Cloud Images of 3km Height at 17:28:28~17:35:02 and 17:35:02~17:41:35

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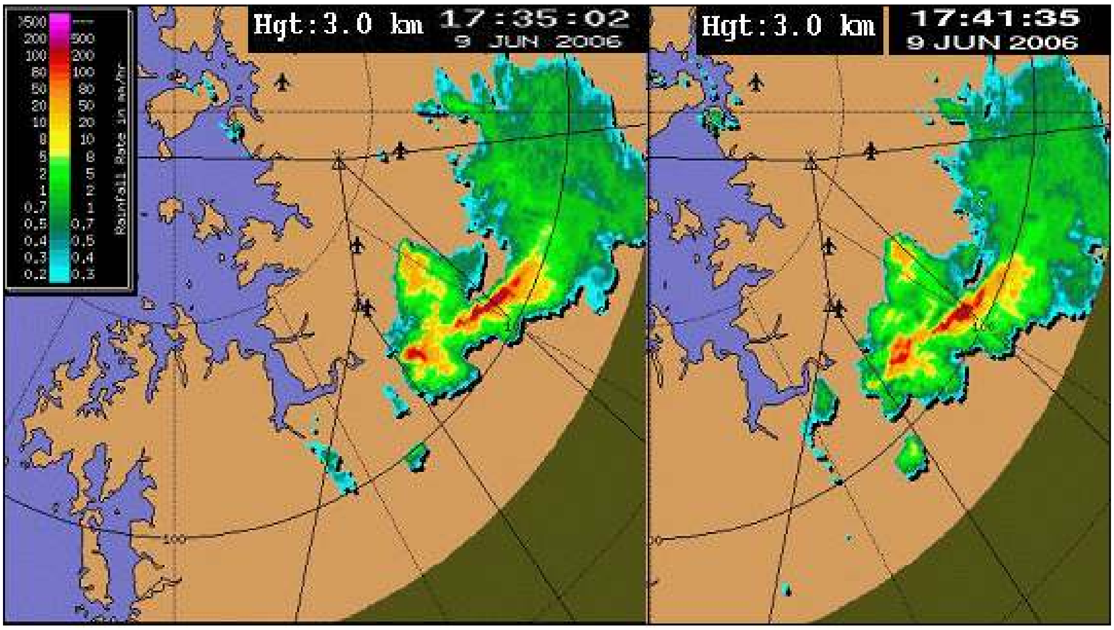
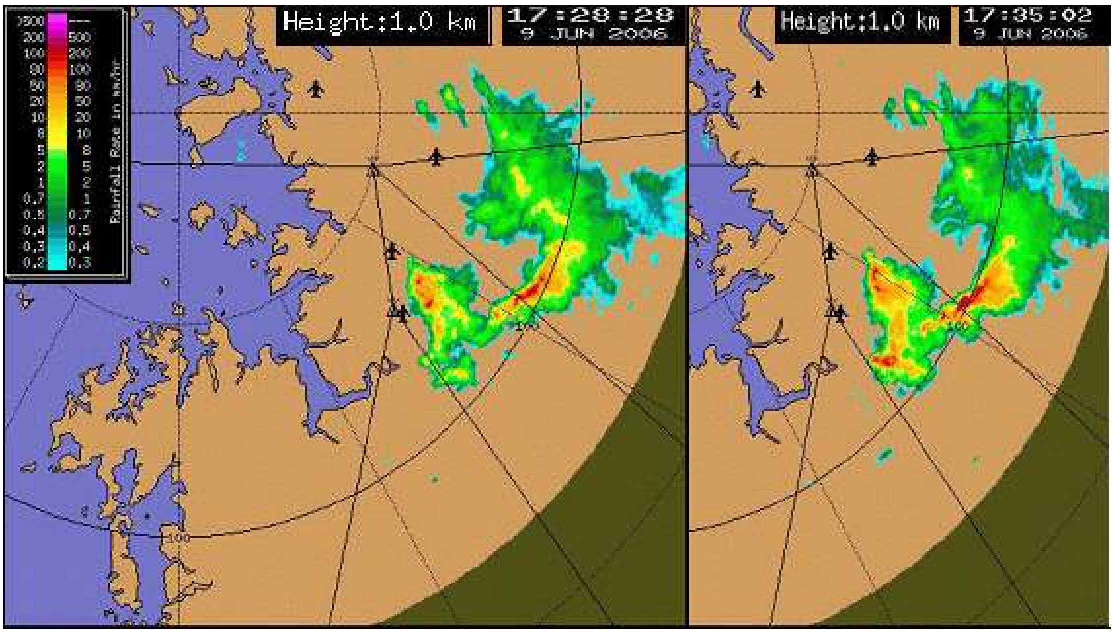
[25] Installation is completed on June 30 of 2000 in Inwang Mountain, Yeongjong Island in the first phase of airport construction by Incheon Airport. They started using from January of 2001 by Aeronautical Weather Station of Korea Meteorological Administration. Capable of detection of Wind Shear and Microburst within 30km from antenna with effective doppler up to 120 km and detection up to 480 km.



[Picture 5] Cloud Images of 3km Height at 17:35:02~17:41:35 and 17:41:35~17:48:08

The weather condition of 1km height displayed from 17:28:28 to 17:41:35, at TDWR next to the control seat in Seoul Approach Control are shown in [Picture 6].

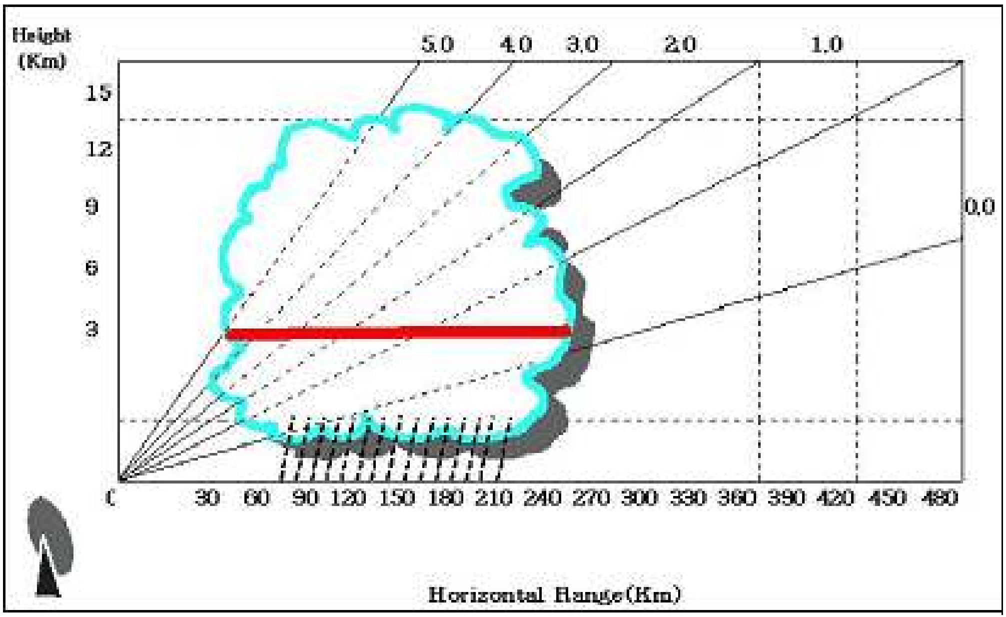


[Picture 6] Cloud condition of 1km Height displayed in Seoul Approach Control

1.7.2 Terminal Doppler Weather Radar

TDWR is a device to measure the distance and direction to an object using elapsed time and direction of microwave (Echo) received by antenna which is sent and reflected from a target based on the properties of microwave to be straight, uniform speed, and disperse, etc.

TDWR obtains the information of weather condition in the area via detecting spatial distribution and time change by rotating the antenna in 360° at each step of angles increasing from 0.7° to 45° as shown in the [Figure 11].



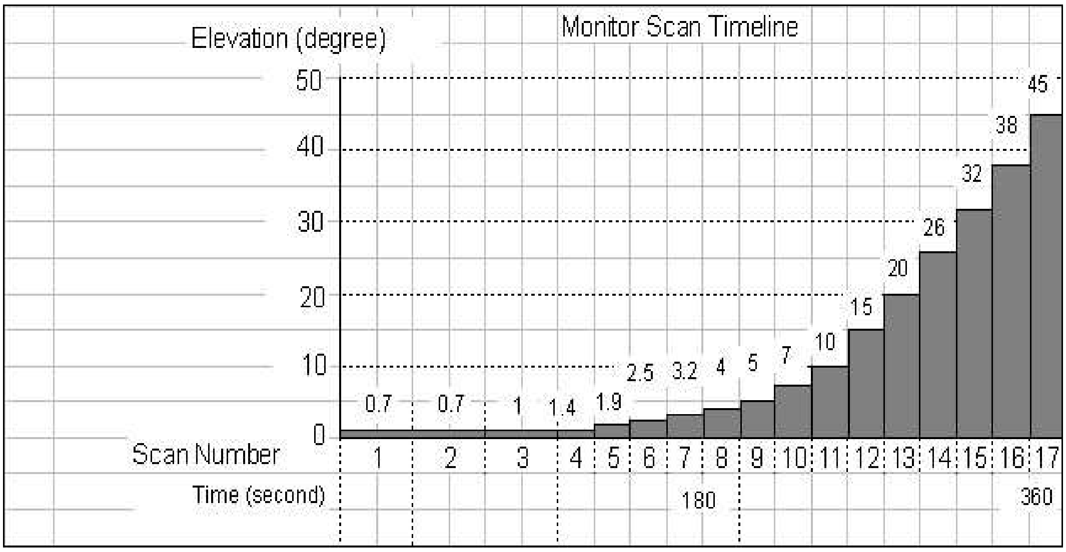
[Figure 11] Detecting Method of TDWR

The echoes observed with TDWR on June 9, 2006 are shown in the [Pictures 3, 4, 5 and 6], and the time displayed as 17:28:28, 17:35:02 in the display is the one which started the observation, and 17:41:35 the radar started observation at. In addition, the image displayed on the radar display is the condition of echo prior to the next stage of observation as shown in the following table.

Time on Display	Echo on Radar display	Remarks
17:28:28	17:28:28~17:35:02	Observation Started at Displayed time
17:35:02	17:35:02~17:41:34	
17:41:35	17:41:35~17:48:07	

[Table 1] The time on display and Echo on Radar display

The [Figure 12] shows the scan timeline of TDWR, and the elapsed time for observation is 6 ~ 7 minutes although the time could be somewhat different depending on the weather condition.



[Figure 12] Elapsed Time for Scanning of TDWR

Three displays of TDWRadar[26] are installed in the console of control room in Seoul Approach Control, and the cloud condition detected by TDWR was being shown as echo[27] on the display.

The intensity of echoes are displayed by colors within echo area depending on rainfall rate per hour (more than 0.5 ~ 500 mm) and the height from 1 km to 10 km and distance from 30 ~ 480 km can be adjusted with radar antenna.

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26 1 at controller's console in Gimpo Airport, 1 at approach controller's console, and 1 at team leader's console.

27 Phenomena displayed on radar display when microwave from radar transmitting antenna hits a target (aircraft, precipitation, etc.) and received for the measurement of direction, distance and strength.

1.7.3 Propagation of Weather Information

According to the Article 2 of operation manual, Asiana Airlines, the flight operations officer should collect operational information including “the weather information of departure, en-route, destination, and alternate airport” and provide it to a captain.

Even though the ROFOR, ARFOR, and SIGMET[28] information consisted of telegraphic format was received from Aviation Weather Office to the terminal[29] in Asiana Airline through Aeronautical Fixed Telecommunication Network (AFTN) on the day of accident, the information was not input to Flight Movement Monitoring Control System (FMC) which was used in briefing for the crews at the flight operations control center of Asiana Airlines in Gimpo Airport.

The crew of flight 8942 stated that they figured out the information about en-route forecast and area forecast based on the weather forecast and SIGMET information, weather radar images, weather satellite images, etc. through a PC [Figure 7][30] connected to the internet and TDWR.

[Picture 7] Weather PC in Asiana Airline’s Flight Operations Control Office in Gimpo Airport

[28] SIGMET consist of thunderstorm, windstorm, turbulence, mountain wave, sandstorm, volcanic ashes.
[29] Operations control team of Asiana Airline, Operations control office of Kimpo and Jeju Airports, and etc.
[30] It is a system to provide additional weather information by Aeronautical Weather Station. It is an unofficial information system to which users can connect when need of weather information.

The operations control team of Asiana Airlines did not use the information of en-route forecast, area forecast, and SIGMET information which was officially announced through AFTN. Instead, the operator in the operations control team was obtaining the weather information including forecast through direct internet connection to AMO.

1.8 Aids to Navigation

1.8.1 Airport Surveillance Radar

Flight 8942 was guided by radar vectors of Seoul Approach Control using ASR for approach and arrival control services, the radar was operating in normal.

1.8.2 Instrument Landing System

The runway 14R instrument landing system which flight 8942 used for approach and landing to Gimpo airport was in normal operation in accordance with the remote maintenance monitoring records.

1.8.3 Airport Lightings

According to the records by the airport lighting on-off recording system in Gimpo Airport, runway edge lights, runway center line lights, approach lighting systems, sequenced flashing light, and aerodrome beacon were turned on from 18:02 to 18:15 concerning the operation of flight 8942.

According to the para 3-4-1 of air traffic control procedures, all the airport should be turned on and in operation when in an emergency or an emergency situation is expected. According to the para 3-4-4 of the same procedures, it is prescribed that the approach lighting system should be in operation in day time when prevailing visibility is less than 5 miles.

1.9 Communications

According to the voice recording system of Air Traffic Center and Seoul Approach Control, there was some trouble in the communication between the crew of flight 8942 and the controller on a part of section after the time flight 8942 encountered with the thunderstorm. However, the air traffic control services could be performed.

1.10 Aerodrome Information

1.10.1 Air Traffic Control Service

1.10.1.1 History of ATC

1.10.1.1.1 Air Traffic Center

According to the voice communication and radar track records of en-route control for flight 8942, the en-route controller at northwest sector of Air Traffic Center instructed as “AAR8942 continue descend to flight level 160 and expedite descend until reaching 160 due to traffic” at 17:29:39, and “AAR8942 Turn right heading 040 for spacing” at 17:30:53 in order to make it radar vector to deviate from the airway of B576.

At 17:32:08, the controller at northwest sector instructed as “AAR8942 Clear direct NUMDA” and the pilot of flight 8942 read back as “Direct NUMDA AAR8942.”

At 17:33:05, flight 8942 requested as “Incheon AAR8942 heading 030 due to cloud” and the controller at northwest sector cleared it saying “Roger approved.”

At 17:33:24, the flight data controller at northwest sector notified that “AAR8942 flight level 160, heading 030 weather deviation” while sharing information in order to handover the control of flight 8942 by a direct line to flight data controller in Seoul Approach Control

At 17:34:03, flight 8942 requested as “Incheon control AAR8942, request descend”, and the en-route controller at northwest seat instructed the handover of control saying as “AAR8942 contact Seoul Approach 120.8 for your request, good-bye”.

1.10.1.1.2 Seoul Approach Control

1.10.1.1.2.1 Before Thunderstorm Encounter

According to the voice records of communication and radar track of approach control, the flight data controller at approach control sector of Seoul Approach Control was notified that “AAR8942 flight level 160, heading 030 weather deviation” while sharing information for control handover of flight 8942 by a direct line to the flight data controller at northwest sector of Air Traffic Center.

At 17:34:34, on initial contact with Seoul Approach Control flight, 8942 requested saying as “Seoul approach AAR8942, good afternoon, fly heading 040, maintain 030, maintain flight level 160, information hotel, request descent”, the approach controller gave the clearance saying as “AAR8942 heading 0930, descend to 11,000 ft”.

At 17:36:02, flight 8942 requested to the controller at approach control sector, “Seoul approach AAR8942, request high speed descent”, the controller approved it saying as “AAR8942 approved until further advice”.

At 17:38:48, flight 8942 requested, “Seoul approach request left turn”, and the controller at approach control sector asked, “Say your heading”.

To this question, Flight 8942 responded, “Fly heading 030.” Then the approach controller instructed, “AAR8942 heading 030 approved. Contact arrival 119.9”[31], and flight 8942 read back saying as “030, 119.9 AAR8942”

[31] Based on CVR, the captain said “Ah, ah.”

At 17:39:21, flight 8942 requested to the controller at arrival control sector, “Arrival AAR8942, request left turn heading 330”, the controller allowed it saying as “Roger heading 330, report clear of weather.”

1.10.1.1.2.2 After Thunderstorm Encounter

According to the records of the CVR, the aircraft started to get hit by hails at 17:40:02.

At 17:40:40, the controller at arrival sector asked the crew of flight 8942 whether the aircraft could fly directly to “Anyang VORTAC(SEL)” but he did not receive any response. Therefore, he tried radio contact for four times until he managed to communicate with flight 8942 until 17:41:26. The contact with flight 8942 was successful at fourth trial of radio check (AAR8942, Radio check) and the contact was maintained.

At 17:42:23, flight 8942 requested descending and the controller cleared it to descend to the altitude 8,000 ft and instructed radar vector to the west of Gimpo Airport, so that the flight 8942, heading toward P-73(flight prohibited area), could avoid the area.

At 17:44:51, the captain asked “Please control with caution since the aircraft is damaged and having a hard time for hearing.”, and at 17:45:27, he asked “Please read the speed of aircraft since there is a problem in the aircraft” and the controller notified that the ground speed of aircraft was 330 knots.

At 17:46:00, the controller asked “Is the landing possible?”, and the captain of flight 8942 responded saying as “Yes, I’ll try.” At 17:46:04, the controller requested what kind of damage was like and the captain of flight 8942 answered “There seems to be a slight problem in the nose since the aircraft was hit by a lightning.”

At 17:46:30, the arrival controller said , “Then, I’m going to report to the tower about normal landing”, the captain of flight 8942 said, “Normal landing is impossible and it is now under emergency”, and the controller recognized it was an emergency situation at 17:46:43.

At 17:46:58, the arrival controller requested the captain of flight 8942 about the reason for emergency, and the captain of flight 8942 said, "The nose windshield is broken and there seems to be damage in the nose even though it's hard to see."

Afterwards, the arrival controller provided radar vectors to flight 8942 and, at 17:50:08, he issued approach clearance, "ILS/DME RWY 14R." However, flight 8942 was not flying toward the airport. Instead, it was heading toward Gyeyang Mountain[32] located west of the airport. Therefore, at 17:51:48, the controller issued a climb instruction[33] to an altitude of 4,000 ft, and when the captain of flight 8942 said that there is no mountain in the fore view, the controller instructed a rapid climbing up to an altitude of 4,000 ft again.

At 17:53:27, the arrival controller asked, "What kind of instrument is in disorder?" and the captain of flight 8942 answered, "The speed indicator read pretty much differently in the left and right and the foreside is invisible since the windshield is totally broken." And then, the controller said, "You can depend on us for the fore view" while he was notifying the ground speed of aircraft from radar display and kept providing radar vectors for a second approach.

At 17:58:44, the controller issued the approach clearance, "ILS/DME RWY 14R" in the second time. But the flight 8942 facing the final approach course, at 18:00:53 he asked, "ILS Capturing is not possible?", and instructed climbing of flight 8942 when the captain answered, "No, it's not possible."

At 18:01:04, the captain of flight 8942 asked, "Isn't the current ILS proper?" and the controller said "It is overshot by one and a half mile from the ILS now." Then, at 18:01:12, the captain of flight 8942 said "There isn't enough of fuel, so I'll try capture" while the controller kept providing radar vectors for the approach.

At 18:01:28, the arrival controller asked, "would you like to make no-gyro approach?[34]", and the captain of flight 8942 answered, "Yes, request Close Control right now."

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32 1,296 ft high above the sea and 1,506ft to antenna installed on top
33 Failed in the first approach trial and order go-around
34 A radar guidance control saying "turn right or left" or "stop turn" instead of providing headings of aircraft which has a problem in Gyro-compass or Directional Gyro.

Afterwards, while the controller was guiding the aircraft toward the runway of Gimpo Airport informing the aircraft heading, he said, "Report field in-sight." However, at 18:02:35, the captain of flight 8942 took a go-around.[35]

The captain of flight 8942 asked to the arrival controller, "approach in short pattern[36]" at 18:02:42, "request precise approach" at 18:03:15, and at 18:03:51, the arrival controller was replaced with one who had many experiences for precision approach radar[37].

At 18:05:38, the captain of flight 8942 requested, "Please make good precision approach in this time" and the controller repeatedly notified the ground speed shown on radar display.

At 18:07:07, the captain of flight 8942 said "I'll make the approach for this time with the final a little bit longer," the controller provided radar vectors with a longer final approach than the second one, with precision approach on the final approach course. After the aircraft landed on the runway 14R, the control of the aircraft was handed over to Gimpo control tower at 18:13:57.

1.10.1.2 Utilization of SIMET Information

1.10.1.2.1 Ground for Information Provision

According to the para 2-6-1 of Air Traffic Control Procedure[38], it is prescribed that "Become familiar with pertinent weather information when coming on duty, and stay aware of current weather information needed to perform ATC duty."

In addition, according to the para 2-6-2 of the same procedure, it is prescribed that "controllers shall advise pilots of hazardous inflight weather advisory that may impact operations within their area of jurisdiction, and SIGMET is included in hazardous weather information." It is described that there was some specific advisory phraseology provided as well in the para.

35 Failed in second approach trial

36 Radar guidance control in a short range of air path

37 PAR (Precision Approach Radar): This is radar installed only in military airport in order for controller to control approach while requesting height and heading of aircraft from radar.

38 Publication 2004-40 of Aviation Safety Center of Ministry of Construction and Transportation.

According to the para 2-6-4 of Air Traffic Control Procedure, it is prescribed that "controllers issue pertinent information on observed weather area. And when the pilot requires, he should either provide radar navigation guidance or approve the deviation around the weather area." In addition, according to the the para 2-6-7 of the same procedure, it is mentioned that "controllers may transmit the information to pilot if obtained the information from a pilot or radar."

According to the Article 134 of Operations and Management Regulations[39] for Air Traffic Services by Civil Aviation Safety Administration in Ministry of Construction and Transportation, controllers shall notify it to pilot when he received SIGMET information. In addition, according to the Article 66 of the same provisions, TDWR provides weather information in the vicinity of airport/aerodrome and could be referred to it in the air traffic control services.

Based on the related provisions in Annex 3 and 11 of Convention on International Civil Aviation, Air Traffic Center and Seoul Approach Control use the current and forecasted weather information observed by Aviation Meteorological Office, and Each Air Traffic Control facility contracted the agreement[40] on the weather support services with Aviation Meteorological Office, and specify and practice the tasks of providing and utilizing weather information for each other.

Based on the provisions of the para 8.6.9 of Air Traffic Management, ICAO Doc4444, controllers are recommended to notify to pilot information that an aircraft appears likely to penetrate an area of adverse weather in sufficient time to permit the pilot to decide on an appropriate course of action. In addition, it is noted that airborne weather radar in aircraft generally shows better performance and resolution in detecting adverse weather than air traffic control radar.

1.10.1.2.2 Air Traffic Center

According to the statement by en-route controller at northwest seat, who provided en-route control for flight 8942, he was debriefed about the weather on the day from the one who was relieved from duty when he was taking turns. Even though the controller referred the weather information PC installed near the controller's seat, he stated to believe that the crew members

[39] Notice no. 2005-46 of Civil Aviation Safety Administration
[40] Agreement on support for weather information between Air Traffic Center and AMO.

were operating with better acknowledgement about weather condition since they requested the heading of 30° to avoid cloud.

The control radar, at en-route control sector of Air Traffic Center, did not have a function to detect cloud with significant precipitation. Whereas, the display of control radar at northwest sector is able to receive the data from the airport surveillance radar in Incheon Airport and Gimpo Airport, and the airport surveillance radar in Incheon and Gimpo Airport can detect[41)] cloud with precipitation and display it (Echo[42]) on the radar display at the control sector.

According to the controller at northwest sector at the time, he stated that he did not switch to show echo on the display and was not utilizing the displayed echo for control since the precipitation and the height of cloud was impossible to be discerned from the echo on control radar display and the color of echo was dark blue which was similar to one of aircraft's Data Block[43] with blue or green.

Based on the agreements to support weather information between Air Traffic Center of Ministry of Construction and Transportation, and Aviation Meteorological Office of Meteorological Administration, Aviation Meteorological Office was supposed to debrief the weather information including SIGMET information prior to the controller's duty shift on the day. However, the debriefing was being performed at 09:30 and 17:30 everyday, and the team that was shifted at 13:30 and provided the en-route control services with the accident aircraft was not briefed about the weather information of the day.

The PC for weather information in control room of Air Traffic Center was connected to AMO in Incheon Airport through the internet and was supposed to be seen the observed, forecasted or stored weather information by AMO. However, there was no function of real-time indication for the height of cloud compared with the height of aircraft and there was no aeronautical chart provided for airways to precisely compare and decide the location of aircraft and adverse weather.

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[41] Based on the principle that an obstacle in space can be detected by a microwave that is discharged from ground radar antenna and reflected by metal or water.

[42] Navigation display was indicating the mosaic shape of cloud in uniform color regardless of precipitation strength.

[43] Current flight information showing flight number, altitude, speed, etc. in digital.

When Area Forecast and En-route Forecast including SIGMET and SIGMET information, which were sent through Aeronautical Fixed Telecommunication Network by AMO, was received to the terminal of AFTN in the control room of Air Traffic Center, the personnel in charge of Aeronautical Navigation Meteorological (ANM) was supposed to input the information so that the controller in control room was able to read it.

According to the provisions of the Article 134 of "Operations and Management for Air Traffic Services" of Civil Aviation Safety Administration, controllers have to notify it to pilot when he receives any SIGMET information, even though there were no specific detail about collecting and recognizing SIGMET information and use of pertinent equipment.

According to the provisions of Article 31 of "Regulations for Air Traffic Control Services" of Air Traffic Center, the information should be notified to related control sector and aircraft which would be flied in pertinent area to take an alternate airway when PIREP was received from the pilot in flight. However, there was no provision to collect any SIGMET information other than PIREP and to practice[44] it for control service or to deliver to other pilot.

1.10.1.2.3 Seoul Approach Control

1.10.1.2.3.1 Receipt of SIGMET Information

According to the provisions of the Article 43 of "Operations and Management for Air Traffic Service in Incheon International Airport" of Seoul Regional Aviation Administration, it is prescribed that "Whenever items arises to harm the safety of aircraft, pilot should be notified immediately with pertinent information." and "AMO shall notify it Seoul Regional Aviation Administration at the time of announcing SIGMET information for the Korea Flight Information Region" as per the para 5, Article 5 of Agreements on Weather Support in Incheon Airport with AMO.

44 Either the pertinent aircraft should be guided for avoidance on controller's decision or the pilot be notified with information, so that he could request detour to controller.

There is no AFTN terminal in Seoul Approach Control. However, the messages of AFTN was able to be received by Seoul Approach Control[45] since Automated Radar Terminal System (ARTS) is interlinked with AFTN. Whereas, en-route forecast, area forecast and SIGMET information could not be displayed since specific airport related[46] information could be received from Data Preparation (DPR), which was a parameter tool of ARTS. Therefore, flight data display at the control seat was set[47] to indicate such information only, so en-route forecast, area forecast, and SIGMET information could not to be displayed.

Therefore, the flight data display at the control seat could not show the amended en-route forecast that an effective thunderstorm is expected from 16:00 to 04:00 on the airway between Gimpo and Jeju Airports, and announced at 15:20 on the day of accident, the amended area forecast that an effective thunderstorm is expected in the northern area from 16:00 to 24:00.

Even though Seoul Approach Control had the system to search and detect SIGMET information or forecast stored in AMO through Flight Operations and information System(FOIS[48])located at the team manager's seat or PC connected to AMO, the team manager on the day of accident stated that "I did not search for en-route forecast, area forecast and SIGMET information."

1.10.1.2.3.2 Recognition of SIGMET Information

When the control of flight 8942 was handed over from Air Traffic Center at 17:33:40, the echo as displayed on the display of control radar of approach control seat was near the expected airway of flight 8942 which was heading in 30° as shown in [Picture 8]. In addition, cloud with strong precipitation was displayed on the Terminal Doppler Weather Radar[49] of Incheon Airport near the approach control seat, while the precipitations per hour are indicated in colors as shown in [Picture 6].

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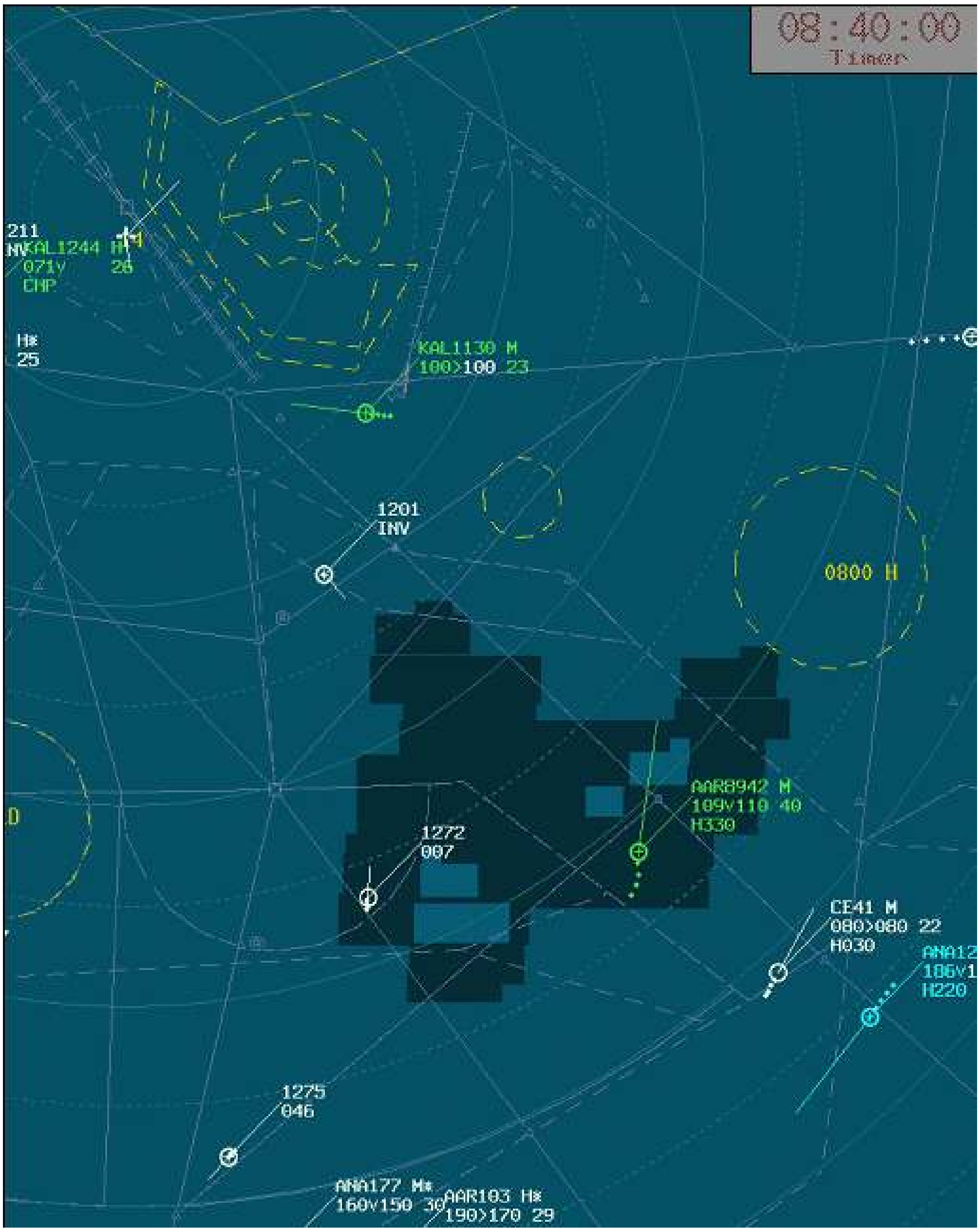
[45] RKSIZAZX. Even though RKSIZTZX received the information, AFTN was structured for only ARTS to receive it.
[46] Bad weather information was transmitted from Kimpo and Incheon Airport. METAR, SPECI were set to receive information only from Incheon, Kimpo, Seoul, and Osan Airport.
[47] The controller in charge of DPR used to set since the operation of Seoul Approach Center near Incheon Airport (2001.3.1).
[48] Started operation at Seoul Regional Aviation Administration since 2001.3.1. It is capable of search for weather information connecting to Aeronautical Weather Station.
[49] Conventionally set to indicate precipitation cloud at 1km height in Seoul Approach Center

[Picture 8] Echo Displayed on Control Radar at 17:36

At 17:34:34, when the approach controller was making an initial contact with flight 8942 maintaining the altitude of 16,000 ft, the location of echo at 5km height was as shown in the [Picture 3] (left), while Terminal Doppler Weather Radar, near the approach controller's seat, was displaying the echo at 1km height[50] as shown in the left side of [Picture 6].

[50] The mode for Terminal Doppler Weather Radar used to be set to AUTO in Approach Control Center. In this case, cloud at 1km height (3,000 ft) is shown.



[Picture 9] Echo Displayed on Control Radar at 17:40

At 17:36:13, when flight 8942 was flying heading 30° about 10 miles southeast of NUMDA, the inbound aircrafts from Jeju and Gimhae Airports to Gimpo Airport were taking detours to the west[51] and east[52] of the echo. In the meantime, the inbound aircrafts to Incheon Airport were avoiding the echo by detouring to the south[53].

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51 KAL1244 (A330): Use the route of B576
52 KAL1130 (B739): Use the route of A582 and G585
53 AAR103 (B777), ANA177 (A320), UAL893 (B777), ANA1293 (B767): Use the route of G585

At 17:38:48, after the pilot of flight 8942 requested left-turn heading 330° prior to KAKSO, the location of echo displayed on the control radar at 17:40:02 when encountering with hailstorm is shown in [Picture 9] and the location of echo on Terminal Doppler Weather Radar beside the controller's seat is shown in [Picture 6].

1.11 Flight Recorders

1.11.1 Flight Data Recorder

Flight 8942 was equipped[54] with SSFDR which was manufactured by Honeywell and contained a capability of 25 hours of recording. The ARAIB retrieved it from the aircraft and extracted the 25hours of data for investigation.

The weather radar of flight 8942 was in normal operational condition from 17:28:21 until encountered with hailstorm, and navigation display for the captain and the first officer was set to ARC MODE, 40 NM to show the weather radar information.

When the crew requested flight 8942's heading of 030° due to cloud, the heading was at 015°.

While flight 8942 obtained the permission for heading 030° from the controller, it was flying heading 035° approximately for 50 seconds until it maintained the heading of 030°, and was heading 025° approximately for 1 minute and 20 seconds before permission for left-turn to 330°.

The flight speed was maintained at 325 knots along the B576 air path, and reduced to about 275 knots. Then, after the permission of high speed descent, the speed was increased and maintained at about 325 knots at 17:37:09, then encountered with the hailstorm. At 17:40:33, the speed was increased up to 346.4 knots[55] and serious change was indicated in the altitude and speed after the aircraft hit by the hails as shown in [Figure 13].

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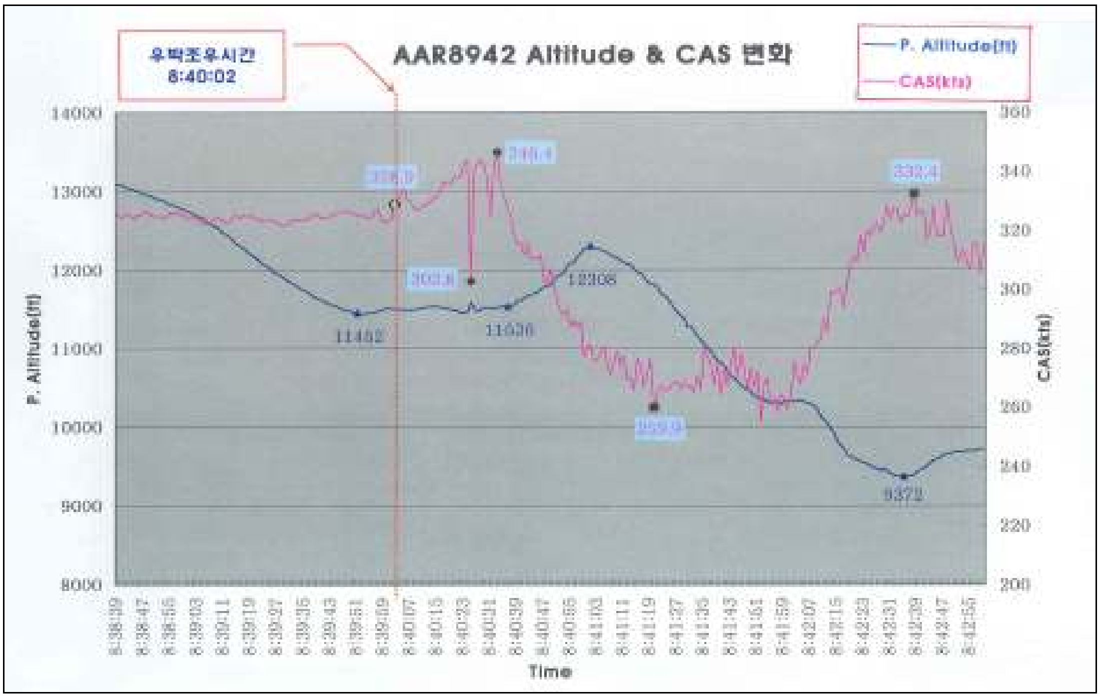
[54] Part No.: SSFDR 9804700-003, Serial No.: 2684

[55] A321 : The max. operational speed (V_{mo}/M_{mo}) is 350 knots below 26,000 ft



[Figure 13] Changes in Altitude and Speed after Hit by Hails

When it got hit by hails, it was located at N37°05’26.7” / E127°25’21.0” at 17:40:02, with the altitude of 11,500 ft, speed of 328.9 knots[56], heading of 347.7°, and bank of 25.3° left while making a left turn.

While flight 8942 was making descent out of an altitude of 13,000 ft on heading 030°, Total Air Temperature (TAT) was gradually increased to the peak of 18.5℃ at 17:40:18 and dropped to 7℃ at 17:40:30 (Temperature Reversal).

At 17:40:26 which is 24 seconds later after the exposure to hails, Auto Thrust System was disconnected, and 1 second later, Auto Pilot System and Flight Director System were disconnected while Master Warning was turned on.

While flight 8942 was approaching and landing on the runway 14R, the frequency was set at 108.7 for ILS receiving LOC, GS, and Deviation.

56 Turbulence Air Penetration Speed of A321 is 265 knots

1.11.2 Cockpit Voice Recorder

Flight 8942 was equipped[57] with SSCVR which was manufactured by Honeywell and contained a capability of 120 minutes of recording.

ARAIB separated it from the aircraft and recording was transcript for the duration from the time when the heading was changed to 040 until the occurrence of accident using the data extracted from channel 5 and 6[58] for investigation.

The quality of recording until 17:40:26 was good while there was a serious noise afterwards to hear and discern the recording.

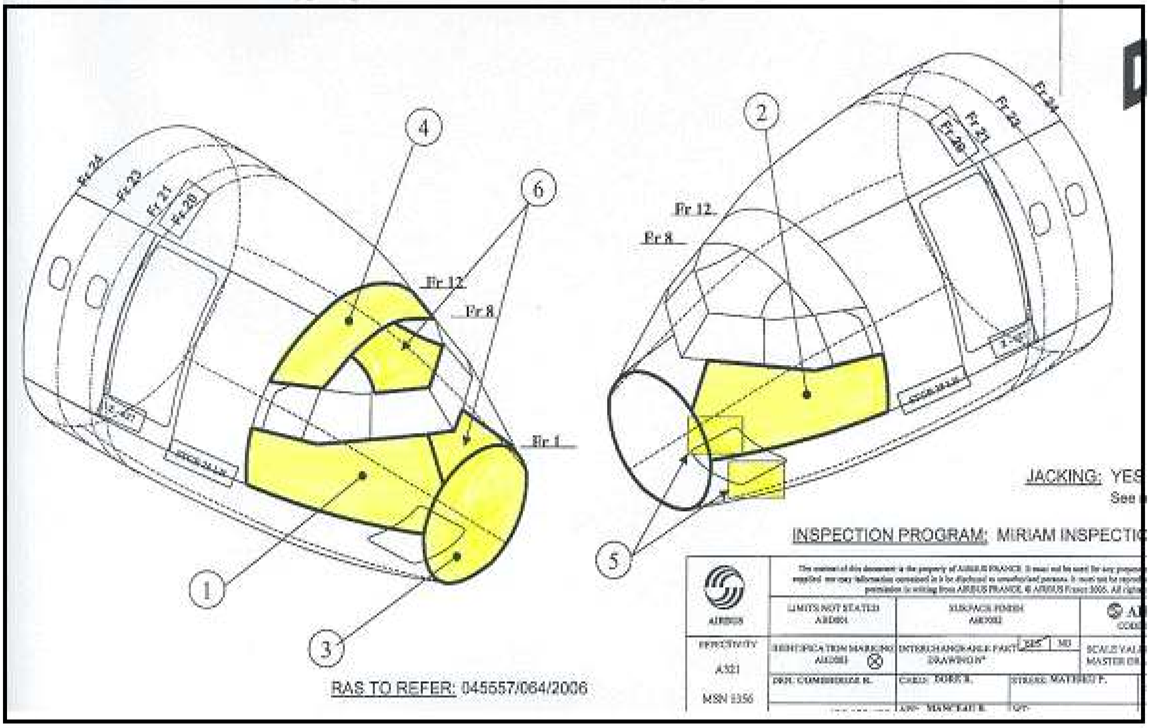
1.12 Structure Damage Information

1.12.1 Aircraft Damage by Thunderstorm

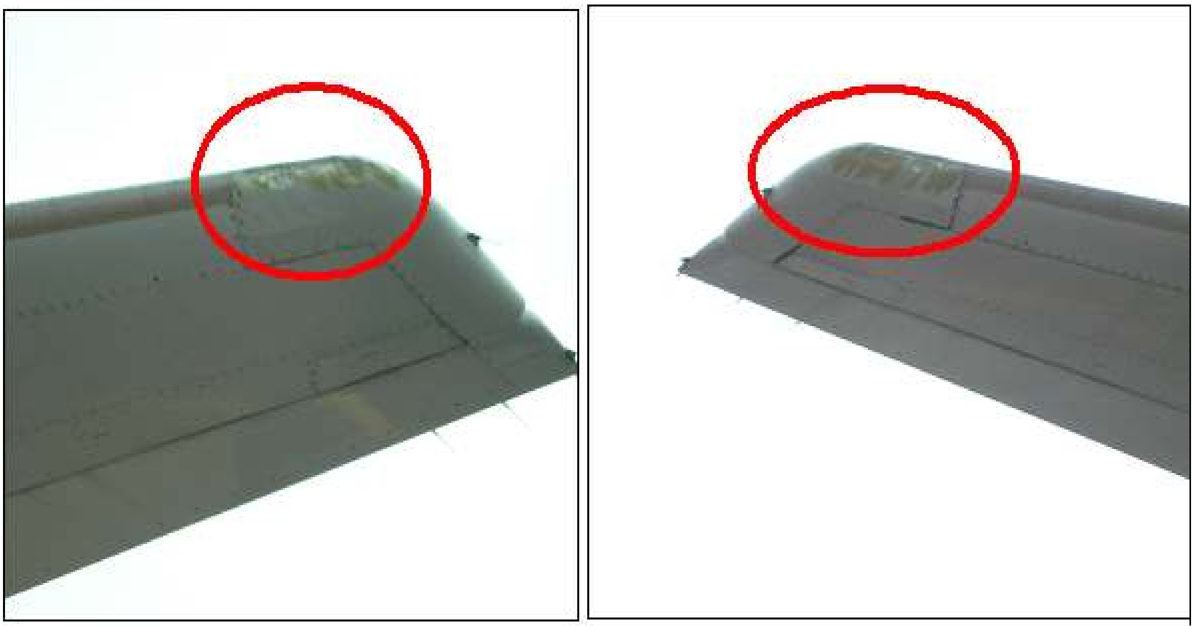
Flight 8942 was damaged in overall after hit by the thunderstorm. In the damaged airframe, the nose of the aircraft was damaged after hit by hails as shown in [Figure 14] and main wing leading edge and horizontal stabilizer leading edge were also damaged.

[Figure 14] and [Picture 10] are indicating the damaged portions due to the thunderstorm. These portions were repaired by replacing the parts for recover of the airworthiness by the airframe repair team dispatched from Airbus Industry, France.

57 Part No.: SSCVR 980-6022-001, Serial No.: 2549
58 Ch-1: Reserved Seat, Ch-2: First officer's Seat, Ch-3: Captain's Seat, Ch-4: CAM (Cockpit Area Mike), Ch-5: Mixed (Ch-1/2/3), Ch-6: 2 hours of CAM



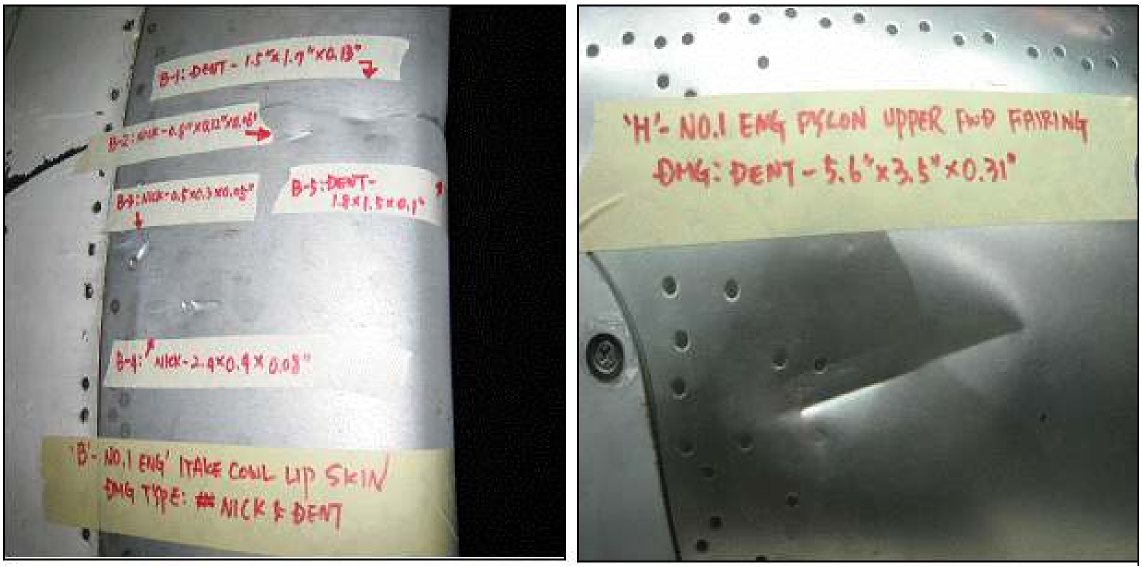
[Figure 14] Damaged Portion Due to Hails : Nose of Airframe



[Picture 10] Tip of Damaged Horizontal Stabilizer Leading Edge

1.12.2 Damage by Radome Separation

Damages on the cowl of No. 1 Engine, and top and inside of Pylon were due to radome detachment as shown in [Picture 11], and left latch to fasten the radome penetrated into the cowl of No. 1 Engine.



[Picture 11] Damaged Portion from Detachment of Radome

1.12.3 Radome Separation

After hit by thunderstorm, the radome was separated from the fuselage. In order to obtain the debris of detached radome, the accident was reported to the police station and if anyone found the debris, he was required to report it. However, there was no reporting.

Some debris from the detached radome caused some damages on the No.1 engine cowl and the bottom of left wing. The shape of radome detachment due to thunderstorm is shown in [Picture 12].

[Picture 12] Damaged Nose of Aircraft

The weather radar antenna installed inside the radome was torn off and thrown on the runway with damage during the course of aircraft landing, and Drive Unit to move the radar antenna installed at Forward Pressure Bulkhead was still attached but damaged.

1.12.4 Cockpit Windshield

The windshield was too much damaged to secure the fore view from cockpit. Even though two windshields in the right sides had cracks, it was visible through the windshields.

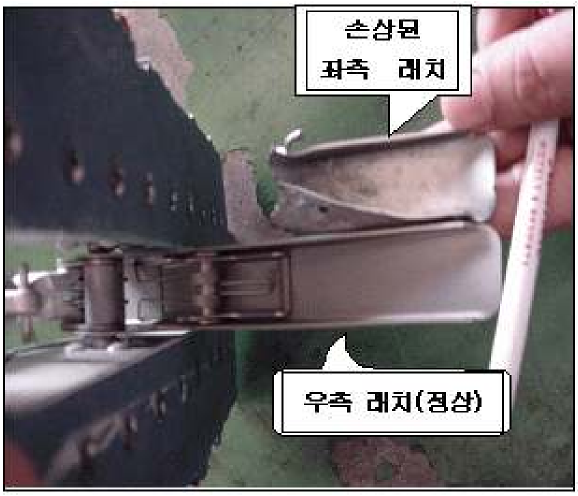
It was confirmed that securing the sight was difficult based on the investigation to measure the range of visibility with runway lights turned on.

The [Picture 13] indicates the damaged windshield. The left Picture was taken from the inside of cockpit and the right one was taken after it was separated from the aircraft.

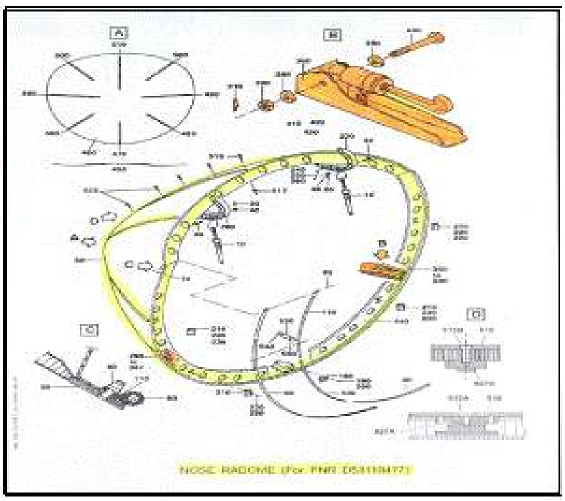
[Picture 13] Damaged Windshield Installed in Aircraft (Left) and After Separation (Right)

1.12.5 Latch Damage and Separation

Of the two latches[59] to fix the radome, the right one was attached to the frame; however, the left latch was separated as shown in [Picture 14] and it caused the damage to the engine cowl and was found inside of it. [Figure 15] indicates the structure of radome.



[Picture 14] Comparison of Latches (L/R)



[Figure 15] Radome Structure

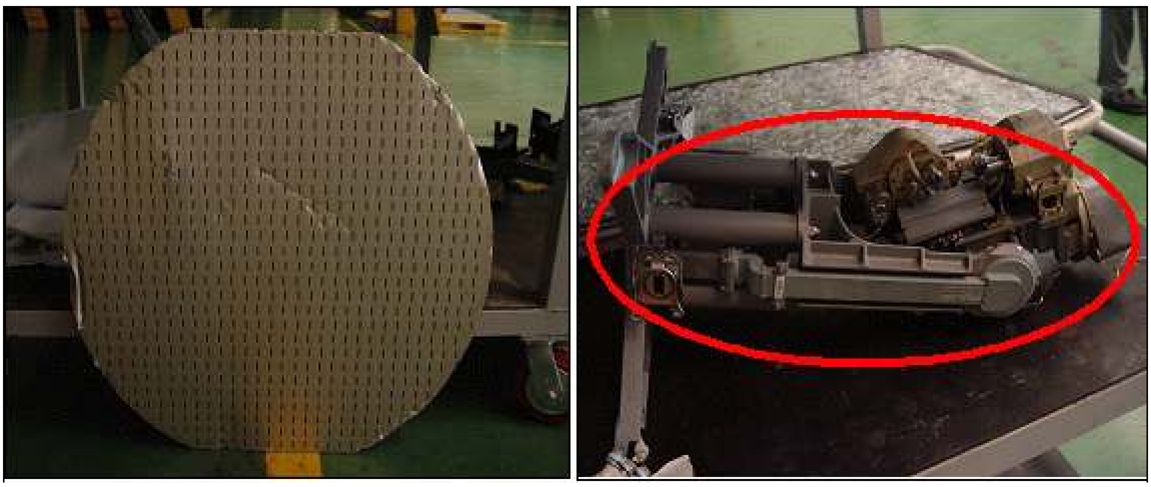
[59] Latch : Installed in airframe and used to fix radome. The device can be opened for the inside inspection of radome and for attachment/detachment of radar antenna, etc. There were two of them install in the pertinent aircraft

[Picture 15] Cowl of No. 1 Engine Where Latch was Found and Damaged Latch

1.12.6 Damage to Weather Radar

Flight 8942 was equipped with the antenna, antenna drive unit, waveguide, and radio guidance switch inside of the radome. When the radome was detached, those parts were damaged due to exposure to the hails as shown in [Picture 16].

One transceiver for weather radar was installed at the avionics compartment[60], and weather radar control unit was installed inside the cockpit. Therefore, there was no surface damage found on the parts.



[Picture 16] Weather Radar Antenna and Antenna Drive Unit

60 Located in front of aircraft with aircraft's electronic parts attached

1.12.7 Aircraft System Failures

According to FDR, CVR, and the statement by the captain, the aircraft was in normal operation prior to hit by the thunderstorm. The defects in auto pilot system, auto thrust system, flight director, etc. were found after the hit by thunderstorm.

After the hit by thunderstorm, warning message and failure message were turned on and developed to a systematic failure in spite that the pilot tried to restore the system.

1.12.7.1 Warning Message

There were 32 warning messages shown on Electronic Centralized Aircraft Monitoring (ECAM) from takeoff (18:13) until encountered with the hails (17:40) and the followings were come up as time passed:

At 17:40, the message of “Anti-Ice L+R Windshield,” then “ADR[61] 3” and “Flight Control ALTN LAW” were turned on while warning messages for Auto Flight System and Auto Thrust System to shut down came on. Then, 6 warning messages including “F/CTL[62] ADR DISAGREE” were turned on.

At 17:45, the warning messages in the rudder such as “AUTO FLT RUD TRIM 1&2 FAULT”, “YAW DAMPER SYS”, etc. were repeatedly came on for 6 times.

At 17:46, 4 messages including “AUTO FLT RUD TRIM 1 FAULT,” etc. were on, and, at 17:50, 4 including “AUTO FLT” came on. Then, at 17:51, 3 messages such as “AUTO FLT” and “AUTO FLT A/THR OFF” were followed. And then, the messages were indicated[63] at 17:59, 18:02, 18:09, and 18:13 respectively.

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[61] Air Data Inertial Reference Unit
[62] Flight Control
[63] 17:59 “F/CTL LAW,” 18:02 “TL ALTN LAW”, 18:09 “F/CTL DIRECT LAW”, 18:13 “F/CTL ALTN LAW”.

1.12.7.2 Failure Messages

There were 52 failure messages in total and they were as followings.

At 17:40, the failure messages for "Windshields in the left and right side of cockpit," "ADR3", and "DMC[64]1(NO FAC[65] Data)", and at 17:41 and 17:42, failure message for "Weather Radar" was on.

At 17:45, "FAC1" and "FAC2" to control rudder for Auto Flight System were shown to be failed.

At 17:46, warning messages for "Auto Flight System Rudder Trim 1&2, Yaw Damper" were turned on repeatedly.

At 17:51, warning messages for "Auto Flight System and Auto Thrust System were disconnected" were indicated again and kept on until the aircraft landed at 18:12.

1.13 Medical and Pathological Information

All the crew members were in possession of valid aircraft health examination certificates and there were no evidence to harm the flight operation.

1.14 Fire

There was no fire in the accident.

1.15 Survival Aspects

There were no injuries to persons in this accident.

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[64] Display Management Computer
[65] Flight Augmentation Computer

1.15.1 Propagation of an Emergency Situation

At 17:46:41, flight 8942 declared an emergency to Seoul Approach Control, and at 17:47:24, Seoul Approach Control notified the emergency landing of flight 8942 to Gimpo Control Tower using direct line. There was recorded that Gimpo Control Tower notified about the emergency landing situation of flight 8942 to the agencies, Gimpo airport, concerned with emergency landing at 17:48[66]using crash phone.

1.15.2 Emergency Responses

The fire station of Korea Airport Corporation in Gimpo Airport was mobilized at 17:49 after being notified at 17:48 about emergency landing from control tower, and was withdrawn from the site at 18:45. Mobilized vehicles were 1 in command car, 7 fire engines, 2 ambulances, and 31 personnel including a rescue team leader. Since flight 8942 landed safely on the runway, there were no rescue efforts made.

1.16 Tests and Research

NTSB, USA and Honeywell, who manufactured the weather radar of flight 8942, had performed precision tests on 159 parts[67] for weather radar of flight 8942. Based on the result of tests, the loaded weather radar of flight 8942 was confirmed to be in operation until the engine stopped after landing as well as prior to the accident.

Airbus Industry of France, BEA, and EASA[68] opened a technical meeting[69] for investigation on failures in Auto Flight System and Auto Thrust System right after hit by thunderstorm including in-depth technical information such as manufacturer's specifications, material properties concerning certifications and tests for allowable failure strength, etc. for the damaged radome, windshield, latches and others.

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[66] Based on logs of rescue team in Gimpo Airport

[67] 159 items including Data Base Version (0003) Check for Soft No. 0405/07

[68] As European Aviation Safety Agency, they are in charge of certifying aviation safety and manufacturing procedure in Europe while the headquarters is located in German.

[69] Technical meeting: Held at Airbus located in Toulouse of France in 2007.2.5 ~ 2.6
Number of Attendees: 10 persons in total (2 from KARAIB, 1 from BEA, 1 from EASA, and 6 from Airbus)

1.17 Organizational and Management Information

1.17.1 Ground School for Flight Crew

According to the provisions for training in Asiana Airlines, a training course should be taken once a year about the weather information such as “Understanding of weather map, Identifying satellite images, Analyses on tracking chart for typhoon, Estimated weather map for bad weather at low/high altitudes”.

Asiana Airlines required one hour of “Aeronautical weather” as a common course and had text books about aeronautical weather such as “Thunderstorm, Radar image, Introduction to typhoon, Aeronautical weather (weather map), Aeronautical weather training (training for student), Aeronautical weather observation and air forecast.”

Trainings regarding Aeronautical Doppler Weather Radar are carried out for persons who change aircraft type or get promoted, and basic course is taken for crews as a flight crew operation manual.

When there was an abnormal case, Asiana Airlines notified it to crews through company system and performed case-study. In 2006, the company performed 3 case studies[70].

In addition, safety information (2006.1.27) and safety memorandum (2006.5.4) of major accidents were issued in 2006.

1.17.2 Flight Crew Simulator Training

A321 Quick Reference Handbook provides the procedure in case of “Windshield/Window Cracked/Arcing” through the Clause 2-26 of “Miscellaneous” chapter. However, the operating procedure and guidance did not provide the procedure when radome is detached and the crews cannot identify the fore view with naked eyes during flight.

[70] B737 (twice), A321 (once)

As per the recurrent training provisions, one simulator training course in the first half of year and one Line Oriented Flight Training (LOFT) course in the second half of year are opened for the crews in Asiana Airlines.

The simulator training in the first half of year focuses on proficiency and evaluation, while the LOFT concentrates on abnormal situation that might happen during flight from departure to destination, while the scenarios are being updated every year.

According to the scenario of LOFT for A321 crews in the second half of year 2005, the situation for “Cockpit Right Windshield Crack” was given and training was performed.

The above mentioned training was given under the condition that Auto Flight System and Auto Thrust System, and Flight Director System were all in normal operation. The captain of flight 8942 completed the course, while the first officer was not subject to take the course in this period.

1.18 Additional Information

1.18.1 Thunderstorm Avoidance

According to AIM, it states that “Do not underestimate the significance of any thunderstorm, and the best way to deal with is to avoid it” and “Any thunderstorm, which is identified as such based on radar information, should be avoided by keeping the distance of at least 20 miles or more. When more than 60 % of flight area is affected by thunderstorm, the whole area should be avoided.”

According to "Supplementary Techniques, Navigation" of A321 manual, it states that "The avoidance of large thunderstorm must be made 40 NM before it. In addition, the area in magenta and red should be avoided at least 20 NM from the fringes at an altitude higher than 23,000 ft and at least 5~10 NM at an altitude of 23,000 ft or lower." Also, it states that "The crews must identify thunderstorm and frequently adjust the tilt of antenna."

According to A321 SOP of Asiana Airlines, it states that "The captain should take enough time before making any avoidance from CB area. The avoidance should be made above CB affected area as much as possible. In addition, it should be determined at least 40 NM before large thunderstorm. The area on navigation display with magenta and red should be avoided at least 20 NM at an altitude higher than 23,000 ft and at least 5~10 NM at an altitude lower than 23,000 ft."

According to the user's manual for weather radar by Honeywell, the followings should be considered in case of choosing avoidance path.

- If possible, it should be at least 20 NM or more from the area in magenta or red.

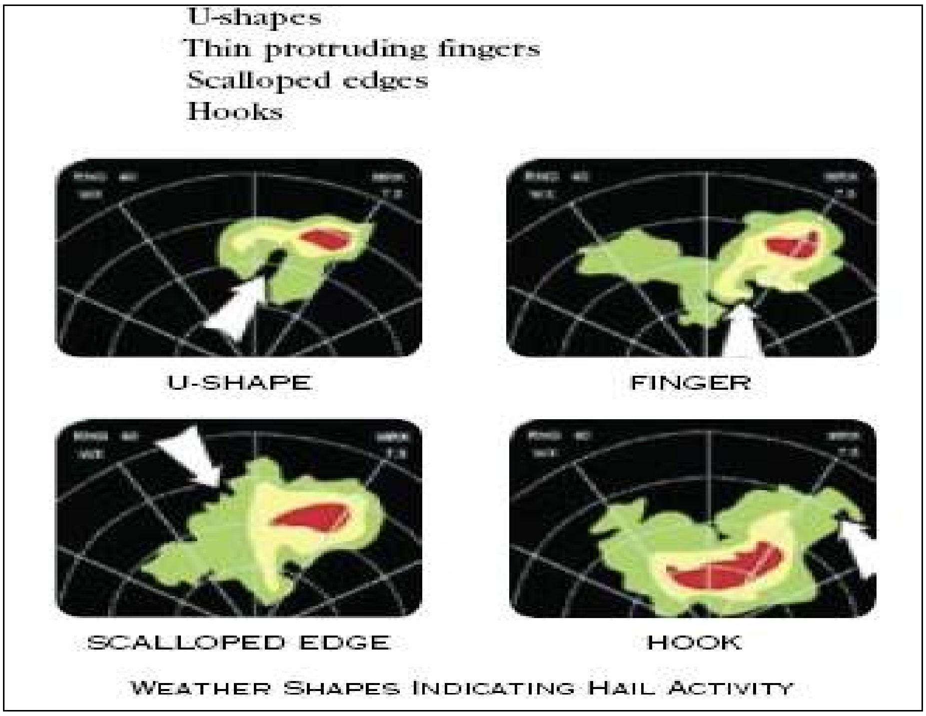
- Unless it is an emergency, the avoidance should be made toward the downside of wind as shown in [Figure 16]. Serious turbulence and hail to cause damage are much less probable above the thunderstorm.

- Discerning turbulence should be made only for identifying turbulence from precipitation. The area in red or magenta should be avoided.

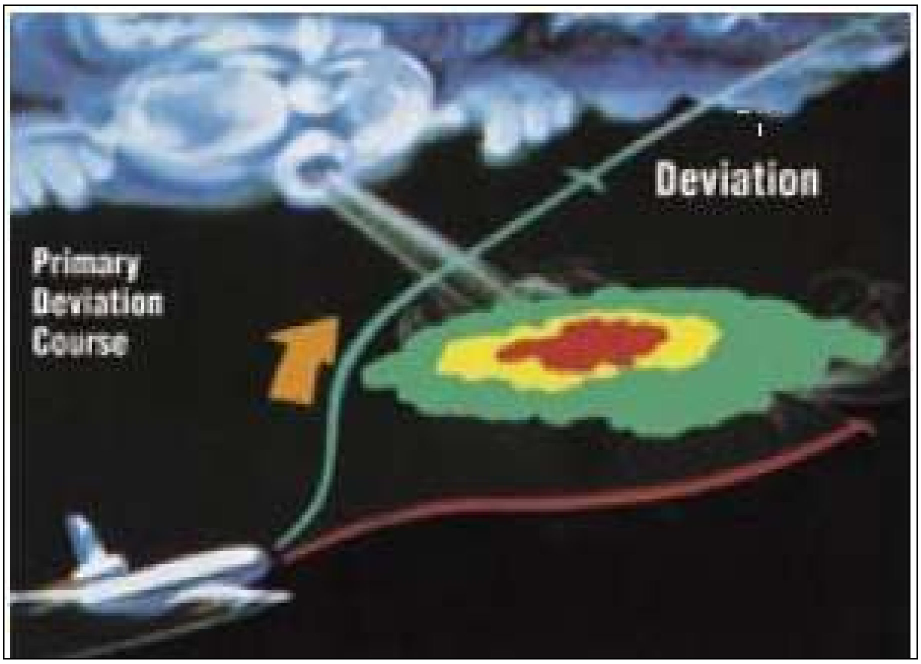
- The shape of thunderstorm on radar is as important as precipitation. The shape of thunderstorm as shown in [Figure 17] implies the existence of hails.

The user's manual[71], the operation guidance by Honeywell, the manufacturer of aircraft weather radar, explains about the shape of thunderstorm having probable hail activities and the avoidance directions as shown in [Figure 16] and [Figure 17].

71 RDR 4B Weather Radar System User's Manual with Radar Operating Guildelines P64, P65



[Figure 16] Direction of Avoidance of Thunderstorm



[Figure 17] Shape of Thunderstorm Having Probable Hail Activities

1.18.2 A321 Standard Operating Procedure

The standard operation procedure for Asiana Airlines A321 type specifies the weather detection in air route, use of aircraft weather radar, procedure to pass through turbulence and rainstorm as followings:

1.18.2.1 Understanding of Enroute Weather

It states that “Efforts should be made to collect weather information in air route during flight, and any probable adverse weather should be avoided in a positive and active manner.”

In addition, it specifies the methods to gather weather information as follows:

- Identify the weather condition by analyzing weather chart upon flight planning
- Verify the unidentified weather with ATC during flight
- Collect the weather information from other aircrafts flying the same route
- Identify the accurate weather information using the weather radar

1.18.2.2 Weather Radar Operation

It specifies the use of aircraft weather radar as follows:

- Efforts should be made to detect and avoid adverse weather using weather radar.

- Navigation display indicates the precipitation in black, green, yellow, and red. It is saturated precipitation in case WX/TURB is in magenta. In addition, the area in red and magenta indicates thunderstorm and hailstorm.

- When operating weather radar, the captain/first officer should select different distances each other to detect weather. When there is an active thunderstorm, the distance and tilt of antenna should be properly adjusted to detect weather.

During flight, the antenna tilt controlling is as follows:

- Below 20,000 ft: Near zero for long range search and slight downward tilt for close range search.
- Above 20,000 ft: Slight downward tilt recommended.

During descent flight, the antenna tilt controlling is as follows:
- Up to 15,000 ft: Change the antenna tilt upward per every 10,000 ft until ground wave disappears on display.
- Below 15,000 ft: Change the antenna tilt upward by 1° per every 5,000 ft until ground wave disappears on display.

The antenna tilt should be set to +3 ~ +4° of horizontal direction when using the weather radar or used at the go around stage.

1.18.2.3 Turbulent Air Penetration

The procedure to penetrate turbulence is specified as followings:

Upon encountering or expecting turbulence, seat belt sign should be turned on and turbulent air penetration speed should be set.

In order to effectively detect turbulence area on navigation display, set it to WX/TURB and 40 NM for distance.

When encountering or expecting moderate or high level of turbulence, give seat belt sign twice and a captain or cabin crews should announce that passengers should not leave the seats and fasten the seat belt.

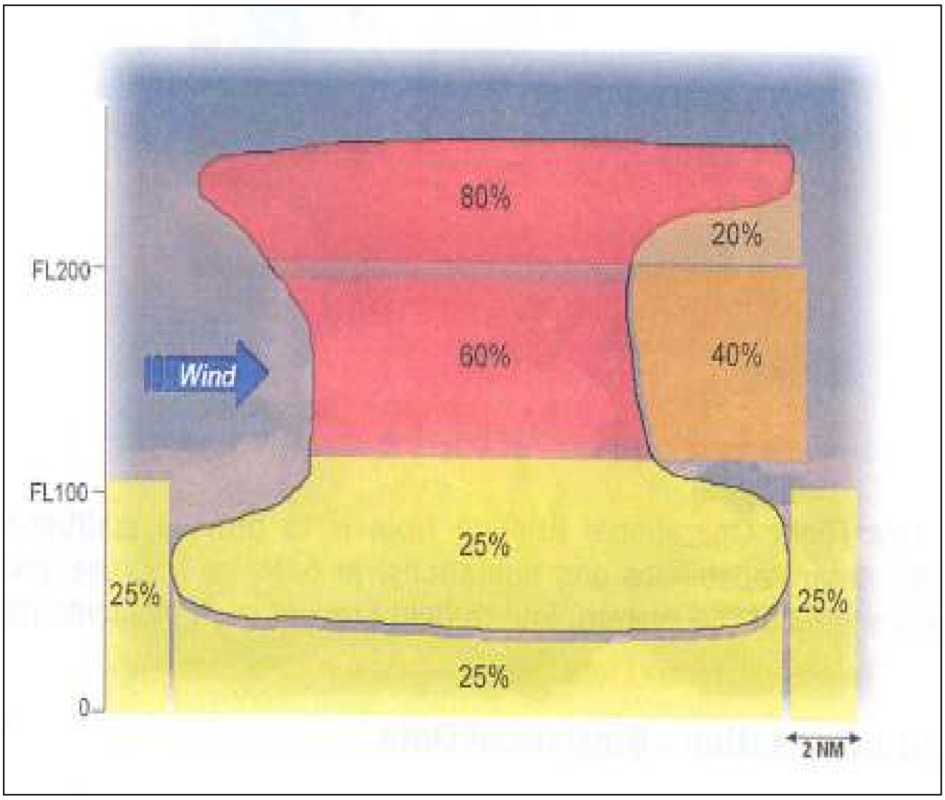
1.18.2.4 Heavy Rain Penetration

The followings are the procedure for heavy rain penetration.

Engine Mode Selector should be set to IGN during flight. Engine Anti-Ice should be used depending on outside temperature and seat belt sign should be turned on.

1.18.3 Formation of Cumulonimbus

The structure of cumulonimbus is shown like a large column containing shower and hail. Since cumulonimbus includes turbulence and large precipitation, it might raise serious risks during flight. The pilot may have difficulties in detecting hail under the cumulonimbus during flight and hail may cause serious troubles.



[Figure 18] Structure of Cb

The distribution of hail per heights inside Cb is commonly shown as in [Figure 18]. Up to 10,000ft height, the hail is evenly distributed by 25% up to 2NM from the center Cb. From 10,000ft to 20,000ft, the hail is distributed by 40% below 60% of anvil of Cb depending on wind direction while the distribution proportion is 80:20 above 20,000ft. Therefore, when aircraft encounters Cb, it should avoid its surroundings. Dry Cb becomes more dangerous than the one with moisture. Cb with moisture may melt down hail since the moisture in the air is acting as a heat conductor.

1.18.4 Testimony

1.18.4.1 Flight Crew Testimony

The flight crew interviews were conducted four times. The first interview was carried out in the office of Asiana Airlines A321 team located in the Gimpo Domestic Airport building after the flight on the day of accident accompanied by the manager of Asiana Airlines preventive safety team. After that, the additional three interviews were carried out in the ARAIB office, and the interview details are described as follows:

The flight crews requested for heading of 030° to fly into the right edge of the entire clouds avoiding the clouds between NUMDA and KAKSO. They chose the direction of 030° since there are many flights in the west side departing from Incheon and Gimpo.

The weather radar contacted the clouds. The distance of 40 NM and antenna tilt slightly upward (+0.25°) were maintained. The clouds were verified visually. They flew to the right side of clouds during flight with the heading of 030° and towards the right side of thunderstorm.

They estimated the haze in front was safer upon entering into the clouds. It was located in the green zone on the radar. They entered into the clouds turning on the engine anti-ice function and reducing the speed from 320 knots to 270 knots. They gave the fasten seat belt signs four times continuously. Before that, they maintained the VMC. The ground was seen below.

After clearing up as maintaining 030°, they said that they requested for turn into 310° (It was 330° according to CVR) and was trying to avoid between clouds. It was under the visual flight. The clouds were appeared when heading for 330°. There were raining, hails falling and lightning, but seemed not get hit by it.

The request for 330° direction was because it was the area with weak eco or no eco and also it was a direction for Anyang. There was a red color but passed it, then there was a red cloud on the right side. During the course, they requested for 330° because of clouds absence and then almost passed the red cloud but the accident occurred.

The hail intensity was changed from weak to intense hail and the windshield was cracked with a “bang” sound after black liquid was shown through the windshield. Then, the auto thrust system and auto flight system was disconnected. Immediately, they changed to the manual flight and directed the first officer to take action against the warning message and failure message displayed.

The sequence of accident was shaking of aircraft, small sized hail, big sized hail, some sort of black ink, “bang” and cracking of windshield. It seemed not get hit by a lightning. After hit by a hail, the crack on the windshield was spread out by a size of palm. After passing of thunderstorm, the flight was under VMC.

The “ADR” message was displayed, but there was no action taken during procedure. Then, the “FAC 1+2” message was displayed so they turned off and then on the FAC, but FAC was not turned on.

The flight director system was not operated. The noise was too big to communicate or to have a conversation. The speed of the captain side directed 330 knots while the speed of the first officer side directed 240 knots.

The flight crews requested the controller for calling of speed and the controller did. Comparing the speed with controller, it was similar to the speed displayed in the captain’s side. So it was referred during the flight. Although there was no vision, the controller guided very well.

The aircraft kept banked to the left and there were many difficulties in manual flight due to noise and shaking. They tried for reengage of the auto flight system and auto thrust system, but not engaged. The auto thrust system was connected for a second but turned it OFF due to twisting of the aircraft and they did not turn it back ON.

After the sound of “bang,” they informed to cabin crew that there was a serious emergency situation without detailed explanation. The captain did not give a passenger announcement. After a while, the emergency situation was announced and informed to the company.

After two go-arounds, they landed successfully at the third trial. With a big help of the controller for guidance, the aircraft could land safely. The first trial was failed due to its low altitude and deviation from the final course and then made a go-around at 1,000ft by a direction of controller. The second trial was failed since they could not visually identify the runway at 500 ft.

The ILS system indicated the glide slope and azimuth, but was not armed. they referred to the Glide Slope and AZ indication, but it was difficult to follow the indication possibly due to bad characteristics of the aircraft.

After checking the fuel of 4,500 lbs remaining upon second turnaround, they requested for a short pattern and the controller guided to a long final approach pattern with narrow width and guided with precision approach method at the final approach.

In the third trial, the runway could be identified at 500ft as approach to the final from the slightly right side and the runway centerline light was seen through the windshield at 200ft, and then made a landing. If tried on the Runway 14L, it could not be seen because of absence of runway centerline lights.

After stoppage on the runway, the crews checked the outside condition with the help of control tower and checked the passengers were ok. The flight crews requested the ground crews for the towing, but they asked if landing run could be done to open the runway as soon as possible since it took time for a tow car to arrive at the site.

Therefore, positioned the Follow Me Car on the left front side and asked the first officer to verify the centerline of taxiway as opened the window and stuck the head out. The crews could verify the centerline outline through the low edge of the windshield cracked during the landing run.

The crews said that they did not receive the bad weather information. They did not adjust the antenna tilt as flying in the direction of 030°. There was no ground clutter on the weather radar images. The crews requested for the high speed descent because there was no cloud and no flight approaching to Gimpo in front as listening of radio communication. The company radio frequency was always opened.

The captain stated that all the systems of the aircraft were operated normally before encountering with the hails and the weather radar was also normally operated.

1.18.4.2 Cabin Crew Testimony

The cabin crews of flight 8942 stated as follows:

The cabin crews joined to the captain's second flight between Jeju and Gimpo. There was no separate briefing about the turbulence. The seat-belt sign was on during course. The seat belt sound rang twice immediately before excessive shaking.

There was a feeling of aircraft's winding and a sound of pebble falling. The cabin crews worked in the front side said that there was a sound of falling of something or hitting.

There was no flash and no sound of "bang." The aircraft was heavily shaking as it was under turbulence. There was no captain's announcement but there were about three cabin announcement of warning to the passengers without informing the situation. During approach, do not use interphone to the cockpit as much as possible.

During preparation for landing after the signal of 10,000ft, it was checked that there was a noise at the front side from the 3rd or 4th row. When they were about to call to a captain, he gave an interphone call. He said that "the aircraft is damaged by the bad weather condition and I'll go for the emergency landing. We're at emergency situation."

1.18.5 Summary of Technical Meeting

With reagard to the accident, a technical meeting was held between the ARAIB, the BEA, the EASA, the Airbus on the detachment of the radome, damaged windshield and autopilot system disconnection, and the following are the meeting main agenda and the summary of the discussion:

1) When encountered with a hail storm, the outer surface of the windshield was severely damaged that the flight crew's visibility was impaired, thus review the structural strength of cockpit windshield.

2) The radome was damaged and detached from the aircraft when encountered with a hail storm, therefore, review the design strength and the allowable impact limit in order to prevent this kind of occurrences in the future.

3) Analyze the design, installed number and properties of latches and establish a plan to reinforce them since the radome is fixed with two latches on the lower part in such type of aircraft involved in this accident so that the entire radome could be detached upon partial damage to the radome.

4) Identify the cause why the auto pilot system was disconnected when the radome was detached from the aircraft, and review a method to supplement the relevant system for the prevention of the autopilot disconnection in such cases.

5) Review a method to include an emergency landing procedure in the manual in case that a pilot cannot secure the vision in front due to damage to windshield.

Discussion results on Item 1)

In such type of an accident, it was inevitable that the outer surface of windshield was broken due to the hail size and the aircraft speed but there was no deformation occurred in the airframe. In addition, the windshield was compared with other products manufactured by PPG, and it was verified that the structure of material and strength of the windwhield was equivalent, and it was designed to resist to the outside impact and pressure difference in accordance with European Union Air Regulations (JAR 25.0631/25.0775)

A) ARAIB opinion

However, it could lead to a more serious accident if flight crew would maneuver an aircraft without acknowledging the detachment of entire radome. Therefore, the ARAIB presents an opinion that a warning system to identify the detachment of radome is necessary for a flight crew in a cockpit and add such opinion in the Safety Recommendations Section.

B) BEA opinion

All effects resulting from the loss of radome (radar, predictive windshear, airspeeds) were indicated to the crew with timely and clear message. BEA also highlights that FCOM 3.042.34, in the pages related to unreliable airspeed and ADR check procedure, explicitly identifies radome loss as a possible cause. Consequently, all relevant information was indicated to crew.

Discussion results on Item 2)

The radome protects the radar antenna, localizer of ILS and glide slope antenna and is designed to make the air flow smooth at the fuselage nose.

It was designed[72] that the electric wave emitted from the radar to be penetrated with an optimal condition when absorbed into or went through the radome and the radome was also manufactured to resist to a lightning and passed the crush test not to break when hit by a hail. It was also considered to detect a gust in an appropriate time and to meet the optimal condition aerodynamically when designed the thickness and material, and it was designed with a composite sandwich shell.

A) ARAIB opinion

Therefore, it was confirmed that the breakage of radome shows its excess of the design limit, and as shown in the Section 2.6.1 above, the entire radome was detached since (1) the radome was broken and detached by increase of pressure as the air entered into the hole of the radome or (2) the radome was lifted by the untied latches supporting the radome due to impact by the hail.

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[72] Class A, CAT 1 Requirement of RTCA DO 213

B) BEA opinion

BEA investigated the hook latches and concluded that "the radome hook latch was in the locked position when the handle was ripped off." The second latch was found closed. Those 2 facts contradict this scenario of untied latches.

Discussion results on Item 3)

The methods were compared with other type of aircrafts in locking the radome. The radome of the aircraft manufactured by Boeing are locked by several latches or bolts; on the other hands, the radome of Airbus series (A321, A330, A300-600) are locked by only two latches. In the meeting, it was discussed about the weak point in design of possible detachment of radome due to impact from outside.

A) ARAIB opinion

In addition, ARAIB indicated that the hailstorm certification requirement[73] was not properly applied in the radome design and decided to present the opinion of radome performance test and standardized test to EASA if added to the Safety Recommendations.

B) BEA opinion

The comparision with other radome designs is not relevant because there is no technical evaluation that would demonstrate that one radome design would have a better hail impact resistance than other. BEA has no evidence from in service experience that the Airbus design would be more prone to damage to hail than other designs. The investigation doesn't highlight any link between the number of radome attachment points (four instead of only two) and the detachment of the entire radome. Two similar cases of total radome loss, reported by another aircraft manufacturer, suggest that having more attachment points is not a solution to the problem.

[73] Required condition of strength test performed at the manufacturing design phase resisting not to be broken when

There are no hail strike damage certification requirements, so that the statement of a certification requirement not properly applied is inappropriate. There is, however, a requirement that the airplane must be designed to ensure capability of continued safe flight and landing after impact with a bird. The investigation doesn't establish any link between the loss of the entire radome and flight safety. The necessity of elaborating certification requirements is thus not demonstrated. The occurrences reported to the BEA don't support the need of such a recommendation.

Discussion results on Item 4)

The auto pilot system, auto thrust system and flight director are designed to be disconnected in case the radome is detached due to the thunderstorm since the speed cannot be accurately indicated and various data cannot be obtained in terms of aerodynamics due to unsteady air flow by the separation phenomena of the air flow in the direction of flying. In addition, everybody agreed that it was inevitable result to avoid the major defects occurred in the systems such as loss of function to control the operating range of rudder because the flight augmentation computer could not a certain speed.

A) ARAIB opinion

It was verified that the aircraft speed was described which must be followed upon the cruise level when the speed difference is occurred in the speed meter read by a captain and a first officer in a cockpit. In such case, the warning message is displayed when the speed limit exceeds by 4 knots; however, at this time of warning, the aircraft is already damaged. Therefore, the board requested the manufacturer to review the system to display the warning before reaching to the limit.

B) BEA opinion

The autopilot system, auto thrust system and flight director are designed to disconnect if air data (speed, angle of attack,) is inconsistent. It is inappropriate to qualify as "major defects" the necessary and safe disconnection of the mensioned systems under such flight conditions. Regarding the issue of the control of the operating range of the rudder, the crew received a dedicated warning and an ECAM indication to use rudder with care. It is therefore considered that the crew received adequate information to dear with the situation.

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radome encounters with hailstorm.

The damages to the event aircraft did not result from overspeed or from didcrepancy between Captain and F/O airspeed indications, but from impact with hailstones while aircraft was within speed limits. It would be impossible to detect the speed discrepancy before it occurred. The margins between VD/MMD and VMO ensure that exeeding VMO by 4 knots will not result in aircraft damage.

Discussion results on Item 5)

It is discussed to add the emergency landing procedure in the manual in case the vision is not secured for a pilot due to damage of windshield. According to the Abnormal Procedures of A319/A320/A321, it describes to maintain the altitude at 23,000ft or below and put the cabin pressure mode selector switch on manual (MAN) when cockpit windshield is broken. If sparkle occurs in a windshield, it directs to pull out the circuit breaker.

A) ARAIB opinion

However, beyond such procedure, ARAIB requested to add the description of the detailed and practical procedure in the manual for safe landing when a pilot cannot secure the vision in front due to breakage of a windshield.

In addition, the board members discussed about a single radar system installed in a domestic aircraft, A321-100 operated by Asiana Airlines. In principle, the airline company should install dual radar system for safe flight, but it was confirmed that the operating company itself decided to install a single system considering the economical aspect and it was not the fact that the manufacturer or EASA approved.

B) BEA opinion

Following this discussion, Airbus is ammending the FCOM and QRH by adding the following notes;

- Use autoland in case of impaired visibility;
- Opening of the sliding window can be considered if autoland is not possible.

Concerning the topic of dual or single radar system, the BEA agrees with Airbus comments;

- A dual radar system is not needed for safe flight. Actually about 90% of aircraft have a single radar system. The other 10% are fiftted with a dual system for less dispatch restrictions only.

- Airbus approves installation of a single radar system. Airbus proposes the dual system as an option. Having a dual radar system installed would not have helped during subject event since the radar antenna was destroyed, so that two systems (if there had been two) would have responded as did the one installed on aircraft. In addition, with a single or dual system the weather detection capability is strictly the same as with only one WXR Transceiver active. The advantage of a dual installation is only in terms of availability; when one transceiver fails, the second one can be switched on.

2. Analysis

2.1 General

Flight crews of flight 8942 possessed the valid certificate required for aircraft operation and the qualification conditions were all appropriate. They also took a sufficient rest before flight and there were no medical factors found which affects their job performance.

Flight 8942 has been authorized properly and furnished with appropriate equipment, and proper maintenance has been performed. The weight and balance of the aircraft were within the regulated limit, and there were no evidences found that there were defects in airframe structure, flight control system or engine system.

It was confirmed that the transceiver of weather radar loaded in the aircraft was normally operated at the time of accident as a result of detail analysis performed by Honeywell, the manufacturer.

In the accident investigation analysis of flight 8942, it reviewed accident sequence, SIGMET information, air traffic control service, and damage to aircraft when encountered with thunderstorm etc.

2.2 Accident Sequence

2.2.1 Thunderstorm Avoidance

On the day of accident, thunderstorm clouds in a wide range have been formed between flight route of NUMDA and KAKSO as shown in [Figures 3, 4, and 5].

Flight crews of Flight 8942 stated that “we flew towards the right fringe of the thunderstorm cloud zone as keeping the cloud zone on the left side of flight axis. When entering into the light clouds, the location of the aircraft on the navigation display was in the green zone which was right side of the red zone.”

Even if considering all the statements made by the flight crews, the aircraft heading of 030° which was intentionally chosen to avoid the thunderstorm was the direction of wind blowing which could not have a sufficient avoidance distance.

According to the Flight Data Recorder, it was not appropriate to maintain the aircraft heading which could not keep the enough distance from the thunderstorm as approaching it after selecting the flight direction to 030°.

Comparing the criteria of thunderstorm avoidance distance stated in the A321 manual of Asiana Airlines (Supplementary Techniques) and the Standard Operation Procedure (SOP), A321 manual adopts the criteria of distance from Magenta, Read Area and Fringes; on the other hands, SOP adopts the criteria of distance only from Magenta and Red Area excluding Fringes. It may influence the flight as excluding the Green Area close to big thunderstorm when deciding the avoidance route by the flight crews of Flight 8942.

In spite that there were communications about the thunderstorm avoidance in other aircrafts at the time of accident and located in the thunderstorm area with red color near KAKSO, Flight 8942 chose the aircraft heading towards the wind direction. Therefore, it is estimated that it was not appropriate decision.

2.2.2 Alertness for Thunderstorm

There was no mention or briefing by the flight crews of flight 8942 about the thunderstorm during flight to avoid the thunderstorm cloud area with heading direction of 030°.

It can be comparable that flight crews are very accustomed to the verifying procedure regarding aircraft status, surrounding environment or crew’s intention etc. through training.

In addition, the flight crews of flight 8942 flew towards the thunderstorm clouds with speed of 325 knots under permission of controller. Although maintaining of such speed is not a violation of regulation, it is not a normal action that flight crews usually take by maintaining such speed until entering into the thunderstorm under the circumstances that turbulence is expected after acknowledging the thunderstorm cloud area.

The flight crews of flight 8942 fixed the tilt angle of weather radar antenna to +0.25 degree and the distance range on the navigation display system to 40 NM during descending from 16,000ft to 11,000ft as flying to the heading of 030°.

However, flight crews commonly find out the height of clouds, range and intense etc. by adjusting an antenna tilt and distance when detecting thunderstorm clouds and flight crews must try to detect a thunderstorm by adjusting an antenna tilt and range according to “User’s Manual” of weather radar manufacturer and “A321 SOP” of Asiana Air.

Therefore, it is estimated that the flight crews did not keep an eye on the thunderstorm and did not pay appropriate attention inferring from the following:
The flight crews did not mention or brief the existence of thunderstorm cloud and its avoidance method when displayed on the Navigation Display, did not try any action to detect the exact cloud area with weather radar, flew towards the edge of thunderstorm maintaining the insufficient distance from the thunderstorm cloud and flew at 325 knots requiring high speed descent as approach to the cloud.

2.2.3 Flight Crew Decision Making

In spite the wind direction at a flight altitude of flight 8942 was checked to approximately west wind, the flight crews flew towards the right edge of wind direction of cloud area and did not correct the heading to west side of the cloud area, rather they flew towards the cloud area. It is verified that they did not follow the instruction of keeping the distance of 20 miles or over from a thunderstorm in the technical manual.

In the first statement of the flight crews, they stated that “We tried to go through the weak area by turning left leaving the red zone on the left after flying the right edge of the cloud area. As checked the clouds get thinner when maintained 030°, we requested the turn to 330° and we were under flying between cloud and cloud.”

However, according to CVR, the captain directed the first officer the left-turn when approached to the thunderstorm and the controller directed to turn left to 330° and asked to report when avoided the thunderstorm. Immediately after it, the captain said to himself that “Oh~ No Clear of Weather.” and then after 28 seconds, the aircraft was exposed to the thunderstorm again for 36 seconds as encountering with the thunderstorm. Therefore, it is estimated that left-turn was not appropriate direction.

The action taken by the flight crews of flight 8942 to go through the weak zone between thunderstorms was prohibited action[74] according to the manual and it was also verified that such flight was not unavoidable situation.

In spite, the flight crews of flight 8942 tried to go through between the thunderstorms by turning left and it encountered with the thunderstorm by delayed turn due to miscommunication with approach controller.

2.2.4 Emergency Landing

The windshield of flight 8942 was damaged as almost as impossible to secure the vision after encountering with hailstorm. The automatic thrust system, automatic flight system and flight indication system were not normally operated, and speed meters of flight crews indicated differently each other. Due to detachment of radome, the communication was very difficult as exposed to serious noise and the aircraft showed the tilting phenomena to the west side.

Under such circumstances, the flight crews of flight 8942 landed successfully after three approach trials on the Runway 14R of Kimpo Airport.

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[74] According to USA FAA AC00-6A and Flight Weather Manual of JEPPENSEN, it says that “Avoid approach to between two precipitation zones unless 40 miles are secured.”

In the first trial, flight 8942 failed to enter into the final approach route and performed go around as indication by a controller. In the second trial, the flight crews of flight 8942 could not visually identify the runway and performed go around.

During go around, the flight crews of flight 8942 checked the remained fuel of 4,500lbs and requested for the short distance traffic pattern and the controller guided flight 8942 to the final approach route with precision approach procedure.

The flight crews of flight 8942 stated that "during the course, we verified the runway through the left window at an altitude of 500ft and verified the Runway Centerline Lights through the damaged windshield at an altitude of 200ft, and we could land on the runway stably by referring it."

The flight crews of flight 8942 received the approach and landing train by using Raw Data through simulation system and all the signals of blind landing apparatus were valid. However, it is estimated that the captain completed his mission by safely landing the aircraft under the exceptional situation and condition as a person who should take ultimate responsibility in safety.

In the pilot's manuals, FCOM and QRH of two representative manufacturers of Boeing and Airbus, it did not mention the specific measurement at the time of encountering with hailstorm. It only describes the direction in case of unreliable speed indication and window cracking, but it does not describe the direction in case of encountering with thunderstorm.

It is recommended to call a flight crew's attention to hailstorm by describing the hail strike in OEB (Operational Engineering Information) of manufacturer or FCOM about the characteristics of hail and its avoidance maneuvering, handling of abnormal system after encountering with hail, and actions needed to be taken as a separate item similar to the case of Windshear[75] or Microburst[76].

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[75] Windshear: It is defined as a changing rate of wind speed and/or direction per unit distance. It can be either vertical or horizontal, and it can be occurred in any atmospheric layer. It is usually generated at the time of strong temperature changes and near the surface of the ground where a thunderstorm exists.

[76] Microburst: It is a sudden gust occurred by spread to all directions upon collision of wind with the surface of the ground as wind starts from the underneath of cumulonimbus cloud.

2.3 SIGMET Information

2.3.1 SIGMET Observation and Forecast

At 15:20, AMO announced the amended en-route forecast including thunderstorm (SIGMET) forecast effective from 16:00 on the day of accident to 04:00 of next day. At 15:20, it also announced the amended area forecast including SIGMET effective from 16:00 to 24:00 on the day of accident, and they were transmitted on the Aeronautical Fixed Telecommunication Network.

On the other hands, SIGMET information was announced twice to be effective from 15:30 to 16:30 and from 18:30 to 21:30 on the day of accident and it was forwarded on the AFTN. However, there was no SIGMET information effective for 2 hours between 16:30 and 18:30 when flight 8942 was under flying. Then, according to the en-route forecast, the area forecast and the data detected by the Terminal Doppler Weather Radar, it is analyzed that there was SIGMET existed at the time when 8942 was encountered with the thunderstorm and damaged by the hailstorm.

According to Article 3.4 in Annex 3 of International Civil Aviation Organization (ICAO), it stipulates that the AMO(MWO) shall continuously watch out the weather condition which may impact to flight operations within their jurisdiction. However, it is estimated that AMO was inadequate in the observation and the analysis by not announcing the bad weather information between 16:30 and 18:30 which was continuously existed between 15:30 and 21:30.

2.3.2 Utilization of Images

The Air Carriers of Korea and the air traffic control facility use the weather information observed by weather radar and satellite of Korea Meteorological Administration in a wide range to the flight operations related work through the internet to AMO. However, it is analyzed that its usage is not efficient due to difficulty in identifying the exact location of adverse weather in connection with the en-route or the airspace because the image map projected only shows the outline of Korea territory and boundary of province.

Although the weather radar and the satellite were not developed for the sole purpose of aviation, its usage level and safety flight operations will be improved in the civil aviation field which needs all weather flying if aerial map is additionally displayed since they are well developed weather information system which can be visually seen all together in a real time over the all airspace of Korea.

The en-route map is shown on the terminal doppler weather radar installed in the Incheon Airport; however, it needs to be complemented since its usage is not efficient due to no display function of supplement route, fixes and aerodrome indication.

2.3.3 Propagation System of SIGMET Information

2.3.3.1 Asiana Airlines

The flight crew could not read the SIGMET forecast or information on the related en-route and airspace through the terminal for self briefing to flight crew since the en-route and area forecast, and SIGMET information are not input to Flight Operations Monitoring and Control System. However, the flight crews of flight 8942 stated that “we could grasp the information through the PC for weather connected to the internet with AMO.”

Flight crews can draw out the information of approximate location of precipitation cloud and precipitation intensity observed by weather radar and satellite through the PC connected to AMO. However, such information is not sufficient to apply to the en-route flight exactly since it does not include the map displaying the route or airspace area. The weather condition could be read by referring the weather chart; however, it is also insufficient to apply to the flight due to absence of map showing the route.

The en-route forecast, area forecast and SIGMET information is the weather information officially propagated by AMO in accordance with the relevant regulations of ICAO Annex 3, and it shall be verified by a receiver (flight operations person in charge) immediately after sending to apply it in a timely manner.

In addition, it is estimated that it could be helpful to plan and decide more exactly the necessity of avoidance against the adverse weather located in the expected airway or airspace by comprehensively analyzing the image data from the weather radar or satellite through the PC connected to weather information web site additionally provided by AMO.

Therefore, it is estimated that it is necessary to install the AFTN terminal to the location in charge of the flight control or operation control services and it is also necessary to complement and improve the system which can be accessed and searched for weather information or forecast including SIGMET information through the flight crews' briefing terminal.

2.3.3.2 Air Traffic Center

The weather information including SIGMET information announced by AMO is propagated to controllers in the control room on a telegraph message format through the connection to the air control system of traffic center by AFTN. In addition, the weather information such as weather image data detected by national weather radar network, satellite and Terminal Doppler Weather Radar of Incheon Airport can be obtained in a real time through the PC for weather installed in the control room. Therefore, it is estimated that there was no problem found in receiving the necessary weather information.

2.3.3.3 Seoul Approach Control

Inferring that the information of en-route forecast, area forecast and SIGMET information which is officially propagated through the AFTN by AMO could not be systematically received, and the staffs on duty on the day of accident did not use the flight operations and flight information system or the internet, it is estimated that the system was not inadequate to receive and use the forecast or any other information concerning with SIGMET in an appropriate time.

In order for an approach controller to receive and identify the forecast concerned with SIGMET and SIGMET information SIGMET information which transmitted by AMO, the flight data management (DPR) should be revised and supplement as linking it to the AFTN and the automatic radar terminal system so that it can be directly shown on the flight data display in a controller's seat.

In case approach controllers need to verify the detail area and the map after seeing the SIGMET information or forecast in a form of number or text displayed[77] in control seat, it is estimated that it can be applied to the approach control services if the controller searchs the web site of AMO and identifies the accurate weather information.

2.3.4 SIMET Information Advisory

2.3.4.1 Air Traffic Center

It is estimated that and the ATC approved the flight crews' request assuming that they flew observing the clouds and the SIGMET information was not delivered to flight 8942, since the weather information was not input and shown on the en-route control display due to no effective SIGMET information announced at the time of flight of flight 8942 in a jurisdiction area and the flight crews of flight 8942 requested the heading of 30° to avoid the clouds.

According to the statement of the controllers on the day of accident, the forecast including SIGMET or SIGMET information, which was not corresponding to the flight hours of flight 8942, was received. However, it were that Air Traffic Center does not announce the hazardous weather advisory broadcasts in accordance with the Article 2-6-2 of Air Traffic Control Procedure and Air Traffic Center only provides the information to aircrafts only when received the pilot weather report (PIREP). Therefore, it is estimated to be helpful in deciding the avoidance flight by identifying the existence of thunderstorm if the forecast including SIGMET or SIGMET information provided by AMO in accordance with the relevant regulations[78] is delivered to an aircraft under jurisdiction.

2.3.4.2 Seoul Approach Control

The approach controller did not advise flight 8942 about the eco location although he saw the flight flying to the vicinity of eco which displayed in a black color on the control radar display, since there is a regulation that controllers shall approve when flight crew request avoidance in relation with weather and he presumed that the flight crews performed the thunderstorm

[77] Receive and display in a real time immediately after MWO's announcement
[78] Article 5 and 6 of Convention to Weather Support Job between ATC and MWO, in accordance with Article 31, Clause 1, Air Traffic Control Job, and Clause 2-6-2 of ATC Procedure.

avoidance flight better using the airborne weather radar inferring their request of head direction to 30° for avoidance.

The intensity of precipitation was being displayed identifying by colors on the Terminal Doppler Weather Radar display, but the controllers at the time stated that they only referred to the eco displayed on the radar. Inferring the fact that it stipulates that the terminal doppler weather radar can be referred in accordance with the Operation and Management Manual of air traffic services and the international regulations such as Annex 3 or 11 of ICAO does not stipulates the duty of using the terminal doppler weather radar, it is estimated that the controllers depended on the cloud avoidance request by the flight crew of flight 8942 rather than judging the condition through the terminal doppler weather radar display.

As in the case of this accident, it is necessary that a controller can advise or recommend an avoidance to flight crew referring to the information obtained by seeing the eco shown on control radar or terminal Doppler weather radar display when an aircraft flies to the eco zone by flight crews' judgment and request. It is estimated that the concerned regulation should be amended or complemented for implementing the above requirements.

In addition, if a controller can access to forecast or information related to SIGMET at the approach control seat and he/she can compare and analyzes the eco displayed on the control radar and the terminal Doppler weather radar with the forecast and information , the controller may judge whether it is generated by the SIGMET phenomena or not and it is estimated that the controller can also actively advise the eco location with a reasonable distance and recommend the appropriate avoidance direction in accordance with the para 8.6.9 of ICAO Doc4444.

Although there was SIGMET information[79] within the Seoul approach control airspace announced by AMO on the day of accident, the controllers at the time did not announce the warning broadcasts for the hazardous weather advisory. However, if controllers announce the warning as stipulated in the para 2-6-2 of ATC Procedures in case a pilot does not receive SIGMET information in preflight briefing or flies without proper attention, it shall be helpful to aware the existence of SIGMET and give a motivation for appropriate use of aircraft airborne weather radar beforehand.

[79] It does not apply because the bad weather information was not announced during the flight of 8942.

2.4 Air Traffic Control for Emergency Aircraft

2.4.1 Radar Approach Control

It is estimated that the controller of Seoul approach control center reassured the flight crews asking that “You can depend on the controller for the view’’ when the flight 8942 declared the emergency situation and stated no vision, and the controller provided the appropriate radar vectors as informing the ground speed shown on the control radar under the situation that the flight crew could not follow the guide instructions due to the malfunction of the speed indicator and as providing the speed and heading information necessary for flight.

Especially, it is estimated to be an appropriate action that the controller instructed for ascending in a timely manner when the aircraft was deviated from the final approach course and headed towards ground obstacles due to its uncontrollable speed.

It is also estimated to be an appropriate air traffic control to immediately replace with the controller who has more experience in control by precision approach radar (PAR) upon request by the captain of precise approach after the second missed approach so that the switched controller did magnify[80] the radar display looking the distance of the final approach course more precisely, descend the altitude appropriately as the distance to the runway, guide the aircraft until the landing on the runway by instructing the aircraft to position into the approach course and transfer the control to the control tower after landing.

2.4.2 Response to Emergency Aircraft

It is estimated to be appropriate action that flight 8942 declared the emergency situation to the Seoul Approach Center at 17:46:41, the Gimpo control tower prepared for the emergency landing at 17:47:24 and announced the situation to the related agencies in Gimpo Airport by crash phone at 17:48.

[80] If magnifying the screen, there is an extended line from the centerline of runway and it displays the distance to a runway every one mile.

According to the para 3-4-4 of ATC Procedures, it stipulates that the approach lighting systems shall be operated during day time in case of the prevailing visibility less than 5 miles; however, it is estimated to be late for Gimpo Control Tower to turn on the lighting systems 14 minutes after the awareness of emergency on the day of accident.

2.5 Hail Impact Mark

The hail size measured from the damage parts is approximately 2.0 cm or above in diameter inferring from the damaged mark on the Wave Guide connected to the radar antenna as shown in the Picture 17] and the hails hit in a thick dense. Considering the hail mark, it is estimated that the aircraft encountered with the hail under the cumulonimbus clouds.

The radar antenna was damaged by facing with the external environment installed the inside of the radome by detachment of radome. The antenna was still attached to the aircraft during flight after encountering with the thunderstorm and then fell on the runway due to impact upon landing.

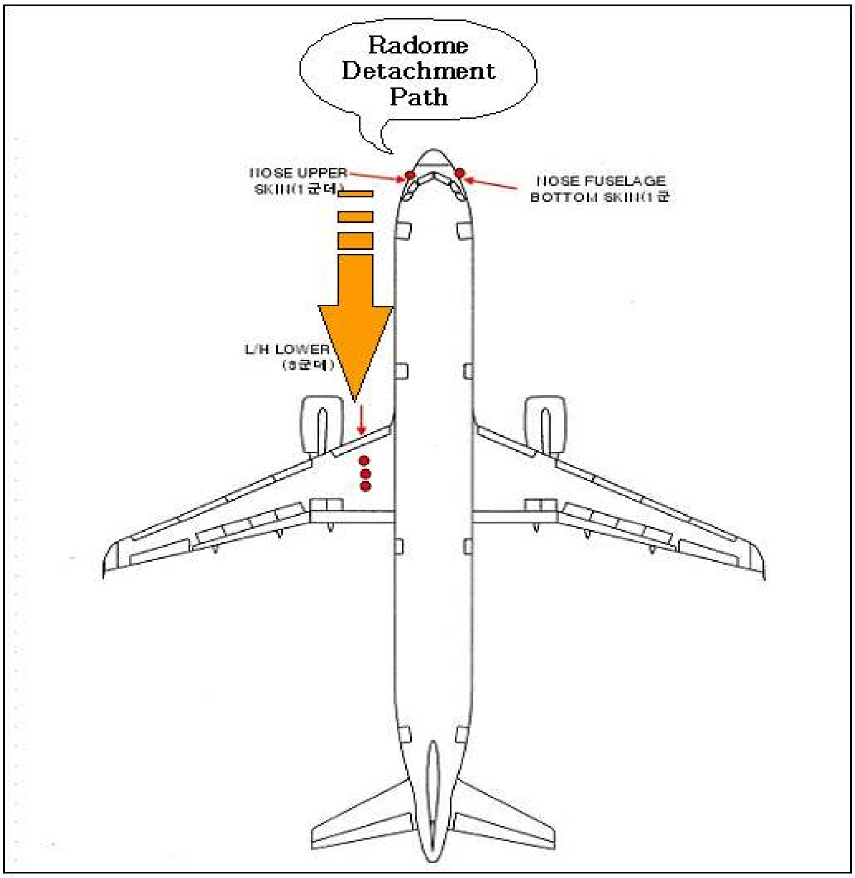
[Picture 17] Hail Size and Intensity

2.6 Damage to Aircraft by Hail Encounter

2.6.1 Radome Separation

According to FDR, flight 8942 was at an altitude of 11,500 ft with a speed of 328.9 knots at 17:40:02, and it is presumed that it encountered with the thunderstorm at 347.7° of heading during left turn flight and then the radome was detached during flight for 36 seconds until 17:40:38.

As shown in [Figure 19], the hail hit the cockpit windshield and the radome and damaged to the radome made of composite material. It is presumed that (1) the radome was broken more and more and then detached due to increase of pressure as the air entered into the inside in case of puncture to the radome, or (2) it was detached from the aircraft as lifted by untied latch which support the radome due to impact by hail hit. It is analyzed that the case (1) is highly feasible and that only this case has to be considered.



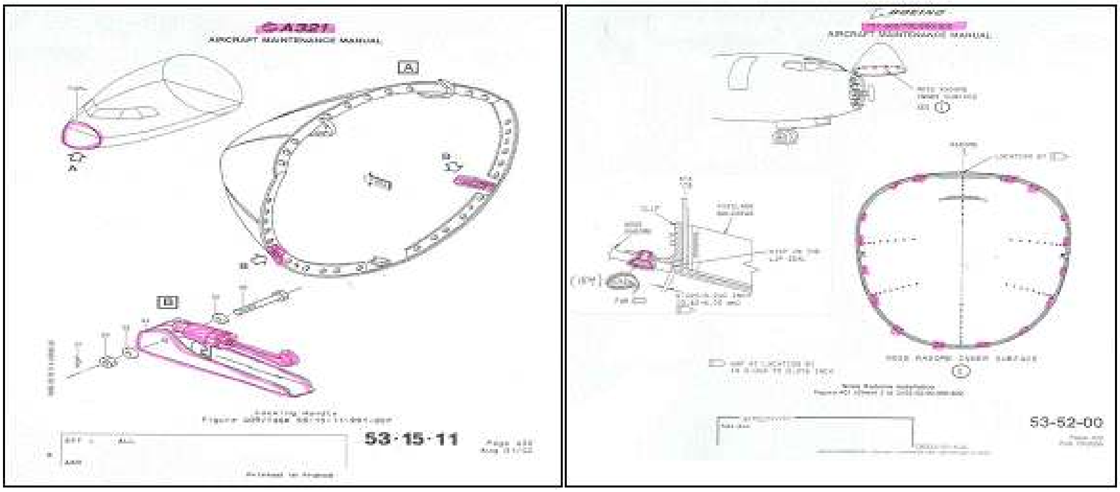
[Figure 19] Inference of Radome Detachment

2.6.2 Comparison of Radome Installation Methods

There have been cases that the radome was damaged by hailstones when an aircraft encountered with a thunderstorm accompanied by hailstones. As shown in [Picture 18], it shows the damage to the radome due to the hail and it was still attached to the airframe in spite of the damage to the radome. Although it was severely damaged and partially detached, the radome itself was not detached. The shape of damage to the front radome can be seen in [Picture 18] due to the hailstorm.

[Picture 18] Shape of Damage to the Front Radome Due to Hailstorm

The aircrafts of Airbus Series (A321, A330, A300-600) have two latches installed to the lower part of the radome at 4 o'clock and 8 o'clock direction; on the other hands, the aircrafts of Boeing Series (B737, B747, B777) have 6 or 8 latches installed on the circumference of radome in an even space and they are fixed by 16 bolts for B777 in order to protect the radome from detachment.



[Figure 20] Installation of Radome – Fix with 2 Latches (Left), Fix with 16 Bolts (Right)

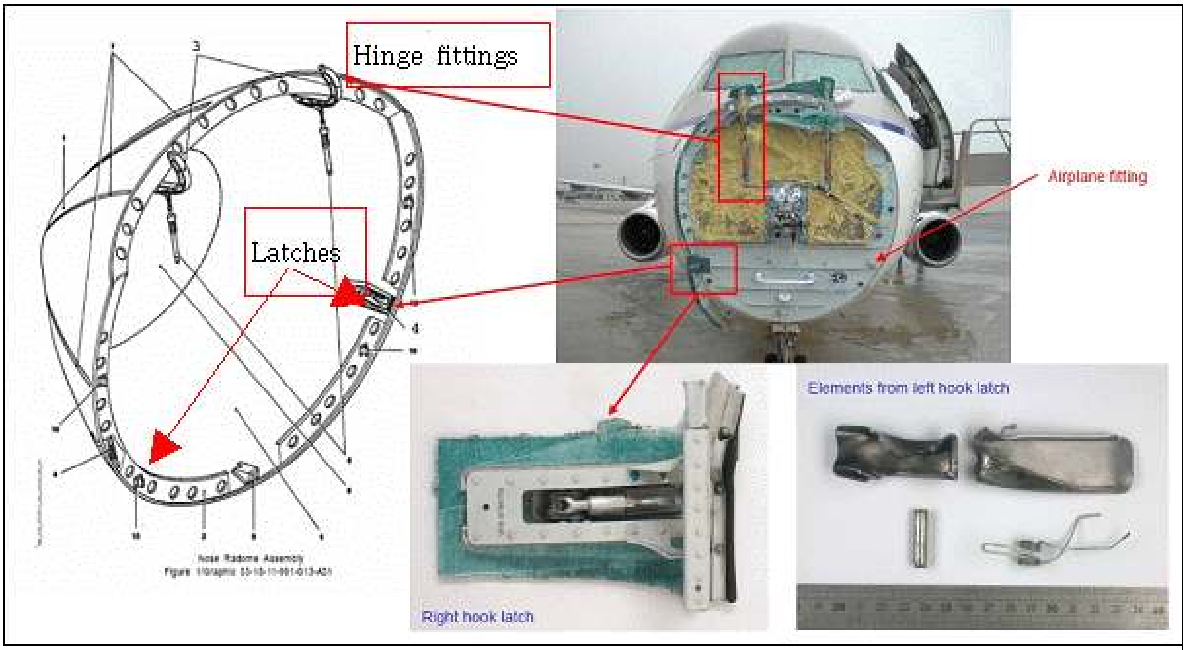
In this accident, the entire radome was detached from the aircraft, and similar case was investigated three times in the Airbus aircraft series. [Figure 20] shows the representative examples comparing the installation pattern of the radome between Airbus aircraft (A321) and Boeing aircraft (B777).

2.6.3 Test and Analysis of Damaged Latch

In the field investigation, the right latch was attached to the airframe but the left latch was detached from the airframe pierced into the left engine cowl. The France BEA analyzed the damaged parts of latch in their lab to determine the probable breakup scenario of the radome’s left hook latch.

2.6.3.1 Installation Position of Latch

[Figure 21] shows the location of parts installed in the aircraft and damaged pattern analyzed in the France BEA research lab.

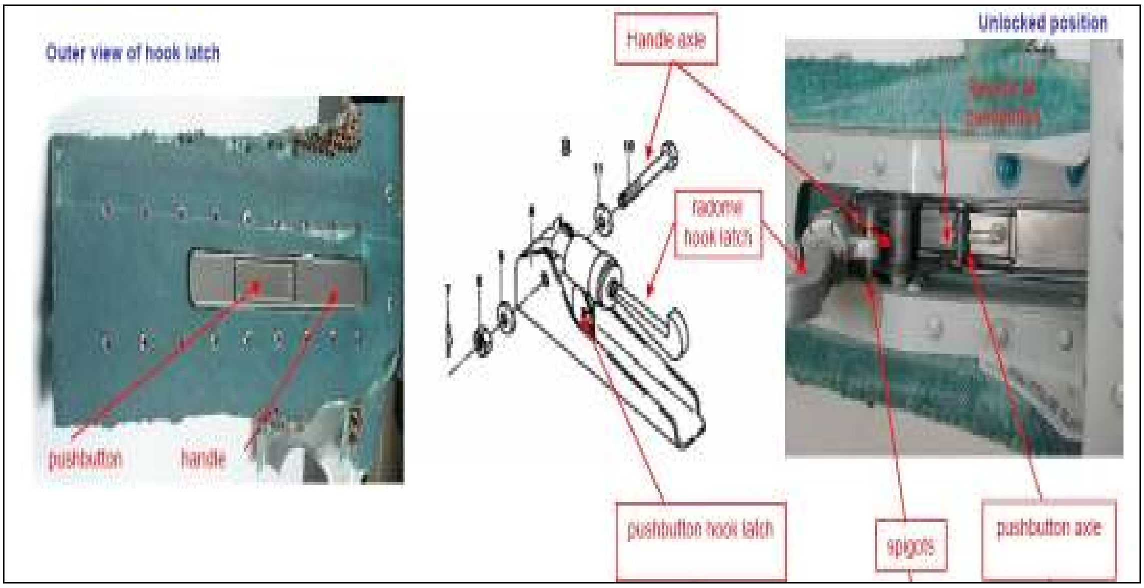


[Figure 21] Location of Latch Installed in the Aircraft and Damaged Pattern

The radome is attached to the airframe by two hinge fittings and it is tightly attached to the aircraft front structure by two adjustable hook latches. The right hook latch was still attached into the original location but the partial right latch was discovered in the left engine cowl.

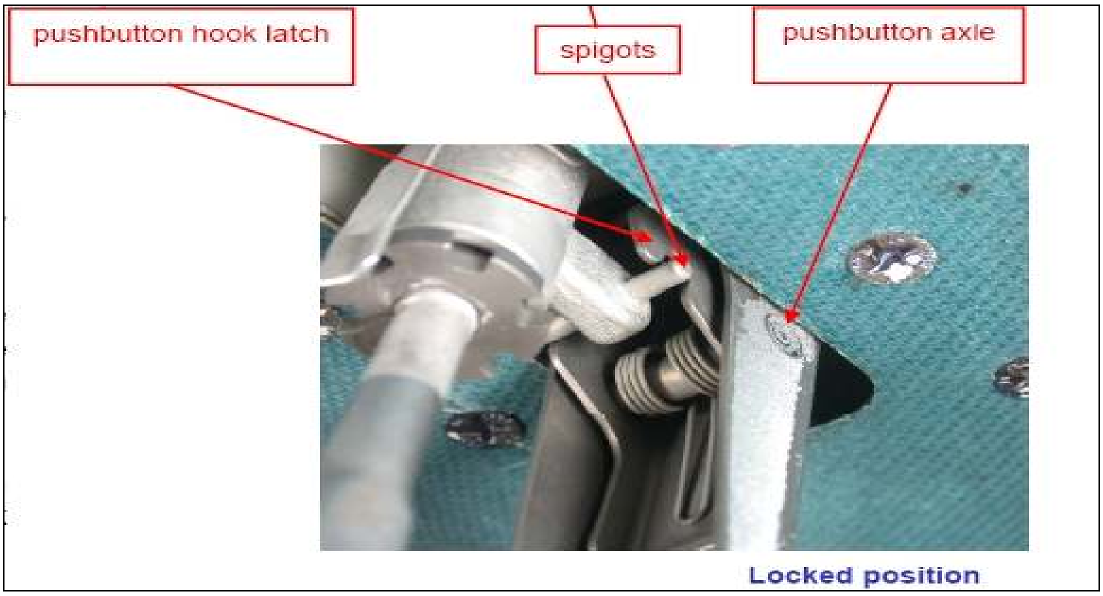
The hook latch handle is used to hang/unlock the radome hook latch in the airplane fitting. The pushbutton locks the handle in the direction of handle shut. If pushing the mark of “push” on the back side of the handle, it is unlock.

In the unlocked position, the handle can be moved around the center of axle. The pushbutton latches are unlocked from the spigots on the radome hook latch. The return spring of pushbutton grips the radome hook latch making it align with the handle [Figure 22].



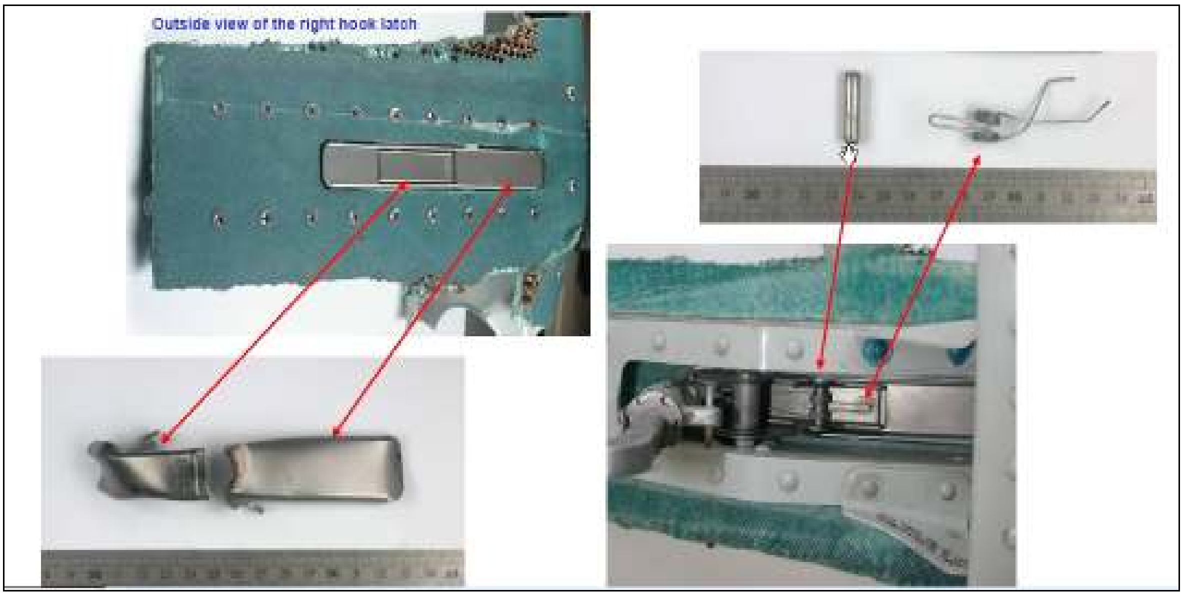
[Figure 22] Location of Hook Latch

In the locked position as shown in the [Picture 19], the pushbutton hook latches are hanged to the spigots. The pushbutton is directly connected to the radome hook latch. The handle has a same type of surface with the radome airframe structure surface.



[Picture 19] Locked Position of Latch

[Picture 20] shows the damage parts from the left hook latch. The damaged part is the pushbutton marked as “PUSH,” the axle pushbutton spring and the rear part of the locking handle detached from pushbutton.

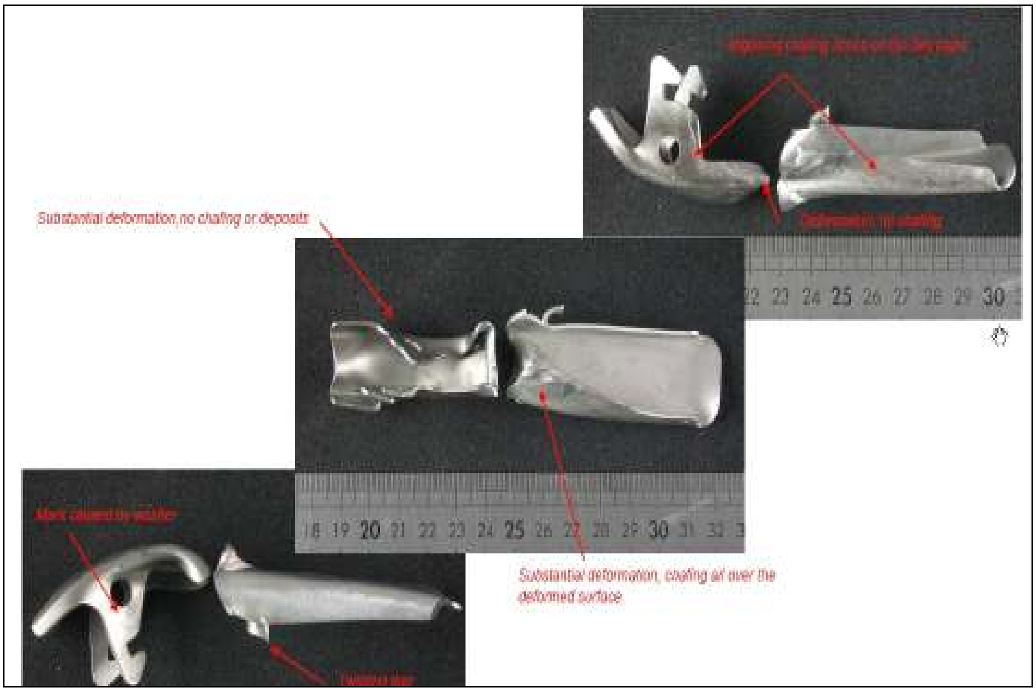


[Picture 20] Damaged Parts of the Left Hook Latch

2.6.3.2 Test of Left Handle

As shown in the [Picture 21], the rear part of the handle was deformed by the contact with foreign object. As shown in the right upper picture, it was deformed by pressure and cut by touching with the parts nearby, but there was no chafing mark found. There were many deformations found in the left part of the picture in the middle but no chafing or deposits were found.

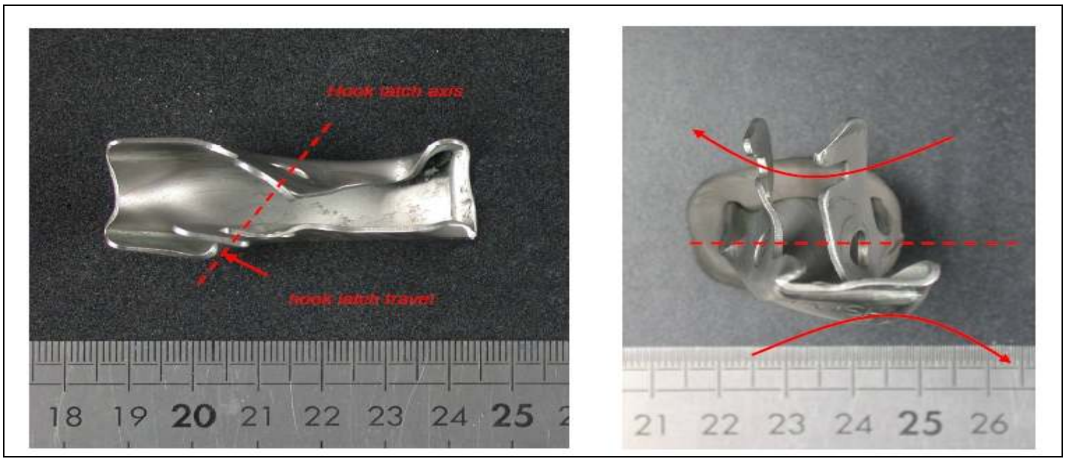
There were many deformation found in the left side and chafing was also found on the entire surface deformed. There were mark made by washer and twisting found as shown in the left lower picture.



[Picture 21] Damage to the Left Handle

2.6.3.3 Test of Pushbutton

The hook latch moves along its axle. The left picture on the [Figure 22] shows the deformed pushbutton. The reason of deformation was that the high energy applied to the pushbutton. The direction applied was the direction of bent arrow. As shown in [Picture 22], the indentation of hook latch was by spigots.



[Picture 22] Deformation of Pushbutton

The left arrow shows the resisting direction applied horizontally to the pushbutton and the right arrow is the direction of pushing force applied to the handle. As shown in the [Picture 23], the force in a reversed direction was applied to the handle and the pushbutton. Such applied force made the rear part of the handle torn out as in the pushbutton.

[Picture 23] Damage to the Left Handle and the Pushbutton

2.6.3.4 Test of Pushbutton Axle

The following pictures were taken to test and analyze the pushbutton axle. There were three bending found in the axle, and the extremities of the axle were flattened and the crushing on the opposite side with thickness of 1mm was located at 2 mm from the extremity of the axle [Picture 24].

[Picture 24] Damage to Pushbutton Axle

[Picture 25] Load Applied to the Pushbutton Axle

The force direction applied to the axle was marked with thick arrow and the red color indicates the load applied through the handle and the blue color indicates the load applied through the pushbutton. Opposing loads were exerted through the handle on one side and through the pushbutton on the other, respectively [Picture 25]. These high energy loads lead to disengagement of the axle.

2.6.3.5 Test Results and Analysis

The findings from examination of the pushbutton hook latches shows as belows

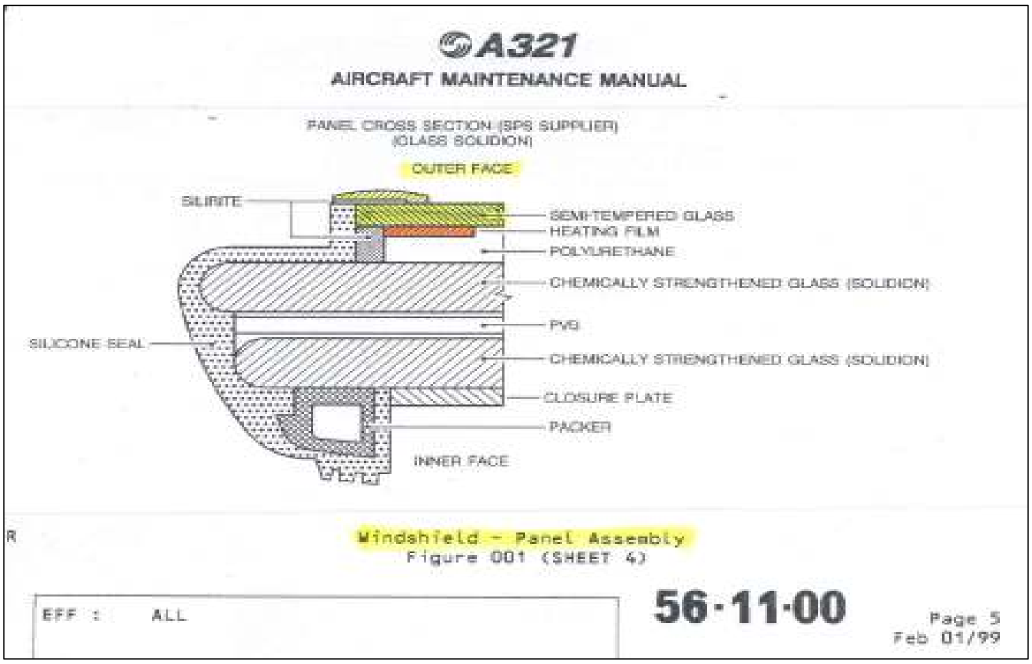
- The left radome hook latch was in the locked position when the handle was ripped off.
- The tearing off was the consequence of opposing loads, exerted between the hook latch and its handle at the level of the pushbutton.
- The high level of energy present during this tearing off is incompatible with an impact by the hook latch on the engine nacelle.
- It is highly likely that the handle was pulled off by the radome body after the latter was damaged. This scenario explains the origin of the loads opposed to the locking loads exerted on the pushbutton. In addition, this is compatible with the observations made on the hook latch handle.

The Korean ARAIB reviewed and accepted the result of the latch examination by the BEA. However the ARAIB concluded that that in any case the shroud rings and the latches should be attached to the aircraft, and in this context that there should be appropriate measures provided to enhance the total strength of the radome, such as increasing the number of latches installed, materials, and its allowable strength not to be detached from an aircraft in case of breakage by outside impact.

2.6.4 Damage to Windshield

The size of the cockpit windshield shown in the [Figure 23] is 89.0 cm in width and 63.9 cm in height with a rhombic shape and its weight of 34.4kg and it is manufactured by "Saint Gobain Sully, France."

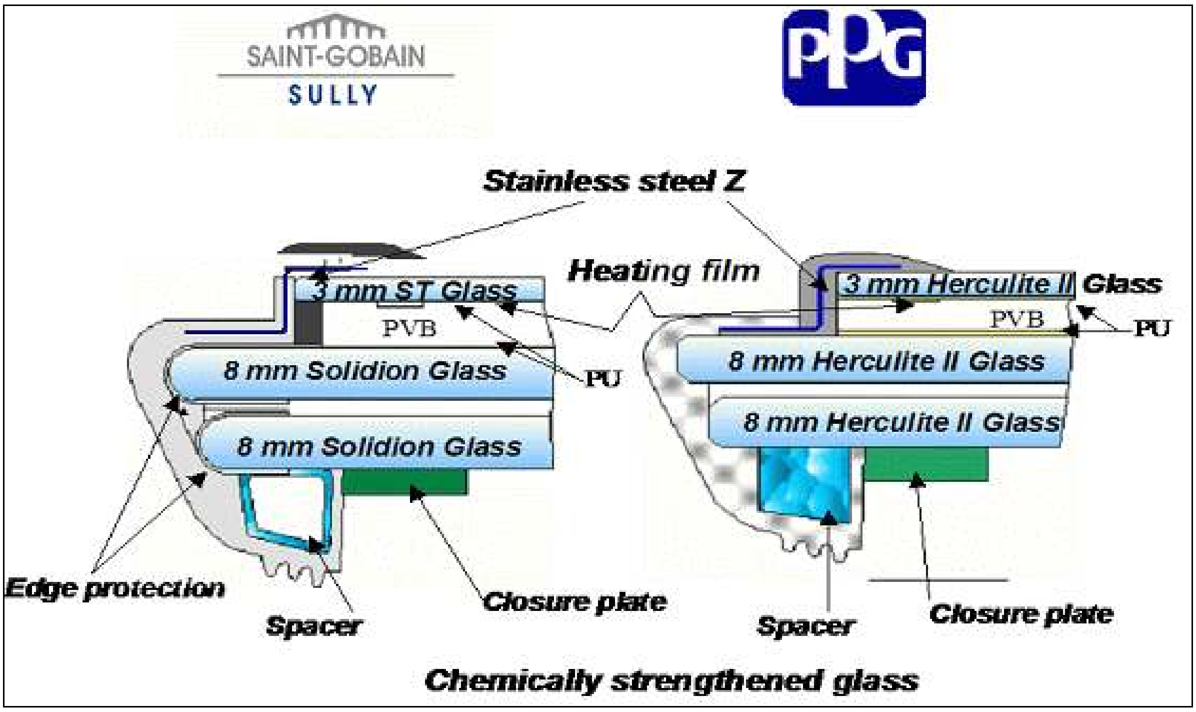
As stated on page 5 of Aircraft Maintenance Manual 56-11-00, the windshield was made of several glass layers with specific material overlapped and manufactured for flowing of electric current all the time during flight by inserting heating film between the glass surface and polyurethane. When the current flows into the heating film, it emits the heat to cover the windshield surface to protect from icing.



[Figure 23] Structure of the Aircraft Windshield

When encountering with the thunderstorm, the windshield was damaged by the hail at 17:40:02 and the defect message of "left/right WINDSHIELD WHC" on MCDU[81],[82] displayed and "ANTI ICE L+R WINDSHIELD" of the ECAM[83] warning message displayed. Inferring from these messages, it is estimated the Anti-Ice Switch of the aircraft was on the "ON" position.

Inferring from the damaged pattern of the windshield, it is estimated that the hails with 2.0 cm ~ 3.0 cm in diameter hit the outer face of the windshield heavily. It was sufficiently resisted from the wind outside since the inner face was not damaged; on the other hands, it was very difficult to secure the vision since the surface glass of the outer face was severely damaged.



[Figure 24] Comparison of Windshield Manufactured by SGS (France) and PPP (USA)

A windshield currently used in the aircrafts is mainly manufactured by SGS (France) and PPP (USA) and it is composed of chemical composite glass and its strength and thickness meets the regulations. [Figure 24] shows the windshield comparison between two representative windshield

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81 MCDU: It stands for Multi-Purpose Control and Display Unit.
82 WHC: It is a message of Windshield Heat Control and the message presents that the heating film did not properly function due to breakage of the outer glass.
83 ECAM: It stands for Electronic Centralized Aircraft Monitoring.

manufacturing companies of SGS (France) and PPP (USA) and it is verified that there is no difference found in size, strength and properties by the manufacturers' technicians during the technical meeting.

According to European Union Air Regulations[84], a cockpit windshield is designed to resist when an aircraft flying with cruise mach of 0.86 at an altitude of 8.000ft is hit by a bird with 4lbs of weight or the maximum cabin pressure differential is occurred.

ARAIB is estimated that the detail flying procedure is added to the Manual for safe landing by a pilot being securing the vision in front in case of cockpit windshield breakage.

2.7 Number of Airborne Weather Radars

As a result of investigation into the weather radar installed in an aircraft operated by Asiana Airlines, more than two weather radar system are operated in most of aircrafts as shown in [Table 1] but one weather radar system is operated in Boeing B737 (10 aircrafts) and Airbus A321-100 (2 aircrafts).

항공기 탑재 기상 레이더 현황

2007.04.26 현재

순번	보유기종	보유대수	기상레이더 형식	레이더 제작사	장착수량/대	비고
1	B737-400	7	RTA – 4A	Honeywell	1	
2	B737-500	3	RTA – 4A	Honeywell	1	
3	B767-300	7	RTA – 4B	Honeywell	2	
4	B767 CGO	1	RTA – 4B	Honeywell	2	
5	B747 COMBI	5	RTA – 4B	Honeywell	2	
6	B747 PAX	2	RTA – 4B	Honeywell	2	
7	B747 CGO	6	RTA – 4B	Honeywell	2	
8	B777	7	RTA – 4B	Honeywell	2	
9	A320-200	5	RTA – 4B	Honeywell	2	
10	A321-100	2	RTA – 4B	Honeywell	1	
11	A321-200	9	RTA – 4B	Honeywell	2	
12	A330-300	5	RTA – 4B	Honeywell	2	
비고	※ 특기할 사항					

[Table 2] Number of Weather Radar Installed

84 JAR 25.0631 Bird Strike Damage, JAR 25.0775 Windshield and Windows.

An aircraft used in the air transport business must equip the obliged wireless facility in accordance with Article 40 of Aviation Act and one weather radar (limited to an aircraft used in the international air transport business) in accordance with the No. 7, Clause 1, Article 122 (Wireless Facility) of Enforcement Decree of Same Act.

Since one weather radar system is installed in the Aircraft B-737 as shown in the [Table 2], ARAIB recommended installing two systems for safety. However, Airbus Company replied that it is not forced to install two systems.

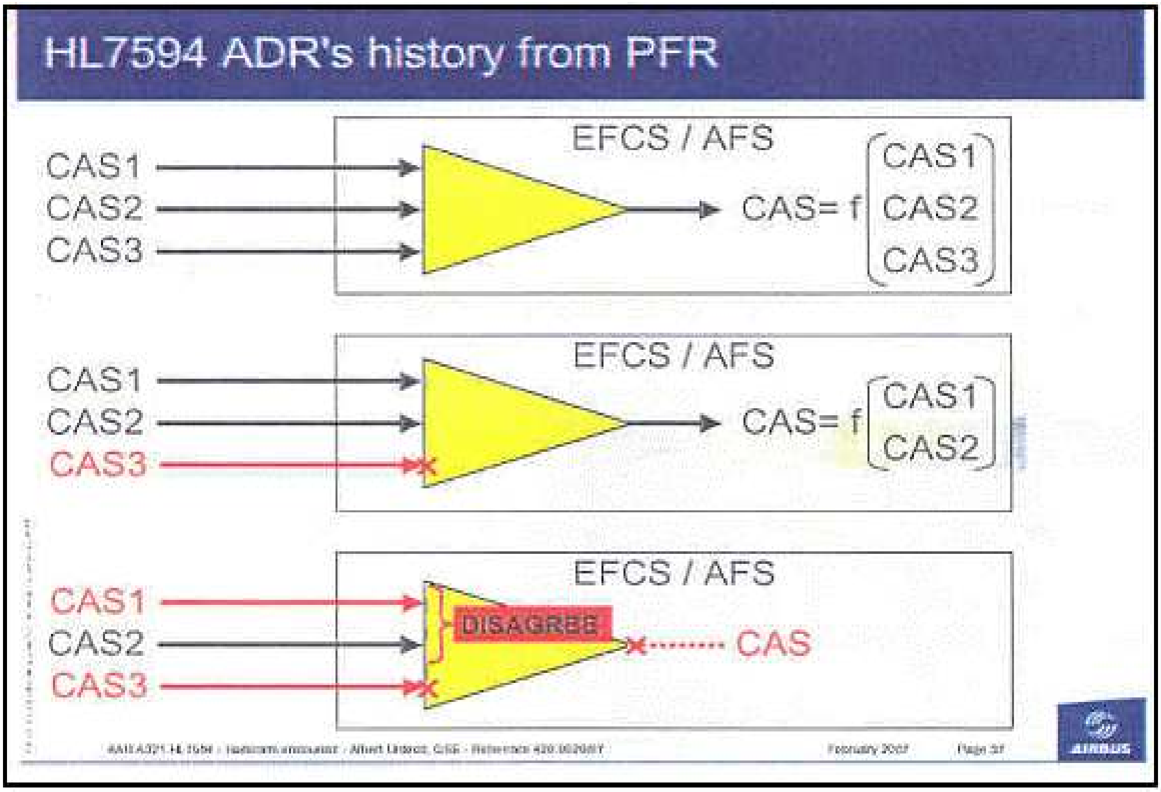
2.8 Analysis of System Failure

The analysis of defects in system was performed based on the Aircraft Maintenance Manual, Aircraft Schematic Manual, Aircraft Wiring Manual and Trouble Shooting Manual.

The FDR and the message displayed on MCDU in the cockpit shows that the auto pilot system, auto thrust system and flight director system were disconnected upon encountering with the hailstorm.

It is presumed that the auto pilot system was disconnected by difference in speed input entering into the Air Data and Inertial Reference System (ADIRS) computer because of disturbance of air flow in the dynamic/static pressure pipe after detachment of radome and at the same time the inconsistency in speed was detected by the Flight Augmentation Computers (FAC) 1 and 2 which controls yawing.

As the radome was detached, there was a change increased aerodynamically by the change of the air flow in the direction of flight. There are three identical Air Data and Inertial Reference System Unit (ADIRU). Each of them computes and provides air data from the 3 probe sources to the users (including EFCS and AFS). When one of the sources differs from the 2 others, it is eliminated and systems compute airspeed with the 2 remaining sources. If then those sources also differ, system consider sources as unreliable. [Figure 25] is the diagram showing this procedure.



[Figure 25] Input Data to Weather Data INS (ADR)

The auto thrust system was shut off by not sending the input signal to the FMGC[85] which performs functions in general as its function was not performed properly as displaying the message of the flight maneuvering panel where the flight crews enter the established speed upon encountering with the hailstorm.

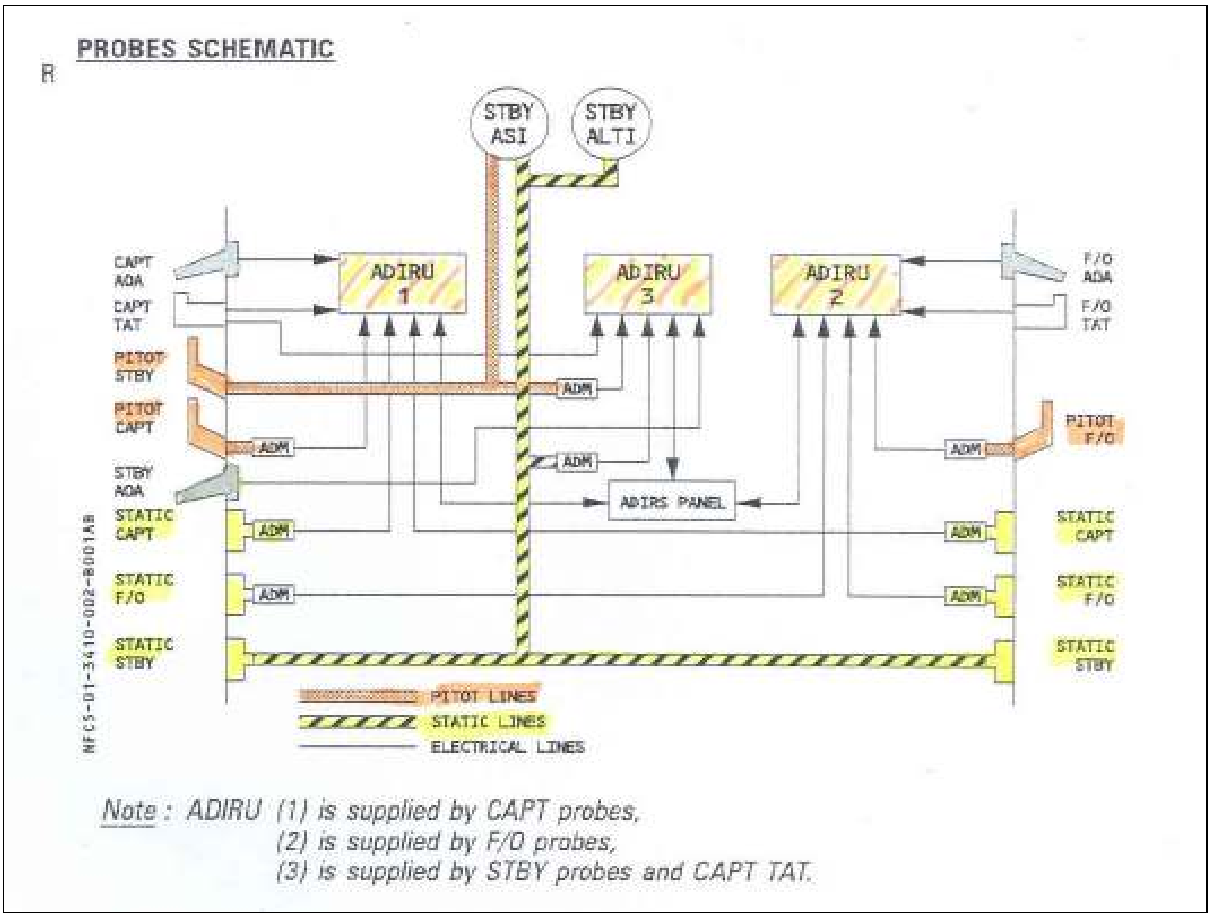
Therefore, it is estimated that the FMGC could not send the command signal to EIU[86] and the difference was occurred in the feed back signal resulting in the shut off of the auto thrust system.

When the 3 speed sources were disturbed to the point that discrepancy conditions in monitoring systems were tetected, auto-pilot, auto thrust and flight directors disconnected as per design.

85 Flight Management Guidance Computer
86 Engine Interface Unit

It is analyzed that the main cause of disconnection in the aircraft systems was that the essential probe could not detect the dynamic/static pressure accurately which was installed on both front sides of the aircraft as the air flow was scattered by not flowing smoothly due to detachment of radome from the airframe.

These probes detect the sudden change in air pressure and outside temperature as the outside air flow and then display them on the computer, speed meter and altimeter. [Figure 26] shows the schematic diagram of probes in relation with speed.



[Figure 26] Schematic Diagram of Probes

According to the Instrument Landing System Data recorded in FDR, the glide slope showing the up/down signal during landing and the localizer data showing the left/right signal were normal and it was verified that the flight crews made a landing with the help of controller by referring the G/S and LOC under the difficult condition for landing maneuver without vision.

3. Conclusions

ARAIB came up with the investigation results in three categories of Findings Related to Probable Causes, Findings Related to Risk and Other Findings based on the factual information and analysis of the accident of flight 8942.

Findings related to probable cause are comprised of factors which affected or almost affected factors into the accident. In this category, it is related to the unsafe acts, unsafe conditions or safety deficiencies which played a key role in occurrence of the accident.

Findings related to risk are comprised of the risk factors which potentially affect the aviation safety. Although there is no clear evidence that some of the investigation results actually affected to the accident, it is classified into unsafe acts, unsafe conditions and safety deficiencies including organization and systematic risk factor which might harm the aviation safety. In addition, this category includes the possible risk factors of safety deficiencies which needs a sort of safety plan in the future although some of investigation findings are not related to this accident.

Other findings are comprised of factors that reinforce the aviation safety, resolve a point at issue or clarify ambiguous items. Although some of findings are not always the analytical results in this category, it is items that are interested in general and included in accident reports following the form of International Civil Aviation Organization in order to teach and train about the information and safety and to use for the purpose of improvement.

Note: The findings of accident investigation are the key part of the report and it is published solely for clarifying the safety deficiencies and risk items to prevent from any further accidents. It violates the International Aviation Law and International Best Practices including Clause 3.1, Article 3 and Clause 5.4.1, Article 5 of ICAO Annex if the findings are used for the purpose of blame or liability.

3.1 Findings Related to Probable Causes

The flight route selected by the flight 8942 crew in order to avoid the thunderstorm was not separated enough by distance from the thunderstorm, and the alertness to the thunderstorm paid by the flight crew during descending was not sufficient, and the flight direction chosen when in close proximity to the thunderstorm was not appropriate to avoid the thunderstorm.

3.2 Findings Related to Risk

1. Flight 8942 was maintaining high decending speed when encountered with the thunderstorm.

2. The speed of flight 8942 was increased to 346.4 knots almost close to the maximum operating speed (350 knots) after disconnection of auto thrust and auto pilot systems.

3. The noise generated after the detachment of radome seriously hindered conversations between the flight crew and the communication between the flight crew and the approach control. .

4. The cracked cockpit windshield seriously impeded the flight crew from having visual contact with the runway and making a landing.

5. The disconnection of auto thrust, auto pilot and fight director systems seriously impeded the flight crew from making a stable landing.

6. Asiana Airlines did not use the weather forecast or SIGMET information officially dispatched by Aviation Meteorological Office through AFTN by means of having them input in the FMC, instead obtained the necessary weather information including weather forecast by means of logging into the weather information system provided additionally by Aviation Meteorological Office.

7. SIGMET information was not announced by Aviation Meteorological Office although it existed between 16:30 and 18:30 on the day of accident.

8. It is stipulated in a relevant agreement that the weather forecaster of Aviation Meteorological Office should conduct a weather briefing to the Air Traffic Center controllers, however, on the day of accident, the briefing was not conducted to the group of the controllers on duty who provided the ATC services to flight 8942.

9. The controllers of Seoul Approach Control could not receive directly in their control seats SIGMET information officially provided by Aviation Meteorological Office, instead, they used a system of obtaining weather information by logging into the weather information system provided additionally by Aviation Meteorological Office, which was insufficient to receive on time the weather forecast or SIGMET information announced at irregular hours.

10. Under the weather condition of visibility of 5 miles or less in Gimpo Airport, the airport lightings were switched on by the Gimpo Tower controller 14 minutes after the controller was aware of the emergency landing declared by flight 8942, the timing of which was inappropriate.

11. Air traffic control and Seoul approach control were not operation the broadcasting system on the SIGMET information for the aircraft flying in their control areas.

3.3 Other Findings

1. The flight crew of flight 8942 were certified and qualified for this flight, and airworthiness cerificate of the aircraft was valid.

2. The regulated maintenance was performed on flight 8942, and no defects were found in its structure or systems prior to the accident.

3. The weight and balance of flight 8942 were within the specified limits, and the fuel loaded was appropriate for a flight between Jeju Airport and Gimpo Airport.

4. Asiana Airlines selected the weather related training for flight crew as an annual based regular training subject, and was in possession of training materials on the thunderstorm charactersitics and avoidance, and the training on aircraft radar was included in flight crew initial and transition/upgarde training syllabes.

5. When the Seoul Approach controller, as deemded necessary, selects radar detected altitude and distance on the terminal doppler weather radar monitor located next to the control seat, the monitor displays the intensity and range of echoes in colors, however, SIGMET can't be detected on the monitor.

6. The echo area was shown in black color on the control radar display in Seoul Approach Control while flight 8942 was flying in its control area, however, the intensity of the echoes could not be identified by the system.

7. The Air Traffic Center controller gave permission when flight 8942 crew requested heading 030° to avoid clouds about 15 miles south of NUMDA, and also notified it to Seoul Approach Control.

8. Seoul Approach Control received the information from Air Traffic Center in advance that flight 8942 was flying at a heading of 030° in order to avoid clouds, and gave permission to maintain heading 030° after establishing radio contact with flight 8942.

9. Echoes were displayed on the monitors of the control radar and the terminal doppler weather radar in Seoul Approach Control, however, the controller did not provide advice on the echo positions or did not recommed to avoid echoes since the flight crew had requested heading 030°.

10. Air Traffic Center was receiving in the controller's seat SIGMET related forecast or SIGMET information announced by Aviation Meteorological Office, and was making reference to cloud distribution or precipitation area by searching for observational images of Aviation Meteorological Office weather radar and weather satellite on the personal computer for weather information.

11. When the flight crew declared an emergency situation and informed of having no foreview, the approach controller tried to reasuure the flight crew, saying, "You can depend on the controller for the view," and gave a timely instruction to climb when the aircraft was flying toward mountaineous terrain deviated from the final approach course.

12. After flight 8942 executed two missed approaches due to inappropriate handling of speed and altitude, the controller was substituted in a timely manner with a more experienced controller in precision approach radar, and this controller vectored the aircraft to the runway safely in a method of precision approach, providing the appropriate altitude and heading by magnifying the control radar display.

13. Aviation Meteorological Office produces and announces route forecast, area forecast and SIGMET information, and on the day of the accident, the route forecast and area forecast including thunderstorm effective for flight 8942 was announced and dispatched through AFTN.

14. According to the observation records of the weather satellite, weather radars and terminal doppler weather radar, there were isolated rain clouds accompanied by heavy precipitation in the air space where the aircraft encountered with the hailstorm.

15. Due to the unavailability of an aeronautical chart drawn of enroute or location of aerodrome on the display of the weather radar or weather satellite images, it was difficult for the controllers or civil aviation related personnel to accurately identify the enroute associated with SIGMET.

16. According to the FDR recording and the result of precise examination of the airborne weather radar conducted by the weather radar manufacturer, the weather radar transceiver was operating normally.

17. Radar components installed inside the radome and forward pressure bulkhead were damaged by the exposure to the outside due to the radome detachment.

18. The left radome hook latch was in the locked position when the handle was ripped off.

19. The origin of the loads opposed to the locking loads exerted on the pushbutton.

20. The latch was detached by the huge external force and it penetrated into the engine cowling as it was detached from the radome.

21. The handle was pulled off by the radome body after the latter was damaged.

22. There was no hailstorm certification requirement established on the radome design of A321 type aircraft.

3.4 Consultation of Draft Final Report

In accordance with Annex 13, Paragraph 6.3, the ARAIB of the State responsible for the conduct of the flight 8942 accident investigation forwarded a copy of the Draft Final Report to the BEA (State of Design and Manufacture) on August 9, 2007, inviting their significant and substantiated comments, and the ARAIB received the BEA's comments to the Draft Final Report on October 1, 2007.

After then, the ARAIB exchanged the opinion on the Draft Final Report with the BEA two times, and the Draft Final Report was amended accordingly. However, since not all of the BEA comments were able to be accommodated, with an agreement of the BEA forwarded on December 7, 2007, it was decided to append them in this section as follows:

4. Safety Recommendations

On the bisis of these findings, the ARAIB developed safety recommendations to Asiana Airlines, air traffic control facilities (Air Traffic Center, Seoul Approach Control), Meteorological Administration (Aviation Meteorological Office) and Aircraft Manufacturer (Air Bus Industry, France and EASA, in Germany).

Asiana Airlines

1. Establish and Implement the “Action Plan for Prevention of Similar Accident” including the followings (AAR0603-1):

    - Reinforce the education on the thunderstorm characteristics, avoidance flight procedure and use of the aircraft weather radar.

    - Add the approach and landing training using RAW DATA into the subject of the regular flight simulation device.

    - Review of flight crews’ flight procedure for efficient reaction against the similar emergency situation.

2. Supplement the details of “Weather Deviation” described in the A321 SOP in accordance with the A321 Manual (FCOM) and review a plan for a method and criteria applied to the thunderstorm avoidance maneuvering sharing the same concept among all flight crews (AAR0603-2).

3. Establish a plan for the aviation managers of Aviation Management Team and General Management Team to use the information or forecast including bad weather officially provided through the AFTN (AAR0603-3).

4. Supplement and improve the system so that flight crews can search using the terminal for briefing and access to the information or forecast including bad weather (AAR0603-4).

Air Traffic Control Facilities (Air Traffic Center, Seoul Approach Control)

1. Perform the education for the controllers stressing about the weather information and forecast and announce the warning of "bad weather conditions during flight" in order for the controllers to actively advise the flight crews about the bad weather information. (Common) (AAR0603-5)

2. Improve the system for the controllers to access to the bad weather related information and perform the education about the radar performance for enhancement of usage of the terminal Doppler weather radar and operating method of the terminal. Install more terminals and review/supplement of the regulations in use if necessary. (Seoul Approach Control Station) (AAR0603-6)

Meteorological Administration (Aviation Meteorological Office)

1. Supervise continuously on the localized bad weather condition after forecasting of bad weather and educate the staffs in charge about the case study to deliver the effective bad weather information to the users including control centers. (AAR 0603-7)

2. Consider to establish a method to improve the usage of image data from the weather radar of Weather Administration, weather satellite and terminal Doppler weather radar including the en-route by adding/supplementing the aeronautical chart. (AAR 0603-8)

3. Perform the briefing to ATC controllers when the duty is shifted as stipulated by the relevant Convention. (AAR 0603-9)

Airbus Industry, France

1. Consider the measures to enhance the total strength of the radome, such as increasing the number of latches installed, materials, and its allowable strength not to be detached from an aircraft in case of breakage by outside impact. (AAR 0603-10)

2. Consider the measures to let the crew identify the radome detachment by all means such as aural warning or warning light system in case of radome detachment from an aircraft. (AAR 0603-11)

3. Provide a plan to include the safe landing procedure under emergency into the aviation manual in case no vision is secured due to the damage to a cockpit windshield. (AAR 0603-12)

⇒ The Airbus already answered this recommendation by adding the notes to FCOM and QRH dealing with windshield cracking.

European Aviation Safety Agency (EASA)

1. Consider the Hailstorm Certification Requirement in the radome design and establish a way to obtain the data of radome performance test and standardized test. (AAR 0603-13)

IV. Appendix

Appendix 1 : Comments from BEA on the ARAIB's Draft Final Report

Appendix 1: Comments on ARAIB Aircraft Accident Report(Draft)

1. BEA's Opinion on Subtitle 2.6.2 (Comparison of Radome Installation Methods)

Airbus provided the ARAIB with consistent statistics. This is helpful in estimating the relative risk of such an event occurring again and the relevancy of the associated recommendations. Airbus reports two similar events, over 100 million flight hours and 50 million flight cycles. BEA suggests adding these figures.

"As shown in [Picture 18], it shows the damage to the radome due to the hail and it was still attached to the airframe in spite of the damage to the radome. Although it was severely damaged and partially detached, the radome itself was not detached. The shape of damage to the front radome can be seen in [Picture 18] due to the hailstorm."

ARAIB has not documented the conditions (eg hailstones size, density and numbers, airspeed, altitude …) that the aircraft in the pictures were subject to, and has not compared them to the conditions encountered by HL7594. Therefore no conclusion can be drawn on the hail storm withstanding capability of the A320 compared to the other aircraft shown in the report. The fact the radome wasn't completely detached could be explained by a lower airspeed (as recommended to the crew when hail encountered is suspected) or by a less severe hail encounter.

During the technical meeting, Airbus showed pictures of Airbus radomes having sustained severe hailstorm damage without perforation or detachment. The sole valid conclusion that may be drawn from the radome damage review is the exceptional severity of the hail conditions encountered by HL7594.

Finally, another major manufacturer indicated to Airbus having a couple of records of radome separation similar to HL7594, again resulting from flying into an extremely severe hailstorm. Airbus reviewed their in-service records. The records do not show a single unlatching of radome over 100 million flight hours and 50 million flight cycles in-service experience."the aircrafts of Boeing Series (B737, B747, B777) have 6 or 8 latches installed"

The comparison with other radome designs is not relevant because there is no technical evaluation that would demonstrate that one radome design would have a better hail impact resistance than another. BEA has no evidence that the Airbus design would be more prone to damage from hail than other designs.

The investigation doesn't highlight any link between the number of radome attachment points (four instead of only two) and the detachment of the entire radome. Finally, another major manufacturer indicated to Airbus having a couple of records of radome separation similar to HL7594, again resulting from flying into an extremely severe hailstorm. The investigation doesn't establish that the loss of the entire radome would have more impact on flight safety than a damaged radome as shown on the picture 18.

2. BEA's Opinion on a Phrase in Page 97

"…...as the air flow was scattered by not flowing smoothly due to detachment of radome from the airframe." (Phrase in Page 97)

On the phrase stated above, the BEA commented as the following:

The air flow could have been scattered without radome detachment, in the case of the sole detachment of parts of the radome's skin.

3. BEA's Opinion on Item 22 of Subtitle 3.3(Other Findings)

The sentence suggests that the absence of hailstorm certification requirement is limited to the Airbus A321. BEA suggests "There is no hailstorm certification requirement established on the radome design of any aircraft."

4. BEA's Opinion on Safety Recommendation AAR 0603-10 in Chapter 4

From the BEA point of view, regarding the comments above, any recommendation on the number of installed latches is not appropriate. On the one hand, the statistics for radome separation demonstrate that the design is effective. On the other hand, it is not demonstrated that the number of latches has any link with the risk of a complete radome separation.

5. BEA's Opinion on Safety Recommendation AAR 0603-11 in Chapter 4

BEA does not agree with this recommendation. All effects resulting from the loss of the radome (radar, predictive windshear, airspeeds) were indicated to the crew with timely and clear messages. BEA also highlights that FCOM 3.02.34, in the pages related to unreliable airspeed and ADR check procedure, explicitly identifies radome loss as a possible cause. Consequently, all relevant information was indicated to the crew.