ARAIB/AAR1105

Aircraft Accident Report

Crash Into The Sea After An In-Flight Fire

Asiana Airlines

Boeing 747-400F, HL7604

International Waters 130 km West Of Jeju Int'l Airport

28 July 2011

24 July 2015

Aircraft and Railway Accident Investigation Board

This aircraft accident report has been prepared in accordance with the Article 25 of the Aviation and Railway Accident Investigation Act of the Republic of Korea.

According to the provisions of the Article 30 of the Aviation and Railway Accident Investigation Act, it is stipulated;

The accident investigation shall be conducted separately from any judicial, administrative disposition or administrative lawsuit proceedings associated with civil or criminal liability.

And in the Annex 13 to the Convention on International Civil Aviation, Paragraphs 3.1 and 5.4.1, it is stipulated 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 the activity to apportion blame or liability. Any investigation conducted in accordance with the provision of this Annex shall be separate from any judicial or administrative proceedings to apportion blame or liability.

Thus, this investigation report shall not be used for any other purpose than to improve aviation safety.

In case of divergent interpretation of this report between the Korean and English languages, the Korean text shall prevail.

Aircraft Accident Report

Aviation and Railway Accident Investigation Board. ***Crash Into The Sea After An In-Flight Fire, Asiana Airlines, Boeing 747-400F, HL7604, International Waters 130 km West Of Jeju International Airport, 28 July 2011.*** **Aircraft Accident Report ARAIB/AAR-1105. Sejong Special Self-governing City, Republic of Korea.**

The Aviation and Railway Accident Investigation Board (ARAIB), Republic of Korea, is a government organization established for independent investigation of aviation and railway accident, and the ARAIB conducts accident investigation 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 objective of the investigation by the ARAIB is not to apportion blame or liability but to prevent accidents and incidents.

The main office is located in Sejong Special Self-governing City.

Address: #94, Dasom 2-ro, Sejong Special Self-governing City, 339-012
Tel.: (82)-44-201-5447
Fax: (82)-44-201-5698
e-mail: araib@korea.kr
URL: http://www.araib.go.kr

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Abbreviations

ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area Control Center
ACM	Air Cycle Machine
ACMS	Aircraft Condition Monitoring System
AFOLTS	Automatic Fire Overheat Logic Test System Cards
AOC	Air Operator Certificate
APB	Aft Pressure Bulkhead
APU	Auxiliary Power Unit
ATA	Air Transportation Association
ATC	Air Traffic Control
AWB	Airwaybill
CCL	Cambridge Communication Ltd
CCTV	Closed-Circuit Television
CDU	Control Display Unit
CG	Center of Gravity
CMC	Central Maintenance Computer
COSPAS/SARSAT	COsmicheskaya Sistema Poiska Avariynich Sudov/Search And Rescue Satellite-Aided Tracking
CRM	Cockpit Resource Management
CSMU	Crash Survival Memory Unit
CST	Coast
CVR	Cockpit Voice Recorder
DC	Direct Current
DG	Dangerous Goods
DGR	Dangerous Goods Regulations
EICAS	Engine Indication and Crew Alerting System
EIU	EFIS/EICAS Interface Unit
ELT	Emergency Locator Transmitter
ETA	Estimated Time of Arrival
EUROCAE	European Organization for Civil Equipment
FAA	Federal Aviation Adminstration
FCOM	Flight Crew Operations Manual
FDE	Flight Deck Effect
FDR	Flight Data Recorder
FMC	Flight Management Computer
FOB	Fuel On Board
FOM	Flight Operations Manual
FOQA	Flight Operations Quality Assurance
fpm	feet per minute

FS	Fuselage Station
G	Gravity
HF	High Frequency
IATA	International Air Transport Association
IC	Integrated Circuit
ICAO	International Civil Aviation Organization
ICN ACC	Incheon Area Control Center
KAL	Korean Airlines
kg	kilogram
KPa	Kilopascal
L.A.	Los Angeles
LCD	Liquid Crystal Display
LOFT	Line-Oriented Flight Training
MAWB	Master Airwaybill
MAC	Mean Aerodynamic Chord
MCRC	Master Control and Report Center
METAR	Meteorological Aerodrome Report
MHz	Megahertz
MIE	Minimum Ignition Energy
(M)LDW	(Maximum) Landing weight
MSA	Minimum Safety Altitude
MSDS	Material Safety Data Sheets
(M)TOW	(Maximum) Takeoff Weight
MU	Management Unit
(M)ZFW	(Maximum) Zero Fuel Weight
NFPA	National Fire Protection Association
NNC	Non-Normal Checklist
N.O.S.	Not Otherwise Specified
NOTOC	NOtification TO Captain for special load
NTSB	National Transportation Safety Board
PBE	Protective Bleeding Equipment
PF	Pilot Flying
PGMEA	Propylene Glycol Monomethyl Ether Acetate
PLF	Present Leg Fault
PM	Pilot Monitering
POM	Pilot Operations Manual
QRH	Quick Reference Handbook
ROV	Remotely Operated Vehicle
SACOM	Satellite Communication

SHI	Shanghai
SMS	Safety Management System
STA	Station
STC	Supplemental Type Certificate
TEM	Threat and Error Management
TOD	Top Of Decent
ULB	Underwater Locator Beacon
ULD	Unit Load Device
UN	United Nations
UPS	United Parcel Service
U.S.	United States of America
VHF	Very High Frequency
VSD	Video Smoke Detection
Wh	Watt hour
WS	Wing Station
3D	Three Dimension

Crash Into The Sea After An In-Flight Fire

- ○ Operator: Asiana Airlines
- ○ Manufacturer: The Boeing Company
- ○ Type: B747-400F
- ○ Registration Mark: HL7604
- ○ Location: International waters 130 km west of Jeju International Airport N33˚15'04.56" E124˚59'31.02"
- ○ Date & Time: 28 July 2011, about 04:11 (Korean Standard Time)

Synopsis

On 28 July 2011, about 04:11, Asiana Airlines flight 991, a B747-400F airplane, a scheduled cargo flight from Incheon, Republic of Korea, to Shanghai, China, crashed into the international waters about 130 km west of Jeju International Airport after the flight crew reported a cargo fire to Shanghai Area Control Center (SHI ACC) near a reporting point SADLI on airway A593 about 03:54 and attempted to divert to Jeju International Airport.

Aboard the flight were two pilots. Due to this accident, they were fatally injured, and some portions of the fuselage separated from the airplane in midair. The wreckage of the airplane was distributed under the sea in the area 3 km by 4 km in southwest-northeast direction.

The Aviation and Railway Accident Investigation Board (ARAIB) determined that the cause of this accident was「A fire developed on or near the pallets containing dangerous goods but no physical evidence of the cause of the fire was found. The fire rapidly escalated into a large uncontained fire, and this caused some portions of the fuselage to separate from the aircraft in midair, thereby resulting in the crash.」

As a result of this investigation, the ARAIB makes 5 recommendations to Asiana Airlines, 11 recommendations to the Ministry of Land, Infrastructure and Transport (MOLIT), 3 recommendations to the Boeing Company, and 1 recommendation to ICAO.

1. Factual Information

1.1 History of Flight

On 28 July 2011, about 04:11 Korean Standard Time[1], Asiana Airlines flight 991, a B747-400F airplane, HL7604 (hereafter referred to as AAR991), a scheduled cargo flight from Incheon, Republic of Korea, to Shanghai, China, crashed into the international waters about 130 km west of Jeju International Airport (hereafter referred to as Jeju Airport) after the flight crew reported a cargo fire to SHI ACC near a reporting point SADLI on airway A593 about 03:54 and attempted to divert to Jeju Airport.

Due to the crash impact and fire, the captain and the first officer (FO) were fatally injured, the aircraft was destroyed, and the cargo shipments were damaged, incapable of being recovered, or washed away.

AAR991 was a scheduled international cargo flight operated at night under the instrument flight rule in accordance with the Aviation Act of the Republic of Korea and the Convention on International Civil Aviation.

The captain and the FO showed up at the flight crew ready room of Asiana Airlines in Incheon International Airport (hereafter referred to as Incheon Airport) an hour before the scheduled time of departure[2] and signed the "show-up log," respectively.

The line mechanic stated that on 28 July, about 02:00, the flight crew arrived at the airplane and that the captain performed the ramp inspection. The loadmaster stated that about 02:15, under the guidance with him, the captain inspected the loaded status of dangerous goods and other shipments in the main

1) Unless otherwise indicated, all times in this report are Korean Standard Time, based on a 24-hour clock.
2) At 02:45 on 28 July 2011.

deck cargo compartment.

The transcript[3] of ATC radio communications shows that at 03:04:28, AAR991 took off from runway 15L in Incheon Airport. From this moment, the captain[4] took control of radio communications.

At 03:05:48, AAR991 made initial contact with Seoul Area Control Center (SEL ACC) after takeoff and was instructed to climb to 34,000 ft and fly direct to MALPA. At 03:12:19, the flight crew were advised to contact Incheon Area Control Center (ICN ACC).

At 03:12:35, AAR991 was climbing to 34,000 ft on a permitted route when it made initial contact with ICN ACC, and at 03:13:05, was allowed to fly direct to NIRAT.

At 03:26:05, ICN ACC instructed AAR991 to change its radio frequency to 124.52 MHz. From this moment, the FO mainly assumed control of radio communications, but the captain also occasionally made communication. At 03:26:21, the crew were instructed to fly direct to SADLI, and at 03:50:46, ICN ACC advised AAR991 to contact SHI ACC on frequency 134.0 MHz.

At 03:51:15, AAR991 stated that it was maintaining at 34,000 ft and flying direct to SADLI when it made initial contact with SHI ACC.

At 03:52:39, SHI ACC instructed AAR991, "AAR991 radar contact, off-set 5 miles right of track," and the flight crew carried out this instruction at 03:52:51.

The Aircraft Communications Addressing and Reporting System (ACARS)

3) Unless otherwise indicated, all communications records hereinafter are excerpts from the ATC transcript.
4) When the ATC transcript was prepared, voices of the captain and the FO were identified with the help of Asiana Airlines' B747-400 captain.

messages[5] received by the ground station were as follows: about 03:53, "EQUIPMENT SMOKE," "EQUIP COOLING," and "CGO DET 11 MN DK"; and about 03:54, "CGO DET 6 MN DK" and "CGO DET 10 MN DK."

At 03:54:23, the FO stated, "Shanghai control, Shanghai control, AAR991 request emergency descent, emergency, declare emergency due to fire main deck. Request descent, and descent to one-zero thousand."

At 03:54:37, SHI ACC gave AAR991 a descent clearance and instructed it to turn at its discretion, and the FO acknowledged this instruction. The radar data of ICN ACC shows that AAR991 started descending at 03:54:59.

At 03:55:08, the FO requested a diversion to Jeju Airport, stating "We have fire main deck, AAR991, return to Jeju AAR991," and SHI ACC approved the request.

At 03:58:03, SHI ACC instructed AAR991 to maintain 10,000 ft, however, followed by no response from AAR991. At 03:58:25, SHI ACC requested KAL886 flying near AAR991 to relay any information from AAR991 to SHI ACC. KAL886 stated that AAR991 was descending to 10,000 ft and flying direct to Jeju.[6] According to the radar data of ICN ACC, AAR991 was flying at 16,000 ft at a ground speed of 452 kt on a heading of 345°.

At 03:59:13, AAR991 requested a radar vector to Jeju. At 03:59:50, SHI ACC instructed AAR991 to fly heading 045, and AAR991 acknowledged this instruction.

At 03:59:26, according to the ATC transcript, the sound of the FO's breathing

5) ACARS messages were further received as shown in Section 1.6.5.2.
6) Between 03:55:29 and 03:57:48, SHI ACC and AAR991 tried to communicate about descent altitude and a change of destination but failed to understand each other's intention, whereas KAL886 comprehended their communication.

through an oxygen mask was recorded four times when he communicated with SHI ACC.

The last ACARS messages received by the ground station about 04:00 are as follows: "YAW DAMPER UPR," "RUD RATIO DUAL," and "FLAPS CONTROL."

At 04:00:23, SHI ACC instructed AAR991 to contact ICN ACC on 124.52 MHz for a radar vector to Jeju, however, AAR991 stated that it was unable to contact on this frequency. Consequently, SHI ACC instructed the crew to monitor frequency 134.0 MHz.

The radar data of ICN ACC shows that at 04:01:43, AAR991 was flying at 8,200 ft at a ground speed of 404 kt on a heading of 033°, and after this, AAR991's altitude, ground speed, and heading changed inconsistently[7].

At 04:02:00, SHI ACC instructed AAR991 to contact Fukuoka Area Control Center (FUK ACC) on 133.6 MHz. At 04:02:10, the FO stated, "AAR991" and 12 seconds later, added, "Fukuoka AAR991 mayday mayday mayday, we have cargo fire, request direct to Jeju please," followed by no response from FUK ACC.

At 04:03:01, the FO called SHI ACC and stated that it was unable to contact FUK ACC. Consequently, SHI ACC instructed AAR991 to pass information to KAL886 and let KAL886 relay the information to FUK ACC and ICN ACC.

At 04:03:01, the flight track data of the Incheon radar shows that AAR991's transponder code in Mode 3/A was set to 7700 from 6353 when the aircraft was flying at 8,500 ft at a ground speed of 410 kt on a heading of 027°.

7) Refer to [Figure 2], [Figure 3], and Appendix 3 (Radar Data of ICN ACC).

At 04:03:24, KAL886 advised AAR991 that it would relay its message to ICN ACC, and the FO stated, "Yes, now direct Jeju heading 030." KAL886 informed AAR991 that SHI ACC gave it heading 045, and the FO acknowledged this instruction.

At 04:04:14, SHI ACC instructed KAL886 to use another transmitter to contact ICN ACC on 124.52 MHz, to request heading to Jeju from its present position, and to report back to SHI ACC. Regarding this, KAL886 gave an affirmative response.

At 04:05:30, the captain[8)] called KAL886, and KAL886 responded, "Relay from Incheon Control, from Incheon Control, maintain heading 060, radar vector for final, and you may descend to 7,000 ft." At 04:05:52, KAL886 again relayed the message, "Maintain heading 060, radar vector for final, and descend to 7,000 ft," followed by the captain's response, "Descend 7,000 ft."

Beginning 04:06:25, the captain called "Korean Air" twice. At 04:06:30, KAL886 responded, "Stand by, stand by," followed by the captain's statement at 04:06:32, "Ah··· we are now that rudder control is not working and seems to be fired··· (jamming)."

At 04:06:41, SHI ACC instructed KAL886 to contact ICN ACC on 124.52 MHz, and at 04:07:16, instructed AAR991 to try contacting KAL886 on 124.52 MHz, followed by the captain's acknowledgement.

At 04:07:34, the captain stated, "We have to open the hatch, hatch." Subsequently, KAL886 instructed AAR991 to change its frequency to ICN ACC frequency 124.52 MHz.

8) From this moment, the captain took control of radio communications.

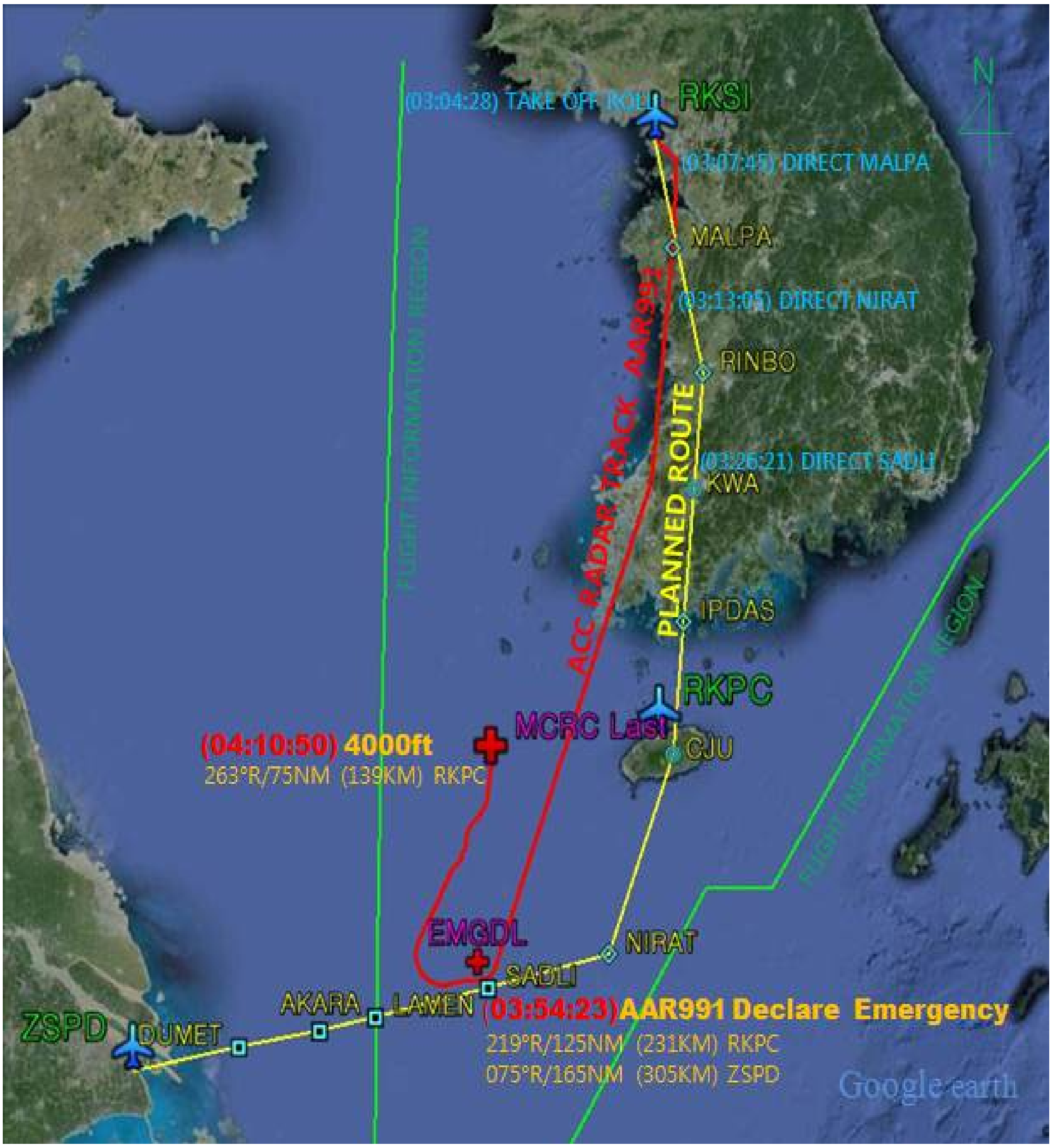
At 04:08:52, ICN ACC instructed KAL886 to relay the message to AAR991 that JEJ APP established radar contact with AAR991 and that AAR991 should contact JEJ APP on 121.2 MHz. At 04:09:08, KAL886 relayed this message to AAR991.

At 04:09:47, the captain said to JEJ ACC, "Rudder control… flight control, all are not working." The FO said to JEJ ACC, "Did you contact? Uh… do you contact us?" and JEJ ACC responded, "AAR991… yes, I can hear you."

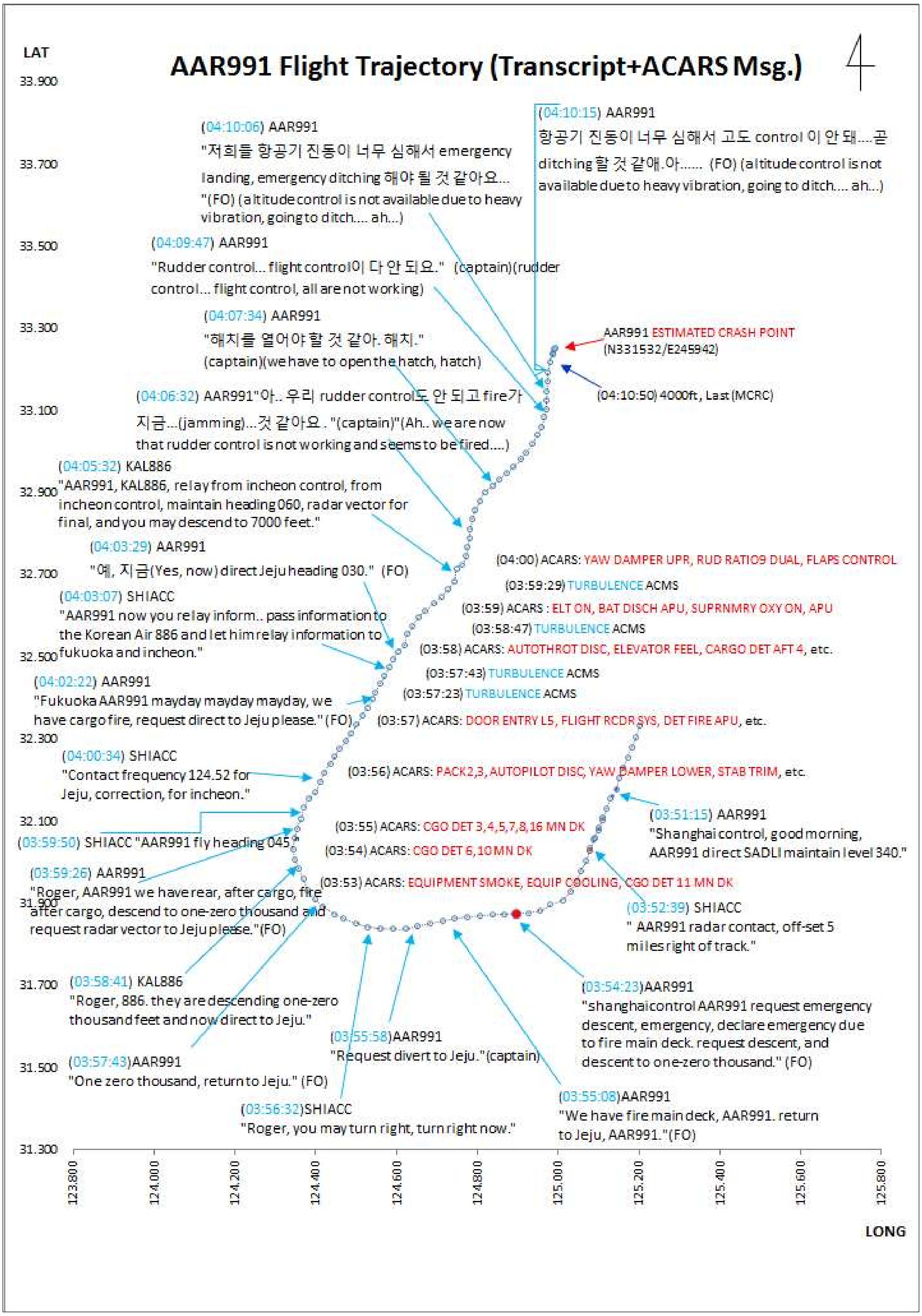
At 04:10:06, the FO stated, "We have heavy vibration on the airplane, may need to make an emergency landing, emergency ditching," and JEJ ACC responded, "Yes, say again, please." He stated, "Altitude control is not available due to heavy vibration, going to ditch… ah."

At 04:10:26, JEJ ACC asked AAR991, "Can you make approach to Jeju?" and subsequently, tried to contact AAR991 three times, however, followed by no response from AAR991.

[Figure 1] shows AAR991's whole flight track from the takeoff point to the crash point. [Figure 2] and [Figure 3] are AAR991's horizontal and vertical flight track, respectively, from pre/post-emergency declaration to the crash, reconstructed on the basis of ICN ACC radar data, with major ATC radio communications and ACARS messages incorporated. The upper and bottom figures in [Figure 3] depict the vertical flight track based on distance from the crash point, and time elapsed after 04:00:10, respectively.

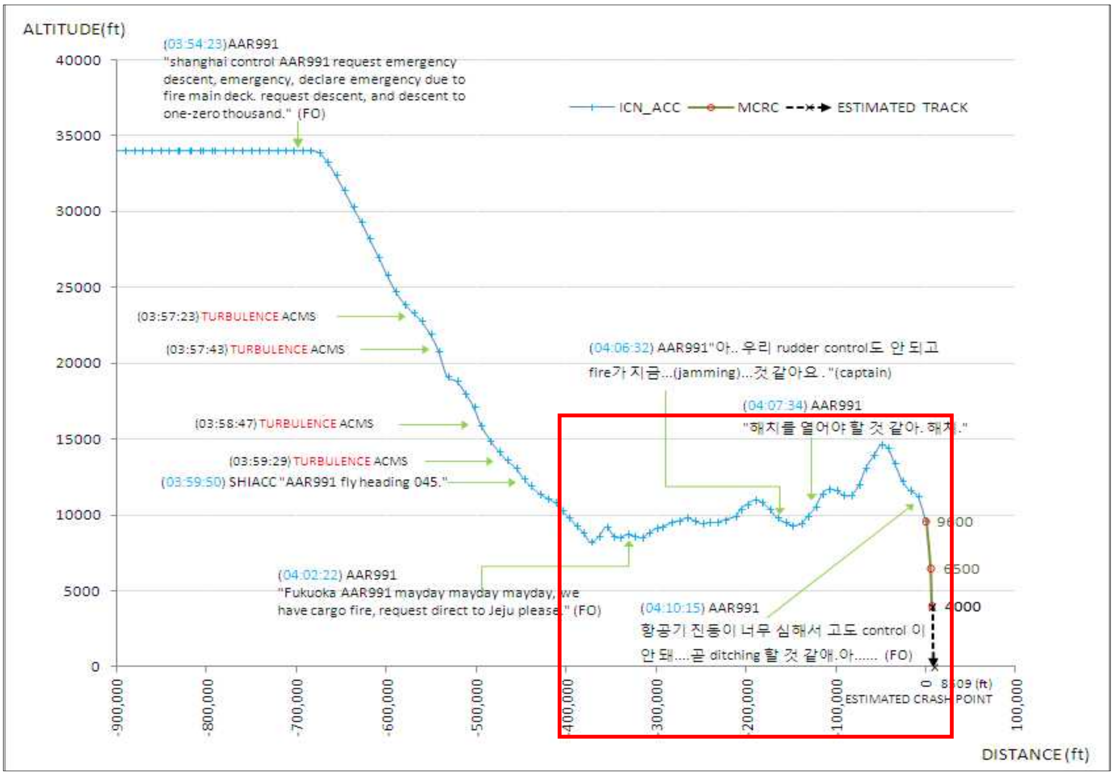


[Figure 1] AAR991's Whole Flight Track

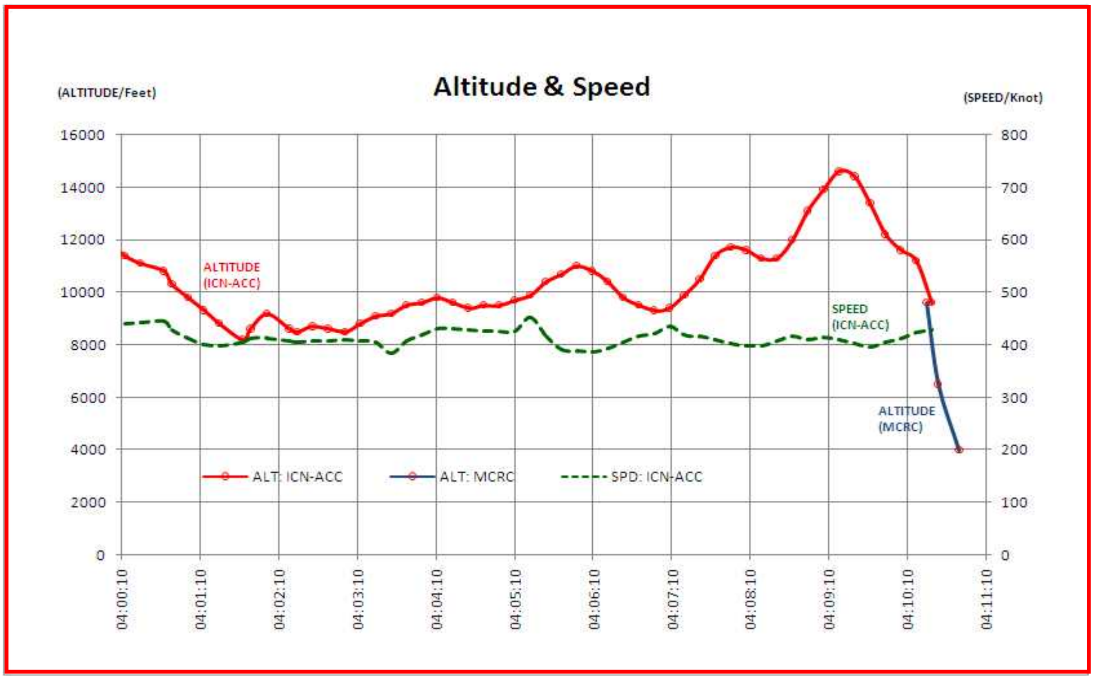


[Figure 2] Horizontal Flight Track before/after Emergency Declaration Including Major ATC Radio Communications & ACARS Messages

Vertical Flight Track Based on Distance from the Crash Point



Vertical Flight Track Based on Time Elapsed after 04:00:10



[Figure 3] Vertical Flight Track Including Major ATC Radio Communications & ACARS Messages

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other
Fatal	2	0	-
Serious	0	0	-
Minor/None	0	0	-

1.3 Damage to Aircraft

The aircraft was destroyed by in-flight fire damage and impact forces caused by the crash into the sea.

1.4 Other Damage

Cargo shipments aboard the aircraft were damaged, incapable of being recovered, or washed away due to fire, impact forces by the crash, and submergence in seawater.

1.5 Personnel Information

1.5.1 The Captain

The captain (male, age 52) was hired by Asiana Airlines on 2 July 1991. After working as B737 and B747-400 first officer, he was promoted to B737 captain on 24 December 1996, and to B747-400 captain on 3 July 2001.

The captain held a valid air transport pilot license, B737 type rating, B747-400 type rating, an aeronautical radio operator license, level 4 ICAO English Proficiency Certificate[9], and a first-class airman medical certificate[10],

9) Term of Validity: 05 Mar. 2008 - 22 Dec. 2011.
10) Term of Validity: 09 Dec. 2010 - 31 Dec. 2011.

issued on 9 December 2010, with the limitation that he must wear corrective glasses during flight; possess a reserve pair of corrective glasses.

The company's personnel record shows that the captain had accumulated 14,123 total flight hours including 2,501 hours as the ROK Air Force pilot. Since hired by Asiana Airlines, he had flown 4,726 hours in B737 airplanes including 3,340 hours as pilot-in-command, and 6,896 hours in B747-400 airplanes including 5,666 hours as pilot-in-command. He had flown 946, 269, 86, and 27 hours in the 1 year, 3 months, 1 month, and 1 week, respectively, before the accident flight.

The captain's training record shows that, as part of regular ground training, he received his half-yearly[11)] B747-400 type training on 25 February 2011 and common subject training on 19 April 2011. He also received his CRM training on 17 December 2010 and recurrent training in a flight simulator on 2 March 2011. He passed his proficiency check and line check on 3 March 2011 and 2 June 2011, respectively.

As for the captain's whereabouts in the 72 hours before flight, he operated AAR965 (Los Angeles-Beijing-Incheon) on 24 July 2011. His family stated that he, as usual, took a walk near his apartment and did house chores like cleaning his house on 25 (Mon) and 26 (Tue) July. On 27 July (Wed), he departed his home in Cheongju[12)] for his mother's house in Seoul[13)] and rested there to prepare for the AAR 991 flight.

His colleagues stated that the captain was active and very considerate of

11) In order to meet the flight crew recurrent training criteria required by Flight Safety Regulations, Asiana Airlines semiannually offers ground training, flight training, and a check in the first and second half of the year, in accordance with the flight crew training regulation.

12) Cheongju is located approximately 150 km from Incheon Airport, and it takes approximately 3 hrs 30 min by public transportation from Cheongju to Incheon Airport.

13) Seoul is located approximately 40 km from Incheon Airport, and it takes approximately 1 hr by public transportation from Seoul to Incheon Airport.

others' feelings. His medical record shows that he had no special medical history or hospitalization record, and that he had no health problem which could have affected his flight performance.

1.5.2 The First Officer

The first officer (male, age 43) was hired by Asiana Airlines on 2 April 2007. He was promoted to B767 first officer on 5 February 2008 and B747 first officer on 4 November 2010.

The first officer held a valid air transport pilot license, B767 type rating, B747-400 type rating, an aeronautical radio operator license, level 4 ICAO English Proficiency Certificate[14], and a first-class airman medical certificate[15] with the limitation that he must wear corrective glasses during flight; possess a reserve pair of corrective glasses.

The company's personnel record shows that the first officer had accumulated 5,211 total flight hours including 3,010 hours as the ROK Air Force pilot. Since hired by Asiana Airlines, he had flown 1,709 hours in B767 airplanes as second-in-command and 492 hours in B747-400 airplanes as second-in-command. He had flown 748, 232, 77, and 18 hours in the 1 year, 3 months, 1 month, and 1 week, respectively, before the accident flight.

The first officer's training record shows that, as part of regular ground training, he received his half-yearly B747-400 type training on 25 January 2011 and common subject training on 10 February 2011. He also received initial CRM training on 28 November 2007, regular CRM training on 10 February 2011, and recurrent training in a flight simulator on 25 February 2011. He passed his proficiency check on 26 February 2011.

14) Term of Validity: 05 Mar. 2008 - 23 May 2013.
15) Term of Validity: 12 Oct. 2010 - 31 Oct. 2011.

As for the first officer's whereabouts in the 72 hours before flight, he operated AAR588 (New York-Brussels-Incheon) on 24 July 2011. His family stated that he had his usual daily life like taking a walk near his house, except for receiving 8-hour recurrent type training at work on 26 July.

His family and colleagues stated that the first officer was a family man, sincere and active in doing everything, with a strong sense of responsibility, and that he did not drink any alcohol, smoke, or take any illegal medication and was in good health. His medical record shows that he had never had special medical history or hospitalization record since hired.

1.6 Aircraft Information

1.6.1 Aircraft History

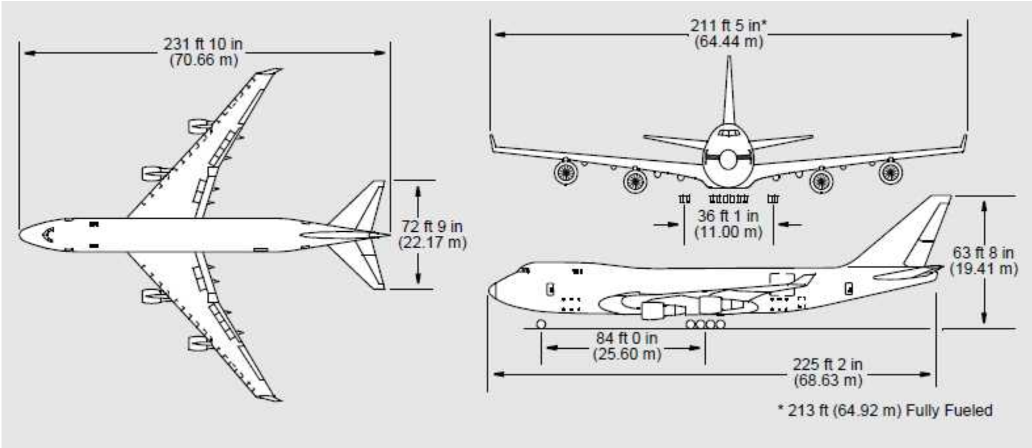
The aircraft, HL7604, whose serial number is 29907, was manufactured[16)] by the Boeing Company on 15 February 2006 as a B747-48EF freighter. On 22 February 2006, it was delivered to Asiana Airlines and registered under the Korean Airworthiness Authority. The aircraft held a valid airworthiness certificate issued on 24 February 2006.

The aircraft had accumulated 28,752 total flight hours and 4,799 total cycles at the time of the accident.

It was equipped with four CF6-80C2B1F engines manufactured by General Electric. Their thrust amounted to 57,900 lb × 4, and the APU model was PW901A.

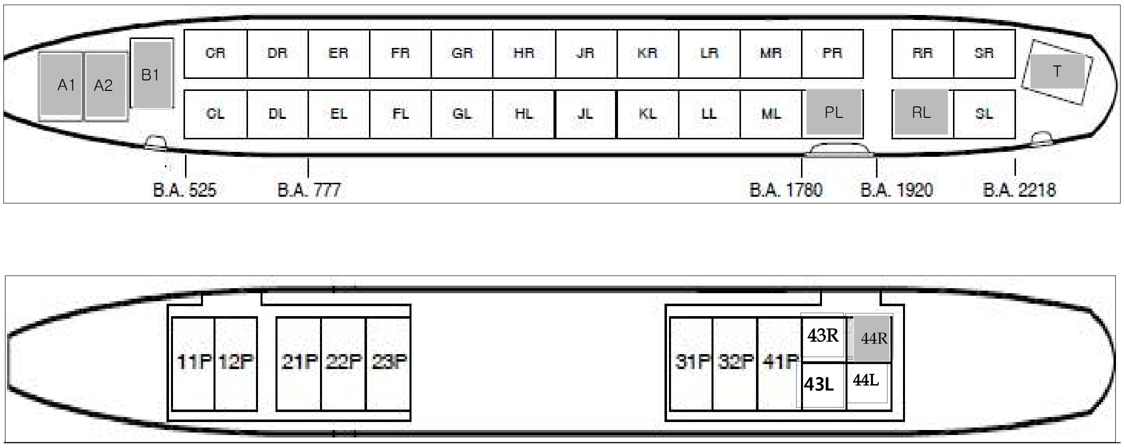
The dimensions of the aircraft are shown in [Figure 4].

16) Manufacturing Line Number: 1370; Manual Application Number: 103.



[Figure 4] Dimensions of the Aircraft

On the upper deck of the aircraft were 8 seats for passengers and supernumerary crew members. The cargo configuration of AAR991 is shown in [Figure 5].



[Figure 5] Main Deck (Top) & Lower (Bottom) Cargo Compartments

※ Gray Positions: No Cargo Shipment

1.6.2 Scheduled Maintenance and Fault History

Scheduled maintenance performed in the 5 months before the accident[17] is shown in [Table 1].

17) From 4 March to 25 July.

Category of Scheduled Maintenance	Cycle	Latest Performance Date
1A	750 hrs	26 Jan. 2011
2A	1,500 hrs	14 Mar. 2011
3A	2,250 hrs	01 May 2011
4A	3,000 hrs	08 Jun. 2011
4C	36,000 hrs	14 Jan. 2011

[Table 1] Scheduled Maintenance in the 5 Months before the Accident

Review of the maintenance history of the 5 months before the accident confirmed that there were 208 faults and corrective actions on the aircraft journey log. Out of these faults, those with the air conditioning and pressurization (ATA[18] 21), electrical system (ATA 24), equipment and furnishings (ATA 25), and fire detection system (ATA 26), which were determined to be of interest, and their corrective actions were examined.

There were 11 faults with the air conditioning and pressurization system. As faults repeatedly occurred with outflow valves, both left and right valves were replaced. In particular, on 18 April 2011, as the "EQUIP COOLING" warning message was displayed on AAR774 (Frankfurt/Incheon), the aircraft diverted to and landed at Koltsovo Airport in Russia. This fault turned out to be with the equipment cooling printed circuit assembly, which was then replaced.

Ten faults occurred with the electrical system, but five of them were concerned with the generator while the other five with the replacement of bulbs in the switches.

There were 22 faults with the equipment and furnishings, which were mainly

18) ATA stands for the Air Transportation Association, which categorizes the aircraft system by number, and this categorization is universally used by the aviation industry.

related to a pallet power drive unit (PDU) and a locking device.

Three faults occurred with the fire detection system. On 26 April 2011, as the "AFT CGO 4 LOOP" message was displayed, the fire detection system was tested on the ground after landing, but no fault was found. Aisana Airlines determined that "AFT CGO 4 LOOP" message was a false fire warning due to moisture. Smoke detectors sometimes false alarm due to moisture and thus, the Boeing Company issued a service letter[19)] about actions to correct such a fault. The remaining two faults with the fire detection system were concerned with engine fire detector loops.

1.6.3 Aircraft System

1.6.3.1 Air Conditioning and Pressurization System

The air conditioning and pressurization system converts hot pneumatic air at high pressure, which comes from the engines, to temperature controlled conditioned air at low pressure and distributes the converted air to the various airplane compartments including flight deck.

Air flown into the compartments is discharged overboard through the modulation of the pressurization outflow valves aft of the airplane, and accordingly, cabin pressure is regulated.

The airplane is equipped with three air conditioning packs. In each pack, pneumatic bleed air is metered through a flow control and shutoff valve and is initially cooled in a heat exchanger.

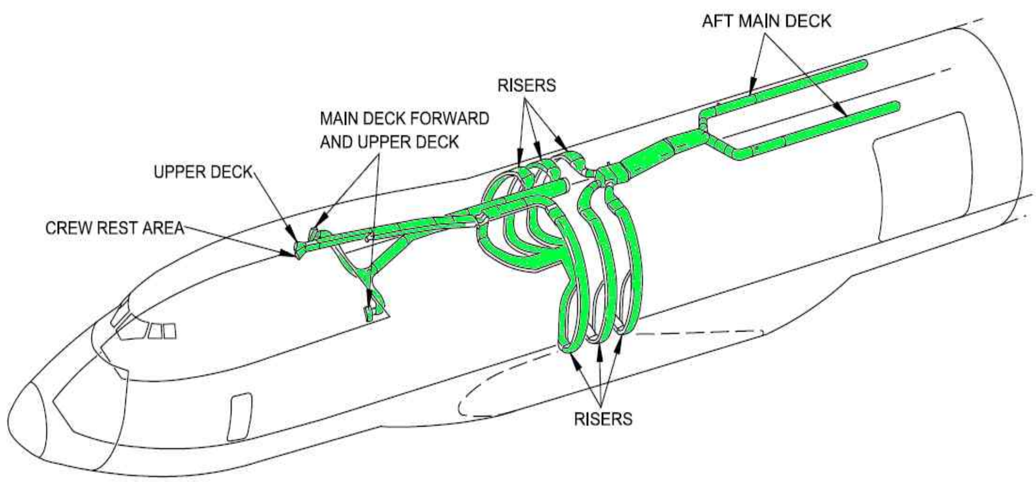
During flight, ram air is the cooling medium, and during operation on the

19) Doc No.: 747-SL-26-020; Issue Date: 17 Mar. 2004; Title: *Cargo Compartment False Fire Warnings Due To Moisture.*

ground, a fan on the air cycle machine (ACM) cools the air.

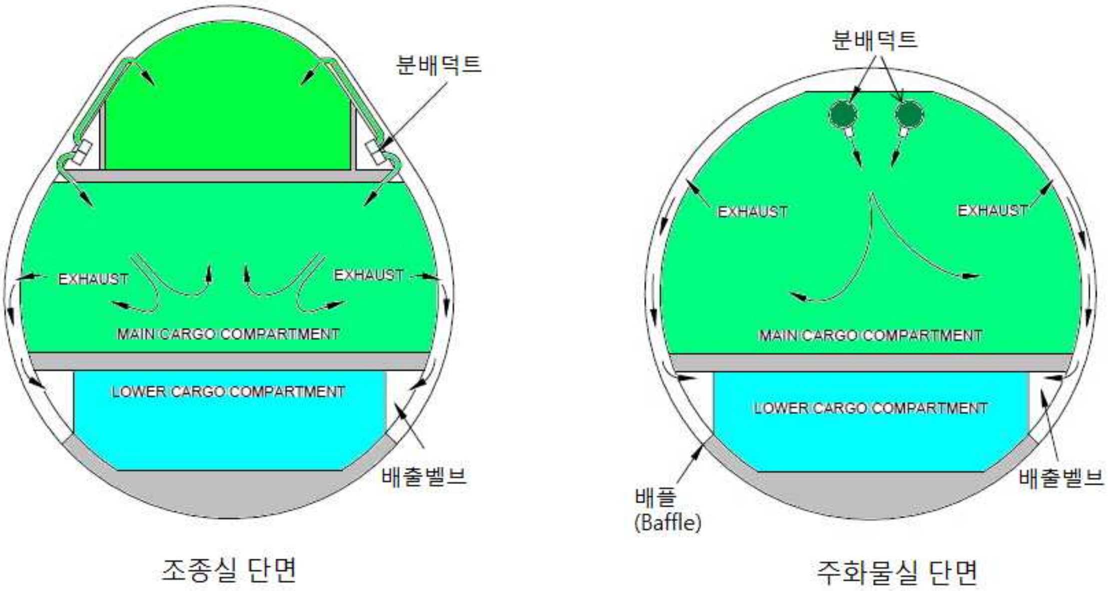
As shown in [Figure 6], cool air leaving each of the air conditioning packs flows into a single conditioned plenum chamber, and as necessary, flows to the flight deck, crew rest area, upper deck and cargo compartments through the main distribution manifold.

The temperature controller mixes cool air from the packs with hot air from the engines to generate air at the temperature required by the cabin and then distributes it to each compartment of the airplane.



[Figure 6] Distribution Ducts in the Aircraft

As shown in [Figure 7], air leaving each of the air conditioning packs flows into a plenum chamber and is distributed to the upper deck and main deck cargo compartment through the distribution ducts, and to the lower cargo compartment through diffusers in the ceiling. The air then flows either forward to an overboard valve or aft to outflow valves and is discharged overboard for appropriate airplane pressurization.



[Figure 7] Air Flow in the Aircraft

The forward equipment racks are cooled by either air conditioning pack air, or by a fan in the forward cargo compartment left sidewall which draws air from the forward cargo compartment for cooling. A second fan in the forward cargo compartment right sidewall exhausts hot air into the forward cargo compartment.

The aft equipment racks are cooled by two lavatory and galley vent fans which draw hot air and exhaust it into the bulk cargo compartment and out through the pressurization outflow valves.

When there is a fire in the forward equipment racks during flight or a pilot puts an equipment cooling control switch in the "OVRD" position, two fans for cooling forward equipment racks stop their operation and the "smoke override valve" is open, thereby exhausting air in the racks overboard.

When the "MAIN DECK ARM" switch is pressed, two of the three air conditioning packs shutdown and airflow to the cargo compartments (main deck and both lower lobes) is shutoff. One pack continues to operate to provide fresh air to the flight deck and supernumerary area to prevent smoke from entering occupied areas.

When the " CARGO FIRE DEPRESS/DISCH" switch is pressed, two outflow valves open. Through these open valves, air is exhausted to reduce cabin pressure.

1.6.3.2 Fire Warning and Detection System

The fire, smoke, or overheat detection systems give the flight crew visual and/or aural indications of abnormal conditions in the engines, APU, cargo compartments, landing gear, wings, lavatories, crew rest, and E/E compartment. In the cockpit are two speakers sounding fire warnings, two master warning light indicators and an EICAS[20] screen displaying related messages.

The pilot's overhead panel contains a FIRE/OVHT test button. This button is used to test the fire, overheat, and smoke detection systems for engines, APU, wing leading edge, main deck cargo compartment, and lower cargo compartment.

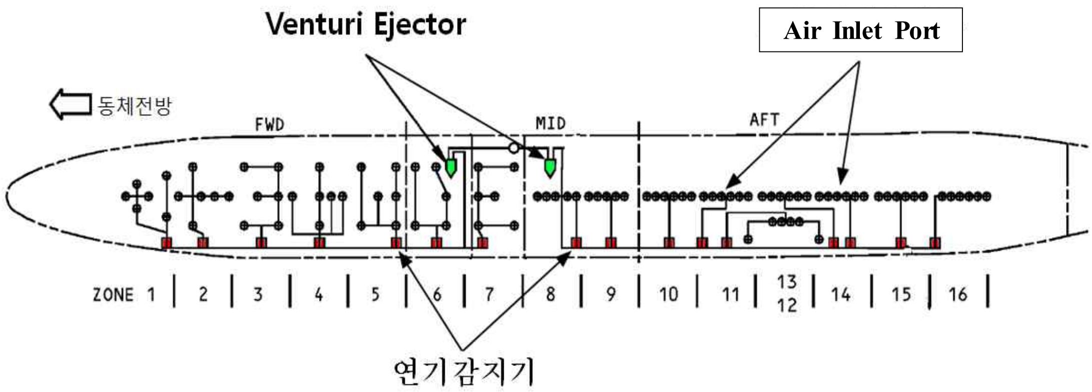
There is a separate fire loop for each engine nacelle and cowling - two for each engine - to detect any engine fire and overheat condition.

A smoke detector unit is installed in each lavatory to monitor for the presence of smoke.

The main deck cargo compartment on a frighter are divided into a total of 16 fire zones, each of which has two smoke detectors for a total of 32 as shown in [Figure 8]. The forward and aft lower cargo compartments are equipped with

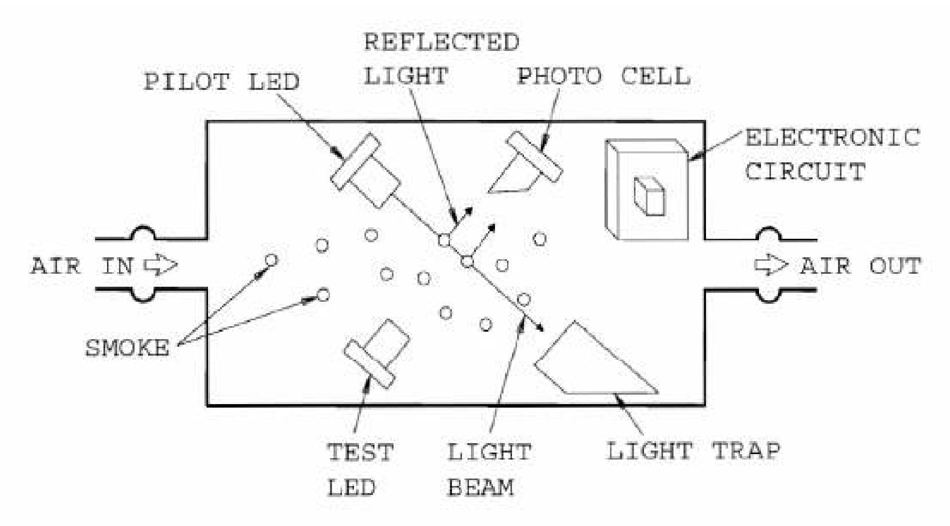
20) Engine indication and crew alerting system (EICAS) is an integrated system providing flight crew with aircraft engines and other systems instrumentation and warnings.

a total of 16 detectors.



[Figure 8] Smoke Detectors in the Main Deck Cargo Compartment

Cargo smoke detection results in the master warning/caution light illuminating, fire bell, and an advisory EICAS message. [Figure 9] shows the smoke detector's basic operating principles.



[Figure 9] Smoke Detector

A smoke detector installed between the supply air duct and exhaust air duct detects smoke in the equipment cooling system, thereby creating an EICAS message for the flight crew.

1.6.4 Weight and Balance

According to Asiana Airlines' loading management procedures, a loadmaster in the cargo department prepares an airplane's weight and balance data by using a computer program and provides such data to flight crew members before departure.

The weight and balance data of AAR991 is as follows:

TOW	273,471 kg	MTOW	394,625 kg
ZFW	224,891 kg	MZFW	276,691 kg
LDW	258,412 kg	MLDW	302,092 kg
Takeoff Fuel		48,534 kg	
Trip Fuel		15,059 kg	
Cargo Weight		65,937 kg	

The permissible range of the center of gravity (CG) in accordance with a flight manual, the operating range of CG in accordance with company rules, and the CG in accordance with a flight plan are shown in [Table 2].

(Unit: % MAC)

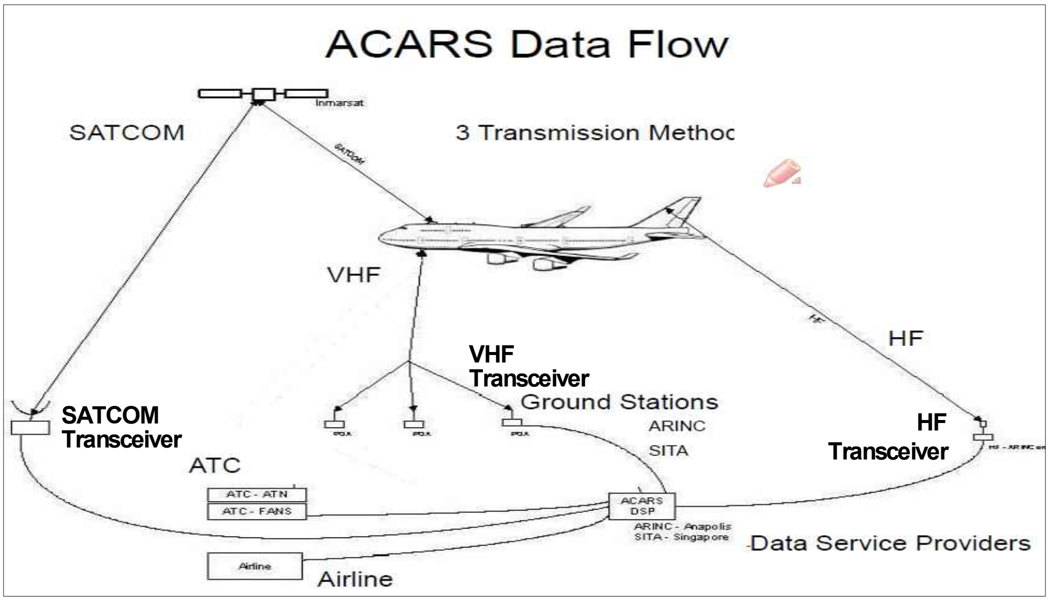
Category	ZFW		TOW	
	Fore	Aft	Fore	Aft
Flight Manual's Permissible Range of CG	16	33	11	33
Company's Operating Range of CG	16.1	32.2	16.1	32.2
Flight Plan's CG	27.31		25.98	

[Table 2] CG Data

1.6.5 ACARS

1.6.5.1 General ACARS Information

The Aircraft Communications Addressing and Reporting System (ACARS) is a digital data-link system that provides data communication between an airplane and ground stations by using radio or satellite communications (HF, VHF, SATCOM) as shown in [Figure 10].



[Figure 10] ACARS Data Flow

ACARS replaces voice communication of the airlines' operation control with data communication. It can reduce flight crew's workload since specific data can be automatically transmitted if certain conditions are met. Also, it can manually transmit message data at the request of the crew.

Automatically transmitted data is:

- Out, Off, On, In Times: Data is generated due to value changes of the various sensors installed on the aircraft and transmitted shortly after its generation.

- Aircraft Fault Messages: Fault messages from the central maintenance computer (CMC), which are related to EICAS messages, and are sent every minute, but their time stamp has a resolution down to the minute.
- Turbulence and Takeoff Reports: Information from the aircraft condition monitoring system (ACMS)
- Aircraft Position: Information from the flight management computer (FMC)

Manually transmitted data is:

- Estimated time of arrival (ETA) update
- Flight crew identity and payroll
- Flight data such as flight number, departure and arrival airports, and fuel on board
- General text messages

The ACARS Present Leg Fault (PLF) reports are different from the FDR data, and they have the following characteristics:

- An ACARS CMC report may contain maintenance messages and associated EICAS messages. The maintenance messages are time stamped in hours and minutes with the time that the maintenance message was generated by the CMC, but an ACARS CMC report will not include a time stamp for the associated EICAS message. For an EICAS message to be reported, the EICAS message must be correlated to a maintenance message within a specific time window.

- ACARS messages, unlike the FDR data stored at a regular interval, are discontinuous snapshot data generated only when certain conditions are met through the system logic. That is, out of fault data generated from an airplane, only the data subject to certain conditions is converted into messages.

1.6.5.2. ACARS Messages

ACARS messages received from AAR991 include the following three information: aircraft position data; turbulence data; and EICAS fault messages.

Aircraft position data is generated according to a change in waypoint[21] as shown in [Table 3], allowing the aircraft position to be traced.

Order	Time	Latitude	Longitude
1	03:07:58	N37.213	E126.369
2	03:14:26	N36.439	E126.369
3	03:17:27	N36.237	E126.345
4	03:21:27	N35.556	E126.312
5	03:24:20	N35.330	E126.285
6	03:26:38	N35.153	E126.264
7	03:53:49	N31.533	E124.588
8	03:56:58	N31.514	E124.229

[Table 3] Aircraft Positions

Turbulence data is generated when the aircraft vertical acceleration G is more than 1.3 G or less than 0.7 G at more than 50 ft radio altitude from takeoff to landing. Every data is transmitted about 20 seconds after its generation.

As shown in [Table 4], turbulence data was transmitted five times in total. The data was transmitted once at 03:05:09 during takeoff when the aircraft climbed to 120 ft for 20 seconds and then, four times during cruising.

After the pilots reported a fire to SHI ACC at 03:54:23, the aircraft descended by 9,433 ft for 2 minutes and 6 seconds between 03:57:03, second data transmission time, and 03:59:09, fifth final data transmission time. The average descent rate per minute was 4,492 fpm[22].

21) When passing a waypoint during flight, a message is transmitted.

Flight Leg	Data Transmission Time	Time	Altitude (ft)	Speed (kt)	G	Heading (deg)	Pitch (deg)	Roll (deg)
Takeoff	03:05:09	03:04:49	211	97	1.03	152	0	0
		03:05:09	331	172	1.32	152	14	-1
Cruising	03:57:23	03:57:03	23,478	337	1.04	300	0	10
		03:57:23	22,333	336	1.35	312	-2	18
Cruising	03:57:43	03:57:23	22,333	336	1.35	312	-2	18
		03:57:43	20,697	345	1.32	328	-5	34
Cruising	03:58:47	03:58:25	17,690	348	0.91	345	-4	15
		03:58:47	15,490	363	1.33	011	-5	32
Cruising	03:59:29	03:59:09	14,045	358	1.13	022	0	5
		03:59:29	13,294	351	0.66	026	-3	5

[Table 4] Turbulences

EICAS (FDE[23], flight deck effect) messages received by the ground station via ACARS and their levels are summarized in [Table 5], and more details are contained in Appendix 1.

Also, ACARS messages received by Asiana Airlines for about an hour before the crash (03:04:49 - 04:10:50) are found in Appendix 2, along with time-based aircraft status and events.

About 03:59, the EICAS message that the Emergency Locator Transmitter (ELT) was on was displayed but the signal was not received by the Mission Control Center (MCC). More details of the ELT are specified in Section 1.15.2 of this report.

22) (23,478 - 13,294) ÷ 146 (sec) × 60 (sec).
23) FDE messages displayed on an EICAS in the cockpit require the flight crew's action or reference.

Time	FDE Messages	Level -Note-
03:53	EQUIPMENT SMOKE	S
	EQUIP COOLING	C
	CGO DET 11 MN DK	S
03:54 [24]	CGO DET 6, 10 MN DK	S
03:55	CGO DET 7, 16, 5, 4, 3, 8 MN DK	S
03:56	PACK 2, 3	A
	SATCOM SYSTEM	S
	A/P SINGLE SYS	S
	YAW DAMPER LWR	A
	STAB TRIM, STAB TRIM 2	A
	AUTOPILOT DISC	W
03:57 [25]	DET APU FIRE	A
	FMC LEFT	A
	DOOR ENTRY L5	A
	FLIGHT RCDR SYS	S
03:58	AUTOTHROT DISC	C
	ELEVATOR FEEL	S
	BTL LOW CARGO A	S
	CGO DET AFT 4	S
03:59	BAT DISCH APU	A
	SUPRNMRY OXY ON	A
	APU	A
	ELT ON	A
04:00	YAW DAMPER UPR	S
	RUD RATIO DUAL	A
	FLAPS CONTROL	C

-Note- Message Levels

W Warning: indicates an operational/airplane system condition which requires immediate corrective action.

C Caution: indicates an operational/airplane system condition which requires immediate crew awareness and some prompt compensatory action.

A Advisory: indicates an operational or airplane system condition that requires crew awareness for possible future compensatory action.

S Status: is necessary when determining the dispatchability of the aircraft, and some messages are included in the Minimum Equipment List (MEL).

[Table 5] Select EICAS (FDE) Messages

24) At 18:54:23, pilots declared an emergency and at 18:55:08, notified a main deck cargo fire to the ATC.

25) About 4 times of turbulences were reported from 18:57:03 to 18:59:29.

1.7 Meteorological Information

1.7.1 Precipitation and Temperature of Incheon Airport

Data on precipitation[26] and temperature of Incheon Airport in the 27 hours before AAR991's departure is shown in [Table 6].

Unit: mm, ℃

Date \ Time		00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
27	P	5.0	1.0	-	-	0.5	3.0	22.5	0.0	8.5	22.0	56.5	9.0	-	-	-	-	-	13.5	22.0	0.0	0.0	2.5	2.0	0.0
	T	25	25	24	24	24	24	24	24	24	24	24	24	25	25	26	27	25	25	26	25	24	23	23	24
28	P	0.5	0.0	0.0	0.0	Takeoff from Incheon Airport about 03:05																			
	T	25	26	26	26																				

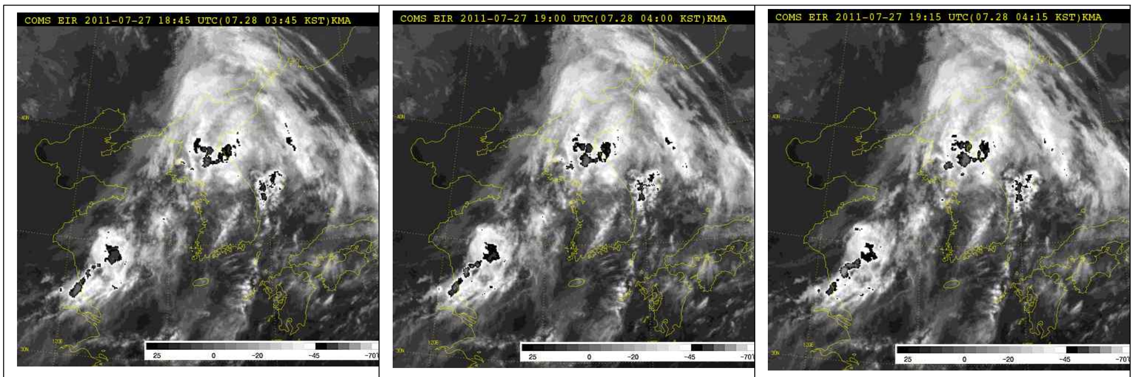
—Note— - : No precipitation; 0.0: There is precipitation, but less than measurable unit.

[Table 6] Precipitation & Temperature of Incheon Airport in the 27 Hours

1.7.2 Area Weather Condition

Weather observations made by a meteorological satellite from 03:45 until 04:15 on 28 July are shown in [Figure 11]. The exact altitude of cloud is difficult to identify, but the weather conditions over Jeju Island and the accident site indicated that a southwest current of air and a westerly current of air flowed in at the middle and upper levels, respectively. Also, there were no convective cloud[27] or other unusual weather phenomena.

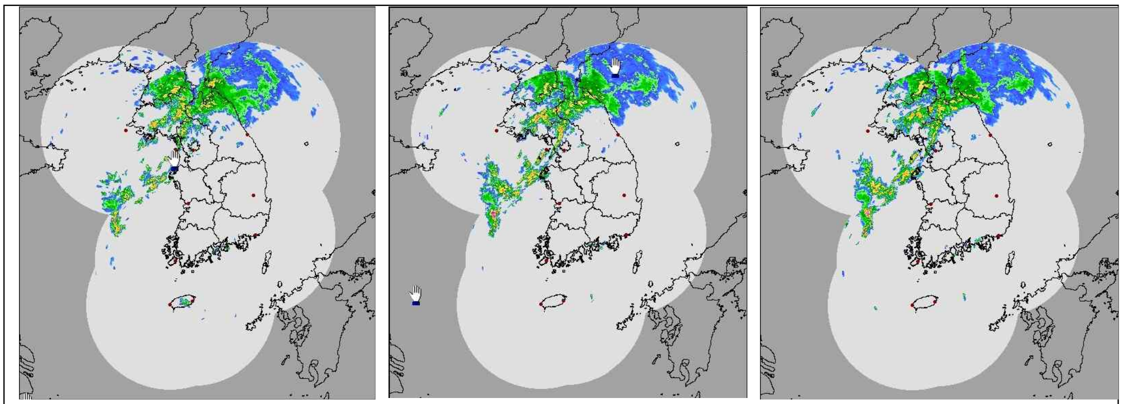
26) Data from the Korea Aviation Meteorological Agency in Incheon Airport, and the unit of precipitation is mm.
27) A cloud with heavy rain, turbulence, and hail.



28 July at 03:45 | 28 July at 04:00 | 28 July at 04:15

[Figure 11] Weather Observations Made by a Meteorological Satellite

Weather observations made by a weather radar[28] from 03:30 until 04:10 on 28 July are shown in [Figure 12], and there was no cloud with rain over Jeju Island and the accident site.



28 July at 03:30 | 28 July at 04:00 | 28 July at 04:10

[Figure 12] Weather Observations Made by a Weather Radar

At the time of the accident, two airplanes operated by China Eastern Airline and Asiana Airlines were flying at 33,000 ft on airway A593 and at 37,000 ft on airway B576, respectively. The pilots of the two airplanes stated that over the accident site, there was no turbulence or cloud with rain, and that there were a weak wind and a clear sky.

28) 10 nationwide radars with a surveillance radius of 250 km.

1.7.3 Weather Conditions of Departure and En-route Alternate Airports

A METAR weather report filed when AAR991 took off from Incheon Airport about 03:05 was as follows:

"METAR RKSI 271800Z 20020KT 9999 FEW010 BKN018 OVC080 26/22 Q1007 TEMPO -RA=" (Surface wind 20 kt at 200, Visibility 10 km, Overcast at a middle level, Temperature 26℃, Pressure 1007 mb)

A METAR weather report of Jeju Airport designated as an emergency landing airport by AAR991 after a cargo fire, filed at 04:00 on the day of the accident, was as follows:

"METAR RKPC 271900Z 21009KT 150V300 9999 SCT030 BKN180 29/21 Q1010 NOSIG=" (South-southwest surface wind at 9 kt, Variable from southeast to northwest, Visibility 10 km, Broken at an upper level, Temperature 29℃, Pressure 1010 mb)

Upper wind[29) over Jeju Island (observatory location: N33.28° E126.16°) is shown in [Table 7].

Observation Time	4,000 ft (agl)	6,000 ft (agl)	10,000 ft (agl)
27 July 21:00	195° at 30 kt	195° at 28 kt	210° at 25 kt
28 July 09:00	205° at 28 kt	206° at 26 kt	210° at 22 kt

[Table 7] Upper Wind Data

1.8 Aids to Navigation

The radar system of ICN ACC was in normal operation throughout the

29) Upper wind is observed every 12 hours and was used to calculate the crash position from the last flight track of AAR991 (altitude).

AAR991 flight, and the flight track of AAR991 recorded in the system is contained in Appendix 3.

1.9 Communications

1.9.1 Voice Communications Between the Aircraft and ATCs

Voice communications exchanged between AAR991 and ATCs from takeoff at Incheon Airport to impact were transcribed, and the transcript can be found in Appendix 4.

1.9.2 Direct Line Communications Between ATCs

When AAR991 declared an emergency and diverted to Jeju Airport, three ATCs exchanged its flight data[30)] via direct telephone line in order for SHI ACC to transfer the control to ICN ACC through HUK ACC, and the following is the main content of their communications:

- At 04:00:01, HUK ACC requested SHI ACC to "transfer the control to ICN ACC at 124.525 MHz."

- At 04:01:35, SHI ACC notified HUK ACC that "altitude was too low[31)] to contact at 124.525 MHz."

- At 04:01:48, HUK ACC requested SHI ACC to "transfer the control to HUK ACC at 133.6 MHz."

- At 04:03:14, HUK ACC requested ICN ACC to "give an alternative

30) Flight Data: flight number, transponder code, aircraft position and altitude, ATC frequency, emergency situation, etc.
31) About 8,500 ft according to ICN ACC radar data.

frequency because communications were not available at 124.525 MHz."

• At 04:03:17, SHI ACC notified HUK ACC that "altitude was too low to contact at 133.6 MHz, either."

• At 04:03:18, ICN ACC notified HUK ACC that "SHI ACC was requested to use an alternative frequency, 128.37 MHz, to transfer the control."

• At 04:03:42, HUK ACC requested SHI ACC to "transfer the control to ICN ACC at 128.37 MHz."

* SHI ACC did not instruct AAR991 to change its frequency as above, via direct telephone line.

1.9.3 Air Traffic Control Communications Facilities

According to the ATC/pilot communications transcript, when AAR991 declared an emergency due to a cargo fire and diverted to Jeju Airport at 04:00:23, SHI ACC instructed AAR991 to contact ICN ACC at 124.525 MHz in order to transfer the control, but at 04:01:15, AAR991 notified SHI ACC that it was unable to contact ICN ACC. At this time, AAR991's altitude in the ICN ACC radar data was 9,000 ft.

Transceiver antennas operating at 124.525 and 128.375 MHz, two of the frequencies used by ICN ACC to control the aircraft on south and southwest routes of Jeju Island, are located in Seongpanac and Moseulpo on Jeju Island as shown in [Figure 13]. The 124.525 MHz frequency antennas standing 10 m tall are erected on the floor 850 m above sea level, thereby rising 860 m above sea level.

The top of Mt. Halla, 1,950 m above sea level, is located west of the 124.525 MHz transceiver antennas, whereas there are no geographical obstacles west of the 128.375 MHz transceiver antennas.

[Figure 13] 124.525 & 128.375 MHz Transceiver Antennas

1.10 Aerodrome Information

Jeju Airport designated as an en-route alternate airport by AAR991 is operable 24/7 and equipped with airport facilities[32] that allow B747-400 airplanes to take off, land, and park.

At 04:00:04, ICN ACC notified JEJ APP in Jeju Airport via direct telephone line that AAR991 would land in Jeju Airport due to an emergency. Accordingly, Jeju Airport Operator prepared for AAR991's emergency landing.

1.11 Flight Recorders

Two flight recorders, flight data recorder (FDR) and cockpit voice recorder

32) Airport facilities consist of basic and support facilities.

(CVR), installed on the accident airplane were not retrieved.

1.11.1 Flight Data Recorder

The FDR installed on the accident airplane was a SSFDR (P/N 980-4700-042, S/N SSFDR-09943) manufactured by Honeywell.

The FDR on the basis of ED-55[33)] measures 536 mm by 125 mm by 156 mm and weighs 6.8 kg. It consists of a chassis, the CSMU[34)], and the Underwater Locator Beacon (ULB).

The ARAIB recovered the chassis with a severe fire damage but failed to locate the CSMU.

1.11.2 Cockpit Voice Recorder

The CVR installed on the accident airplane was a SSCVR (P/N 980-6022-001, S/N CVR120-07910) manufactured by Honeywell. This CVR on the basis of ED-56a[35)] measures 365 mm by 123 mm by 162 mm and weighs 5.9 kg. It consists of a chassis, the CSMU[36)] and the ULB, and was not recovered.

1.11.3 Underwater Locator Beacon

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33) ED-55 is a technical standard set by EUROCAE in May 1990. It specifies the Minimum Operational Performance Specification and its testing procedures.
34) The CSMU is a module to safely protect flight data against external shock or fire. According to the Minimum Operational Performance Specification of ED-55, the module is designed to protect the inner data against impact shock of 3,400 G or 1,100 degrees of fire for at least 30 minutes.
35) ED-56a is the Minimum Operational Performance Specification developed by EUROCAE in December 1993.
36) The CSMU is a module to safely protect flight data against external shock or fire. According to the Minimum Operational Performance Specification of ED-55, the module is designed to protect the inner data against impact shock of 3,400 G or 1,100 degrees of fire for at least 30 minutes.

An Underwater Locator Beacon (ULB) emits an ultrasonic pulse of 37.5 KHz at an interval of 0.9 times per second in all quadrants for at least one month when triggered by water immersion, and is fitted to FDR and CVR, respectively. The ULB (model: DK-120) manufactured by Dukane Seacom, Inc. was fitted to the accident airplane. Lithium batteries that have a shelf life of six years were fitted to FDR and CVR on 11 December 2009 and 22 February 2006, respectively, and have never been replaced since then. Batteries are operable at a temperature range between -2.2℃ and 37.8℃.

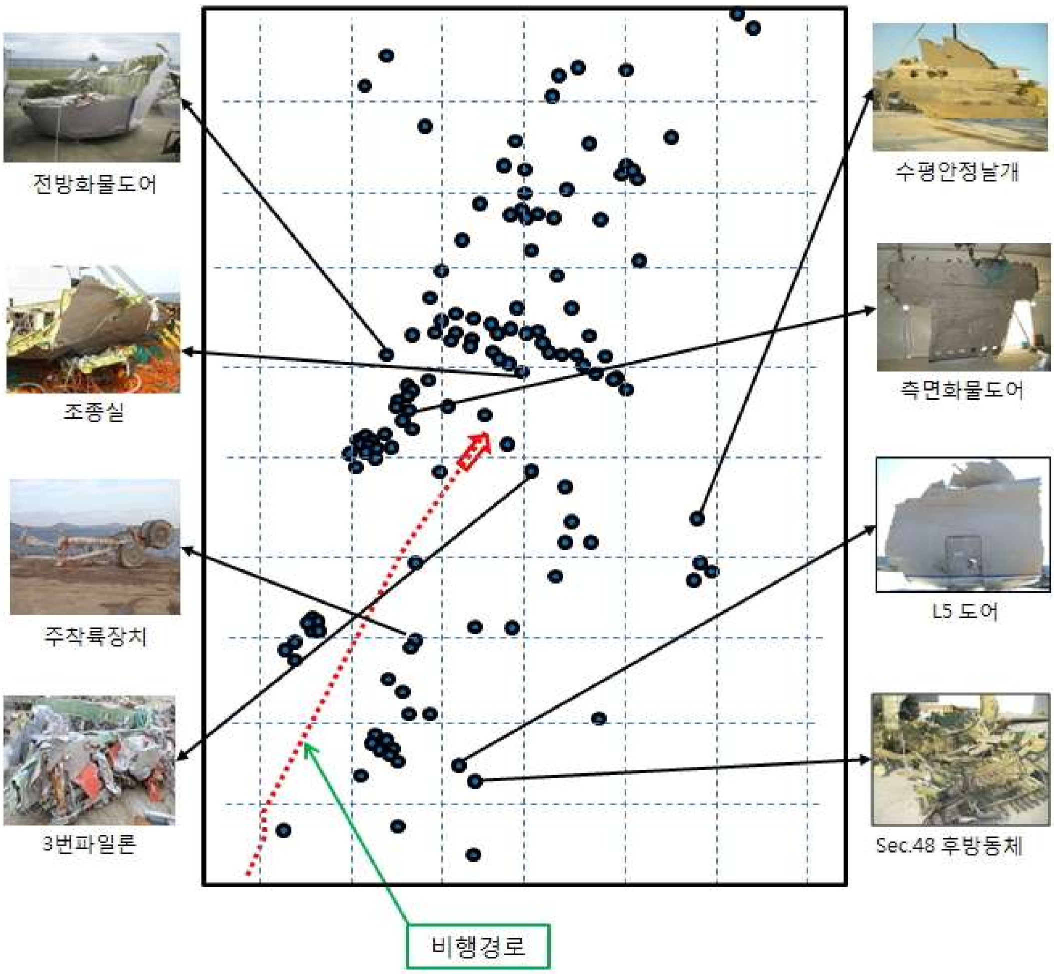
1.11.4 Search Operations for Flight Recorders

Immediately after being notified of AAR991's accident, the ARAIB conducted search operations in four phases to locate the crash site and retrieve flight recorders. The details of the search operations are contained in Appendix 5.

Despite the operations, no ULB signals enabling the estimating of the flight recorders' position were detected. Accordingly, the ARAIB focused search efforts mainly on the flight recorders but failed to recover them.

1.12 Wreckage and Impact Information

As shown in [Figure 14], the wreckage of AAR991 was distributed in the underwater area 3 km by 4 km, 130 km west of Jeju Airport, in southwest-northeast direction. The black dots in [Figure 14] indicate recovery points of the main pieces of the wreckage.



[Figure 14] Wreckage Distribution Map

1.12.1 Accident Site

The depth of the sea where the wreckage is distributed is estimated at 85 m on the west, 87 m in the middle, and 81 m on the east. The average speed of current measured at a sea buoy and the sea floor was about 5 kt and 1 - 2 kt, respectively. The currents at the accident site flowed in a northwesterly direction at high tide and in a southeasterly direction at low tide. The sea floor consisted of mud and sand about 60 cm thick and was generally flat. The average visibility at the sea floor was about 0.5 m. During July and August in 2011, the accident site was hit by seven typhoons[37].

37) Typhoons that influenced the accident site from 12 Jul. 2011 until 5 Sep. 2011: Ma-on (2011-6);

1.12.2 Wreckage Recovery

From 06:00 on 28 July after AAR991 had disappeared from the radar, resources[38] from the Coast Guard, the Navy, and the Air Force were dispatched to the accident site and commenced search operations. From 12:00 on 28 July, the Coast Guard started to recover some floating debris and cargo of AAR991 at the accident site.

On 30 July, the ARAIB took over the floating debris[39] recovered and temporarily stored it at a safe area in Jeju Airport. Additional ships and airplanes[40] for rescuing the pilots and searching for the wreckage were dispatched.

From 1 August, the naval ship was dispatched and searched for the ULB signal.

On 2 August, using a side scan sonar, two search boats of the Japanese salvage company searched for the underwater wreckage and confirmed that the aircraft wreckage was widely distributed on the seabed.

On 17 August, a salvage tug of the Japanese salvage company equipped with recovery equipment[41] located the empennage on which the FDR and CVR were presumed to be installed.

On 20 August, the Japanese salvage company tried to recover the wreckage identified as the empennage but to no avail due to a lack of experience of

Tokage (2011-7); Nock-ten (2011-8); Muifa (2011-9); Merbok (2011-10); Nanmadol (2011-11); and Talas (2011-12).

38) Coast Guard: 5 ships (one 3,000 t, three 1,500 t, one 300 t) and 4 helicopters; Navy: 1 ship and 1 helicopter; and Air Force: 2 helicopters.

39) 869 pieces of debris from the aircraft and cargo in about 60 varieties.

40) 8 ships (Coast Guard: 8, Navy: 2, Korea Hydrographic and Oceanographic Administration: 1) and 3 airplanes (Coast Guard: 2, Navy: 1).

41) A remotely controlled underwater vehicle (working ROV) and a chain sling.

underwater aircraft recovery, deteriorating weather conditions, and difficulty in tying up the underwater wreckage for lifting. Using a remotely operated vehicle (ROV), it picked up three pieces of the aircraft skin.

Until 20 August, the Japanese salvage company recovered three pieces of the aircraft skin, provided coordinates of the wreckage and some images, and then withdrew from the accident site due to the limitations of its underwater recovery ability, and the termination of a tentative contract with Asiana Airlines.

From 6 September until 8, the submarine rescue ship of the Navy recovered three pieces of the aircraft skin located by saturation divers at the site. The portion of the wreckage where flight recorders were installed was recovered, but their rack was gone.

From 27 September until 30 October, the Korean salvage company conducted a recovery operation by using divers and one-boat trawling.

On 29 October, the cockpit was recovered with its upper portion severely compressed, and the bodies of two pilots inside.

During this period, most of the aircraft skin (about 25% of the whole skin and about 10% of the cargo) was recovered by using one-boat trawling. Divers tried to fasten and lift the wreckage presumed to be the rear fuselage, using a large crane but to no avail because it was buried deep in the mud.

The recovered items were moved onto a barge where ARAIB investigators, Asiana Airlines engineers, and Boeing experts assigned a tag number to each item and photographed it for identification, and conducted on-scene investigation. On 2 November, they were moved to a wreckage storage facility near Incheon airport for detailed investigation, then a joint ROK-US investigation[42] was conducted at the facility.

From November 2011 until March 2012, the recovery operation was temporarily suspended due to fast currents and strong winds at the accident site.

From 18 April 2012 to 25, a patrol boat affiliated with the former Ministry of Land, Transport and Maritime Affairs, and the Navy resumed search operations to check the movement of the underwater wreckage and pinpoint their exact locations at the accident site, and as a result, added new wreckage coordinates.

From 10 May until 10 June, a private salvage company[43)] using a pair trawling method recovered 3,421 pieces of the wreckage (about 15% of the aircraft skin and about 5% of the cargo), and the joint ROK-US investigation team determined that a total amount of the recovered wreckage was about 40% of the aircraft skin and about 15% of the cargo.

The ARAIB investigators and Asiana Airlines engineers identified the recovered wreckage and conducted an on-scene investigation. On 18 June, the wreckage was moved to the wreckage storage facility near Incheon Airport, and the second joint ROK-US wreckage investigation[44)] was carried out.

1.12.3 Wreckage Examination

From 1 August 2012 until 8 September 2012, under the supervision of the ARAIB investigators, investigators from the NTSB, the FAA, and the Boeing Company and engineers from Asiana Airlines examined the initial floating debris recovered by the Coast Guard at a temporary storage facility in Jeju Airport.

42) Investigators from the ARAIB, NTSB, FAA, and Boeing Company, and engineers from Asiana Airlines.
43) A company with experience in dealing with the Air Force aircraft marine accidents in Korea, and in searching and recovering underwater wreckage.
44) Investigators from the ARAIB, NTSB, FAA, and Boeing Company, and engineers from Asiana Airlines.

They identified the debris, and assessed its impact damage, the level of direct fire damage and sooting, etc.

The ARAIB collected samples from the wreckage with severe fire damage and sent them to the National Forensic Service for analysis. The analysis result indicated that there is no possibility of a fire caused by explosives.

On 2 November 2011, the floating debris in Jeju Airport and the initially recovered wreckage were moved to the Incheon wreckage storage facility, and until 20 December, the ARAIB investigators and Asiana Airlines engineers conducted the following tasks: identifying wreckage; documenting the location of wreckage on the aircraft; assessing the level of fire damage and sooting of wreckage; classifying cargo shipments and assessing their fire damage; and photographing small pieces of unidentified wreckage.

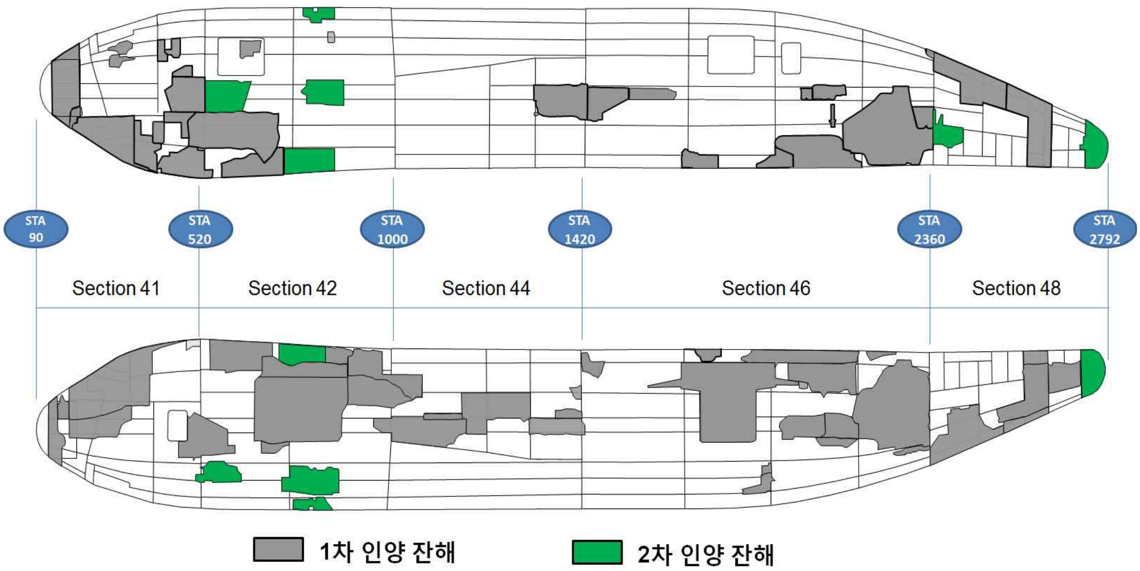
From 5 January 2012 until 20 January 2012, at the Incheon wreckage storage facility, the first joint ROK-US investigation[45)] was conducted in such areas as fuselage/structure, fire, cockpit, and cargo.

The Fire Group conducted a detailed investigation into fire damage for each aircraft location and prepared the first fire map. The Cockpit Group examined the current positions of switches in the cockpit under the microscope. The Cargo Group investigated the overall status of cargo shipments such as whether a fire occurred to them, their pre-accident loading positions, etc. The Fuselage/Structure Group checked the detailed locations of the recovered wreckage against the fuselage diagram and closely examined fire damage and the damaged wreckage. Also, the Group prepared the wreckage map and tagged[46)] the wreckage.

45) Investigators from the ARAIB, NTSB, FAA, and Boeing Company, and engineers from Asiana Airlines.

46) Tag Numbers: 1 - 173 (initial floating debris); 201 - 225 (wreckage recovered by the Japanese salvage company); 504 - 511 (wreckage recovered by the Navy); 1001 - 1153 (wreckage recovered by the Korean salvage company); and 2000 - 3999 (wreckage tagged by the US investigation team).

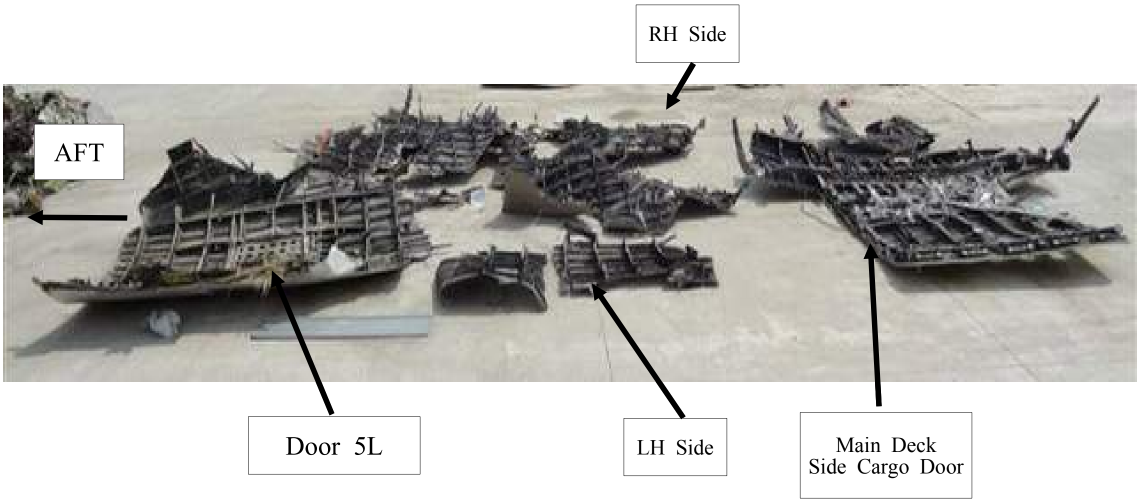
From 28 July 2012 until 3 August 2012, at the Incheon wreckage storage facility, the second joint ROK-US investigation was conducted into all the wreckage including one recovered additionally during May and June in 2012. As a result, the wreckage map was prepared as shown in [Figure 15].



[Figure 15] Wreckage Map

Out of all the wreckage, large pieces or those carrying significant implications for the accident investigation were mostly examined and tagged.

As shown in [Figure 16] and [Figure 17], the wreckage items were positioned in relative close proximity to one another in the yard of the Incheon wreckage storage facility in accordance with the level of fire damage, and their levels of damage and trace of fire were examined and documented.

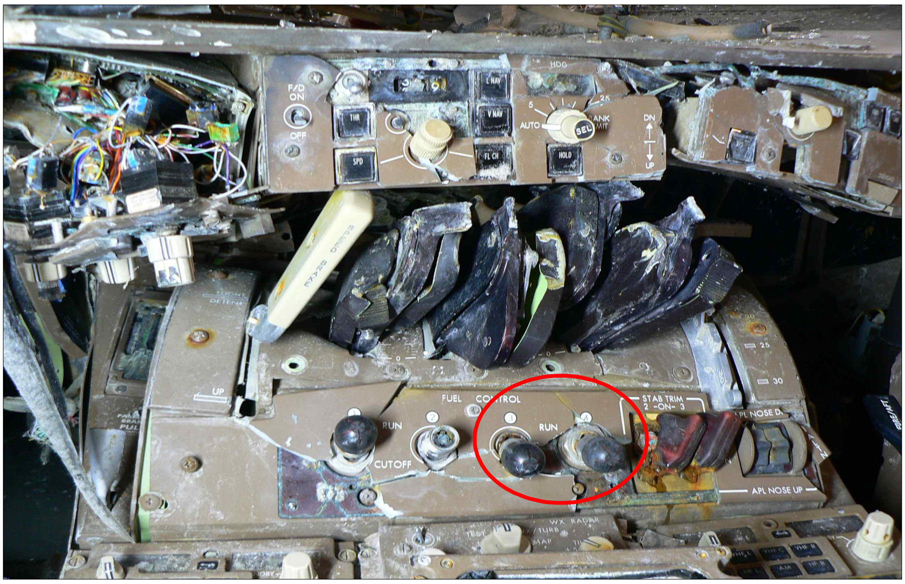


[Figure 16] Severely Fire Damaged Aft Fuselage Structure

[Figure 17] Fuselage Items with Less Severe Fire Damage

The upper section of the cockpit was extensively pressure formed by direct impact of water, which caused the throttle quadrant, switches, and many levers to sustain mechanical damage.

Cockpit instruments and switches were removed and examined to check their indications and operating states at the time of impact. Light bulb filaments of annunciator lights were examined under magnification to see whether the lights were in operation.



[Figure 18] Cockpit (Throttle Quadrant, Fuel Cutoff Switches, & Others)

As shown in [Figure 18], fuel cutoff switches No. 1 and 2 were in the ON position, whereas No. 3 and 4 in the OFF position, but under magnification, it was confirmed that No. 3 and 4 moved to the OFF position due to impact forces.

Light bulb filaments of annunciator lights removed from the cockpit were examined to see whether the lights were in operation. As a result, some annunciator lights with deformed filaments were identified, but it was confirmed that they were not directly related to the accident, and no anomaly was found during the cockpit wreckage examination.

The details of the cockpit wreckage examination can be found in Appendix 6.

As shown in [Figure 19], the cockpit smoke evacuation shutter was found closed, but a well defined soot trail was discovered on the exterior skin of the shutter in the rear fuselage direction.

[Figure 19] Sooting on the Exterior Skin of Cockpit Smoke Evacuation Shutter

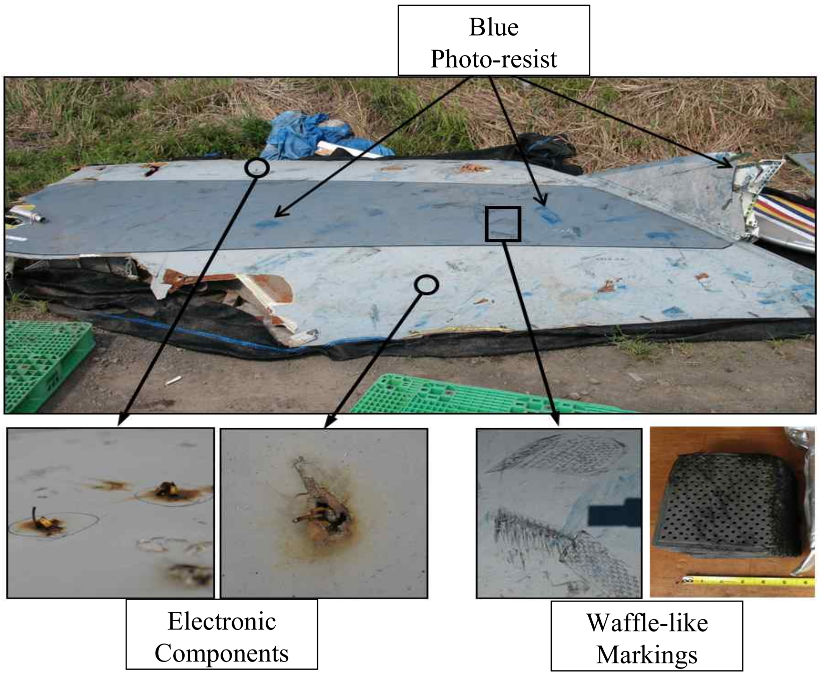
Out of the recovered wreckage, sections between fuselage station[47] (hereafter referred to as FS) 1700 and FS2400 contained direct fire damage. Yet upper fuselage skins and frames forward of FS1700 were also found to be partly sooted, and some of their plastic material was deformed by heat.

The right wing tip was separated from the wing between wing station (hereafter referred to as WS) 1500 and WS1550. The upper portion of the right wing tip contained compressive buckling tearing, whereas the lower portion exhibited tension failure.

As shown in [Figure 20], blue photo-resist was found on the top surface of the right wing. The top surface of the wing contained multiple black waffle-like markings caused by collisions with electronic components containers[48] loaded in position MR, and about 120 electronic components with a diameter of 5 mm, a thickness of 1.2 mm, and a weight of 0.3 g were imbedded in the composite wing upper surfaces.

47) Fuselage stations are numbered in inches from a reference point or the reference datum that is a vertical plane from which measurements fore and aft can be made. The reference point is located 90 inches ahead of the nose of the aircraft, which is FS0. Accordingly, FS1700 is located 1,610 inches from the nose.

48) Black partition boxes in which electronic components are kept.



[Figure 20] Damaged Right Wing Tip

The forward facing surface of the fuel jettison tube as well as the inside surface of a skin fragment in the right wing fracture at WS1516 also contained black waffle-like markings. No indications of hydro forming were found on the top and bottom surface of the wing.

Blue photo-resist was found on the surface of the right inboard spoiler No. 7, and the main deck cargo floor and the upper portion of the left main deck cargo door also exhibited a large quantity of blue and red photo-resist stains.

As shown in [Figure 21], the left and right winglets[49] were separated from the wings, and their fracture areas sustained damage consistent with overspeed. Blue photo-resist was discovered inside the right winglet fracture area, but no black waffle-like markings or blue photo-resist stains were found on the right winglet, the surface of which was relatively in good condition, with no damage by electronic components.

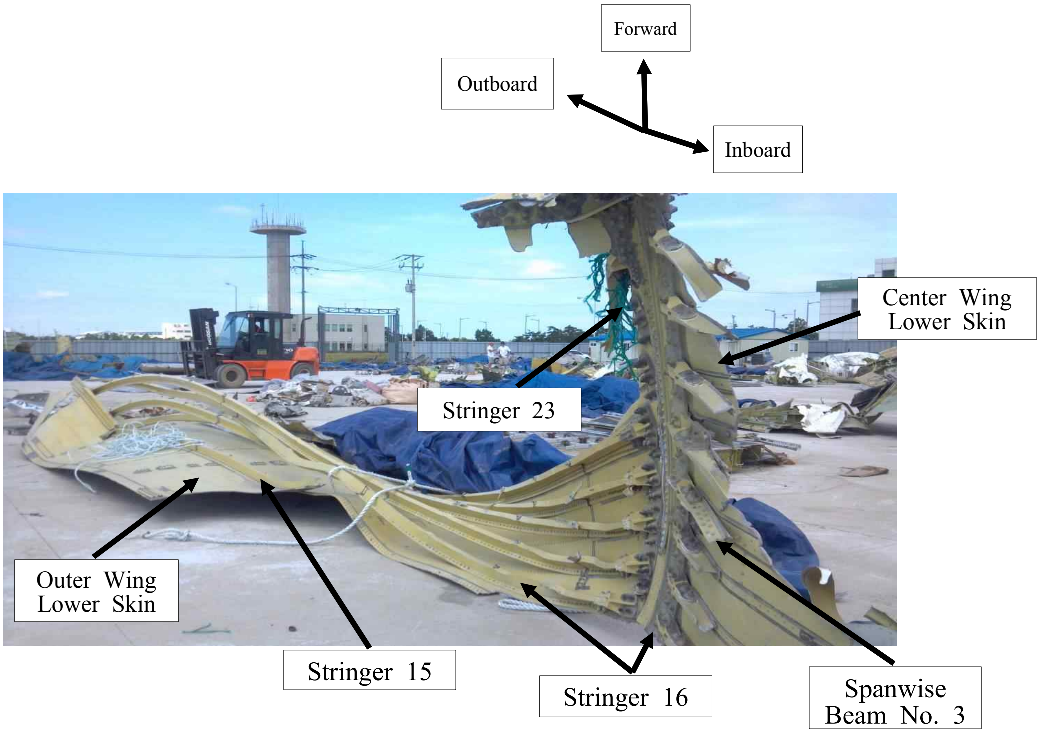
49) A winglet attached to the wing tip in an upward angle of 60 degrees raises the aerodynamic efficiency of the wings.

[Figure 21] Winglets

As shown in [Figure 22], the flight control pulley at FS775 showed sooting and discoloration but did not exhibit thermal damage, and the flight control cables attached to the pulley exhibited rust.

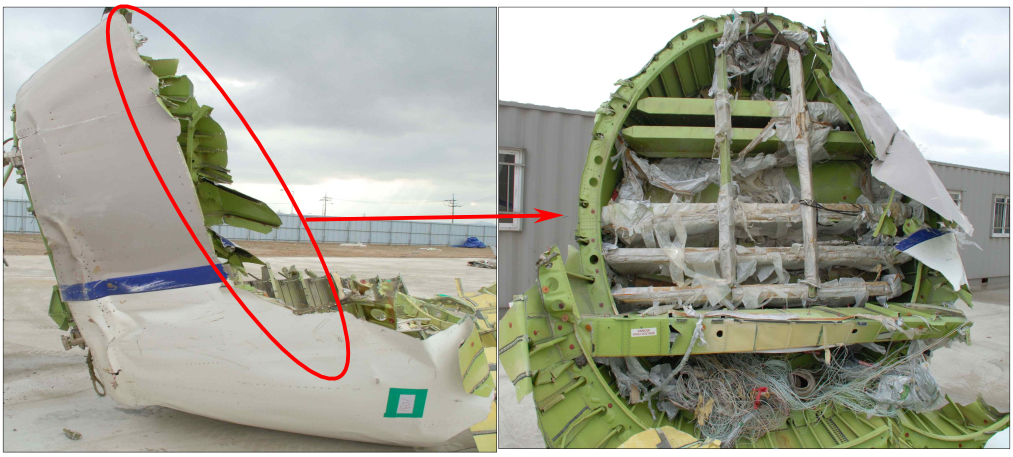
[Figure 22] Control Cables

As shown in [Figure 23], the LH lower wing skin measuring approximately 40 ft by 8 ft was recovered. It includes portions of two center wing skin panels and three outer wing panels. The skin section spans stringer positions 10 through 23 (from the midspar forward to the front spar), but not all of the stringers remain attached.



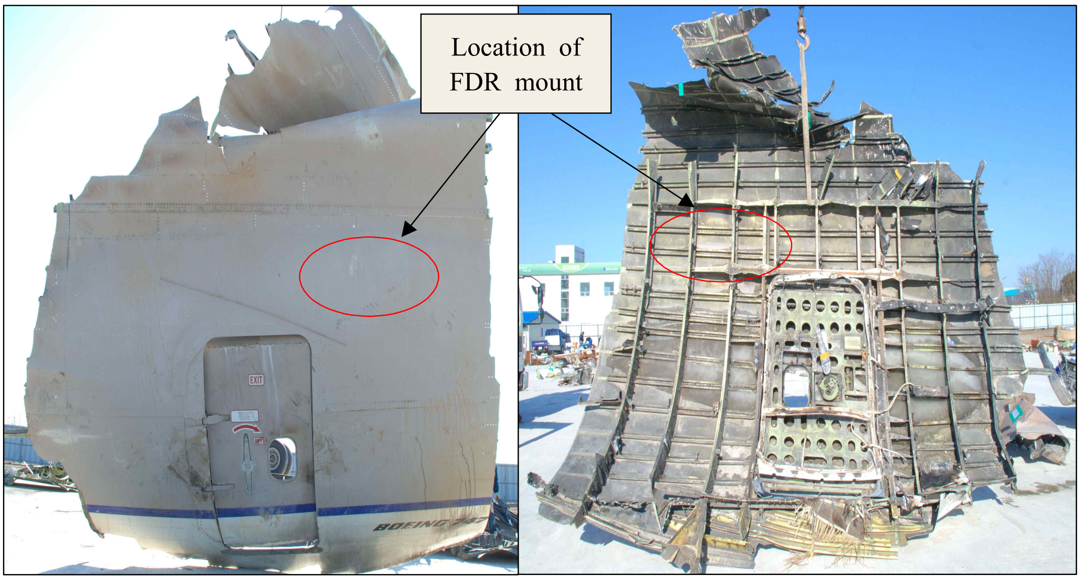
[Figure 23] LH Lower Wing Skin

As shown in [Figure 24], a forward section of the nose cargo door was separated from the fuselage at FS 160/180, and the radome was missing. The skin demonstrated compressive buckling 360 degrees along the leading edge. The forward pressure bulkhead was hydro formed. Upper portions of both sides of the door, including the hinges, were recovered with the cockpit section.



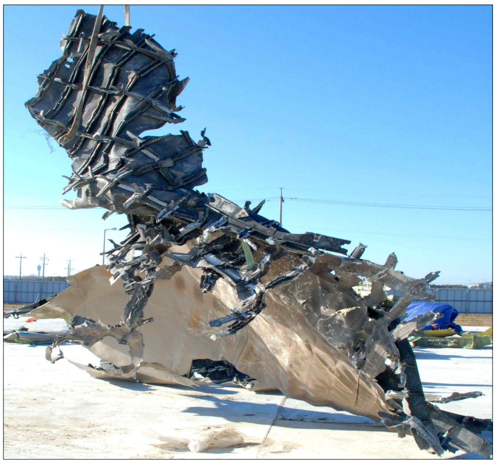
[Figure 24] Forward Cargo Door

As shown in [Figure 25], the flight data recorder rack was separated from the mount aft of the upper portion of the L5 door. The upper portion of the frame was thermally damaged, and its interior surface was heavily sooted. The paint of the exterior skin was partially discolored by inner heat.



[Figure 25] Exterior (Left) & Interior (Right) Sides of L5 Door

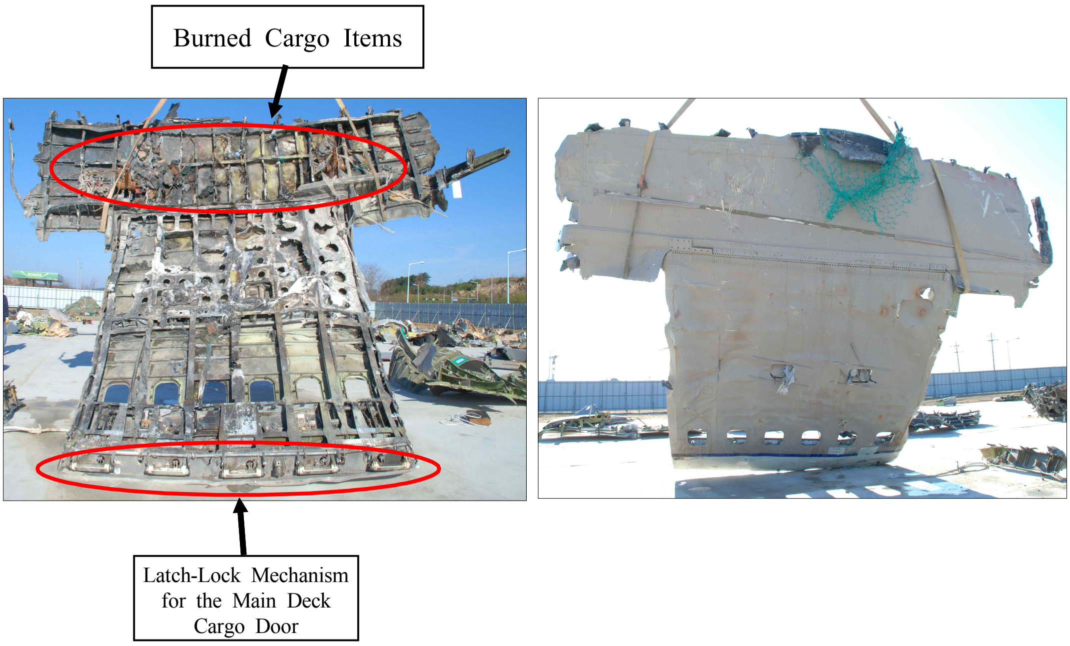
Portions of the wreckage in the region between FS1740 and FS2360 contained direct thermal damage on the exterior skin as evidenced by melting of internal metal structure and discoloration of the exterior paint. As shown in [Figure 26], the skin panel that extended from FS2180 and FS2360 sustained severe thermal damage as evidenced by twisted and melted stringers and ribs, holes on the surface, and paint discoloration on the exterior of the skin. The skin panel also contained areas which were burned through.



[Figure 26] Fire Damage to the Skin Between FS2180 & FS2360

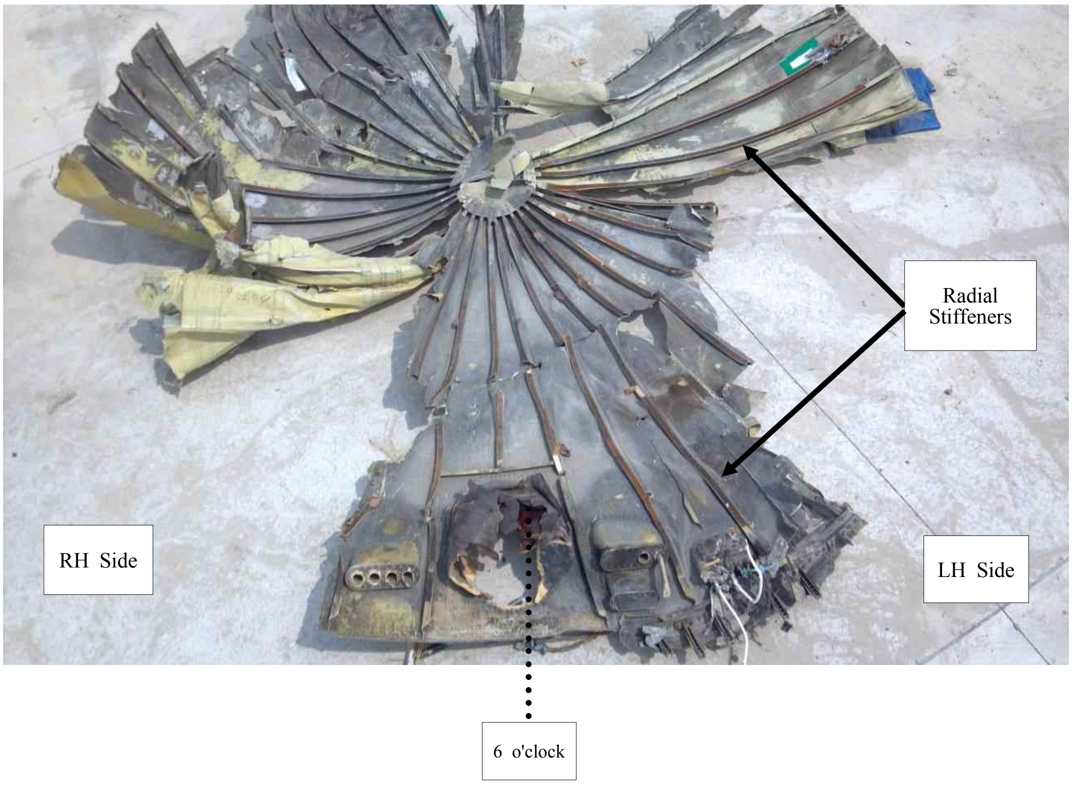
As shown in [Figure 27], the inner insulation materials of the main deck cargo door aft of the left fuselage were burned. Some cargo items were melted and stuck to the upper side of the door hinge, but the aircraft's surface touching the melted cargo items did not exhibit fire damage.

The latch-lock mechanism of the main deck cargo door was in a closed position, and the paint of the exterior skin turned yellow by heat.



[Figure 27] Interior (Left) & Exterior (Right) Sides of Main Deck Cargo Door

As shown in [Figure 28], approximately 80% of the aft pressure bulkhead (APB) at FS2360 was recovered broken into six major pieces. Portions of the wreckage sustained fire damage consisting of sooting, and some fragments of the skin remained after fire. Almost the entire RH side of the bulkhead is accounted for, whereas part of the LH side disappeared.



[Figure 28] Aft Pressure Bulkhead

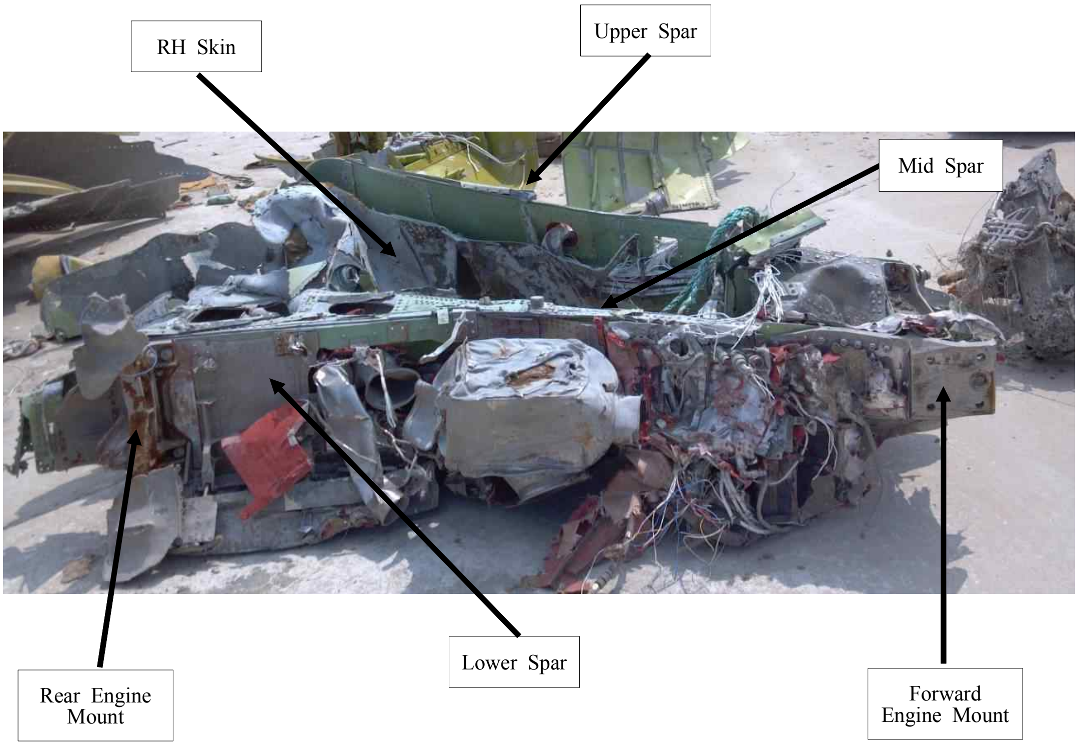
There is an outboard portion of the LH bulkhead from approximately fuselage stringer S-14L to S-24L missing as well as a smaller outboard LH section from approximately S-1L to S-8L. Fracture surfaces of the bulkhead web are a combination of web tension failures and shear failures.

Some of the radial stiffener fracture surfaces exhibit signs of pure tension failure while others are from bending. Most of the recovered APB pieces roughly maintain their original form with the exception of tears and punctures.

As shown in [Figure 29], the section 48 of the aft fuselage contained no internal sooting or fire damage but did have external soot accumulation on the underside of the left and right skin panels. Most of the damage appeared to have been caused by impact forces during the crash into the sea.

[Figure 29] Section 48 of the Aft Fuselage

As shown in [Figure 30], the No. 3 pylon includes the majority of the structure from the rear engine mount bulkhead forward to the forward engine mount bulkhead. The pylon also includes remnants of bleed air ducting, fuel lines, wire bundles and other systems but did not exhibit fire or abnormal damage.



[Figure 30] No. 3 Pylon

The rear engine mount bulkhead is separated into two pieces, top and bottom, at the production join. The upper portion of the bulkhead remains attached to the upper spar and is bent forward about the upper spar join at approximately a 45 degree angle.

The RH skin forward of the rear engine mount bulkhead is detached from the pylon and deformed inward into the pylon almost to the horizontal position. The LH skin remains attached to the spars. No signs of fire were noted on any of the pylon structure.

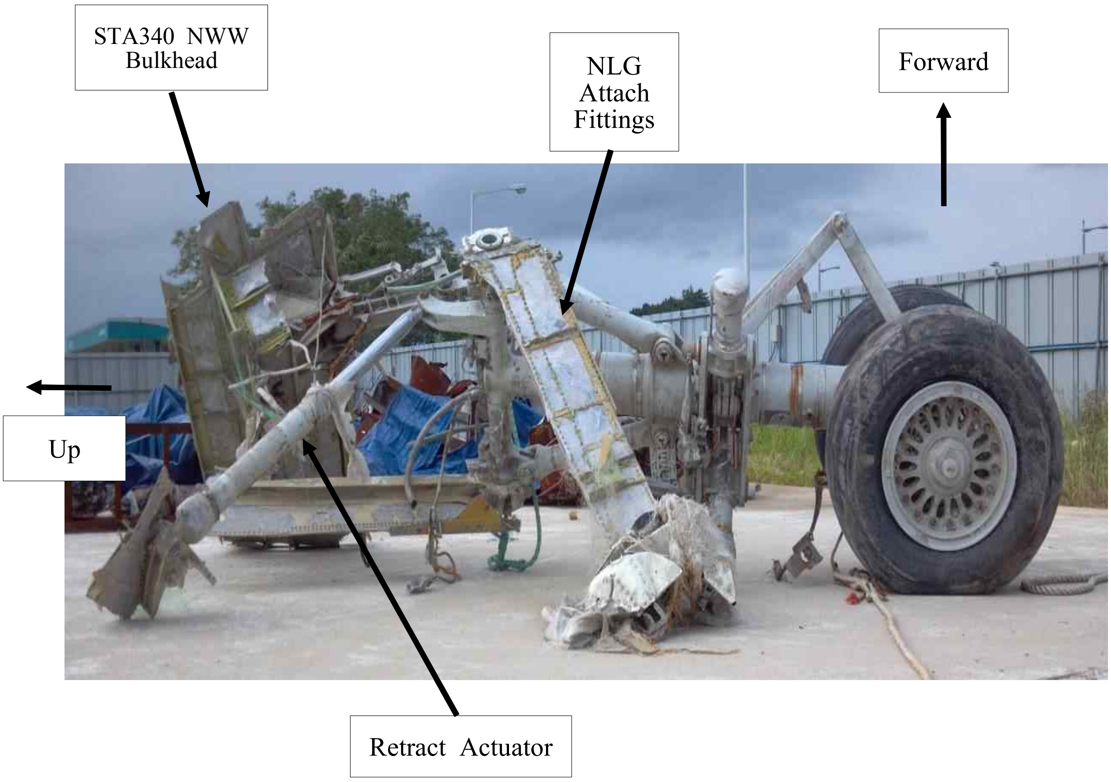
As shown in [Figure 31], the left horizontal stabilizer was separated from the empennage. The remaining skin fragments along the upper and lower fracture areas were bent upwards and demonstrated compressive buckling tearing.

[Figure 31] Left Horizontal Stabilizer

The honeycomb panels along the trailing edge of both the top and bottom surface of the stabilizer were slightly hydro formed, and honeycomb panels along the bottom side were intact, whereas four panels along the top side were not present.

The inboard elevator was separated from the stabilizer just aft of the hinge, and the trailing edge of the outboard elevator was damaged. The outboard tip of the stabilizer was fractured at Station 510 and was recovered separately from the stabilizer.

As shown in [Figure 32], the nose landing gear was recovered relatively intact and contained no fire damage.



[Figure 32] Nose Landing Gear

1.13 Medical and Pathological Information

On 29 October 2010, about 11:00, the bodies of the pilots were recovered at the accident site. On 30 October 2010, about 11:30, professors of the medical school performed an autopsy on the bodies, whose results showed that the cause of death was blunt force injuries due to a plane crash, and toxicology reports indicated no meaningful results.

1.14 Fire

Portions of the aircraft wreckage contained fire damage including sooting. The wreckage has sustained severe damage from FS1700 to the APB, and sooting trails caused by smoke were also found on the exterior of the flight deck's skin.

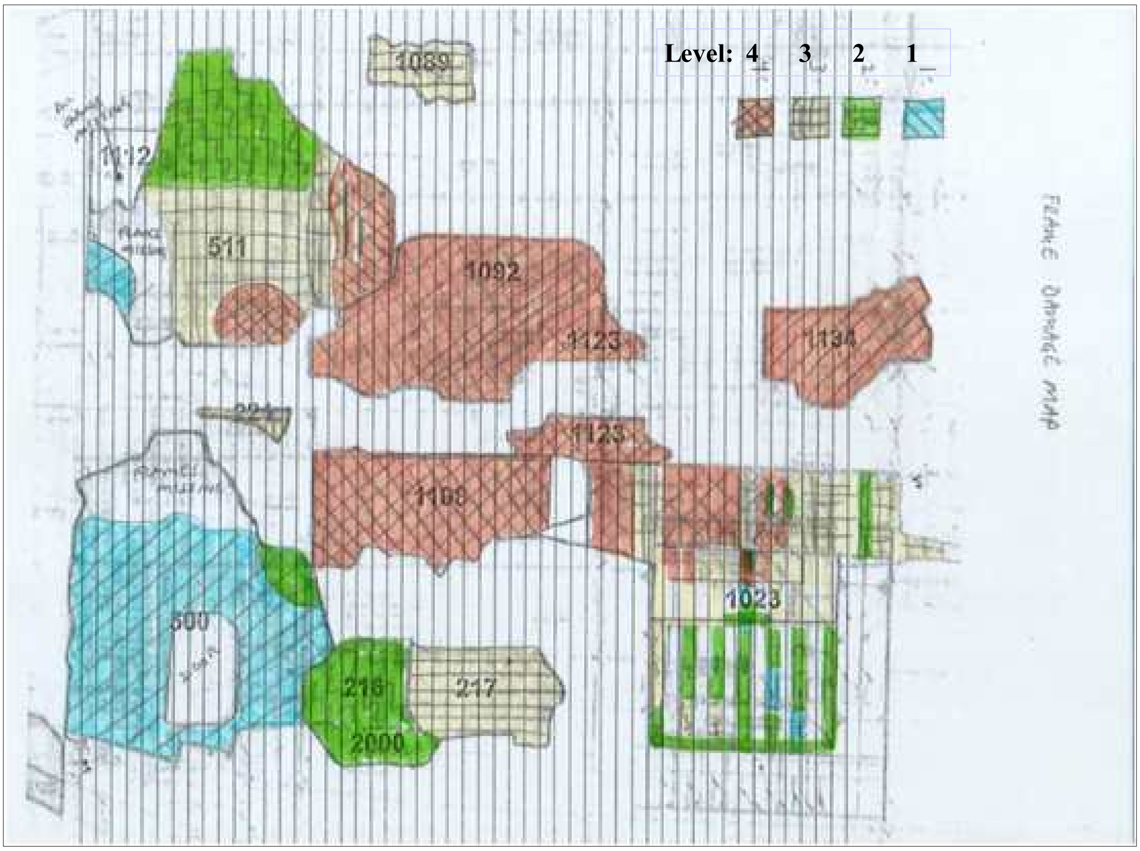
For the examination of the wreckage, a numbering convention was used to grade the level of fire damage sustained. This convention is as follows:

Level 0: No evidence of sooting or thermal damage
Level 1: Soot evidence
Level 2: Minor charring and/or paint discoloration from heat
Level 3: Heavy charring and/or incipient melting
Level 4: Melted/consumed

1.14.1 Fire Damage of the Airframe

1.14.1.1 Wreckage Between FS1700 and APB

The wreckage between FS1700 and APB sustained the most severe fire damage. Detailed thermal damage maps were generated for these portions of the aircraft. These portions were mostly between the aft main deck cargo door and the L5 door as shown in [Figure 33]. This area can be characterized overall as having been exposed to high temperatures as evidenced by severe thermal damage on the interior structure and discoloration of the paint on the exterior of the aircraft's skin.



[Figure 33] Fuselage Frame Thermal Damage Map of the Wreckage Between FS1700 & APB

1.14.1.2 Wreckage Forward of FS1700 and Aft of APB

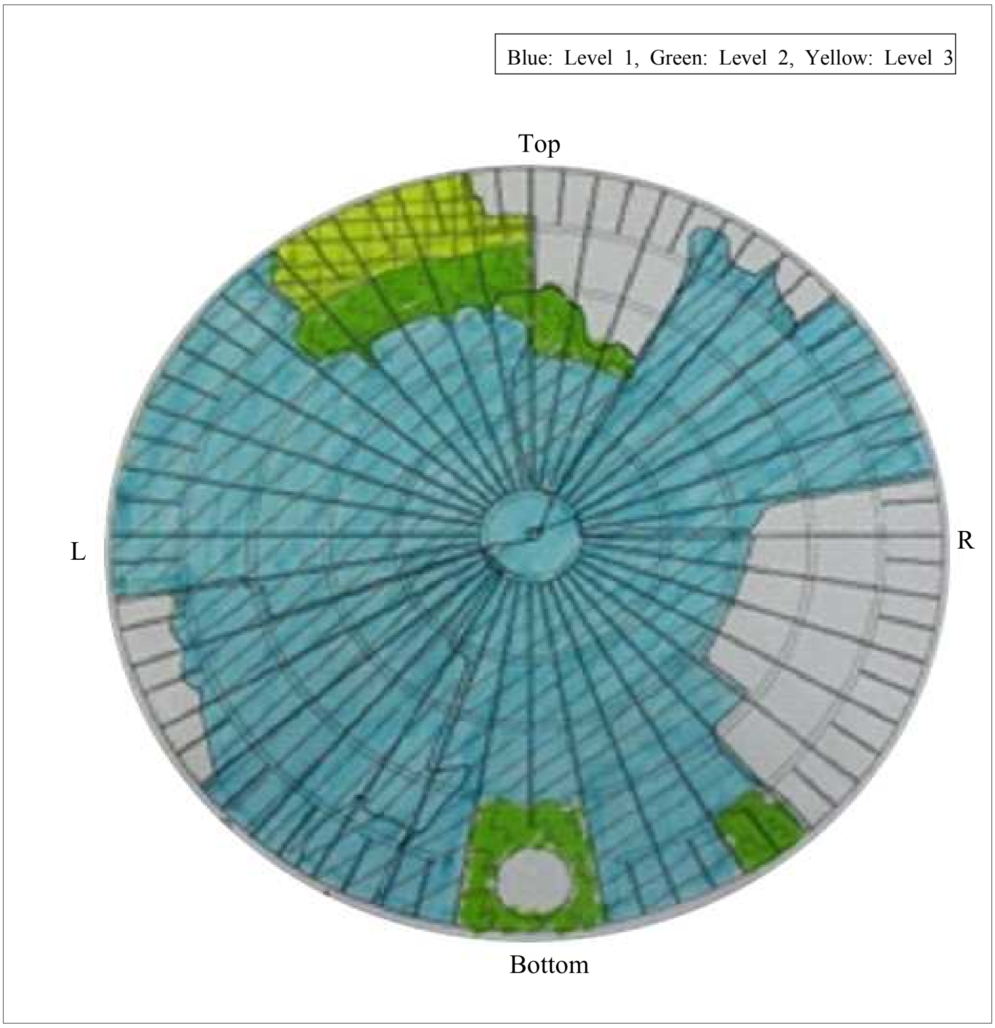
The wreckage forward of FS1700 was generally sooted with areas of more severe damage along the upper areas of the aircraft's attic space and crown[50]. Evidence of sooting was found all the way forward in the main deck cargo compartment on the bottom face of the ceiling liners under the flight deck.

The APB sustained thermal damage originating on the side facing the interior of the main deck cargo compartment. The heavy damage was on the upper section of the bulkhead, with damage also seen on the bottom portion near the APU duct.

50) Crown is the area above seats in the pressurized crew rest section and the ceiling in the cargo compartment.

The thermal damage map of the APB facing the main deck cargo compartment is shown in [Figure 34], and the colourless portions of the map indicate the wreckage unrecovered.

Portions of the wreckage aft of the APB including the pressure bulkhead facing rear fuselage did not have the evidence of fire damage, but on the exterior of the skin panels on the right and left side of the wreckage aft of the APB were soot trails caused by smoke exiting the outflow valves.



[Figure 34] APB Thermal Damage Map

1.14.1.3 Small Miscellaneous Portions of Wreckage

Many pieces of the wreckage of yet undetermined location within the aircraft were also examined for fire damage. These pieces had a range of damage levels from no fire damage to severe melting.

1.14.1.4 Cargo Control Panels

The main deck cargo control panel from FS510 on the RH side and the nose door control panel showed evidence of sooting.

1.14.1.5 Riser Ducts

Four out of the six riser ducts[51)] on AAR991 were recovered. As shown in [Figure 35], all three left riser ducts sustained fire damage which was consistently more severe along the upper glass fiber portions and tapered off towards the bottom. The fire damaged sections were burned such that the resin was consumed leaving only the cloth portion. The remainder of the ducts were undamaged except for sooting on the exterior section. The left forward most riser duct is of significance as it supplies all of the fresh air to the upper deck during a main deck fire.

One of the right riser ducts was recovered, with the upper glass fiber portions separated, and its fire damage was consistent with that of the left ones.

51) Ducts through which conditioned air from the air conditioning system flows to the ceiling of the aircraft, located between FS800 - 1000.

	
Left (3 pieces)	Right (1 piece)

[Figure 35] Riser Ducts

1.14.1.6 Forward Main Cargo Deck Ceiling Panels

As shown in [Figure 36], portions of the ceiling panels belonging to the area under the flight deck had a layer of soot adhering to the surface. Ceiling panels aft of FS360 were also sooted and had a darker appearance.

[Figure 36] Panels Near (Left) & Aft (Right) of FS360

1.14.1.7 Upper Deck Interior Panel

As shown in [Figure 37], the upper deck interior panel, part of the lavatory module wall where emergency equipment is installed, exhibited soot accumulation.

[Figure 37] Upper Deck Interior Panel with the Area of Sooting

1.14.2 Cargo Fire

The cargo configuration of the main deck and lower cargo compartments on AAR991 can be found in [Figure 5]. The main deck cargo compartment was loaded with pallets and one ULD container (at position LL) which was recovered. No evidence of fire damage was found on the inside of the ULD as shown in [Figure 38], but the outside of it was heavily covered in soot.

[Figure 38] Inside (Left) & Outside (Right) of the ULD Container

Films that had been loaded in ULD position MR were recovered with burnt and blackened traces.

There was no fire damage or sooting in the container wreckage located at 44L and 43L of the lower cargo compartment. Edge rails of cargo pallets were found separated from the pallets, and their levels of fire damage are shown in [Table 8], and the serial number of a certain rail could be confirmed as shown in [Figure 39].

Location	Levels of Fire Damage
LR	No evidence of fire
ML	Evidence of burning and sooting
PR	Evidence of sooting and blue dye splatters Cargo net with two strands burnt, the one end with blue dye splatters, the other end with red dye splatters
SL	Evidence of sooting and slight melting
SR	Evidence of sooting and slight melting, some portions with severe corrosion
12P	No evidence of sooting
22P	No evidence of sooting
41P	Out of 20 pallets, one pallet and six edge rails were recovered with no fire damage

[Table 8] Fire Damage Levels of Edge Rails

[Figure 39] Pallet Edge Rail

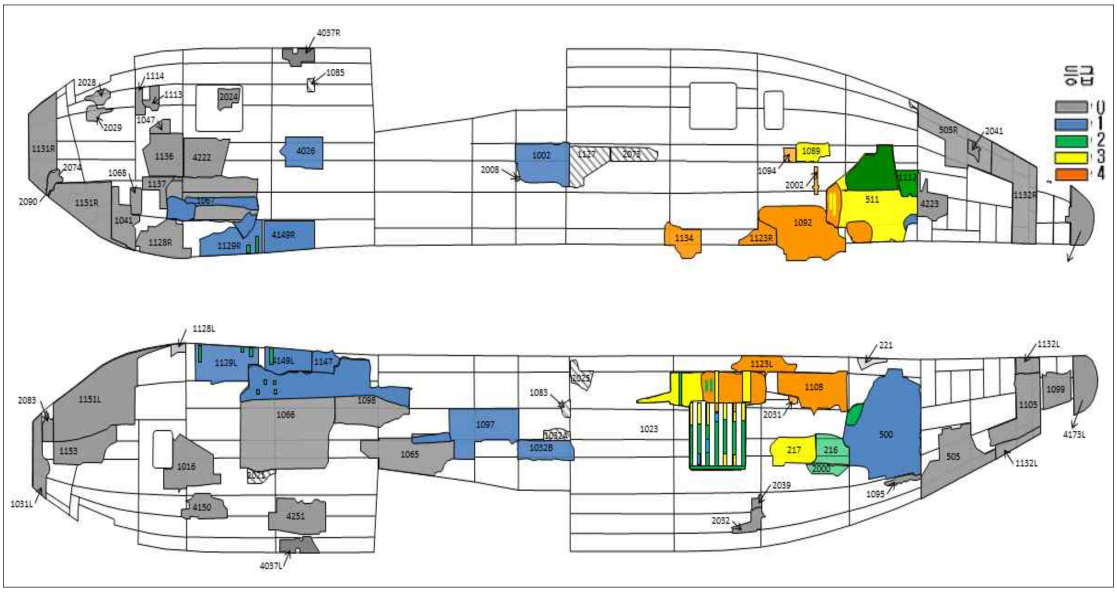
Some portions of films loaded at position LL and fabrics loaded at positions CL, 21P, 23P, and 32P were recovered. Films and fabrics showed the evidence of burning and sooting, and burning, respectively. Besides, round-edged rectangle plastic objects with fire damage, roll films in various sizes, and IC chips of yet undetermined location were recovered.

Recovered debris from the cargoes loaded at positions 11P, 12P, 22P, 31P, 32P, CR, DL, DR, EL, ER, FL, FR, GL, GR, HR, JR, KR, and LL included communications equipment, electronic parts, various reel tapes, computers and their parts, and plastic packaging, but all had no traces of fire damage.

1.14.3 Thermal Damage Map of the Entire Fuselage

Apart from the thermal damage map of the wreckage between FS1700 and APB in [Figure 33], two thermal damage maps at the airplane level - one for the fuselage skin and the other for the fuselage frames - were generated as shown in [Figure 40] and [Figure 41].

Portions of the wreckage forward of FS1700 generally have fire damage consisting of sooting with areas of more severe damage along the upper areas of the aircraft's attic space and crown.



[Figure 40] Thermal Damage Map - Fuselage Frames

[Figure 41] Thermal Damage Map - Fuselage Skin

As shown in [Figure 42], among the farthest forward wreckage (FS480 - 700), sooting was found on the fuselage frame at FS500 on the LH side in the area of the main deck cargo compartment. As shown in [Figure 43], sooting was also found on the upper deck floor beams as far forward as FS520.

[Figure 42] Fuselage Frame at FS500 on LH Side in the Main Deck Cargo Compartment

[Figure 43] Upper Deck Floor Beam at FS520

The farthest forward evidence of thermal heat damage which caused paint discoloration was found on a crown fuselage frame at FS580 on the LH side. This damage is located at a stringer 6.

[Figure 44] Farthest Forward Evidence of Thermal Damage at FS580

1.15 Survival Aspects

1.15.1 Search and Rescue

On 28 July 2011, at 03:59:09, ICN ACC received the information from FUK ACC that "AAR991 declared an emergency and requested diversion to Jeju Airport" and then notified JEJ APP of the situation at 04:01.

At 04:03:01, on the radar screen at ICN ACC were displayed a squawk code 7700 informing an emergency and the CST[52)] code word, and at 04:03, on the radar screen at JEJ APP was displayed a squawk code 7700.

At 04:03:57, ICN ACC received the notification of a cargo fire from KAL886 operating near AAR991.

At 04:10, JEJ APP was notified of the loss of aircraft control and impending emergency descent and ditching by AAR991.

At 04:11:05, the Master Control Report Center (MCRC) of the ROK Air Force declared AAR991 as the flight track of interest, and at 04:12:00, AAR991's track disappeared from the radar screen about 130 km west of Jeju Island.

About 04:12, AAR991's track disappeared from the radar screen of JEJ APP. Jeju Airport prepared for the aircraft's emergency landing, with fire engines ready.

At 04:12:49, ICN ACC inquired of the MCRC about the display of the flight track but was notified that there was no relevant data. Accordingly, at 04:13:00,

52) "CST" appears in the data block when an aircraft's reply to the radar site is not received.

ICN ACC notified the MCRC that AAR991's track disappeared from the radar screen. About 05:08, the MCRC dispatched one patrol aircraft[53] at Gimhae International Airport which is located closest to the accident site.

At 04:15, ICN ACC also inquired of the Coast Guard as to whether distress signal of the ELT was received but confirmed that it was not. The Coast Guard requested by ICN ACC to conduct search and rescue operations at 04:21:00 dispatched two helicopters, which were affiliated with its Jeju Base and Mokpo Base and arrived at the accident site to join search operations about 06:54 and 08:25, respectively.

At 04:30, the Navy was aware of the accident and about 05:38, dispatched one patrol aircraft[54], which arrived at the accident site about 06:04. About 09:30, two naval vessels arrived on scene, and on 29 July, so did two naval minesweepers, one at 07:05 and the other at 07:35.

About 06:20, an Air Force patrol plane arrived at the site and searched the area. About 06:25, it notified the MCRC that the floating debris presumed to be the wreckage of the accident aircraft was found on the water about 130 km west of Jeju Airport. About 06:42, the Coast Guard's ship having conducted search operations since the arrival at the site at 06:15 found the floating debris of the aircraft at N33°15'8", E125°01'7".

The Coast Guard conducted search and rescue operations to find missing pilots for about 3 months with the focus on the estimated crash site, an area 17 km in width by 13.5 km in length.

On 29 October 2011, when one-boat trawling was used for wreckage recovery at the accident site, a portion of the cockpit was recovered. On 30 October,

53) A twin-engine, medium-range, maritime patrol aircraft.
54) A four-engine, turbo-prop, antisubmarine aircraft.

when the interior of the cockpit was examined, the bodies of the captain and the first officer were found with a 4-point seat belt fastened on the left and right pilot seat, respectively.

1.15.2 ELT

The fixed ELT can be activated by a switch on the overhead panel or automatically when the deceleration sensing inertia switch senses the impact of 5G and more. 150 seconds after turned ON, it transmits the aircraft information every 50 seconds thereafter. It is in stable operation for at least an hour at temperatures between −20℃ and +55℃ but is inoperable in the water.

The ELT was manufactured in conformity with the requirements of the COSPAS/SARSAT system[55]. It operates on 406.025 MHz and is mounted at FS2110, S-4L. The external antenna connected to the ELT is mounted at FS2127.5 forward of the vertical stabilizer. The transmitter, whose serial number is A06V2[56], was manufactured by the French ELTA and was installed on the accident airplane on 3 June 2009.

1.16 Tests and Research

In relation to Asiana Airlines' crash accident, Hanseo University in Korea conducted a study on wreckage reconstruction, aircraft fire simulation, and fire cause analysis, and Korea Testing Laboratory (KTL) carried out chemical properties test and analysis of on-board dangerous goods, simulation of cargo loading, and transport condition testing including electrostatic energy-related research and measurements. The results can be found in Appendix 10.

55) The COSPAS/SARSAT system is an international satellite system coordinated by the US, Russia, etc. to detect alert transmissions.
56) Part No.: 95N6088, Serial No.: 05422257.

1.16.1 Wreckage Reconstruction

The ARAIB carried out wreckage reconstruction to allow investigators to easily access a certain portion of the airframe structure, to have a 3D visual reference, and to examine the distribution of destructive forces in the presumably fire-affected area.

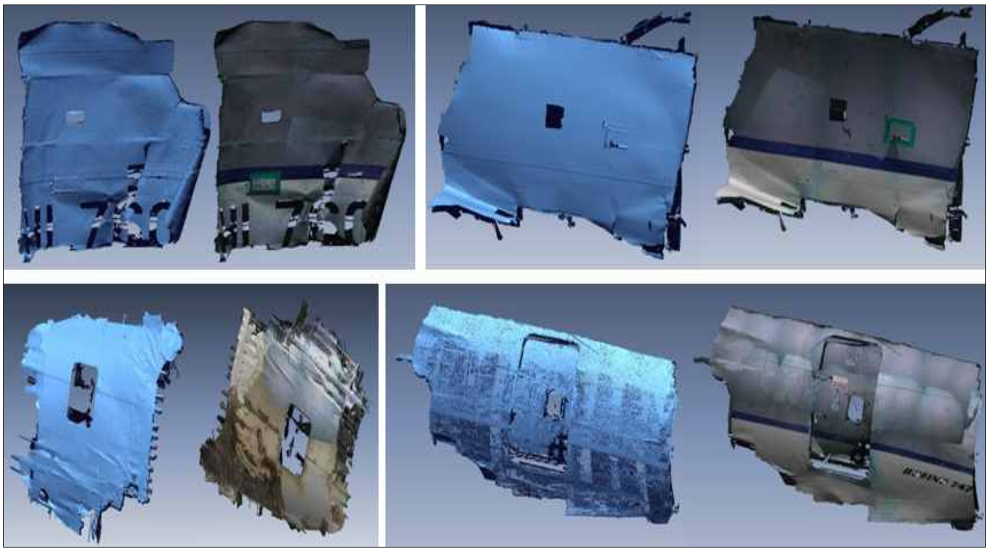
As shown in [Figure 45], the reconstruction focused mainly on Section 46[57] with traces of fire damage, including the APB. In other words, 35 pieces of the recovered wreckage from FS1480 to FS2484, about 1/3 the length of the fuselage, were selected and reconstructed.

The reconstructed wreckage was analyzed for physical damage, thermal damage, etc.

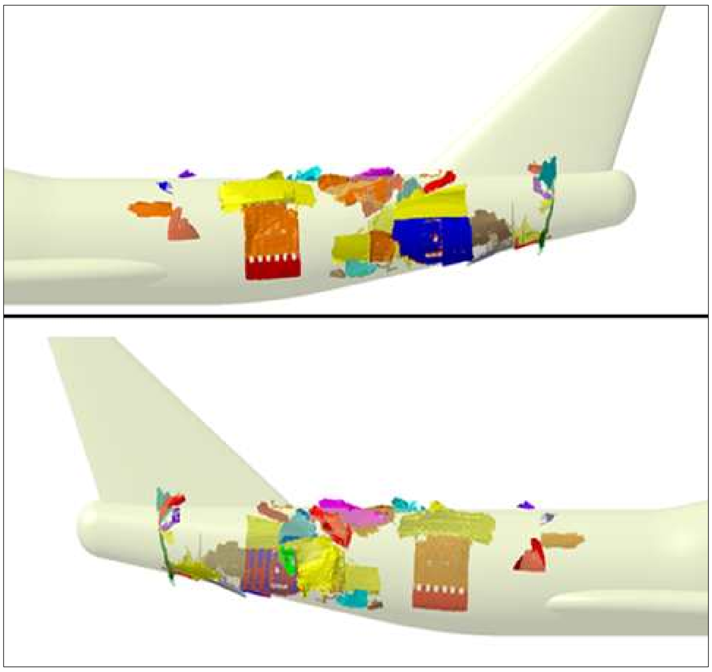
[Figure 45] Wreckage Reconstruction

57) Fuselage from the fore cockpit to the rear end is classified as sections 41, 42, 43, 44, 45, and 46.

Before the selected pieces of the wreckage were attached to the aircraft-shaped framework, noncontact 3D measuring equipment was used to generate measurement data for each wreckage. As shown in [Figure 46] and [Figure 47], the accident airplane's wreckage modeling and 3D software were created on the basis of the measurement data.



[Figure 46] Measurement Data for Each Wreckage



[Figure 47] Wreckage Modeling

1.16.2 Chemical Properties Test and Analysis of On-board Dangerous Goods

The procedures for testing properties and storage environment of the dangerous goods (DG) were developed, and according to the procedures, physiochemical properties of the DG on board were tested (for flash point, ignition point, explosiveness, ignition, combustion, etc.).

The KTL developed flash point testing procedures on the basis of UN TDG Test Section 32, ISO 1516, ISO 1523, ISO 2719, ISO 13736, ISO 3679, and ISO 3680, and the Korea MSDS Testing Lab carried out the testing. Also, the KTL developed ignition point testing procedures on the basis of ASTME 659 Standard Test Method for Autoignition Temperature of Liquid Chemical, and the Korea MSDS Testing Lab conducted the testing.

In addition, Hanseo University purchased the same paint as that on board from the manufacturer and tested it for flammable gas leakage. After the university confirmed whether internal and external closure devices of a paint container were held securely, it enclosed the container in a 1 liter-plastic bag, a similar size of the paint container on board, stored it on the ground at room temperature for 2 hours, and measured volatile organic compound (VOC) emissions. The test revealed that flammable gas was detected at room temperature of 18℃, whereas not detected at 5℃. Besides this test, other flammable gas leakage tests[58] were conducted as well, using a decompression chamber with a volume of about 280 liters to create two aircraft operation environments, cabin altitude (8,000 ft - 10,000 ft) and cruising altitude (32,000 ft - 34,000 ft)[59]. The tests revealed that the VOC was detected at 2.5 parts per million (ppt) at a cruising altitude, whereas not detected at a cabin altitude.

58) On-board dangerous goods - photo-resist/LCD, photo-resist/IC, and paint - were tested for flammable gas leakage. The applicable DG with a measuring device were placed in the decompression chamber that created the environment at an applicable altitude, and VOC emissions were measured.

59) Cabin altitude is the pressure altitude corresponding to the pressure inside the cabin when the aircraft is operated, and cruising altitude is the pressure altitude corresponding to the outboard pressure.

Meanwhile, the KTL examined the minimum ignition energy (MIE) generated when flammable materials among the on-board DG vaporize, through a literature search, and summarized results of testing and research can be found in Appendix 10.

1.16.3 Simulation of Cargo Loading and Transport Condition Testing

By developing test procedures according to cargo loading/packaging forms, physical testing through simulations of packaging and loading of the DG (a physical test on the conditions of the cargo loaded in multiple layers or wrapped in a net or plastic wrap) was performed. So was a test of cargo transport conditions through a simulation of the aircraft operating environment.

The electrostatic energy that can be accumulated in the plastic wrap used for fixing and protecting cargo on the pallet from rain was measured. The ARAIB boarded the freighter operated in the flight leg (Seoul/Tianjin) with a similar flight time to that of the accident plane and measured the remaining electrostatic energy accumulated in the wrap. A summary of the measurements can be found in [Table 9]. See Appendix 10, Section 5 for complete results of the electrostatic energy measurements.

Time Elapsed After Electric Charge	Cargo Location	Packaging	Accumulated Charge (nC)	Electrostatic Energy (mJ)	Tem (℃)	Humidity (%)
35 min	JR	4-step Packaging	X	X	14.6	23.1
			X	X	14.2	23.2
1 hr 20 min	GR	4-step Packaging	X	X	16.7	19.3
			X	X	16.7	19.3
1 hr 35 min	T	4-step Packaging	X	X	10.7	15.5
			X	X	10.7	15.5
1 hr 15 min	SL	3-step Packaging	X	X	11.2	14.2
1 hr	PR	4-step Packaging	X	X	22.7	13.2
			X	X	21.3	11.1
1 hr	ML	4-step Packaging	X	X	22.7	15.0
			X	X	20.0	10.3
1 hr 20 min	RL	4-step Packaging	X	X	18.7	9.6
			X	X	18.6	8.8
1 hr 20 min	GL	4-step Packaging	15.4	0.23	17.8	8.0
			X	X	17.4	8.8

[Table 9] Summary of On-board Measurement

1.16.4 Aircraft Fire Simulation

Hanseo University carried out aircraft modeling through aircraft structure and design analysis, establishment of the fire simulation environment for aircraft with cargo on board, simulation of the state of the interior of the aircraft in case of fire, and analysis of fire propagation in relation to AAR991. Based on ACARS messages, the university simulated the spread of fire on the assumption that fire initially developed in the pallet in position PR or ML. The development of fire in position PR has sustained more similar thermal damage to that of the thermal damage map than the development of fire in position ML. See Appendix 10, Section 7 for results of the aircraft fire simulation.

1.17 Organizational and Management Information

1.17.1 Asiana Airlines

Asiana Airlines was founded in February 1988 and has its headquarters in Osoe-dong, Gangseo-gu, Seoul. As of the day of the accident, the airline operates 14 domestic and 90 international passenger routes, and 23 cargo routes throughout North America, Europe, Southwest Asia, Australia, China and Japan.

The organizational structure of Asiana Airlines is comprised of 6 divisions including operations and maintenance/engineering divisions, 23 departments, 4 foreign regional divisions, 81 teams, 135 branch offices and 6 sales offices.

As of the day of the accident, the airline's fleet consists of a total of 72 airplanes as follows: 2 B747-400 PAX; 2 B747-400 combi; 4 B747-400SF; 5 B747-400F; 11 B777-200ER; 7 B767-300; 1 B767-300F; 10 A330-300; 11 A320-200; 15 A321-200; 2 A321-100; and 2 B737-400.

1.17.2 Safety Management System of Asiana Airlines

Asiana Airlines has established its safety management system (SMS) in 2008 to manage aviation safety.

The SMS provides safety management framework and logical process in order for safety quality assurance activities taken by each division to be conducted according to purposes.

The safety meetings of the SMS are comprised of the safety policy review board and the safety officers meeting.

The safety policy review board, the company's top decision-making body in relation to safety issues, is presided over by President and attended by the heads of the divisions and the head of the safety management team every Monday morning. Its main agendas are as follows: conclusions from the safety officers meeting in the previous quarter; current status of safety accidents on the ground and future countermeasures; current status of hard landings and safety measures; and other safety-related issues and follow-up measures.

The safety officers meeting is held every quarter, presided by the executives of the safety and security division, and attended by safety officers of each division. The main agendas are as follows: implementation of resolutions of the safety policy review board and discussion about major pending safety issues. In the safety meeting like this, issues requiring cooperation of other divisions and corporate-level decision-making are discussed.

The SMS enables a decision-making process for risk management. In this process, the risk of all hazards in relation to flight operations is contained within an acceptable level; the risk of hazards is assessed in terms of probability and potential consequences of accidents; and the risk is reduced by taking economic feasibility into account.

1.17.3 Flight Crew Training of Asiana Airlines

1.17.3.1 Dangerous Goods Handling Training

In accordance with 「Flight Crew Training Manual of Asiana Airlines」, a professional instructor provided the captain and the FO with the DG handling training for 4 hours during their initial training. The captain and the FO received their most recent refresher training for one hour on 22 July 2010 and 28 October 2010 during their yearly recurrent training, respectively.

The content of the DG handling training is as follows: general principles and framework; limitations; DG list; labelling and marking; recognition of undeclared DG; storage and loading procedures; notification to the captain; regulations on passengers and crew members; and emergency response procedures.

The DG training instructor stated that he had trained the pilots with an emphasis on cargo safety standards for lithium-ion batteries and cargo fire procedures during the first half-yearly type training in 2011 after the fatal UPS crash in the United Arab Emirates on 3 September 2010. Also, he added that he had sent notification to the pilots. The notification was about the summary of SAFO10017 issued by the FAA in relation to the UPS crash and Regulation for Dangerous Goods by Air Transport developed by the Ministry of Land, Infrastructure and Transport (MOLIT).

1.17.3.2 CRM Training

According to 「Flight Crew Training Manual of Asiana Airlines」, the flight crew should complete 21 hours of initial CRM training after hired and 2 hours of recurrent CRM training every year. Also, they should receive 7 hours of joint CRM training every three years along with cabin crew, aircraft mechanics, flight dispatchers, and other personnel with the aim of understanding and cooperating with different fields.

Recently, the captain received his joint CRM training on 17 December 2010, and the FO completed his recurrent CRM training on 10 February 2011.

The pilots in the captain upgrade and instructor designation courses should receive the CRM training suitable for their applicable tasks. In particular, the instructor pilots should be given 4 hours of the recurrent CRM training once a year.

The content of the flight crew initial CRM training is as follows: TEM; culture; decision-making; situational awareness; teamwork; communication; stress and fatigue; command and leadership; automation; checklist and briefing; and monitoring and workload management.

The content of the recurrent CRM training is as follows: selection and review of one subject among the initial CRM curriculum; introduction of CRM techniques and accident prevention programs in foreign countries; air accident case study; and group discussion.

1.17.3.3 Emergency Equipment Training

According to 「Flight Crew Training Manual of Asiana Airlines」, the captain and the FO received 10 hours of initial training and 1 hour of recurrent training once a year, which were dedicated to emergency equipment procedures in response to an emergency situation and other unpredicted situations during operation.

More specifically, the content of the training is as follows: breathing protection equipment and fire suppression training; emergency evacuation training; emergency exit training; fire extinguisher training; oxygen equipment training; flotation device training; ditching training; and participation in and practice of emergency training.

1.17.3.4 Ditching Training

According to 「Flight Crew Training Manual of Asiana Airlines」, the captain and the FO received initial ditching theory training during the basic training after hired and recurrent training during the regular ground training.

After the A320 of US Airways ditched in the Hudson River off midtown

Manhattan in 2009, Asiana Airlines gave emergency ditching training to all flight crew members by using a simulator in the first half of 2009.

The captain and the FO were given the training for emergency ditching due to complete engine shutdown after takeoff in a B747-400 and B767 simulator, respectively.

1.17.3.5 Fire Simulation Training

A B747-400 simulator manufactured by CAE[60] on 12 August 1994 was delivered to Asiana Airlines on 4 December 1994. Asiana Airlines contracted an outside training company to train and evaluate its flight crew in a flight simulator.

The flight crew training and evaluation guidelines[61] are prepared by Asiana Airlines in accordance with the flight crew training program approved by the Korean government. The company's semiannual recurrent training and evaluation items are developed separately for captain and the FO according to type and distributed in advance to them to prepare themselves for training and evaluation. Simulator instructors of the outside contractor use the guidelines provided by Asiana Airlines to train and evaluate[62] the flight crew.

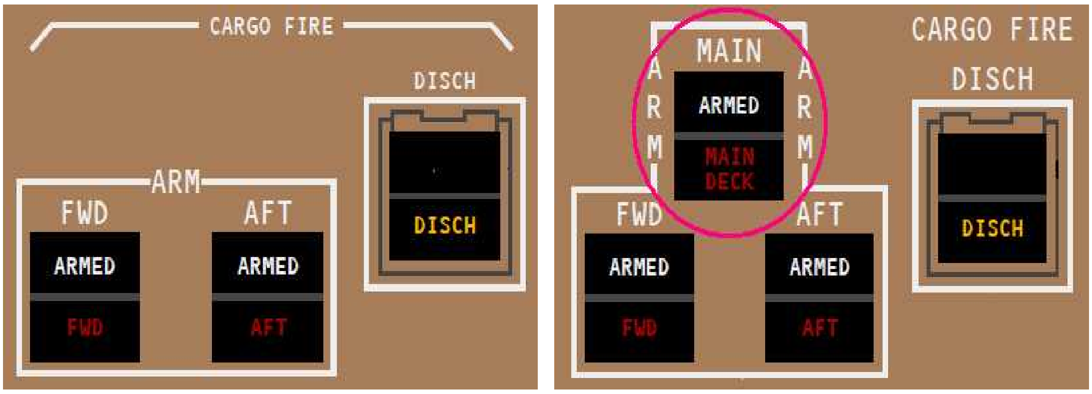
As the simulator is configured as a passenger version of the B747-400, there is no main deck cargo ARM button as shown in [Figure 48], and accordingly, simulator instructors are unable to give a full Fire Main Deck training for B747 freighters. As a result, during briefing before the simulator training, they refer to a cargo plane's panel diagram and the flight crew operations manual.

60) The world's biggest simulator manufacturing company in Montreal, Canada.

61) Asiana Airlines' B747-400 training and evaluation guidelines in the first and second half of 2011 can be found in Appendix 8.

62) The details of B747-400 transition and recurrent training, checks, and fire-related training which were given to AAR991's captain and the FO can be found in Appendix 8.

During the simulator training, the instructors simulate a main deck cargo fire by giving trainees verbal instructions associated with the fire and using the passenger plane's lower cargo deck fire message instead.



[Figure 48] Fire Suppression Panel of Passenger (Left) & Cargo (Right) Plane

1.17.4 Non-normal Procedures for Fire Main Deck

1.17.4.1 Selection of 25,000 ft for Main Deck Cargo Compartment Firefighting Altitude

The Boeing Company has selected the altitude of 25,000 ft for Class E cargo compartment firefighting altitude as optimal based on studies of National Fire Protection Association (NFPA), FAA and other literature available. In establishing the FL250 diversion altitude, the company also assessed other factors such as flight crew physiological tolerance (e.g. decompression sickness, and hypoxia), crew oxygen, and terrain clearance.

NFPA data indicates that the minimum re-ignition energy varies inversely with the square of the pressure and concludes that approximately 4 times the ignition energy is required to rekindle a fire at 25,000 ft in comparison to that of 5,000 ft.

1.17.4.2 Revision of FCOM[63)]

After the fatal UPS crash in 2010, the Boeing Company revised the "non-normal procedures for Fire Main Deck" in the flight crew operations manual (FCOM) by reinforcing two items in the procedures and issuing the Bulletin AAR-83 on 10 May 2011.

The revised procedures are as follows: first, the main deck cargo fire arm switch must be "ON", then to prevent excessive smoke accumulation on the flight deck, either pack 1 or 3 must be operating, whereas pack 2 control selector must be "OFF"; and second, the aircraft must expedite a climb or descent to 25,000 ft and stay at 25,000 ft as long as possible, and after the descent has been started, the approach and landing must not be delayed.

The "PACK" was newly added to step No. 9 (Do not accomplish the following checklists), so pilots are prohibited from operating packs once landing is initiated.

The QRH's non-normal procedures in relation to AAR991's fire can be found in Appendix 9.

1.17.4.3 QRH Possessed by the Accident Flight Crew

The "QRH" possessed by the accident flight crew on the day of the accident, in which non-normal procedures for Fire Main Deck were specified, were issued on 1 April 2011. Asiana Airlines received the revised non-normal procedures for Fire Main Deck[64)] valid from 10 May 2011 on 16 May 2011 and distributed them to its flight crew on 1 August 2011 after the accident.

63) The flight crew operations manual (FCOM) issued by the aircraft manufacturer deals with the aircraft system, performance, normal procedures, non-normal procedures, limitations and supplementary procedures.

64) Bulletin AAR-83 issued by the Boeing Company.

Asiana Airlines' staff member in charge of manual distribution stated that, as there is no deadline for distributing the Bulletin, upon receipt, he reviews and reports it to the relevant authorities and then distributes it.

On 12 April 2011, Asiana Airlines posted a plan for revising the procedures for Fire Main Deck along with the main content of such revision on the Intranet flight crew bulletin board. According to log-in records, the captain and the FO read this notice.

1.17.4.4 Implementation of the Non-normal Procedures for Fire Main Deck

In accordance with Asiana Airlines' "FOM,"[65] the flight crew should possess their own "POM" and QRH[66] during operation of the aircraft.

The QRH possessed by the flight crew contains the non-normal procedures of passenger, combi, and cargo planes. The combi plane's Fire Main Deck procedures were presented first, followed by the cargo plane's procedures since the passenger plane does not have the non-normal procedures for a main deck cargo fire due to the absence of a main deck cargo compartment.

The B747-400 flight crew should find the applicable non-normal fire procedures[67] coincident with the aircraft's registration mark at the top of the page of the QRH and implement them.

1.17.5 Asiana Airlines' Post-accident Actions

65) FOM deals with regulations on general operations and flight operations. FOM provides policies, guidelines, standards, and procedures regarding general operations and flight operations to Asiana Airlines' staff concerned with air transport business.
66) Manual issued by an aircraft manufacturer with the aim of ensuring the flight crew's quick decision and actions in non-normal situations.
67) The procedures applicable to combi and cargo planes are different from each other. The main difference is that in a combi plane, a designated flight crew member should confirm the presence of smoke or fire, whereas in a cargo plane, a climb or descent to 25,000 ft should be expedited. Refer to Appendix 9 for the Fire Main Deck non-normal procedures of combi and cargo planes.

1.17.5.1 Simulator Session of Fire Main Deck Procedures

After the accident, Asiana Airlines, under the supervision of the ARAIB investigators, conducted two Fire Main Deck demonstrations in the Asiana B747-400 simulator, with Jeju Airport designated as an arrival airport.

☐ First Session (on 4 August 2011)

During the session, Asiana Airlines' B747-400 captain was the left seat PF while the FO was the right seat PM. Investigators of the Operations Group, a captain from the Boeing Company, and Asiana Airlines' persons concerned were present.

The gross weight (GW), ZFW, FOB, and center of gravity (CG) of the aircraft were set as 272,110 kg, 242,670 kg, 29,480 kg, and 24.5%, respectively. The winds were established as 220/25 kt aloft.

The session began when the instructor announced event by stating "Fire Main Deck" at a location 125 nm (230 km)[68] southwest of Jeju Airport. There were no aural or visual alerts in the cockpit since the simulator supported only a passenger plane.

The flight crew implemented the Fire Main Deck procedures in the QRH. After landing, using the ILS approach, at runway 06[69] of Jeju Airport, they ran the evacuation checklist.

During this procedure, the captain failed to use speedbrakes for expedited descents and experienced difficulty adjusting his oxygen mask harness.

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68) A point close to where AAR991 was aware of a fire.
69) Refer to Appendix 7 for the ILS approach chart for runway 06 in Jeju Airport.

The FO failed to select 100% oxygen on his O2 mask since he did not confirm the position of O2 supply currently set while donning the mask. He also experienced difficulty setting his respective communication panel, which led to a delay in the execution of the Fire Main Deck checklist.

The aircraft began to achieve its landing configuration and standard speed 19.5 nm (36 km) from the landing point.

From the declaration of a main deck cargo fire to touchdown, it took 31 minutes.

☐ Second Session (on 17 September 2012)

The second session simulated the LOFT in which the aircraft made an emergency landing at Jeju Airport. Asiana Airlines' B747-400 captain was the left seat PF while the FO was the right seat PM. Investigators of the Operations Group and Asiana Airlines' persons concerned were present.

The GW, FOB, and CG of the aircraft were set as 272,160 kg, 29,480 kg, and 24%, respectively.

The aircraft was located 120 nm (222 km) southwest of Jeju Airport. When a main deck cargo fire was declared at 34,000 ft and 300 kt with no wind, the flight crew implemented the applicable procedures in the QRH, increased speed up to Vmo,[70] and descended to 25,000 ft.

The TOD point at 25,000 ft was set as a point 55 nm (102 km) from Jeju Airport. Using the speedbrakes to the maximum, the aircraft descended to the MSA at the maximum sink rate at 360 kt.

70) Vmo (Maximum Operating Speed): this speed limit may not be deliberately exceeded in any regime of flight (climb, cruise, or descent).

As the aircraft reached 3,000 ft approximately 18 nm (33 km) from Jeju Airport, it decreased to Vref. As speed reduced, the aircraft achieved landing configuration of gear down and flap 30 and then made the ILS landing at runway 06. After touchdown, the flight crew ran the evacuation checklist on the runway. It took approximately 12 minutes from descent at 25,000 ft to touchdown and took approximately 10 nm (19 km) to achieve landing configuration at 360 kt.

Over a year after the accident, Asiana Airlines provided all B747-400 pilots with the LOFT, on the presumption of AAR991's main deck cargo fire, during which they made an emergency landing at Jeju Airport.

1.17.5.2 Flight Crew Training in Dangerous Goods and Cargo Loading

After the event, Asiana Airlines provided its B747 and B767 flight crew with training for a better understanding of cargo.

The company offered a two-day training course nine times in total. On the first day of training, types of cargo shipments and their loading procedures, and general and practical information on cargo including DG were taught, and on the second day, trainees visited Incheon Airport Asiana Cargo Service Office and observed the whole process from cargo acceptance to loading.

1.17.5.3 Revision of Freighter Operating Procedures

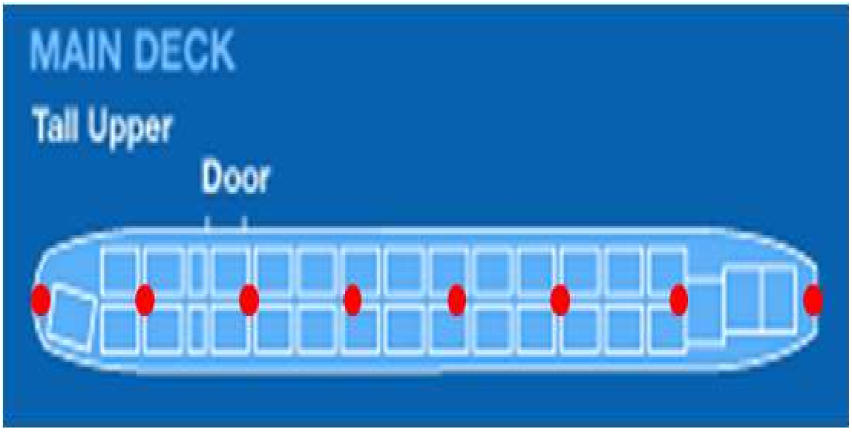
As of 31 December 2012 (Rev. 10), Asiana Airlines newly added "Chapter 9 Cargo" to "POM" to bring B747-400 freighter operating procedures together from scattered regulations and establish specific procedures for various in-flight situations including false cargo fire warning. Also, the company required its B747-400 pilots to apply the revised POM during cargo flight.

The added content are as follows: main terms; items to be confirmed before flight; DG; special cargo; cargo compartment classification; false cargo fire warning; emergency response guidance; on-board weight and balance system; life raft; decompression door; emergency escape device; and miscellaneous.

1.17.5.4 Plan for Installing CCTVs on B747-400 Freighters

As shown in [Figure 49], according to Asiana Airlines' data, in 2013, the company started installing CCTVs, which enable the flight crew to monitor a fire situation in the cockpit, in cargo compartments of a total of 12 B747-400 airplanes including freighters to be delivered after the AAR 991 accident. As of July 2015, a total of 8 CCTVs have been installed, and the installation will be completed by 2016.

This fire surveillance camera system is comprised of a monochrome camera in a main deck cargo compartment, an LCD monitor in the cockpit, a video server, and related software. In case of a fire in the cargo compartment, the flight crew will be provided with video imagery of fire along with an aural alert as shown in [Figure 50].



[Figure 49] Installation Locations of CCTVs

[Figure 50] Video Footage of Smoke/Fire Detection

1.17.6 Cargo Handling Training of Asiana Airlines

The cargo handling manager of Asiana Airlines stated that, in accordance with DG training regulations specified in the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air, IATA dangerous goods regulations, and MOLIT Regulation for Dangerous Goods by Air Transport, Asiana Airlines' employee responsible for DG acceptance shall receive DG training suitable for Duty Category 6[71)] in the DG training institutions approved by the ICAO, IATA, or MOLIT.

Training for Duty Category 6 includes the following curriculum: general principles and systems of DG handling; limitations; general obligations of shippers; DG classification; DG list, packaging requirements; packaging specifications; labelling and marking; DG shipment documents and relevant documents; acceptance procedures; recognition of undeclared DG; DG storage and loading procedures; notice to captains; regulations on passengers and crew members; and emergency response procedures. Among DG training courses, training for Duty Category 6 has the longest training hours and the most training subjects. Initial and recurrent DG training courses for Duty Category 6 take 40

71) Duty Category 6: training for employees of airlines or ground handling companies which accept dangerous goods.

and 24 hours, respectively. Within 24 months after initial training, recurrent training is offered. Trainees are subjected to tests to check their understanding of course material. A score of 80% is considered passing. Also, their training records are stored per each branch office for at least three years.

In addition, to ensure the safe transport of DG, Asiana Airlines also requires its airport cargo service employees, apart from its DG acceptance staff, to complete Duty Category 6 DG training and then perform cargo handling services including DG handling on site.

Basically, loadmasters must complete DG training, and weight and balance training by freighter types[72]. They also must receive DG training for Duty Category 6.

Weight and balance training by freighter types consists of revised weight and balance procedures and revisions, and practice of weighing and balancing. After the completion of training, only those who passed a qualification test given by the cargo service team can obtain a loadmaster certificate of the applicable type. Initial and recurrent weight and balance training courses take 40 and 16 hours, which are minimum training hours, respectively. The certificate is valid for three years after the issue date. Loadmasters should complete recurrent training and pass a re-qualification test before the expiry date to maintain their qualification.

The loadmaster of AAR991 completed a 40-hour DG training and a 24-hour weight and balance training.

1.17.6.1 Training of Cargo Handlers

The cargo handling manager of Asiana Airlines stated that, in accordance with

72) B747-400F and B767.

the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air, IATA dangerous goods regulations, and MOLIT Regulation for Dangerous Goods by Air Transport, employees of Asiana Airport, a company offering ground handling services[73] to Asiana Airlines, completed training suitable for Duty Categories 7/8[74]. Under the regulations, the training program shall consist of 4 hours of initial training and 2 hours of recurrent training within 24 months after the completion of the initial training, but Asiana Airport offers recurrent training annually to enhance DG safety management.

In addition, Asiana Airport's cargo handlers are given in-house duty training according to their given duties, twice a year for 2 hours each (one in the first half year and the other in the second half year). After the completion of the training, they begin to perform their duties such as handling, storing, and loading of cargo, consignment, and mail.

Cargo handlers of AAR991 completed DG training and in-house duty training.

1.17.7 Safety Inspection of Asiana Airlines by MOLIT

The Office of Civil Aviation under MOLIT is responsible for supervising the commercial aircraft registered in Korea. As of the day of the accident, there is a total of 47 air safety inspectors consisting of professionals in each specialty: 10 inspectors responsible for supervising international air transport operators; and 37 inspectors responsible for supervising domestic air transport operators and small air transport operators and for certifying aircraft maintenance organizations.

73) Guidance for port entry and departure of the aircraft, loading management and power support, provision of aircraft operation information, services in relation to boarding, entry, and departure of passengers and crew members, equipment rental, and aircraft cleaning.

74) Duty Category 7: training for employees of airlines or ground handling companies which accept general cargo, exclusive of dangerous goods.
Duty Category 8: training for employees of airlines or ground handling companies which are involved in handling, storing, and loading of general cargo, consignment, and mail.

A total of 10 inspectors, consisting of 6 operations inspectors and 4 airworthiness inspectors, are responsible for international air transport operators. They issue the AOC to them and perform an on-scene inspection. Inspectors in charge of Asiana Airlines consist of 1 operations inspector and 1 airworthiness inspector. In November 2012, MOLIT increased the number of the inspectors to 17[75] to ensure seamless safety inspection activities in response to the reduced inspection time caused by a rapid increase in the number of low cost carriers.

1.17.7.1 Aviation Safety Management System

According to MOLIT's "aviation safety regulations," once air transport operators receive the AOC and begin operations, they are subjected to year-round aviation safety inspection. MOLIT applied systematic inspection methods to aviation safety inspection. In addition, to manage unsafe factors repetitively and with emphasis, the Ministry has divided year-round safety inspection activities into three categories, which are regular inspection, concentrated inspection, and potential risk inspection, and conducted them.

Regular inspection means essential inspection and scheduled inspection which are regularly performed by aviation safety inspectors according to MOLIT's annual inspection plan. For this inspection, a detailed monthly inspection plan is established based on the inspection checklist by area specified in the "Manual for Aviation Safety Inspector."

In accordance with the "Manual for Aviation Safety Inspector", concerns identified during the regular inspection are addressed in the following three ways: correction action in case of violation of various standards and procedures; improvement recommendations for suggesting safety enhancement measures; and on-site correction in case of minor factors which have no direct influence on

75) 17 inspectors: 6 (operations), 6 (airworthiness), 2 (cabin), 2 (flight dispatch), 1 (DG).

safety and can be corrected for a short period of time.

According to MOLIT's aviation safety inspection records, from January 2010 to the day of the accident in July 2011, 279 times of regular inspection were performed on Asiana Airlines, and during this period, a total of 75 concerns were identified and then were addressed by 18 corrective actions, 50 improvement recommendations, and 7 on-site corrections. Asiana Airlines completed all these 75 activities, which were not related, however, to this accident, and its percentage of concerns was at an equivalent level of other Korean airlines.

On the basis of a separate inspection plan, concentrated inspection is performed on concerns which require intensive and extensive verification or are repetitively identified by the analysis/review of regular inspection results. A separate team conducts this inspection to come up with findings and prepares the countermeasures by analyzing them.

On the basis of a separate inspection plan, potential risk inspection is performed to identify potential risk factors and then recommend improvement measures to operators when there is a need to reassess problems with operators' safety management system in the event of frequent cancelations, malfunctions, and serious incidents.

In December 2010, MOLIT performed concentrated inspection on the SMS and operations sectors. As a result, the following safety concerns were notified in writing to Asiana Airlines, and related improvement actions were taken.

- Improvement recommendations about 7 SMS operation-related safety concerns identified as inadequately addressed although Asiana Airlines was performing safety activities such as safety target management, hazard identification and management, etc. according to the SMS manual approved by the government

- Improvement recommendations about 8 safety concerns in relation to inadequate implementation of operations quality management, improper follow-up measures of the FOQA, etc.

In April 2011, potential risk inspection of Asiana Airlines was performed to ensure safe operations by checking whether the airline prepared and implemented countermeasures against incidents and whether it acted on improvement recommendations. As a result, the following safety concerns were notified in writing to Asiana Airlines, and related improvement actions were taken.

- According to a result of checking the implementation of business improvement directives (15 cases), SMS improvement directives (7) and operations improvement directives (8) were being implemented, whereas safety enhancement directives (4) including general inspection of B747-400 wings were already implemented.

1.17.7.2 Post-accident Safety Measures

The aviation safety inspector of MOLIT stated that the Ministry took the following post-accident safety measures: "Special Inspection"; "General Inspection of the Fire Detection System and the Reinforcement of Pilot Training"; and "Aircraft Fire Prevention Measures."

○ **Special Inspection**

After the accident, MOLIT conducted a special inspection of Asiana Airlines from 16 to 19 August to check the conditions of the air cargo and DG transport management, the compliance with DG transport standards, etc. As a result of the inspection, a total of 3 improvement recommendations were made as follows: strengthen DG training for a cargo handling contractor's employees; improve the management of the DG manual; and enhance the quality control of air cargo containers.

- Inadequate DG training for a cargo handling contractor's employees: Those handling dangerous goods were supposed to receive proper job training according to their given duties (12 types) such as transport, ground handling services, etc. but they performed their duties after given a different type of DG handling training.
- Improper management of the DG manual: Without approval of MOLIT, Asiana Airlines changed training material about DG packaging procedures of its DG manual.
- Inadequate quality control of air cargo containers: The maintenance of containers, pallets, and nets is outsourced for repair, but institutional mechanisms for maintenance quality control were unsatisfactory.

○ **General Inspection of the Fire Detection System and the Reinforcement of Pilot Training**

On 14 August 2011, Korean Airlines' B747-400 cargo airplane made an emergency landing at Incheon Airport due to a fire warning during the landing phase. The on-scene investigation revealed that it was a false fire warning because a smoke detector detected, as smoke, vapor caused by the inflow of moist external air. As a result, MOLIT prepared the following safety measures to ensure safe operations of the national airplanes.

- Conduct general inspection of the normal operation of the fire protection and suppression systems of B747 airplanes as well as all type freighters
- Train pilots on response procedures referenced in the QRH, etc. in the

event of a fire warning

- Establish measures to improve cargo loading procedures so that the inflow of outside moisture can be minimized

○ **Aircraft Fire Prevention Measures**

In December 2011, before the investigation conclusion of the ARAIB comes out, MOLIT prepared preemptive safety measures in areas likely to be the causes of a fire, thereby reinforcing prevention activities.

- Enhance air cargo safety supervision
- Establish a DG safety management system
- Reinforce aircraft fire prevention activities
- Reinforce inspection of the conditions of aircraft maintenance support

1.18 Additional Information

1.18.1 Classification of the Cargo Compartment

In accordance with the Korean Airworthiness Standards 25.857, the cargo compartment is classified into either A, B, C or E classes, and the requirements of the compartments of each class are as follows:

○ Class A. A Class A cargo or baggage compartment is one in which-- (1) The presence of a fire would be easily discovered by a crew member while at his station; and (2) Each part of the compartment is easily accessible in flight.

○ Class B. A Class B cargo or baggage compartment is one in which-- (1) There is sufficient access in flight to enable a crew member to effectively reach any part of the compartment with the contents of a hand fire extinguisher; (2)

When the access provisions are being used, no hazardous quantity of smoke, flames, or extinguishing agent will enter any compartment occupied by the crew or passengers; and (3) There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station.

○ Class C. A Class C cargo or baggage compartment is one not meeting the requirements for either a Class A or B compartment but in which-- (1) There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station; (2) There is an approved built-in fire extinguishing or suppression system controllable from the cockpit; (3) There are means to exclude hazardous quantities of smoke, flames, or extinguishing agent from any compartment occupied by the crew or passengers; and (4) There are means to control ventilation and drafts within the compartment so that the extinguishing agent used can control any fire that may start within the compartment.

○ Class E. A Class E cargo compartment is one on airplanes used only for the carriage of cargo and in which-- (1) There is a separate approved smoke or fire detector system to give warning at the pilot or flight engineer station; (2) There are means to shut off the ventilating airflow to or within the compartment, and the controls for these means are accessible to the flight crew in the crew compartment; (3) There are means to exclude hazardous quantities of smoke, flames, or noxious gases from the flight crew compartment; and (4) The required crew emergency exits are accessible under any cargo loading condition.

The lower cargo compartment of AAR991 is a C-class cargo compartment, and the main deck is an E-class cargo compartment.

1.18.2 Cargo Loaded on AAR 991

1.18.2.1 Cargo Unloading and Loading History of AAR991

On 28 July 2011 at 00:05 before leaving for Shanghai, AAR991 arrived at Incheon Airport as flight AAR786 (Frankfurt-Incheon) and unloaded the whole cargo.

From 01:00 to 02:02 on 28 July 2011, 58,265.8 kg of cargo, which is 60 cases by master airwaybill, was loaded on 30 pallets and 5 containers at Incheon Airport. As shown in [Figure 5], 35 positions including 24 in the main deck and 11 in the lower cargo compartment were used.

At positions of main deck, CL, CR, DL, DR, EL, ER, FL, FR, GL, GR, HL, HR, JL, JR, KL, KR, LR, ML, MR, PR, RR, SL and SR were loaded Code M (318 cm × 244 cm) pallets, and at position LL was loaded a Code M container. Positions A1, A2, B1, PL, RL and T were empty.

At position 11P of the forward lower cargo compartment was loaded a Code A (318 cm × 224 cm) container, and at positions 12P, 21P, 22P and 23P were loaded Code M pallets.

At positions 31P, 32P and 41P of the aft lower cargo compartment were loaded Code M pallets, and at positions 43L, 43R and 44L were loaded AKE (153 cm × 156 cm) containers. Position 44R was empty.

1.18.2.2 Cargo Manifest for Incheon Departing Cargo

The total weight of Incheon departing cargo was 39,331 kg by 48 AWBs, and the cargo acceptance time at Asiana Airlines' export storage area was from 27 July at 10:11 through 28 July at 00:06. For security check during acceptance, X-ray screening and explosive trace detection were conducted.

The total weight of cargo transshipped to AAR991 at Incheon Airport was 18,934.8 kg by 12 AWBs as shown in [Table 10], and the weight by departure point is as follows:

Departure Point	Flight No.	Arrival Date & Time	Weight (kg)	Remarks
Osaka	AAR191	27 July 20:15	258.6	DG
Fukuoka	AAR131	27 July 13:10	1,024.9	
	AAR133	27 July 20:40	128.3	
Delhi	AAR768	27 July 12:00	145.0	
Manila	AAR704	27 July 05:00	931.0	
	AAR702	27 July 17:45	21.0	
Frankfurt	AAR542	27 July 12:20	865.0	
Los Angeles	AAR2831	27 July 07:50	1,285.0	
	AAR965	26 July 05:25	11,201.0	
San Francisco	AAR2831	27 July 07:50	3.0	DG
Seattle	AAR2377	27 July 11:30	3,072.0	

[Table 10] Cargo Transshipped at Incheon Airport

As shown in [Table 11], from 27 July at 17:00 through 28 July at 00:30, Asiana Airlines classified cargo according to the assigned master airwaybill numbers and loaded it on the ULDs. When loading the ULDs on the aircraft, the company matched the serial number assigned to each ULD with the applicable position in the cargo compartments according to its load plan.

Loading Order	ULD		Packages (No.)	Weight[76] (kg)	Main Content	Port of Loading /Remarks
	Position	Serial No.				
Order of Loading Cargo on the Main Deck (loading through the side door)						
1	CR	PMC14612OZ	4	940	LED BACKLIGHT UNIT, SILICON	
2	DR	PMC12829OZ	15	865	NETWORKING EQUIPMENT	LA, US
3	ER	PMC14867OZ	17	1,400	NETWORKING EQUIPMENT	LA, US
4	FR	PMC14070OZ	39	1,450	IC	
5	GR	PMC15639OZ	29	2,246	NETWORKING EQUIPMENT	LA, US
6	HR	PMC11554OZ	20	2,645	NETWORKING EQUIPMENT	LA, US
7	JR	PMC14089OZ	18	2,550	NETWORKING EQUIPMENT	LA, US

Loading Order	ULD Position	ULD Serial No.	Packages (No.)	Weight 76) (kg)	Main Content	Port of Loading /Remarks
8	KR	PMC13317OZ	103	2,925	CKD LIGHTUNIT SET, LEAD FRAME, LED PKG, SLF INDUCTOR, MOULD PARTS, PCB, CABLE	
9	LR	PMC15592OZ	5	3,134	FRUIT (CHERRY)	Seattle, US
10	MR	PMC15223OZ	68	3,494	LED, ELBOW FITTING, ADHESIVE PLASTIC, SEMICONDUCTOR DEVICE PART, SUITABLE FOR MANUFACTURING PRINTED CIRCU, LABEL, FACING HEAD UNIT	
11	SR	PMC14489OZ	18	1,520	IC, T R PACKAGE, EZ CLEAN, SILICON, COMPRESSOR	
12	SL	PMC14841OZ	40	2,480	HARD DISK DRIVE FOR PLAY STATION, DIFFUSION FILM, EITAXIAL WAFER, CASE POLE SPACER BOTOM, BRAZE FILLER PASTE, MAS FLOW EQUIPMENT	
13	RR	PMC15301OZ	24	1,260	TFT DISPLAY GLAS SCREEN NEC RELAYS, EITAXIAL WAFER, CASE POLE SPACER BOTOM, BRAZW FILLER PASTE, MASS FLOW EQUIPMENT, DIE ATTACH FILM	
14	CL	PMC12988OZ	22	1,370	FABRIC, IC DRIVER SOURCE	
15	DL	PMC11437OZ	6	1,590	LED BACKLIGHT UNIT	
16	EL	PMC12174OZ	54	1,975	LEAD FRAME, SLF INDUCTOR, MOULD PARTS	
17	FL	PMC12854OZ	18	2,495	NETWORKING EQUIPMENT	LA, US
18	GL	PMC15528OZ	19	2,000	CHIP ON WAFER, ELECTRICAL GOODS, IC, SILICON	
19	HL	PMC11340OZ	3	1,454	BRAKE HOSEFITTING, BOLT	
20	JL	PMC14695OZ	40	1,878	TRANSFER ROLLER, COMPUTER, PLATE, ANTTENA PART, PCB SOURCE, CKD BACKLIGHTUNIT, SECURITY PRODUCT	
21	KL	PMC12355OZ	13	3,050	SEMICONDUCTOR, WAFER, TRANSFER, CYLINDER DIA 125MM QUINTEC, ELECTRODE FOR CCFL	
22	LL	AMA08668OZ	260	2,990	PHOTOMASK, IC	
23	**PR**	**PMC13389OZ**	**65**	**1,575**	**LITHIUM-ION BATTERY, PAINT, AMINES LIQUID CORROSIVE, AUTOMOTIVE PART, PHOTO COLOR RESIST, FLAMMABLE LIQUID**	**DG Loaded**
24	**ML**	**PMC11978OZ**	**161**	**1,790**	**FLAMMABLE LIQUID, PCB, CMOS,**	**DG**

Loading Order	ULD Position	ULD Serial No.	Packages (No.)	Weight[76] (kg)	Main Content	Port of Loading /Remarks
					CONNECTOR, IC, SILICON, COMPRESSOR, BAG SHIELDING	**Loaded**
Order of Loading Cargo on the Lower Deck						
1	23P	PMC13363OZ	60	1,730	SHAFT SUB ASSYETC, IC DRIVER SOURCE, WOVEN FABRIC	
2	22P	PMC15460OZ	8	1,680	DENSE LOADER, EITAXIAL WAFER TFT DISPLAY GLASS SCREEN, CASE POLE SPACER BOTOM, BRAZE FILLER PASTE MASS FLOW EQUIPMENT	
3	21P	PMC12799OZ	24	1,182	IC DRIVER SOURCE, CLEANING DISK, MULTI LCD INSPECTION EQUIPMENT, FILM GUIDE, TEXTILE FABRICS WOVEN	
4	11P	AAP06606OZ	150	1,545	PHOTOMASK, HYNIX MEMORY CHIP, MASK, CIS WAFER	
5	12P	PMC15494OZ	4	2,584	POLARIZING FILM	
6	31P	PMC15520OZ	5	1,910	POLARIZING FILM	
7	32P	PMC13821OZ	36	2,415	AUTO PARTS SEAL, COMPUTER PARTS, SAFEELIA PIT EM150 (PRODUCT NAME), BOBBIN ASSEMBLY, TEXTILE FABRICS, WOVEN FABRIC, SATELLITE RADIO PART	
8	41P	PMC12697OZ	19	2,650	PMC PALLET STACK (PMC _____ OZ) 10699, 11508, 12617, 13173, 13473, 13853, 14126, 14384, 14771, 14864, 15104, 15161, 15455, 15497, 15520, 15845, 15860, 15917, 16136	
9	43L	AKE20493OZ	36	363	MEMORY, SYSTEM LSI	
10	43R	AKE28149OZ	15	363	IC, SYSTEM LSI	
11	44L	AKE21128OZ	18	440	EXPRESS CARGO	
Total Weight of Cargo				65,938		

[Table 11] Cargo Manifest of AAR991

1.18.3 Dangerous Goods

As shown in [Table 12], dangerous goods loaded on the accident flight were products of 6 companies covered under 8 master airwaybills. All of these shipments were loaded on the main cargo deck. Two of them, photo-resist/IC,

76) A total weight including the ULD, net, packaging materials, etc.

were located on the pallets situated in positions ML and PR, and the remaining 5 shipments were located on the pallet situated in position PR. Both positions ML and PR were adjacent to the main deck side cargo door. The dangerous goods included flammable liquids, corrosive liquids, and lithium-ion batteries.

Dangerous Goods	AWB No. 988 -	Port of Departure	Total weight (kg)	Net Q'ty*	Item Description
Lithium-ion batteries	-63857393	Osaka Japan	258.6	243.6 kg	-Lithium-ion battery for hybrid automobile
Photo-Resist/IC	-68738121	Incheon	114	41.58 L	-Sensitizing solution for raising the sensitivity of semiconductor
	-68738110		386	166.32 L	
	-68738132		621	272.16 L	
Photo-Resist/LCD	-68693542	Incheon	679	477 L	-Liquid synthetic resin for coating LCD panel
Amines Liquid Corrosive N.O.S.	-68119586	Incheon	8	5 L	-Anti-static agent for preventing static electricity -Mixed liquid for preventing dust from attaching to paint and impurities from attaching to various products
Paint	-68527056	Incheon	22	12 L	-Paint for damp proof insulation of electronic circuit
Inspection Seal Lacquer	-68019571	San Francisco US	3	0.236 L	-Seal lacquer for preventing loosening of bolt/nut

* Net weight or volume of the dangerous goods before packed.

[Table 12] Dangerous Goods Loaded on AAR991

1.18.3.1 Lithium-ion Batteries

A lithium-ion battery is a secondary battery[77], which uses a lithium salt in an organic solvent, consisting of positive and negative electrodes, thin film, electrolyte, and a container. The positive electrode is a metal oxide, and the negative one is made from carbon. They are used to coat a thin film of aluminum and copper, respectively, thereby forming electrode plates after being dried. According to a metal oxide, lithium-ion batteries are categorized into LCO (Co), NCM (Ni, Cd, Mn), NCA (Ni, Co, Al), LMO (Ni, Mn), and LFP (Ni, Fe, P).

77) Electric energy storage device which can recharge and discharge repetitively.

Lithium-ion batteries shipped onboard the accident airplane were regulated as Class 9[78)] UN3480, Packing Group Ⅱ, dangerous goods. They were in either a 6-cell or 12-cell configuration for use in hybrid electric vehicles. The individual cells were rated at 24.4 - 24.8 Ah at 3.65 volts and 89.1 - 90.5 Wh. The shipment contained a total of 18 lithium-ion batteries, including 15 of the 12-cell configuration and 3 of the 6-cell configuration.

As shown in [Figure 51], 12-cell batteries were packed 1 per box in 15 fiberboard boxes, whereas 6-cell batteries, 2 per box in 2 fiberboard boxes, and the remaining one was packed individually, so there was a total of 17 fiberboard boxes. The entire shipment was prepared on a single pallet wrapped in plastic and loaded at the main deck PR position.

[Figure 51] 12-Cell (Left) & 6-Cell (Right) Lithium-ion Batteries

[Figure 52] 1-Cell Battery

78) Class 9 is classified by ICAO as miscellaneous dangerous substances and articles including lithium-ion batteries, dry ice, etc.

[Figure 52] above shows a 1-cell battery measuring 148×91×26.5 mm and weighing 0.69 kg. The manufacturer stated, in case of a battery fire, it can be extinguished by carbon dioxide, nitrogen, water, and powder extinguishant (ABC extinguishant).

1.18.3.1.1 Results of Testing Lithium-ion Batteries by the Manufacturer

The lithium-ion battery manufacturer provided data in relation to the testing of 50 cells produced between 2 March and 14 May 2009 according to the method and standards prescribed in the "UN Recommendations for Transport of Dangerous Goods."

- The manufacturer's test report indicated the cells were subjected to an altitude simulation test, thermal test, vibration test, shock test, external short-circuit test, impact test, overcharge test, and forced discharge test, and that they passed all of them.

In addition, one of the lithium cells produced from each lot[79)] was extracted randomly to conduct tests such as nail penetration, submergence, and contact with chemical substances, and all the tests showed no exceptions that would lead to thermal runaway or fire.

The nail penetration test simulates a worst case failure by short-circuiting the battery at 10% and 100% state-of-charge (SOC). Based on a risk assessment from this testing regime, the manufacturer has adopted 10% SOC as the standard for all of its lithium-ion battery shipments.

1.18.3.1.2 Manufacturer's Inspection Before Packing

79) Product unit of a specific number produced in one batch.

The manufacturer stated that each battery produced is subjected to quality assurance inspections before packed for shipment, and added that cells and stacks loaded onboard the accident aircraft all passed them.

- Cell inspection items are visual inspection, insulation film condition inspection, internal short-circuit inspection, and physical characteristics inspection.
- Stack inspection items are size inspection, weight inspection, and visual inspection.

1.18.3.1.3 Packing Container

The Dangerous Goods Declaration for the shipment of lithium-ion batteries loaded onboard the accident airplane indicated that packaging was in accordance with ICAO TI Packing Instruction 965.

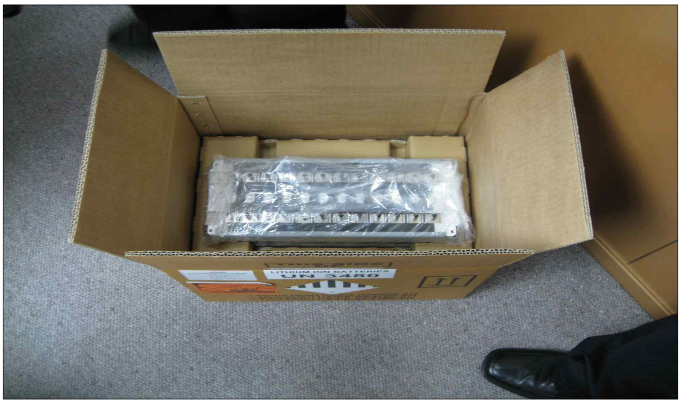
The packing containers used for the lithium-ion battery shipment were specification 4G/Y40 fiberboard boxes. The packing weight limit for each box used for Packing Group Ⅱ materials, such as lithium-ion batteries, was 40 kg.

The manufacturer stated the reason for packing at or below 40% of the packing weight limit was that the safety margin was taken into consideration. Under the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air, the lithium-ion per package quantity limitation for cargo aircraft is 35 kg.

1.18.3.1.4 Packing and Shipping

The produced batteries have the terminals covered with insulating material to prevent external short-circuit in transit and are packed as shown in [Figure 53].

The polyethylene wrapping has a melting point of 122℃.



[Figure 53] Batteries Wrapped in Plastic

The lithium-ion batteries were wrapped with polyethylene and secured with fiberboard inner packaging material fit for the shape of the battery. A sheet of impact-resistant bubble wrap was placed in the top of the box and closed to complete the packaging.

The manufacturer stated that the product is kept in a separate place with temperatures between 20 - 30℃ before shipping, that humidity does not affect battery performance, and that there had been no abnormal cases during sea, land, and air transport of the lithium-ion batteries. [Figure 54] shows the final packaging of lithium-ion battery shipment in a production plant.

[Figure 54] Final Packaging of Lithium-ion Battery Shipment

1.18.3.2 Photo-Resist/IC

This product is used for integrated circuit (IC) manufacturing and is regulated as Class 3 UN1993, Packing Group Ⅲ, flammable liquid. As shown in [Figure 55], transparent photo-resist solution was contained in either a purple- or yellow-labeled glass container. The dangerous goods declaration indicates that packaging was in accordance with ICAO TI Packing Instruction 366.

[Figure 55] Purple & Yellow-Labeled Containers

The main component in product is propylene glycol monomethyl ether acetate (PGMEA), which makes up 50 or more percentage of its weight.

The product is stored and transported between 0 and 10℃. The safety of the product is not affected by temperatures that exceed 10℃, but the quality of the product is compromised and no longer marketable. The manufacturer said that it is not necessary to maintain the aircraft cargo compartment at a specific temperature since the product is packed so as to maintain optimum temperature until destination.

The MSDS[80] indicates the following: the flash point[81] of the product is 4

80) Material safety data sheets (MSDS) conform to the United Nations' Globally Harmonized System of

2℃; high-temperature heat, sparks, and flames should be avoided during handling; explosion proof facilities should be used; and acrid smoke and poisonous gases are generated if the product is exposed to high temperatures or during fire.

The shipment included a total of 127 brown glass containers (1 gallon per container). These containers were covered with black plastic bags. Four[82] of these glass containers were placed in one UN specification fiberboard box into form-fitted Styrofoam blocks (providing 360° bracing and maintaining temperature) with blue ice and a digital temperature recorder to keep the product cold. There was a total of 32 fiberboard boxes packaged in such a way.

The manufacturer handled the process from packaging to loading the product onto a transport vehicle. Yet its person in charge of DG packaging was not aware of the dangerous goods handling procedures and just understood that the product should be safely handled in a special custom-made box (UN specification) to be protected from damage in transit.

The manufacturer contracted the third-party dangerous goods handling agent approved by the Korean government on 20 June 2011 to transport the boxes by land, and the agent completed the shipper's declaration for dangerous goods without opening any of the boxes.

They were loaded on pallets at positions ML and PR. Five overpacks[83] made by binding 29 small packaging boxes were loaded at ML, and one overpack made by binding three small packaging boxes was loaded at PR.

Classification and labelling of Chemicals. The MSDS outlines the dangers, composition, safe handling, and disposal of hazardous chemicals.

81) A flash point is the lowest temperature at which a product can vaporize to form an ignitable mixture in air.

82) Three glass containers were contained in one fiberboard box.

83) Repacking with wood or strong protective material for protection or transport convenience.

1.18.3.3 Photo-Resist/LCD

This product is a highly flammable liquid and is regulated as Class 3 UN1866, Packing Group Ⅲ, flammable liquid. The dangerous goods declaration indicates that packaging was in accordance with ICAO TI Packing Instruction 355. The main component in product is propylene glycol monomethyl ether acetate (PGMEA), which makes up 50 - 60% of its weight, and is similar to the aforementioned photo-resist solution.

The MSDS indicates that the flash point of the product is 43 - 47℃ and that the product may explode in the case of heating. Photo-resist is used for LCD manufacturing, and it is either a bright blue or bright red liquid, designated by the "B" or the "R" in the product name. The integrity of the product is sensitive to temperature and light.

The product was contained in 53 brown plastic 10-liter containers, each of which was filled with 9 liters of a blue or red liquid. As shown in [Figure 56], the containers were each enclosed in clear plastic bags and were packed 2 per 1 fiberboard box inside Styrofoam inserts with blue ice to keep the product cold. There was a total of 27 fiberboard boxes. The manufacturer packed two digital temperature recorders[84)] with each bulk shipment to ensure safe transportation and prevent the product from being compromised.

These 27 boxes were contained within three[85)] fiberboard box overpacks and loaded on a pallet at position PR.

These plastic containers are made of high-density polyethylene with a polyethylene screw cap that has a Teflon coated gasket. They were subjected to

84) This temperature gauge can check only the highest temperature inside of the box to confirm the marketability of the product.

85) Ten fiberboard boxes each packed into two overpacks and seven fiberboard boxes packed into one overpack.

a 12-hour inverted leak test, a 120 cm high drop test, and a 20 Kpa pressure test for 5 minutes.

[Figure 56] Photo-Resist & Internal Packaging of Each Package in Shipment

This product is stored at 5℃ in the manufacturer's facility and transported in a refrigerated truck to a dangerous goods handling agent. The safety of this product is not affected by temperatures that exceed 5℃, but the quality of the product is compromised and no longer marketable.

The manufacturer's person in charge stated that they have not had any leaking containers in 8 years of shipping this product, and that no containers had been returned due to a defective product.

1.18.3.4 Amines Liquid Corrosive N.O.S.

This product is a corrosive liquid and is regulated as Class 8 UN2735, Packing Group Ⅲ, corrosive material. The dangerous goods declaration indicates that packaging was in accordance with ICAO TI Packing Instruction 856. The main component is ethoxylated alkylamines, which makes up 90% of its weight. Its flash point is greater than 100℃.

The MSDS indicates that the product has no special risks of flammability or explosion. It is a clear colorless liquid.

The product was supplied to a domestic company by a French company, and was repackaged and transported through a cargo agent. The cargo agent classified the product, selected packaging materials, and completed the shipper's declaration for dangerous goods. The cargo agent packed dangerous goods every three months on behalf of the domestic company. The agent's person concerned stated that he checked the plastic containers for leakage prior to further packaging activities, and that they have not had any product in an unsatisfactory condition, i.e. a leaking container.

This shipment consisted of one 5-liter plastic container. This container was placed into a plastic bag which was then tied closed, and as shown in [Figure 57], Styrofoam sheets were form fitted around the container within the fiberboard box with "Corrosive" labels affixed. The shipment was loaded at ULD position PR.

[Figure 57] Exemplar Final Packaging of Amines

1.18.3.5 Paint

This product is provided by a Japanese supplier to a domestic company which supplies it to the Asian region through a distribution company. It is regulated as Class 3 UN1263, Packing Group Ⅱ, flammable liquid. The dangerous goods declaration indicates that packaging was in accordance with ICAO TI Packing Instruction 364. The main component in product is Ethylcyclohexane, which makes up 50 - 60% of its weight.

The MSDS indicates that it has a flash point of -1℃ and that vapor may form an explosive mixture in air, exceeding -1℃. It is a blue transparent liquid. The product should be stored at temperatures below 35℃ (below 25℃ according to the AWB).

The shipment included a total of 12 metal containers of product (open or close by screwing the metal lid), each with 1 liter of product. As shown in [Figure 58], the containers were packed 12 per box inside Styrofoam inserts.

[Figure 58] Exemplar (Left) & Final (Right) Packaging of Paint

The products were packed in one UN specification 4G fiberboard box and overpacked. The shipment was loaded on a pallet and transported to a dangerous goods handling agent. The agent visually inspected the shipment on the pallet for damage and attached "flammable" labels, and completed the shipper's declaration for dangerous goods. The entire shipment was loaded at ULD position PR.

1.18.3.6 Lacquer for Seal Inspection

This product is a colored paste and is regulated as Class 3 UN1263, Packing Group Ⅲ, flammable liquid. The dangerous goods declaration indicates that packaging was in accordance with ICAO TI Packing Instruction Y344. The main component in product is ethanol, which makes up 30 - 60% of its weight. It has a flash point of 42.8℃.

As shown in [Figure 59], the shipment included a total of 16 plastic tubes of product, approximately 15 grams per tube, and the total amount of product was 0.236 liters. The tubes of the product were packed in one fiberboard box with "flammable" labels affixed. The shipment was located on a pallet in ULD position PR.

[Figure 59] Final Packaging of Torque Seal Shipment & the Product

1.18.4 Statements of the Cargo Handlers

The Cargo Group interviewed the Asiana loadmaster and 9 Asiana employees who handled the dangerous goods shipments and obtained written statements, the content of which is as follows:

As part of Asiana's cargo shipment acceptance process, all of these shipments were x-rayed at the Asiana Airlines cargo terminal of Incheon Airport, with the exception of the lithium-ion batteries which departed Kansai International Airport in Japan and the lacquer which departed San Francisco International Airport in the US.

Out of the dangerous goods in [Table 12], the photo-resist solutions[86) of the two companies described in 1.18.3 were temporarily stored in the cool room at the Asiana facility prior to being loaded onto the two pallets. The lithium-ion batteries[87) and three dangerous goods[88) including paint and lacquer were stored in Asiana's temporary DG storage area which is a permanent area for storing the dangerous goods in isolation from other general cargo. This area is also used to temporarily store the dangerous goods shipments in transit or for export, prior to being loaded onto pallets.

On 27 July 2011, about 22:05, the dangerous goods were collected for placement on two pallets. Asiana Airlines' employee in charge of handling transit cargo inspected packaging, labelling, marking, and related documents of the lithium-ion battery shipment. Then, the shipment was brought to the build-up area[89) in the warehouse.

After loaded on a pallet, the shipment is normally wrapped in plastic twice, but at the time, it was done so three times due to rain forecast. Around 23:30, the build-up of the two pallets was completed. The loadmaster then signed for

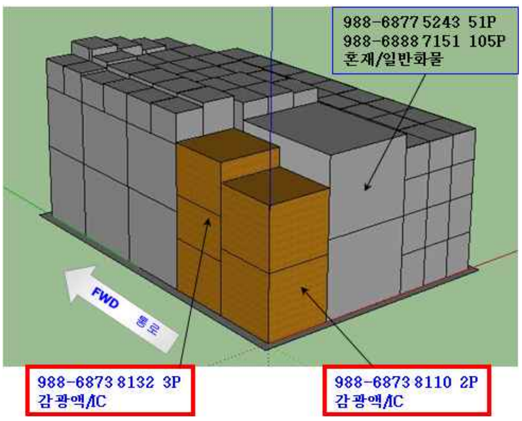
86) MAWB No.: 988-68738110 (2), 988-68738132 (3), 988-68693542 (3), and 988-68738121 (1).
87) MAWB No.: 988-63857393 (1).
88) MAWB No.: 988-68119586 (1), 988-68527056 (1), and 988-68019571 (1).
89) A build-up area does not mean a specially designated separate area, being a place in the warehouse where loading of export cargo is carried out.

the dangerous goods shipment, and the two dangerous goods shipment pallets were weighed and loaded.

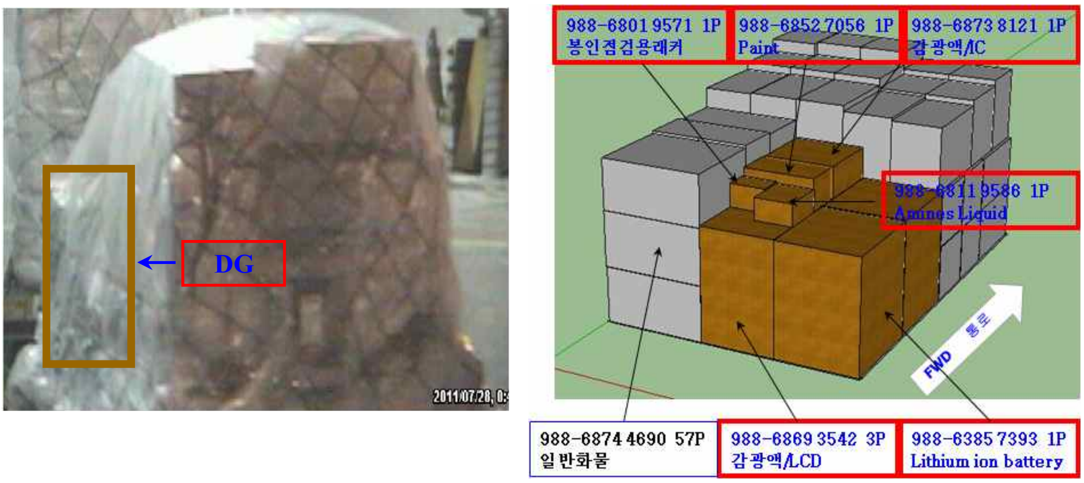
Neither the loadmaster nor any of the nine cargo handlers noted any damage, leakage, or other problems with the dangerous goods shipments during the cargo checks in their statements.

The CCTV images on the left in [Figure 60] and [Figure 61] show the two dangerous goods pallets, PMC11978OZ and PMC13389OZ, which were being transported to be loaded into ULD positions ML and PR, respectively, on 28 July, about 00:47. The images on the right in [Figure 60] and [Figure 61] show the simulations of the build-ups of the two dangerous goods pallets, which were created based on the Asiana cargo handlers' recollection of package positioning on the pallets.

The two pallets of dangerous goods were loaded onto the airplane between around 01:00 and 02:00 on 28 July 2011. At about 02:15, the captain of AAR991 was then informed of the nature of the dangerous goods shipments onboard by the loadmaster, and was escorted to the two dangerous goods pallets in ULD positions ML and PR.



[Figure 60] CCTV Image (Left) & Simulation of Build-up (Right) of Pallet PMC11978OZ (ULD Position ML)



[Figure 61] CCTV Image (Left) & Simulation of Build-up (Right) of Pallet PMC13389OZ (ULD Position PR)

At approximately 02:30, the captain signed the Notification to Captain for special load (NOTOC[90]), weight & balance sheet, load manifest, and cargo loading check list.

1.18.5 Maintenance and Repair of Cargo Container/Equipment

The maintenance records for the ULDs that were loaded on the accident airplane were reviewed. The records cover any maintenance issues that arose over the past year. No uncorrected defects were noted. All reported damage had been repaired in accordance with the supplier's instructions.

On 11 August 2011, the Cargo Group visited Asiana's cargo facility at Incheon Airport. During the visit, the conditions of approximately 20 ULDs were checked while observing cargo loading on a 747-400SF (HL7414) airplane that is similar to the accident aircraft. Approximately 20 ULDs were checked and found

90) A document that notifies the captain of dangerous goods and other special load (animals/DG, etc.) among all shipments at the cargo departure airport. NOTOC lists the location and quantity of cargo, type of packaging, and procedures to follow in the event of an emergency, which are in accordance with international standards (Technical Instructions for the Safe Transport of Dangerous Goods By Air by ICAO, Part 7, 4.1).

to be all serviceable.

Some of the containers had visible repairs. The pallet nets were all found to be serviceable and properly installed.

Approximately 25 ULDs in the Asiana warehouse were checked, and all were serviceable. So were two AKE containers in the warehouse.

Asiana Airlines installs a thick protective plastic sheet under flammable liquid cargo, in addition to the two sheets of thinner plastic used to cover the palletized loads, as a means of preventing any possible leakage and also for security reasons.

1.18.6 Cargo Handling System

The main deck cargo handling system of the accident airplane, which consists of drive units, conveyance, and restraints, was manufactured by Telair International and was installed under an FAA issued Supplemental Type Certificate (STC).

The Cargo Group checked the maintenance records for the main deck and lower cargo handling systems for the accident airplane. These maintenance records covered repair history for the last two years. Review of these records revealed only normal maintenance of the systems.

On 11 August 2011, the Cargo Group visited Asiana's cargo facility at Incheon Airport. During the visit, the group checked the conditions of the cargo handling system on B747-400SF (HL7414), which was found to be serviceable.

1.18.7 Dangerous Goods Handling Procedures

Asiana Airlines' cargo handling procedures conform to international and domestic standards. All air cargo procedures are documented in the Asiana Cargo Service Operation Procedure in its current revision. More specifically, standards of the DG, transport documents, cargo handling and loading, and dealing with accidents are referenced in Chapter 9 of this manual.

In addition to the aforementioned procedures, Asiana Cargo at its Incheon Airport facility has additional guidance in the form of an "Additional Dangerous Goods Handling Procedures to IATA Dangerous Goods Regulations (DGR)", last revised in August 2011. This guidance also includes specific procedures utilized by Asiana Cargo acceptance personnel to prevent the acceptance of undeclared dangerous goods.

Cargo agents intending to offer dangerous goods shipments at Asiana Cargo's Incheon facility are required to register with the air carrier as a "Dangerous Goods Handling Agent" by submitting IATA Dangerous Goods Regulations (DGR) training completion documentation for personnel involved with preparing documentation and inspecting dangerous goods shipments, prior to offering to Asiana Cargo.

As of the day of the accident, Asiana Cargo has a roster of 96 freight forwarder/cargo agent entities approved to offer dangerous goods cargo at its Incheon facility.

All dangerous goods must be tendered loose to be visually examined. Asiana Cargo dangerous goods specialists, using the DG acceptance checklist made by Asiana Airlines on the basis of IATA DGR, carry out DG acceptance inspection. More specifically, they inspect documentation, packaging conditions, marking, and labelling of the DG in accordance with the checklist.

Since the dangerous goods need to be isolated due to their different characteristics from those of general cargo, an employee is separately allocated for access control. During acceptance/release of the dangerous goods, the external conditions of the dangerous goods packaging are checked while the records of acceptance/release are maintained. To prevent a leakage during transport of liquid dangerous goods, a company regulation requires the shipments to be overpacked.

The dangerous goods are barred from being loaded onto a bulk cargo compartment where ULDs are not used. After the dangerous goods are loaded, a checker and a loadmaster separately prepare and sign their own dangerous goods field checklist for confirming the following: packaging conditions when loaded; dangerous goods recognition tags; regulations on DG segregation; damage; documentation; compliance with loading regulations; and preparation of NOTOC. The dangerous goods recognition tags for DG shipments in positions ML and PR contain such information as DG class, UN number, weight, and exclusive transportation by freighter. These tags are hung on the pallet nets instead of being affixed.

1.18.8 Interview with Asiana Airlines Flight Crew and Others

From 4 August 2011 through 11, the Operations Group investigators, a captain from the Boeing Company, and Asiana Airlines' persons concerned carried out interviews with a total of 15 people including a simulator instructor and pilot examiner, captain, first officer, flight dispatcher, emergency equipment ground school instructor, dangerous goods instructor, and line mechanic.

The following is the summaries of the interviews about Asiana flight crew's fire-related training, etc.

○ **Simulator Instructor, etc.**

Boeing contract instructors teach Asiana Airlines' procedures as well as evaluate trainees, and must have a Korean pilot license. They are also required to ride the cockpit jump seat biannually.

Asiana Airlines' simulator is configured as a B747-400 passenger aircraft, mirroring HL7418. There is no Fire Main Deck non-normal malfunction option[91)] on the instructor panel, and the overhead panel switch does not have the cargo depressurization option.

Instructors use a schematic from Asiana FCOM to simulate the Fire Main Deck scenario. The instructor has students point to the switch they would be pushing to activate the main deck depressurization.

○ **B747-400 Captains**

According to the statements of B747-400 captains, Fire Lower Deck procedures were included[92)] in the simulator training syllabus in the second half of 2011.

When asked about when was the last Fire Main Deck training, two captains answered they did not remember. During the Fire Main Deck training, when the instructor gives the situation, pilots follow the QRH checklist and "imagine" that the simulator is a cargo airplane at time of the scheduled fire because the Asiana simulator is a passenger configuration. Before entering the simulator, the instructor discusses the cargo fire with trainees and teaches them three buttons for the Fire Main Deck in the briefing room. In the simulator, the instructor sets the situation (cargo fire), and messages then come up for the "lower cargo fire", but not the main deck. Pilots follow the Fire Main Deck checklist and don the

91) Fire simulation artificially made by the instructor in the back seat.
92) The accident flight crew’s simulator training in the second half of 2011 was scheduled after the accident.

O2 mask. The 25,000 feet level off in the fire main deck checklist is a procedure, and depressurization results in a lack of oxygen.

Asiana's O2 masks are all full face masks. One of the captains was trained on O2 masks from Boeing when he first received his B747-400 training. O2 masks are trained at Asiana in ground school by use of hood for PBE training instead of the actual airplane O2 masks. During initial ground and recurrent training, they are learned from textbooks. During preflight, 100 percent and normal switches on the O2 mask module are checked, and so are the emergency knob and O2 flow pressure.

Captains received information on the dangers of lithium-ion batteries and in-flight fire in ground school, and several relevant notices have been posted on the Intranet. The last notice one captain remembered was the one about a call for caution in dealing with lithium-ion batteries.

In the simulator, instructors instruct pilots to don O2 masks[93].

When a captain operates a cargo airplane, he checks with NOTOC and cargo loading, then walks around to inspect the dangerous goods after the cargo is loaded.

○ **B747-400 First Officer**

He said captains conduct walkarounds on the aircraft while first officers check the cockpit. When he had his last trip with the captain of the accident airplane, the captain walked around the aircraft and checked the main deck, as required. He stated that captains check the security of cargo and ceiling clearance (2 inches) during their walkarounds.

93) One pilot stated that sometimes he would practice donning the mask but it was not required during simulator training, and that it would depend on the instructor.

He said dangerous goods are also checked based on NOTOC, and that crew members should be aware of where they are loaded.

○ **B747-400 Chief Pilot**

He said since you cannot practice Fire Main Deck in a simulator, Boeing instructors inform trainees of a Fire Main Deck situation and have them imagine it. They help them note the differences by using FCOM.

He said training changed after the fatal UPS 6 crash in 2010 to include "cargo fire" in the training syllabus.

○ **B747 Flight Dispatcher**

When asked why the flight was carrying extra fuel (tankering[94)]), he said it was normal when flying to China since fuel was expensive there and it was cheaper to carry it.

○ **Manager of B747-400 Training Program**

He made the simulator profiles as well as LOFT scenarios and ground school schedules as per flight crew training regulation (FCTR). He develops the draft program, then sends it to Boeing for review. When the review process is completed after two months of discussion over the content, the final program is finally made.

The subject of Lower Cargo Deck Fire was integrated into the recurrent simulator training in the second half of the year due to the idea of the UPS 6 accident in 2010.

94) Policy of loading extra fuel for the next flight at the airport where fuel price is low.

○ **Line Mechanic**

After the accident airplane arrived at Incheon Airport, he saw the cargo being off-loaded and found nothing unusual. He did not know if the cargo contained dangerous goods and did not see any damaged cargo. He did some checks in the main deck when the aircraft was empty, but there was no damage to the main deck, let alone fluid on the floors.

He ran a transition checklist on the aircraft between flights. He said there were no defect items, and that the weather was clear with no rain during ground inspection.

○ **Emergency Equipment Ground School Instructor**

Pilots receive emergency equipment training once each year, which is delivered through PowerPoint presentations and videos, and they practice with a real life jacket, PBE, and fire extinguisher. The emergency exit door and raft, and emergency survival equipment are trained every year. Fire extinguisher training is just "pretend" and not with a live fire. Emergency evacuation training is carried out every three years.

○ **Dangerous Goods Instructor**

He said an Emergency Response Drill Guide indicating crisis response for captains is kept in the cockpit, along with NOTOC. Additional information about the dangerous goods on the aircraft comes from the shipper's declaration.

He stated that in 2010, Asiana pilots received a lot of lithium-ion battery-related training, including the dissemination of the UPS 6 accident in 2010.

2. Analysis

2.1 ACARS CMC Messages

Among the ACARS CMC messages received from AAR991, maintenance messages in relation to FDE messages were interpreted according to the maintenance manual. This interpretation, which can be found in Appendix 1, consists of the following: time a related maintenance message first became active; maintenance message number; message content; intermittence; activity; related FDE message and number; and FDE level.[95] It also describes required conditions for a message, meaning of a message, and content of a related FDE message.

Analysis of the ACARS messages received by the ground station revealed that, at 03:53:XX,[96] the first fault messages were detected in fire zone 11 at the aft main deck compartment and the E/E compartment.

The FDE message, "CGO DET 11 MN DK," was generated in relation to the maintenance message, "CARGO FIRE MAIN DECK ZONE-11 LOOP-A FAIL." This LOOP-A FAIL message can appear when the following conditions are met: ① The zone 11A detector was in alarm for at least 8 seconds without the Zone 11B detector being in alarm; ② The 11A detector failed to pass a "disagree" test from the zone 11 AFOLTS[97] card; and ③ The wire from the zone 11A detector to the AFOLTS was open circuit when a "disagree" test was performed. Because this fault was correlated to "CGO DET 11 MN DK" and not to "MD CGO 11 LP A,"[98] the zone 11B detector was in alarm or faulted within 20

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95) Levels: Warning, Caution, Advisory, Status.
96) XX indicates that seconds are unknown.
97) They are eight printed circuit cards installed in the E/E compartment, which offer the interpretation of the fire detected signal, system function inspection, fire alarm output, fire detection system's error direction, etc.
98) "MD CGO 11 LP A" was not generated since loop A in the zone 11 was not faulted. In other words, it is assumed that fire was detected.

seconds of the zone 11A detector.

The above message would be consistent with zone 11A and zone 11B detectors being in alarm (detecting smoke) more than 8 seconds but less than 20 seconds apart. In other words, two detectors in zone 11 detected smoke almost at the same time, which, the ARAIB assumes, indicates that there was an in-flight fire near the zone 11 detectors.

The E/E compartment is cooled by a suction fan which draws air from the forward lower lobe left cheek and an exhaust fan which emits air that became hot after passing through the E/E compartment. "EQUIP COOLING" is an EICAS Caution level FDE message that informs the pilots of a problem with the E/E compartment cooling system. One of the several ways this message is generated is when the "EQUIPMENT SMOKE" message, which indicates smoke is detected within the E/E compartment, is displayed for more than 3 seconds.

Subsequently, at 03:54:XX, CGO DET 6 MN DK and CGO DET 10 MN DK messages were displayed, followed by CGO DET 3, 4, 5, 7, 8, and 16 MN DK messages at 03:55:XX. The ARAIB assumes that these messages indicate an in-flight fire, like CGO DET 11 MN DK message.

At 03:56:XX, three FDE messages - PACK 2, PACK 3, and SATCOM - were displayed, which indicates the pilots implemented the Fire Main Deck procedures in the QRH.

At 03:56:XX, the autopilot was disconnected.

From 03:57:23 to 03:59:29, AAR991 descended from 22,700 ft to 13,400 ft. Turbulence data was transmitted four times in total at 03:57:23,[99] 03:57:43,[100]

99) 03:57:23 - altitude 22,700 ft, speed 467 kt, heading 291°.
100) 03:57:43 - altitude 21,300 ft, speed 472 kt, heading 304°.

03:58:47,[101] and 03:59:29.[102] According to weather data and the statements of the pilots who flew over the accident site, there were a weak wind and a clear sky with no cloud accompanied by turbulence or rain over the accident site. Thus, the ARAIB assumes that these four turbulences resulted from the fire's rapid propagation.

After 03:57, the wire running at both upper section near the scene of a fire or under the main deck cargo floor was likely short or open circuit due to the fire. FDE messages associated with system faults are generated by the signal sent through the wire to the EIUs and CMC.

Since the wire, when damaged, is likely to be short or open circuit, faulty signals can be sent to the CMC or EIUs, thereby generating FDE messages. Thus, many of the FDE messages transmitted via ACARS cannot be seen necessarily consistent with actual situations. For example, the message "ELT ON" is generated when the pilots turn on the ELT or when it automatically activates with the impact of 5G and more. Although AAR991 flew for more than 10 minutes after the message was generated, however, its distress signal was not received by the ground stations. Thus, the ARAIB assumes that the message did not mirror an actual situation.

In addition, messages, "DET APU FIRE," "BAT DISCH APU," and "APU" are generated when there is a fault with a fire detector, battery discharge, and a fault with a duct, respectively. The APU was irrelevant to the main deck cargo fire due to the APB and APU firewall, and wreckage examination did not find any evidence of fire. Thus, the ARAIB assumes that the messages generated after 03:57 did not likely reflect actual situations.

From 04:00 until the crash, ACARS messages were not received at all. The

101) 03:58:47 - altitude 16,000 ft, speed 454 kt, heading 344°.
102) 03:59:29 - altitude 13,400 ft, speed 453 kt, heading 011°.

ACARS messages are transmitted via SATCOM and VHF3. The SATCOM system was not in operation at 03:56 when the pilots implemented fire suppression procedures in response to a cargo fire, and thus, the reasons why the messages stopped being transmitted after 04:00 were as follows: ① ACARS MU was so damaged that the messages could not be generated; ② the pilots selected VHF3 to use for voice communications; and ③ VHF3 was inoperable.

According to Asiana's FOM 13.5.2.2 (Data Communications Network Maintaining Procedures), VHF3 shall not be used for voice communications with ATCs in normal times since the use of VHF3 during the operation of the ACARS will stop ACARS messages from being transmitted. Therefore, it is determined that the pilots did not use VHF3 for voice communications. It is likely that the ACARS computer was not powered or damaged.

2.2 Operation Issues

2.2.1 Awareness of Fire and Decision to Divert

At 03:53:XX when ACARS messages, CGO DET 11 MN DK, EQUIPMENT SMOKE, and EQUIP COOLING, were generated, AAR991 was cruising at 477 kt at an altitude of 34,000 ft on a heading of 202°. At 03:54:23, while flying 219°R/125 nm (231 km) from Jeju Airport and 075°R/165 nm (305 km) from Pudong Airport, the airplane declared an emergency due to a main deck cargo fire and requested a descent to 10,000 ft. At 03:55:08, AAR991 notified its intention to divert to Jeju Airport to SHI ACC.

At 03:54:37, SHI ACC gave AAR991 a descent clearance and instructed it to turn at its discretion. ARR991 started descending about 03:54:59, about 1 minute and 59 seconds[103] (maximum time difference) after 03:53:XX when the first

103) As EICAS fault messages are time stamped in hours and minutes, seconds are not provided. Therefore, there is a time error of maximum - 60 seconds when an EICAS fault message and its

ACARS message was generated. The airplane started turning right for diversion about 03:56:12[104] when flying at 28,200 ft, about 3 minutes 12 seconds (maximum time difference) after 03:53:XX. It continued to descend at a steep angle[105] from 34,000 ft[106] to 8,200 ft for about 6 minutes and 55 seconds.

2.2.2 History of Flight Control Based on ACARS Messages

At 03:53:XX, when AAR991 was cruising at 477 kt at an altitude of 34,000 ft on a heading of 202°, ACARS messages, CGO DET 11 MN DK, EQUIPMENT SMOKE, and EQUIP COOLING, were generated, followed by many other messages. About 03:54:59, the airplane started descending from 34,000 ft.

[Figure 62] shows AAR991's vertical flight track, altitude, speed, heading, and major ATC/pilot communications. The FDE message CGO DET 11 MN DK, which indicates that smoke was detected in zone 11 of the main deck cargo compartment, is transmitted when it is correlated to the CMC fault message.

The ARAIB concludes that the EICAS message "FIRE MAIN DECK AFT" must have been displayed in the cockpit, but this message was not transmitted to the ground via ACARS since it was not correlated to the fault message.

At 03:56:XX,[107] AAR991 was descending from 28,200 ft to 23,900 ft. At this time, ACARS messages, PACK 2 and PACK 3, were generated by the

time difference is described. As a result, maximum time difference between two successive messages by the minute is 1 minutes and 59 seconds, whereas minimum time difference is 59 seconds (1 minute 59 seconds - 60 seconds).

104) Heading 258°.

105) Sink rate/min: about 3,700 fpm/5,600 fpm/3,900 fpm/4,900 fpm/3,500 fpm/2,100 fpm/2,290 fpm.

106) ICN ATC radar data on AAR991 is as follows: 34,000 ft (03:54:48) - 30,300 ft (03:55:48) - 24,700 ft (03:56:48) - 20,800 ft (03:57:48) - 15,900 ft (03:58:48) - 12,400 ft (03:59:48) - 10,300 ft (04:00:48) - 8,200 ft (04:01:43).

107) 03:56 - PACK 2, PACK 3, >AUTOPILOT DISC, FLAP SYS MONITOR, >NO AUTOLAND, >YAW DAMPER LWR, >STAB TRIM 2, F/D BAR BIAS, SATCOM DATA, STAB TRIM, SATCOM SYSTEM, NO AUTOLAND, >SATCOM, >NO LAND 3 (03:56:00 - altitude 28,200 ft, speed 470 kt, heading 258°).

pilot's implementing Fire Main Deck procedures, along with STAB TRIM, F/D BAR BIAS, and AUTOPILOT DISC, which indicates a fault with stabilizer trim, disappearance of flight director's guidance, and autopilot disconnection, respectively. Therefore, the pilot was likely flying the airplane manually.

At 03:57:XX,[108)] AAR991 was descending from 23,900 ft to 19,100 ft. ACARS messages generated at this time indicate a fault with door L5, inoperative APU fire detection, bottle low, stabilizer auto trim/cutout, EIU disagree, incapability of autolanding, and a fault with left FMC and FDR.

At 03:58:XX,[109)] AAR991 was descending from 19,100 ft to 14,900 ft. ACARS messages generated at this time indicate smoke detected in the lower cargo compartment, cargo bottle discharge/low, and a fault with FMC and elevator feel computer. The ARAIB concludes that the message "FIRE CARGO AFT" must have been displayed in the cockpit, but it was not transmitted to the ground via ACARS since it was not correlated to the fault message.

It is also concluded that the reason why AAR991's speed momentarily increased to a maximum ground speed of 494 kt at 03:58:29 was that AAR991's transition from automatic throttle control to manual one had resulted in the airplane's failure to maintain speed.

At 03:59:XX,[110)] AAR991 was descending from 14,900 ft to 11,900 ft. ACARS messages generated at this time indicate APU battery discharge, a fault with APU, and operation of supernumerary oxygen and ELT.

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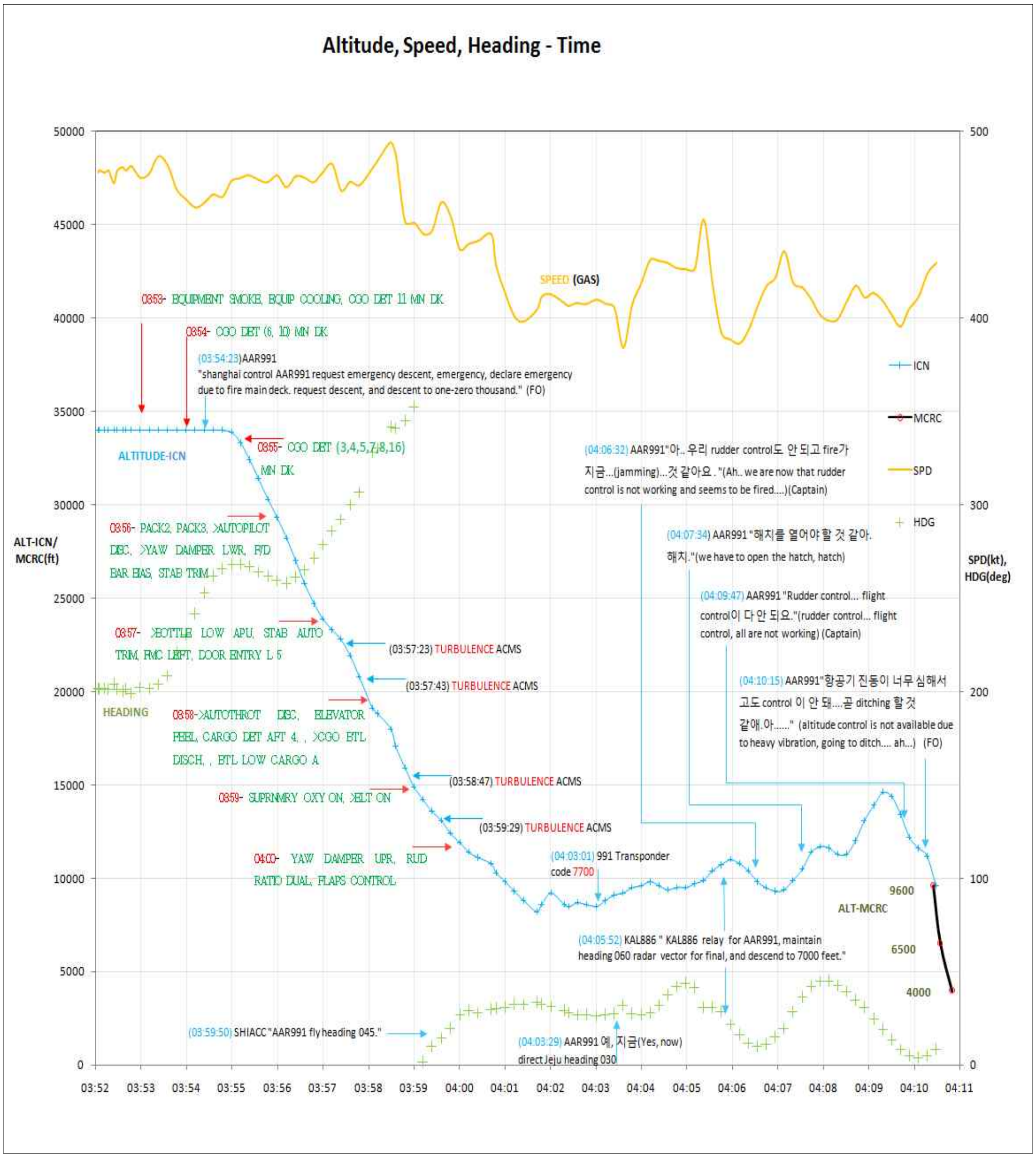
108) 03:57 - >DET FIRE APU, >BOTTLE LOW APU, STAB AUTO TRIM, EIU DISAGREE, FMC LEFT, FMC LEFT, DOOR ENTRY L5, FLIGHT RCDR SYS, STAB AUTO CUTOUT, APU FIRE LOOP B, BOTTLE LOW APU, APU FIRE LOOP A, NO LAND 3 (03:57:00 - altitude 23,900 ft, speed 478 kt, heading 279°).

109) 03:58 - >AUTOTHROT DISC, >CGO BTL DISCH, >FMC MESSAGE, ELEVATOR FEEL, BTL LOW CARGO A, CARGO DET AFT 4 (03:58:00 - altitude 19,100 ft, speed 481 kt, heading 328°).

110) 03:59 - >BAT DISCH APU, SUPRNMRY OXY ON, APU, >ELT ON (03:59:00 - altitude 14,900 ft, speed 451 kt, heading 352°).

At 04:00:XX,[111] AAR991 was descending from 11,900 ft to 9,800 ft. ACARS messages generated at this time indicate a fault with flaps control and rudder control such as upper yaw damper and rudder ratio dual. The messages were not transmitted any more after 04:00:XX.



[Figure 62] Vertical Flight Track Including Altitude, Speed & Heading

111) 04:00 - YAW DAMPER UPR, RUD RATIO DUAL, FLAPS CONTROL, >YAW DAMPER UPR (04:00:00 - altitude 11,900 ft, speed 437 kt, heading 027°).

2.2.3 History of Flight after the Transmission of ACARS Messages

AAR991 that was descending reached an altitude of 8,200 ft[112)] at 04:01:43 and started climbing. After this, the airplane's altitude, ground speed, and heading changed inconsistently until its flight track disappeared from the radar screen about 04:10:50. AAR991's transponder code[113)] was set to 7700 indicating emergency as the airplane climbed to 8,500 ft about 04:03:01[114)].

AAR991 given SHI ACC's instruction to fly heading 045 at 03:59:50 turned right and left repetitively about 7 times until crash, with a heading range between 004 and 045.

When AAR991 informed KAL886 that it was flying direct to Jeju heading 030 at 04:03:29, KAL886 informed AAR991 that SHI ACC gave it heading 045. As Jeju Airport was located 110 nm (204 km) from AAR991 on a heading of 058°, AAR991 deviated about 28° to the left from the route to Jeju Airport. Contributing to this deviation of 28° may be smoke in the cockpit, communications issue, compromised controls, and a defect in the navigation system.

At 04:05:32, KAL886 relayed the message of ICN ACC, "Maintain heading 060, radar vector for final, and descend to 7,000 ft." At this time, AAR991 was flying at 10,300 ft on a heading of 031°, but later turned left to 010°, right to 045°, and again left to 005°, which indicates the airplane's loss of directional control. AAR991 failed to reach an advised heading of 060° until crash.

Between 04:01:43 and 04:09:18,[115)] AAR991 was descending from 14,600 ft

112) Ground speed 404 kt, heading 033°.
113) A transponder is an electronic device that produces a response when it receives a radio-frequency interrogation from the radar on the ground, providing information on the aircraft's location, altitude, speed and situation to the air traffic controller.
114) Ground speed 410 kt, heading 027°.
115) Altitude 14,600 ft, 409 kt, heading 019°.

to 8,200 ft, during which the airplane went up and down about 5 times, and its ground speed (GS) continued to change from 384 kt to 453 kt. After reaching 14,600 ft, as shown in [Table 13], AAR991 continued to descend to 4,000 ft, at which its flight track disappeared from the radar screen of ICN ACC and the MCRC.

Radar	Time	Alt (ft)	Speed (kt)	Descent Rate (fpm)
ICN ACC	04:09:18.305	14,600	409.35	1,020
	04:09:30.061	14.400	401.88	5,099
	04:09:41.828	13,400	395.51	6,120
	04:09:53.592	12,200	404.74	3,047
	04:10:05.405	11,600	411.33	2,044
	04:10:17.146	11,200	424.07	**8,103**
	04:10:28.993	9,600	429.57	
MCRC	04:10:25.000	9,600	-	**20,667**
	04:10:34.000	6,500	-	**9,375**
	04:10:50.000	4,000	-	

[Table 13] Descent Record Between 14,600 ft & Track Disappearance

At 04:06:32, the captain stated, "Ah…we are now that rudder control is not working and seems to be fired… (jamming)." At 04:07:34, he said, "We have to open the hatch, hatch." It is assumed that, at this time, rudder was not operational, and that smoke caused by fire was propagated into the cockpit. At 04:09:47, the captain stated, "Rudder control… flight control, all are not working," which indicates that all control surfaces including rudder were compromised.

At 04:10:15, the FO stated, "Altitude control is not available due to heavy vibration, going to ditch… ah," which was AAR991's last communication record.

As shown in [Table 13], AAR991 was crashing as evidenced by its descent rates, 8,103 fpm between 11,200 ft and 9,600 ft, 20,667 fpm between 9,600 ft and 6,500 ft, and 9,375 fpm between 6,500 ft and 4,000 ft.

2.2.4 Fire-related Non-normal Procedures

The ARAIB assumes that, as many messages influencing flight control were generated due to rapid fire spreading, AAR991 most likely implemented various kinds of non-normal procedures. Four turbulence messages likely indicate that fire got more serious, and AAR991 likely exhibited irregular vertical and horizontal flight tracks due to a flight control failure after reaching 8,200 ft at 04:01:43. Therefore, the size and condition of fire was at a serious level that required inevitable ditching.

As fire rapidly spread, AAR991 had to implement various kinds of QRH procedures. It is assumed, based on ACARS message CGO DET 11 MN DK at 03:53, emergency declaration due to a main deck cargo fire at 03:54:23, and ACARS messages PACK 2 and PACK 3 at 03:56, that AAR991 first implemented non-normal procedures in the Fire Main Deck checklist.

It is likely, based on ACARS messages EQUIPMENT SMOKE and EQUIPMENT COOLING at 03:53, that AAR991 needed to implement non-normal procedures in the Equipment Cooling checklist.

At 03:57, many messages in relation to the APU fire system (APU FIRE LOOP A, APU FIRE LOOP B, DET FIRE APU, >BOTTLE LOW APU) were generated.

It is likely, based on ACARS messages CARGO DET AFT 4, >CGO BTL DISCH, and BTL LOW CARGO A at 03:58 and ATC/pilot communications

"Aft, cargo aft, fire cargo aft," that AAR991 implemented non-normal procedures in the FIRE CARGO AFT checklist.

It is likely, based on a well defined soot trail discovered on the exterior skin of the smoke evacuation shutter in the rear fuselage direction and on the captain's statement at 04:07:34, "We have to open the hatch, hatch" that, due to the entry of smoke and fumes into the cockpit, the flight crew had to implement non-normal procedures in the Smoke Fire or Fumes, or Smoke or Fumes Removal checklist.

At 04:10:06, the FO informed JEJ ACC that inevitable ditching was imminent, stating, "We have heavy vibration on the airplane, may need to make an emergency landing, emergency ditching."

2.2.5 QRH and Fire Fighting Altitude 25,000 ft

At 03:54:23, AAR991 declared an emergency due to a main deck cargo fire, requested SHI ACC to clear a descent to 10,000 ft, then obtained a descent clearance, and at 03:54:59, started descending from 34,000 ft. AAR991 likely implemented non-normal procedures in the Fire Main Deck checklist when it was first aware of the occurrence of fire, but did not maintain 25,000 ft[116)] selected by Boeing as a main deck cargo compartment firefighting altitude.

[Figure 63] shows B747 freighter's non-normal procedures in the Fire Main Deck checklist issued on 1 April 2011 and distributed to the flight crew. PACK 2, PACK 3, and SATCOM SYSTEM messages generated by executing step No. 4 of the procedures were transmitted at 03:56:XX. Step No. 7 of the procedures specifies that the aircraft should climb or descend to 25,000 ft when conditions

116) The fire suppression system for a Class E cargo compartment is, instead of using the extinguishing agent, to stay at 25,000 ft and depressurize the cabin in order to decrease psi to that of the ambient air at 25,000 ft and reduce oxygen, thereby containing fire propagation.

and terrain allow, but AAR991 passed 25,000 ft about 03:56:33[117) and continued to descend. SHI ACC asked AAR991 whether it needed to descend to 10,000 ft (3,000 meters) when the airplane was passing about 22,000 ft about 03:57:36, and the FO responded that AAR991 would descend to 10,000 ft and return to Jeju. Later, AAR991 passed 10,000 ft and continued to descend to 8,200 ft about 04:01:42.

Boeing's Bulletin AAR-83 issued on 10 May 2011 was not distributed to the flight crew, but the revised content was disseminated beforehand on the Intranet.

117) Ground speed 473 kt, heading 269°.

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MAIN DECK

FIRE MAIN DECK
FIRE MN DK AFT, FWD, MID

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

Condition: Smoke is detected in the main deck cargo area(s).

1 Don the oxygen masks.

2 Establish crew communications.

3 SUPRNMRY OXY switch . . . . ON

4 MAIN Deck CARGO FIRE
ARM switch . . . . Confirm . . . . ARMED

HL7436 - HL7616
SATCOM will shut down to prevent overheating.

Two packs are automatically shut down and the associated PACK messages are shown.

Select the pack control selectors that have the PACK messages shown.

5 PACK control selectors . . . . One pack on, two packs **OFF**

Warning! Either pack 1 or 3 must be operating to prevent excessive smoke accumulation on the flight deck.

6 CARGO FIRE
DEPRES/DISCH switch . . . . Push and hold for 1 second

▼ Continued on next page ▼

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[Figure 63] Freighter's Fire Main Deck NNC (1 April 2011)

8.33

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▼FIRE MAIN DECK continued▼

7 Climb or descend to 25,000 feet when conditions and terrain allow.

8 Plan to land at the nearest suitable airport.

9 Do **not** accomplish the following checklists:

CABIN ALTITUDE or Rapid Depressurization

TEMP ZONE

TRIM AIR OFF

10 Checklist Complete Except Deferred Items

▼ Continued on next page ▼

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[Figure 63] Freighter's Fire Main Deck NNC (1 April 2011) (continued)

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▼FIRE MAIN DECK continued▼

Deferred Items

Descent Checklist

Recall . . . . Checked
Autobrake . . . . ____
Landing data . . . . VREF____, Minimums____
Approach briefing . . . . Completed

Approach Checklist

Altimeters . . . . ____

Warning! Inform ground personnel not to open the cargo door until all supernumeraries and crew have exited the airplane and fire fighting equipment is nearby.

Landing Checklist

Speedbrake . . . . Armed
Landing gear . . . . DOWN
Flaps . . . . ____

■ ■ ■ ■

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[Figure 63] Freighter's Fire Main Deck NNC (1 April 2011) (continued)

[Figure 64] compares part of the different non-normal procedures in the Fire Main Deck checklist before and after revision. Step No. 7 in the revised procedures on the right emphasizes 25,000 ft for fire suppression by advising the flight crew to "expedite a climb or descent to 25,000 ft when condition and terrain allow, plan to stay at 25,000 ft as long as possible, and do not delay the approach and landing after the descent has been started."

On the other hand, step No. 7 in the unrevised procedures on the left that were distributed to AAR991 did not emphasize 25,000 ft but in effect instructs the flight crew to maintain 25,000 ft by advising them to "climb or descend to 25,000 ft when conditions and terrain allow." It is likely that AAR991's flight crew interpreted "when conditions and terrain allow" as conditional or determined that fire was a situation where conditions and terrain do not allow.

8.32
ASIANA AIRLINES
747 Flight Crew Operations Manual

MAIN DECK
FIRE MAIN DECK
FIRE MN DK AFT, FWD, MID

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

Select the pack control selectors that have the PACK messages shown.

5 PACK control selectors . . . . One pack on, two packs OFF

Warning! Either pack 1 or 3 must be operating to prevent excessive smoke accumulation on the flight deck.

6 CARGO FIRE DEPRES/DISCH switch . . . . Push and hold for 1 second

7 Climb or descend to 25,000 feet when conditions and terrain allow.

8 Plan to land at the nearest suitable airport.

9 Do **not** accomplish the following checklists:

CABIN ALTITUDE or Rapid Depressurization

TEMP ZONE

TRIM AIR OFF

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8.32
ASIANA AIRLINES
747 Flight Crew Operations Manual

MAIN DECK
FIRE MAIN DECK
FIRE MN DK AFT, FWD, MID

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

5 PACK 2 control selector . . . . OFF

Warning! Either pack 1 or 3 must be operating to prevent excessive smoke accumulation on the flight deck.

6 CARGO FIRE DEPRES/DISCH switch . . . . Push and hold for 1 second

7 Expedite a climb or descent to 25,000 feet when conditions and terrain allow. Plan to stay at 25,000 feet as long as possible. After the descent has been started, do not delay the approach and landing.

8 Plan to land at the nearest suitable airport.

9 Do **not** accomplish the following checklists:

CABIN ALTITUDE or Rapid Depressurization

PACK

TEMP ZONE

TRIM AIR OFF

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[Figure 64] Unrevised (Left) & Revised (Right) Fire Main Deck NNCs

It is also likely that AAR991 failed to stay at 25,000 ft, fire suppression altitude, because the flight crew implemented a combi plane's non-normal procedures in the Fire Main Deck checklist and/or descended intentionally after interpreting fire as serious.

2.2.5.1 Basis for the 25,000 ft Requirement and Result of Non-compliance

The Boeing Company has selected the altitude of 25,000 ft for Class E cargo compartment firefighting altitude as optimal based on studies of the NFPA and other literature of many institutes. The purpose of firefighting at 25,000 ft is to suppress the fire, thereby increasing time available to continue flying to a safe landing location. As a result, the fire may not be extinguished at 25,000 ft and could rekindle and spread during the descent as an increase in oxygen and atmospheric pressure occurs.

Accordingly, the flight crew should not delay landing at the nearest suitable airport for the purpose of suppressing fire at 25,000 ft. If fire broke out at the TOD point, they should descend to make a rapid landing instead of staying at 25,000 ft for fire suppression.

Boeing's B747 manuals for the flight crew failed to specify the basis for the 25,000 ft requirement, the effect and concept of fire suppression at 25,000 ft, and when to descend from 25,000 ft.

If the flight crew implement non-normal procedures in a combi plane's Fire Main Deck checklist, time to start depressurization will become relatively later because the designated crewmember must first verify the presence of smoke or fire before starting the procedures. In addition, if the airplane descends below 25,000 ft, cabin pressure and oxygen will relatively increase according to altitude difference, and the effect of fire suppression will reduce, thereby resulting in the spread of fire.

It is not confirmed that the reason for AAR991's leaving 25,000 ft was that the flight crew mistakenly implemented a combi plane's non-normal procedures in the Fire Main Deck checklist or that the flight crew descended intentionally in full consideration of the condition of fire. AAR991's late action to suppress fire (depressurization) and loss of opportunity to suppress fire at 25,000 ft likely contributed to the spread of fire, based on the theory that the minimum re-ignition energy varies inversely with the square of the pressure.

Judging from the size and condition of AAR991's fire, there is a possibility that, even if AAR991 had suppressed a main deck cargo fire by maintaining 25,000 ft, the fire would not have been extinguished until the TOD point for Jeju Airport, and that, in this case, as an increase in oxygen during the descent had resulted in the spread of fire, the outcome of this accident would not have changed.

In case that the airplane descends from 25,000 ft at IAS 271 kt,[118] AAR991's TOD point[119] will be located about 69 nm from Jeju Airport, which takes about 14 minutes from TOD point to landing. In case of a descent at IAS 360 kt, the TOD point, from which it takes about 10 minutes to land, will be located about 57 nm from Jeju Airport.

In case that the airplane descends at IAS 271 kt (TAS 392 kt, GS 405 kt), it can maintain 25,000 ft for about 10.5 minutes,[120] for which fire can be

118) B747 FCTM page 7.6 Rapid Descent "When the aircraft's structural damage is presented or expected, restrict speed to less than the current one." : AAR991 near SADLI (altitude 34,000 ft, wind 270/13, HDG 266°), AAR991 during return (G/S 465 kt - tail wind 13 kt = TAS 452 kt = IAS 271 kt/M0.78).

119) Data was generated by using Boeing Performance Software (BPS) and Boeing INFLT/REPORT program. Aircraft Weight 260,952.144 kg (575,301 lb = Takeoff Weight 602,901 lb - Trip Fuel until SADLI 27,600 lb), 34,000 ft (SADLI): Ambient Temperature -37°C/-34.6°F, Wind 270/13 kt, 25,000 ft (SADLI): Ambient Temperature -16°C/3.2°F, Wind 230/13 kt.

120) AAR991 reached 25,000 ft, 140 nm (258 km) from Jeju Airport on a heading of 225°

suppressed between 25,000 ft and the TOD point for Jeju Airport. In case that the airplane descends at IAS 360 kt (TAS 511 kt, GS 524 kt), it can maintain 25,000 ft for about 9.504 minutes.[121)]

2.2.5.2 Possibility of Implementing a Combi Plane's Fire Main Deck Non-normal Procedures

Asiana Airlines has four kinds of B747 airplanes (PAX, COMBI, FREIGHTER, SF), and their non-normal procedures are specified in one QRH, which might cause the flight crew to delay and/or make a mistake while selecting applicable procedures in the QRH.

When referring to a freighter's Fire Main Deck non-normal procedures in the B747 QRH, there is a possibility that the flight crew selected a combi plane's procedures in [Figure 67] that were filed right before a freighter's procedures because they failed to check AAR991's registration mark (HL7604) or by mistake. The basis for this assumption is as follows:

First, a combi plane's Fire Main Deck non-normal procedures do not contain the 25,000 ft requirement, unlike those of a freighter, since its main deck cargo compartment is not a Class E cargo compartment.

Second, a freighter's Fire Main Deck depressurization procedure was delayed. When a main deck cargo fire arm switch is armed, PACK 2 and 3 ACARS messages are generated. At 03:53:XX, CGO DET 11 MN DK ACARS message was generated, followed by PACK 2 and 3 ACARS messages at 03:56:XX.[122)] [Figure 65][123)] shows that AAR991's PACK 2 and 3 messages were generated

(N31.8425/E124.529166667). The airplane can maintain 25,000 ft for about 10.518 minutes (71×405/60) since the distance between the point reaching 25,000 ft and the TOD point is 71 nm (140-69).

121) AAR991 can maintain 25,000 ft for about 9.504 minutes (83×60/524) since the distance between the point reaching 25,000 ft and the TOD point is 83 nm (140-57).

122) 03:56:00 - altitude 29,300 ft.

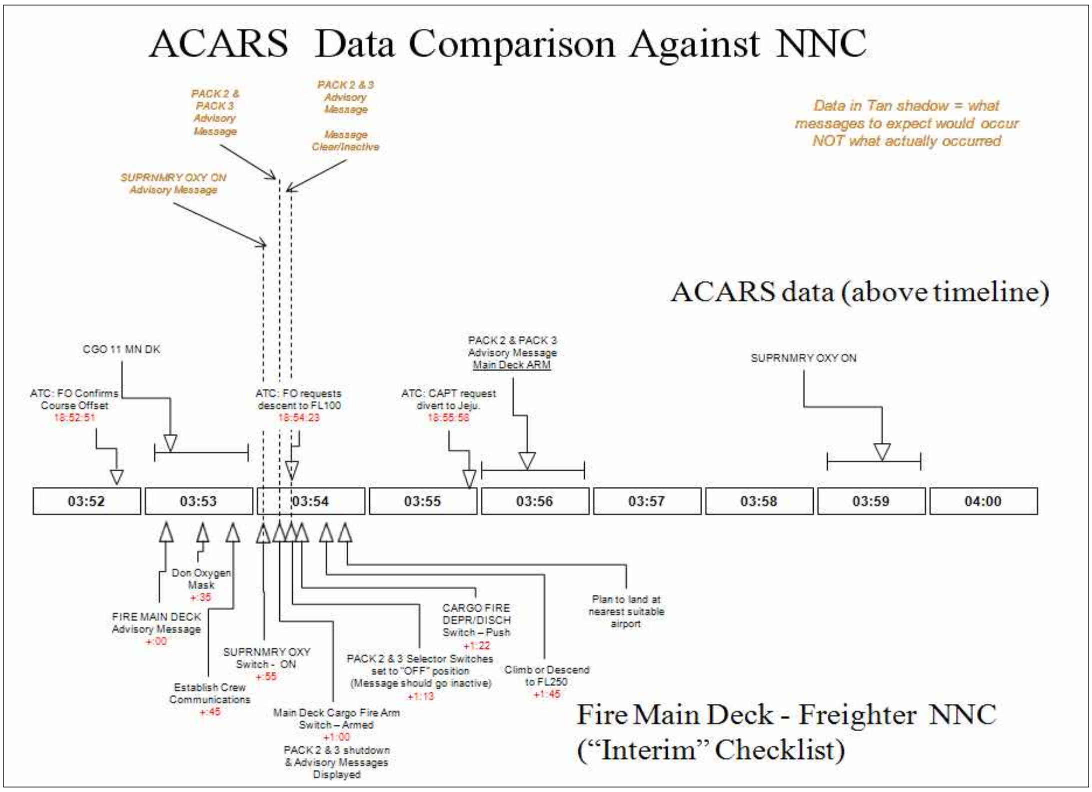
about 2 minutes[124] later in comparison to Boeing pilots' implementation of the non-normal procedures, which indicates that AAR991's Fire Main Deck depressurization procedure was delayed for about 2 minutes. Step No. 1 of a combi plane's Fire Main Deck non-normal procedures is to "instruct the designated crewmember[125] to verify the presence of smoke or fire." If the captain[126] personally verified the presence of fire and continued to implement a combi plane's Fire Main Deck non-normal procedures, the generation of PACK 2 & 3 ACARS messages would be delayed for the time required for fire verification, which explains the time difference of PACK 2 & 3 messages between timeline above and below as shown in [Figure 65].

123) As shown in [Figure 65], data above timeline is based on communications records of AAR991's flight crew and ACARS data. Data below timeline is based on the times calculated and averaged when two Boeing pilots performed the QRH non-normal procedures in a B747 simulator without knowing what emergency they were going to respond to. Data in tan shadow are messages to be expected according to the implementation of the QRH non-normal procedures.

124) Minimum 1 minute to maximum 3 minutes, considering a time error of an EICAS fault message.

125) The designated crewmember normally means a flight attendant, other than flight crew on duty.

126) The FO took control of early radio communications with SHI ACC at 03:51:15 until 03:55:54 when the captain resumed control.



[Figure 65] ACARS Data Comparison Against NNC

Third, as shown in [Figure 66], AAR991's flight crew failed to turn on the supernumerary oxygen switch,[127)] which is specified in non-normal procedures in a freighter's Fire Main Deck checklist, but not in a combi plane's.[128)] Detailed examination[129)] of AAR991's cockpit wreckage revealed that a frangible wire[130)] of the switch guard did not fracture as shown in [Figure 66], and that the supernumerary oxygen switch was in the NORM[131)] position.

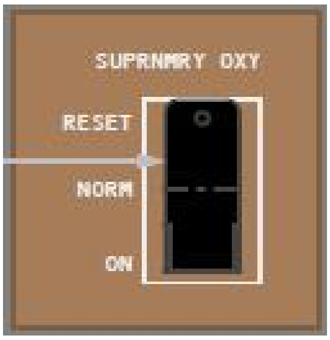
127) The supernumerary oxygen system supplies oxygen from an oxygen storage cylinder to service units located in the cabin and lavatory. Supernumerary oxygen masks are contained in service units. Except the captain and the FO, there was no other occupant on AAR991 who could use supernumerary oxygen in the cabin.

128) It was not confirmed whether a TRIM AIR switch specified in a combi plane's non-normal checklist had been in the OFF position or whether a Landing Altitude switch had been in the MAN position. Cockpit wreckage examination of a TRIM AIR switch revealed that the filaments of the two bulbs each had one major portion loose within the glass enclosure, that no distortion of the major features or of the localized coils was seen, and that the lower two positions had plastic plugs installed.

129) Refer to Appendix 6 Detailed Examination of Cockpit Wreckage.

130) The supernumerary oxygen switch in the NORM position was covered with the guard connected to a frangible wire that provides protection against careless movement. Therefore, the guard should be open to move the supernumerary oxygen switch to the ON position, which fractures a frangible wire.

131) When cabin pressure decreases to an equivalent of 14,000 ft altitude with the supernumerary oxygen switch in the NORM position, the supernumerary oxygen system is automatically operated.



[Figure 66] Supernumerary Oxygen Switch & the Cockpit Wreckage (Right)

Also, if the flight crew had implemented a freighter's Fire Main Deck non-normal procedures in a specified order,[132] SUPRNMRY OXY ON ACARS message[133] should have been generated earlier than PACK 2 & 3 messages, but it was generated 3 minutes after them, at 03:59:XX[134]. The supernumerary oxygen system is automatically operated[135] when cabin pressure decreases to an equivalent of 14,000 ft altitude even without the cockpit's supernumerary oxygen switch in the ON position. According to Boeing's data, SUPRNMRY OXY ON ACARS message is generated about 2 to 3 minutes[136] after the initiation of depressurization[137] (push of CARGO FIRE DEPRES/DISCH switch for 1 sec.).

132) The SUPRNMRY OXY switch must be ON right before a procedure, "MAIN Deck CARGO FIRE ARM switch - Confirm ARMED" accompanied by associated PACK 2 & 3 advisory messages.

133) This message is generated when the supernumerary oxygen switch on the cockpit overhead panel is in the ON position or when cabin pressure exceeds 8.7±.2 psia.

134) Altitude 14,900 ft, ground speed 451 kt, heading 352°.

135) When cabin pressure decreases to an equivalent of 14,000 ft altitude, system operation is initiated by the barometric pressure switch according to aerodynamics principles.

136) It takes about 1 minute for AAR991's cabin pressure altitude (~6,000 ft) to reach 14,000 ft, at which the supernumerary oxygen system is automatically operated, plus it takes about 1 to 2 minutes for the system to respond and for the CMC and EICAS messages to correlate with each other and generate maintenance messages. As a result, it takes about 2 to 3 minutes for ACARS messages to be generated after the initiation of depressurization.

137) According to Boeing's data, cabin pressure altitude increases by 9,000 ft/min until reaching 20,000 ft, and afterward, by 2,500 ft/min until reaching 23,900 ft.

8.29

ASIANA AIRLINES
747 Flight Crew Operations Manual

MAIN DECK

FIRE MAIN DECK

HL7417, HL7421, HL7423

Condition: Smoke is detected in the main deck cargo area.

1 Instruct the designated crewmember to verify presence of smoke or fire.

2 Choose one:

◆Presence of smoke or fire is **verified**:

►►**Go to step 3**

◆Presence of smoke or fire is **not** verified:

A crewmember must monitor the cargo compartment for the rest of the flight.

■ ■ ■ ■

3 MAIN Deck CARGO FIRE
ARM switch . . . . Confirm . . . . ARMED

Pack 3 will shut down.

4 PACK 3 control selector . . . . OFF

5 PACK 1 and 2 control selectors. . . . .One pack on, one pack OFF

6 CARGO FIRE DISCH switch . . . . Push and hold for 1 second

90 minutes of fire suppression are available.

7 TRIM AIR switch. . . . . .Off

▼ Continued on next page ▼

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[Figure 67] Combi Plane's Fire Main Deck NNC (1 April 2011)

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▼FIRE MAIN DECK continued▼

8 Choose one:

◆Airplane is **at or below** 8,000 feet:

►►**Go to step 11**

◆Airplane is **above** 8,000 feet:

►►**Go to step 9**

9 LDG ALT switch . . . . .MAN

10 LDG ALT selector . . . . Set between 8000 8500

11 Plan to land at the nearest suitable airport

12 Do **not** accomplish the following checklists:

LANDING ALT

TEMP ZONE

TRIM AIR OFF

13 Checklist Complete Except Deferred Items

Deferred Items

Before descent

LDG ALT switch . . . . AUTO

Descent Checklist

Recall . . . . Checked

Autobrake . . . . ____

Landing data . . . . .VREF____, Minimums____

▼ Continued on next page ▼

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[Figure 67] Combi Plane's Fire Main Deck NNC (1 April 2011) (continued)

▼FIRE MAIN DECK continued▼

Approach briefing . . . . Completed

Approach Checklist

Altimeters . . . . ____

Warning! Inform ground personnel not to open the cargo door until all passengers and crew have exited the airplane and fire fighting equipment is nearby.

Landing Checklist

Speedbrake . . . . Armed

Landing gear . . . . DOWN

Flaps . . . . ____

■ ■ ■ ■

[Figure 67] Combi Plane's Fire Main Deck NNC (1 April 2011) (continued)

2.2.5.3 Possibility of the Flight Crew's Intentional Descent

The display of FDE messages at 03:53:XX likely required AAR991's flight crew to implement Fire Main Deck and EQUIPMENT COOLING non-normal procedures. The display of BTL LOW CARGO A message at 03:58:XX probably required the flight crew to implement Fire Cargo Aft[138] non-normal procedures. Also, there is a possibility that Smoke Fire or Fumes, or Smoke or Fumes Removal procedures had to be applied since smoke or fumes entered the cockpit.

In AAR991's EQUIPMENT COOLING and Fire Cargo Aft non-normal checklists, there is no requirement for maintaining 25,000 ft, unlike the Fire Main Deck checklist. Also, step No. 8 in the Smoke or Fumes Removal checklist instructs the flight crew to "start a descent and level off at the lowest safe altitude[139] or 8,500 ft, which is higher."

On AAR991, the rapid spread of fire resulted in failures in many systems and the loss of flight control. Turbulence data from the ACMS was transmitted four times from 03:57:23 at 22,700 ft to 03:59:29 at 13,400 ft, which could be an indicator that the fire got more serious.

The possibility can therefore not be excluded that AAR991 made an intentional descent below 25,000 ft in advance after fully considering the following: the flight crew simultaneously had to implement multiple complex non-normal procedures requiring them to maintain different altitudes; there was a future possibility of ditching due to a spreading and worsening fire; and Jeju Airport was not far from the airplane.

138) Refer to Appendix 9 for non-normal procedures in the checklists of Fire Cargo Aft, Smoke Fire or Fumes, and Smoke or Fumes Removal.
139) Mt. Halla is 6,398 ft tall, and the radar minimum altitude of the accident site is 8,000ft.

Meanwhile, AAR991's implementation of depressurization procedures for suppressing a main deck cargo fire was delayed for about 2 (1 - 3) minutes, judging from ACARS messages, PACK 2 & 3 at 03:56:XX and SUPRNMRY OXY ON at 03:59, as shown in [Figure 65].

According to Asiana Airlines' POM, under a non-normal situation, the captain should be in charge of flight control[140] and instruct the FO to implement non-normal procedures, then take control of communications[141] with ATCs while the FO implements the QRH procedures. Yet, after 03:53 when EICAS fault messages were generated, the FO took control of communications for about 1 minute and 31 seconds between the declaration of a cargo fire and the captain's resumption of communications at 03:55:54. If the captain had not implemented the QRH procedures during this time, implementing the applicable procedures would have been delayed. In addition, it is likely that it took additional time for the flight crew to determine the emergency situation, refer to the QRH for applicable procedures, and don oxygen masks.

2.2.6 Ditching

According to the aircraft accident report on the fatal UPS B747 crash in 2010, the Transportation Safety Board (TSB) of Canada studied 15 fire-related aircraft accidents that had occurred between 1967 and 1998, which showed that the time elapsed between the occurrence of an in-flight fire and ditching, emergency landing, or crash was 5 to 35 minutes, and that the average flight time was 17 minutes. In recent accidents involving a B747 main deck cargo fire, it took 19 minutes for South African Airways flight 295 to recognize a fire until its flight track disappeared, and 28 minutes for UPS flight 6 to lose flight control in 2010.

140) Asiana Airlines' B747 POM 4.1.2: Basic principles in case of non-normal situations - the captain should be in charge of flight control and maintain a proper flight path and configuration.
141) Asiana Airlines' B747 POM 2.3.3.4 Communications.

As for AAR991, about 15 minutes 47 seconds (04:09:47) after the generation of the EICAS fault message about 03:53, the captain said to JEJ ACC, "Rudder control··· flight control, all are not working," and it took 17 minutes and 50 seconds for AAR991 to disappear from the radar screen at 04:10:50 when the airplane was flying at 4,000 ft, located at N33˚15'12" E124˚59'34", 139 km (263°/75 nm) west of Jeju Airport.

On the day of the accident, the time of moonrise and civil twilight[142] was 02:58 and 05:22, respectively. The expected time of sunrise was 05:50, and AAR991 disappeared 1 hour and 40 minutes before sunrise, when the intensity of illumination[143] was so low that it was difficult for AAR991 to visually check the surface of the sea and make an emergency ditching.

Judging by the FO's statement at 04:10:15, "Altitude control is not available due to heavy vibration, going to ditch··· ah," AAR991 failed to attempt an emergency ditching and crashed.

After a main deck cargo fire was detected at 03:53:XX, AAR991 descended to 34,000 ft at 03:54:59 and reached 25,000 ft at 03:56:33. It took the maximum 3 minutes and 33 seconds and about 1 minute and 34 seconds for AAR991 to reach 25,000 ft from the detection of a fire and from the initiation of a descent, respectively. It takes about 10 to 14 minutes for AAR991 to make an emergency ditching from 25,000 ft, and thus, if AAR991 with fire damage had immediately descended and attempted an emergency ditching as soon as a fire had been detected, it could have made a ditching before 04:09:47, when the captain had reported the loss of flight control.

142) Civil twilight is defined when the sun is 6° below the horizon, and lasts for about 30 minutes after sunset or before sunrise, This is the limit at which twilight illumination is sufficient for people to carry on activities without artificial illumination although the sun is below the horizon.

143) 28 July 2011 (27 of the lunar calendar) ① about 04:00 - illuminated friction of the moon's disk 8.2% [from last quarter to crescent (29~30)], clear surface illumination 11.02 mlux ② about 05:00 - illuminated friction of the moon's disk 8.0%, clear surface illumination 58.04 mlux.

Checklist instructions[144] for B747 QRH non-normal checklists stated, "In some multiple failure situations, the flight crew may need to combine the elements of more than one checklist. In all situations, the captain must assess the situations and use good judgement to determine the safest course of action. … It must be stressed that for smoke that continues or a fire that cannot be positively confirmed to be completely extinguished, the earliest possible descent, landing, and evacuation must be done. If a smoke, fire or fumes situation becomes uncontrollable, the flight crew should consider an immediate landing. … However, in a severe situation, the flight crew should consider an overweight landing, a tailwind landing, an off-airport landing, or a ditching."

B747 non-normal checklists for AAR991's fire can be summarized as follows: the flight crew should first rapidly and accurately implement depressurization procedures for a main deck cargo fire, maintain 25,000 ft, and attempt to suppress fire until the TOD point for Jeju Airport. Also, the flight crew should check the current condition of a fire, including whether a fire is suppressed, extinguished, or spread, and if a fire is determined to be uncontrollable, they should make an early descent in consideration of ditching.

Currently, it is difficult for the flight crew to decide to make a ditching for the following reasons: they cannot accurately check the condition of a cargo fire, including whether it is suppressed, extinguished, or spread; they cannot determine whether a fire can be contained; and they cannot predict or determine when to lose flight control or whether it is possible to fly to a diversion airport.

Maintaining 25,000 ft for suppressing a main deck cargo fire has been emphasized, whereas it takes about 10 to 14 minutes to make a ditching from 25,000 ft. In this regard, it is necessary to come up with countermeasures against the possibility of missing a time window for ditching as a last resort.

144) Chapter CI (Checklist Instructions), page CI.2.2 - CI.2.3.

Therefore, the ARAIB concludes that the aircraft system should be improved to enable the flight crew in the cockpit, who become aware of an uncontrollable fire, to accurately determine the size and condition of the fire so that they can make a timely decision to descend from 25,000 ft and make a ditching.

In addition, Boeing's B747 manuals for the flight crew should contain specific information on the basis for the 25,000 ft requirement, its effect and concept of fire suppression, and when to descend from 25,000 ft.

2.2.7 Recurrent Training·Evaluation and Improvements to a Simulator

As Asiana Airlines' B747 simulator is configured as a passenger plane, it cannot simulate Fire Main Deck on a freighter. The main content of the revised Fire Main Deck non-normal checklists with the emphasis on maintaining 25,000 ft was disseminated on the company's Intranet, and it was not confirmed whether AAR991's captain and the FO were given their Fire Main Deck training in the simulator.

Asiana Airlines' recurrent simulation training syllabus and evaluation items are notified in advance to the flight crew, and with no change of their content, training and evaluation are conducted, which allows the flight crew to study them in advance and improve the effect of the training. Yet, this kind of pre-notification has also a negative influence on the flight crew's ability to judge and respond to unexpected situations and the effect of the CRM training.

As Asiana Airlines has no B747 freighter simulator, training subjects that cannot be simulated as the same as on a B747 freighter are difficult to be selected as recurrent training subjects, and thus, they are less trained. Also, the subjects that were not incorporated in training and evaluation are given a lower priority on the flight crew's usual study list.

Asiana Airlines should improve its management method of recurrent training and evaluation in order for the flight crew to properly judge and respond to unexpected complex non-normal situations like this accident.

In addition, the company should modify its simulator configured as a passenger version of the B747 so that its flight crew can be realistically trained on non-normal procedures of a combi, cargo, and special cargo plane.

Also, Asiana Airlines should provide a consistent and enhanced simulation training to the flight crew so that they can rapidly don their oxygen masks and do the non-normal checklists in a real-life situation, with their tasks allocated according to regulations.

2.3 ATC and Communications

According to the analysis of AAR991's ATC/pilot communications transcript, while diverting to Jeju Airport due to an emergency after communicating with SHI ACC in ICN flight information region (FIR), AAR991 had to exchange flight information via HUK ACC since there was no direct telephone line between SHI ACC and ICN ACC. As a result, a more rapid information exchange could not be made when the emergency occurred.

After the occurrence of the emergency, AAR991 attempted to communicate with ICN ACC on 124.525 MHz around 10,000 ft but to no avail. Though, instead of using a frequency of 128.375 MHz, AAR991 continued to communicate on 124.525 MHz, in a difficult and complicated way, via other airplanes flying at a higher altitude.

As aforementioned in Section 1.9.3 of this report, AAR991 entered a communication dead zone while descending from 34,000 ft to 10,000 ft because of the location and height of the 124.525 MHz transceiver antennas used for communication with ICN ACC, thereby failing to communicate with ICN ACC.

Unlike the 124.525 MHz transceiver antennas, there seems to be no communication obstacles[145)] between AAR991 and the transceiver for 128.375 MHz used by the ICN ACC south sector, and it is thus assumed that if AAR991 had used 128.375 MHz while flying around 10,000 ft, it could have communicated with ICN ACC.

Therefore, the ARAIB concludes that the use of frequency 128.375 MHz should be contained in the Aeronautical Information Publication (AIP)[146)] to allow airplanes flying at a low altitude in the western zone south of "Jeju VORTAC" on airway A593 and B576 to communicate with ATCs on that frequency, and that this change should be disseminated to SHI ACC and HUK ACC for cooperation.

2.4 Fire

2.4.1 Initial Fire Location

Locations of cargo positions, smoke sampling ports connected to smoke detectors, and fire zones are shown in [Figure 68]. Smoke sampling ports are attached to the ceiling, and if air sample through the ports contains smoke, smoke detectors detect it. Two detectors per zone are installed on the left of the fuselage.

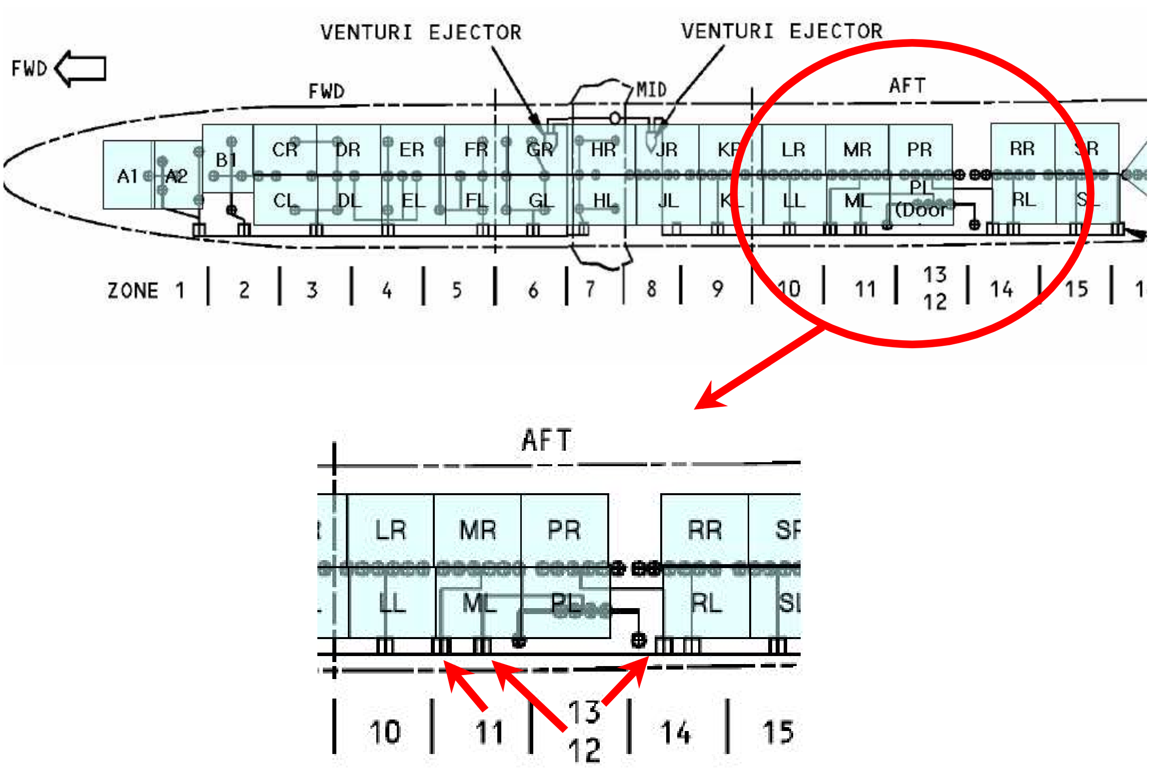
The main deck cargo compartment consists of three fire zones: FWD fire zone 1 - 5; MID fire zone 6 - 9; and AFT fire zone 10 - 16. If smoke is

145) Inspection and official confirmation are needed during a future scheduled flight inspection.
146) Korea's AIP valid at the time of the accident did not contain frequency 128.375 MHz as an ATC frequency for airways A593 and B576.

generated, it enters smoke sampling ports in each fire zone. Smoke detectors in fire zones 10, 11, and 13 detect smoke over cargo positions L, M, and P, respectively. Smoke detectors in fire zone 12 detect smoke by a smoke sampling port installed near the main deck side cargo door.

Fire zone 10 encompasses a cargo position L, which consists of LR on the right and LL on the left based on the nose. Cherries, and IC plates and memories were loaded in cargo positions LR and LL, respectively, but with no flammable materials.

Fire zone 11 encompasses a cargo position M, which consists of MR on the right and ML on the left based on the nose. LED, valves, semiconductor components, viscous clay, and labels were located on the pallet in position MR, with no flammable or self-ignition materials.



[Figure 68] Smoke Sampling Ports, Fire Zones, and Cargo Positions

Flammable liquid (Photo-Resist/IC), printed circuit boards (PCB), complementary metal oxide semiconductor (CMOS), and IC connectors were located on the pallet in position ML. Flammable liquid was Photo-Resist/IC classified as dangerous goods by the ICAO "Technical Instructions for the Safe Transport of Dangerous Goods by Air" and specified in NOTOC.

Fire zone 13 encompasses a cargo position P, which consists of PR on the right and PL on the left based on the nose. Position PL located aft of position ML and near main deck side cargo door was empty. Lithium-ion batteries, paint, Amines liquid corrosive, photo-resist, flammable liquid, and automotive parts were located on the pallet in position PR. All shipments except automotive parts were classified as dangerous goods by the ICAO "Technical Instructions for the Safe Transport of Dangerous Goods by Air" and specified in NOTOC.

Among shipments in the aft cargo compartment, those that can self-ignite or have flammability are located in fire zones 11 and 13. According to the ATC/pilot communications transcript, a fire occurred in the aft main deck cargo compartment, and based on the analysis of ACARS messages, a fire occurred first in the aft fire zones rather than others. Because smoke was initially detected in fire zones 11 and 13 and structural fire damage occurred in the region of pallet locations ML and PR, the ARAIB concludes that the origin of the fire was in or around the pallets where dangerous goods had been loaded onto the aircraft.

2.4.2 Time of Fire Occurrence

FDE messages transmitted via ACARS are not time stamped, and their time of generation thus can be estimated by maintenance messages correlated to them, which are time stamped in hours and minutes.

Among fire-related ACARS messages received by the ground station, FDE message "CGO DET 11 MN DK" was the first generated at between 03:53:01 and 03:53:59, and maintenance message "CARGO FIRE MAIN DECK ZONE-11 LOOP A FAIL" correlated to this message was generated at 03:53.

If the message "CARGO FIRE MAIN DECK ZONE-11 LOOP A FAIL" is correlated to "MD CGO 11 LP A," it indicates a fault with the zone 11A detector, but as the message is correlated to "CGO DET 11 MN DK," the zone 11B detector was in alarm or faulted within 20 seconds of the zone 11A detector. In other words, "CGO DET 11 MN DK" would be consistent with zone 11A and zone 11B detectors detecting smoke (being in alarm) more than 8 seconds but less than 20 seconds apart. Therefore, the ARAIB concludes that a fire occurred on the airplane when the above message was displayed.

FDE messages with no correlation with maintenance messages are not transmitted to the ground station via ACARS. Therefore, FDE messages, FIRE MAIN DECK, FIRE MN DK FWD, FIRE MN DK MID, or FIRE MN DK AFT, were not transmitted to the ground because they were not correlated to maintenance messages. In other words, this means that all fire-related FDE messages were not transmitted to the ground. It is assumed that a fire occurred on the airplane before the generation of the message "CGO DET 11 MN DK."

The ARAIB concludes based on the ATC/pilot communications transcript that, when the FO communicated with SHI ACC at 03:52:51, a fire did not occur or he did not recognize the occurrence of a fire, for he did not mention it, and that a fire broke out at between 03:52:51 and the time when "CGO DET 11 MN DK" was generated (03:53 - 03:54).

2.4.3 Cause of Fire

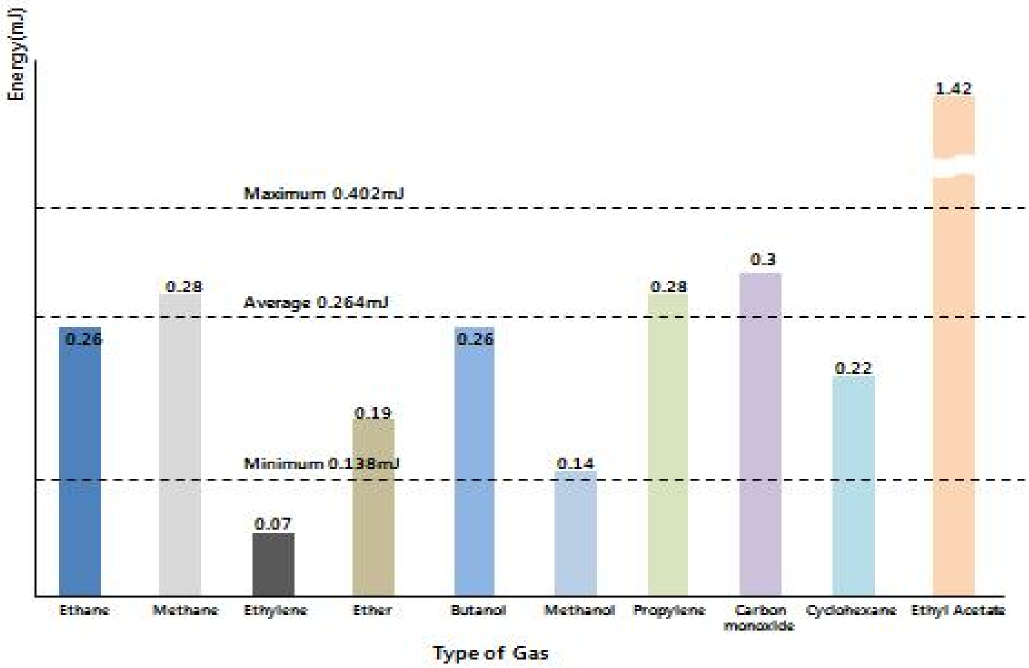
The ARAIB reviewed the accident plane's maintenance records from 5 months before the accident to the day of the accident in order to see whether a fire had occurred due to a short-circuited wire, but found no defect with wires that could have ignited a fire.

Based on the ATC/pilot communications transcript and ACARS messages, it is assumed that a fire occurred first on cargo shipments, including flammable materials, located in positions ML or PR in the aft main deck cargo compartment, but physical evidence of the cause of the fire was not found. There were flammable materials in position ML, and flammable materials and lithium-ion batteries in position PR. Flammable materials can be ignited if the cargo compartment is within flammability limits[147)] due to a certain factor and an ignition source like electrostatic energy exists, and lithium-ion batteries can be self-ignited if exposed to high temperature from external sources. Therefore, the ignition possibility of these two was studied.

2.4.3.1 Ignition Possibility of Volatile Flammable Materials

The ARAIB measured the amount of electrostatic energy that could be accumulated in the plastic wrap used for bundling pallet-loads of products together prior to loading since the Board concludes that electrostatic energy could play a role as an ignition source. As shown in [Figure 69] comparing electrostatic energy with the MIEs, the amount of electrostatic energy varied from a minimum 0.138 mJ to a maximum 0.412 mJ, with the average of 0.264 mJ. The plastic wrap was used to fix or protect cargo from rain.

147) Flammability limits (explosive limits) are normally expressed in terms of volume percentage (%) of combustible gas among mixtures of dispersed combustible materials and air. The highest concentration and the lowest concentration of a gas in air capable of producing a flash of fire are referred to as the upper flammable limit and the lower flammable limit, respectively.



[Figure 69] Comparison of Electrostatic Energy & MIEs

The ARAIB boarded the freighter with a similar flight pattern to that of the accident airplane and verified whether electrostatic energy was generated during flight. When pallets were loaded on the airplane, they discharged all the electrostatic energy that had been charged up on the ground and accumulated in the plastic wrap as they had the same electrical potential as that of the airplane. Electrostatic energy accumulated on eight pallets was measured 1 hour to 1 hour and 20 minutes after boarding.

As shown in [Table 9], 1 hour and 20 minutes after boarding, electrostatic energy was not found on seven pallets except for a pallet in position GL, which measured 0.23 mJ. This result revealed that friction was generated in the plastic wrap, and that static electricity could be built up although the aircraft was electrically bonded to prevent its accumulation.

Paint in position PR provides moisture-proof insulating coating used for manufacturing mobile phones. According to its MSDS, it is regulated as Class 3

UN1263, Packing Group Ⅱ, flammable liquid that should be packed in a metal container, it has a flash point of -1℃, and vapor may form an explosive mixture in air, exceeding -1℃. The product can be exploded when heated. Its chemical composition and the MIEs are shown in [Table 14].

Molecule	Molecular Formula	MIE (mJ)
Ethane	C_2H_6	0.26
Methane	CH_4	0.28
Butanol	$C_4H_{10}O$	0.26
Methanol	CH_4O	0.14
Methylcyclohexane	C_7H_{14}	0.27

[Table 14] Paint's Chemical Composition & MIE

The product should be stored at temperatures between -5℃ and 25℃, but was stored in the temporary DG storage area with a temperature of more than 26℃ for more than 6 hours between its acceptance and loading.

According to the results of wreckage reconstruction study, and testing and analysis in relation to Asiana Airlines' crash accident, a container of the product, tightly closed by internal and external closure devices and inserted in the enclosed plastic bag, was left for 2 hours at room temperature of 18℃, and its volatile organic compound (VOC) emissions were measured, then detected. However, the flammable gas leakage test revealed that VOCs were not detected at a cabin altitude (8,000 ft), environment where the fire occurred on the event aircraft.

In addition, it is confirmed that the product could be ignited by a spark at room temperature, and that comparison of the MIEs of paint's flammable molecules and electrostatic energy measurements revealed that the product, if the surroundings are within flammable limits, could be ignited even by electrostatic energy.

Therefore, if paint is exposed to room temperature of more than 25℃ for over 6 hours, it can emit VOCs. It is assumed that the product, if the surroundings including VOCs are within flammable limits, could be ignited by electrostatic energy. However, it is difficult to conclude, judging from the testing result that VOCs were not detected at a cabin altitude, that paint was ignited. The MIEs of gases emitted by the product when evaporating can be found in [Table 14]. The MIEs of methanol and ethanebutanol were less than an average of electrostatic energy that can be accumulated in the plastic, 0.264 mJ, whereas the MIEs of methane and methylcyclohexane were 0.28 mJ and 0.27 mJ, respectively, which were almost similar to an average of or less than the maximum of electrostatic energy.

2.4.3.2 Ignition Possibility of Lithium-ion Batteries

Lithium-ion batteries in position PR, manufactured by Company A, were in either a 6-cell or 12-cell configuration for use in hybrid electric vehicles. The ARAIB paid a visit to the manufacturer and obtained detailed information on lithium-ion battery cell's design, production quality management, safety test, packaging, and shipment. Also, the Board examined a sample of the battery that had been loaded on the accident airplane and packaging materials, but failed to acquire the data that could prove the ignition possibility of the batteries in normal conditions of transport.

Since an in-flight fire on UPS Airlines flight 1307 occurred on 7 February 2006, 36 aircraft serious incidents involving batteries and battery-operated devices have been reported, and they were involved with smoke, fire, extreme heat or explosion. Among them, 24 serious incidents, of which 15 were involved with fire, were related to lithium-ion batteries, and the rest 12 serious incidents, of which 8 were involved with fire, were related to lithium metal batteries.

On 3 September 2010, UPS Airlines flight 6, a Boeing 747-400F, with lithium-ion batteries on board, developed an in-flight fire. The first of the eight causes of the accident is as follows: "A large fire developed in palletized cargo on the main deck at or near pallet positions 4 or 5, in Fire Zone 3, consisting of consignments of mixed cargo including a significant number of lithium type batteries and other combustible materials. The fire escalated rapidly into a catastrophic uncontained fire."

According to the MSDS of a lithium-ion battery, if the battery has been subject to fire, mechanical damage, disassembly, and electrical stress caused by an abuse, its cell case could rupture in the worst case, which could cause internal hazardous materials to be released. Also, if exposed to excessive heat due to a fire, the battery has the potential to release flammable vapors. Proper extinguishing media are water, CO2, nitrogen, dry chemical and foam. When handled, the battery should avoid extreme fire or heat, water or seawater, strong oxidizers, severe mechanical damage, and terminals' short circuit. It should also be stored in a cool, dry area away from direct sunlight. The MSDS indicates that if exposed to an external short circuit, crushes, modification, or high temperature above 100℃, the battery could release heat and self-ignite.

The lithium cell undergoes a chemical reaction once it is heated to the point of thermal runaway. This chemical reaction generates very high temperatures and pressures within the cell. A cell in thermal runaway can reach 1100+°F. The 1100°F temperature is very close to the melting point of aircraft aluminum, 935°F to 1180°F. A large shipment of lithium cells could generate enough heat to potentially damage the structure of the aircraft[148].

Restricting shipment of lithium-ion cells to Class C cargo compartments would largely mitigate but may not eliminate the hazard. The Halon 1301 fire

148) Excerpt from DOT/FAA/AR-10/31, *Fire Protection for the Shipment of Lithium Batteries in Aircraft Cargo Compartments.*

suppression system in Class C cargo compartments has been shown to effectively suppress the open fire associated with the burning electrolyte.

The battery manufacturer argues that tests revealed that lithium-ion batteries were safe, but the tests conducted by the manufacturer did not show all anomalous cases. As major manufacturers went into competition for cost reduction and high capacity[149] battery, accidents involving lithium-ion batteries' ignition or explosion have occurred. Recalls in response to ignition and explosion of lithium-ion battery-operated computers[150] are shown in [Table 15].

Time	Computer Manufacturer	No. of Recall	Battery Manufacturer	Damage
2009 - 2011	HP	300,000	Nondisclosure	Nondisclosure
Oct. 2008	HP, Dell	600,000	Sony	Nondisclosure
Aug. 2007	Nokia	46,000,000	Panasonic	80 bil ￥
Mar. 2007	Lenovo	Nondisclosure	Sanyo	Nondisclosure
Dec. 2006	Mitsubishi	1,300,000	Sanyo	2 bil ￥
2005 - 2006	9 Manuf. including Dell	9,660,000	Sony	51 bil ￥
Oct. 2005	HP	135,000	Sony	Nondisclosure
May 2005	Apple	128,000	LG Chem	Nondisclosure
Aug. 2004	Apple	28,000	LG Chem	Nondisclosure

[Table 15] Recalls in Response to Ignition & Explosion of Lithium-ion Battery-operated Computers

In the ICAO DGP-WG meeting held in Montreal, Canada, from 6 to 10

149) Safety issues were raised when the electrode board's thickness and density are increased, and the separator diaphragm's thickness is reduced in order to insert more electrodes storing energy into a standardized container.

150) Excerpt from the article, *"Trend Analysis and Prediction of Lithium-ion Battery Materials Technology"* published by the Korea Development Bank.

February 2012, the Korea Electrotechnology Research Institute, which participated in the meeting with the Korean panel, explained the results of a lithium-ion battery safety test, arguing that a ban on air transportation of lithium-ion batteries and a proposal to reinforce related regulations were unreasonable.

2.4.4 Fire Propagation and In-flight Breakup

A fire developed on the aft main deck in or near fire zone 11 or 13 where palletized DG were loaded, and in about 3 to 4 minutes after smoke detection, smoke spread rapidly throughout the main deck cargo compartment.

Smoke was detected in fire zone 11, and so was it in E/E compartment through a suction fan used for cooling the E/E compartment. Melting from intense heat was found along the crown area in positions ML and PR in fire zones 11 and 13, respectively, where flammable materials were loaded. This area located between FS1700 and APB sustained the most severe fire damage.

The ARAIB concludes that smoke and flames spread to the forward and aft of the aircraft along the crown area. Judging by the fact that a well defined soot trail was discovered on the exterior skin of the cockpit smoke evacuation shutter in the rear fuselage direction, and that portions of the ceiling panels belonging to the area under the flight deck and ceiling panels aft of FS360 were sooted, smoke entered the flight deck. Thus, the Board concludes that the flight crew operated the shutter to get rid of smoke.

Among the wreckage with sooting, the farthest forward wreckage was the fuselage frame at FS500 on the LH side in the area of the main deck cargo compartment. The farthest forward evidence of thermal heat damage which caused paint discoloration was found on a crown fuselage frame at FS580 on the LH side. This damage is located at a stringer 6.

Forward portions of the wreckage generally have fire damage consisting of sooting with areas of more severe damage along the upper areas of the aircraft's attic space and crown. The wreckage between FS1700 and APB, where the pallets on positions ML and PR in fire zones 11 and 13 are located, sustained the most severe fire damage. The crown in this area was melted from intense heat.

At position ML between FS1658 and FS1784 were loaded flammable materials, and at position PR between FS1784 and FS1910 were loaded lithium-ion batteries. The fuselage wreckage on the LH side of ML and on the RH side of PR was not recovered. The ARAIB concludes that the wreckage could not be recovered since the aircraft shattered into many pieces due to dangerous goods' explosive energy.

Of the recovered wreckage, that of positions PL and RL aft of ML sustained 2 to 3 levels of fire damage since these positions were empty, whereas that of positions RR and SR aft of PR sustained 4 level of fire damage since combustibles including electronic components were loaded on these positions, which indicates that the right rear fuselage sustained one or two higher levels of fire damage than the left one. Analysis of the thermal damage maps of the recovered wreckage revealed that the fire spread rapidly due to dangerous goods at positions ML and PR.

Portions of the wreckage aft of APB did not have the evidence of fire damage, but on the exterior of the skin panels on the right and left side of the wreckage aft of the APB were long soot trails caused by smoke exiting the outflow valves, which indicates that the valves were at full open positions after the fire occurred. For the outflow valves to fully open, the flight crew must press the main deck cargo ARM button. The ARAIB thus concludes that the flight crew pressed it after becoming aware of the fire.

Blue photo-resist and paint were found on the top surface of the right wing. The top surface of the wing contained multiple black waffle-like markings caused by collisions with electronic components containers loaded at position MR forward of PR. As shown in [Figure 70], electronic components with a diameter of 5 mm in the containers were imbedded in the composite wing upper surfaces. They, made of metal, are glass-to-metal seals used for photoelectronic materials.

[Figure 70] Glass-to-Metal Seals

At position PR were loaded dangerous goods such as lithium-ion batteries, flammable liquids, Amines liquid corrosive N.O.S., paint, and blue photo-resist/LCD. At position MR forward of PR were loaded electronic components used as glass-to-metal seals in [Figure 70]. Dangerous goods at position PR were located across the main deck side cargo door, on the RH side of the fuselage.

The ARAIB concludes that powerful "fire energy" was produced to the extent that photo-resist/LCD and paint in position PR splattered on the top surface of the right wing, about 30 meters from PR, and that electronic components in position MR, shown in [Figure 70], were imbedded in the composite wing upper surfaces. The Board also concludes that this energy was generated by fire-induced explosion of flammable materials and lithium-ion batteries.

Thermal heat damage was mainly found along the crown area that was melted from intense heat. The flight control pulleys and cables did not exhibit thermal deformation or damage since they belonged to the forward section of the aircraft, which was under relatively little influence of heat. Although flight control components that ran along the crown area in the aft section of the aircraft were not retrieved, however, they likely sustained severe thermal damage, considering [Figure 40] Thermal Damage Map - Fuselage Frames.

While burning, photo-resist loaded in position ML generates about 24,000 kJ/kg, which means that the heat release from burning 1,007 kg of photo-resist is about 24,168 MJ or 22.9 mega British Thermal Unit (BTU).[151)]

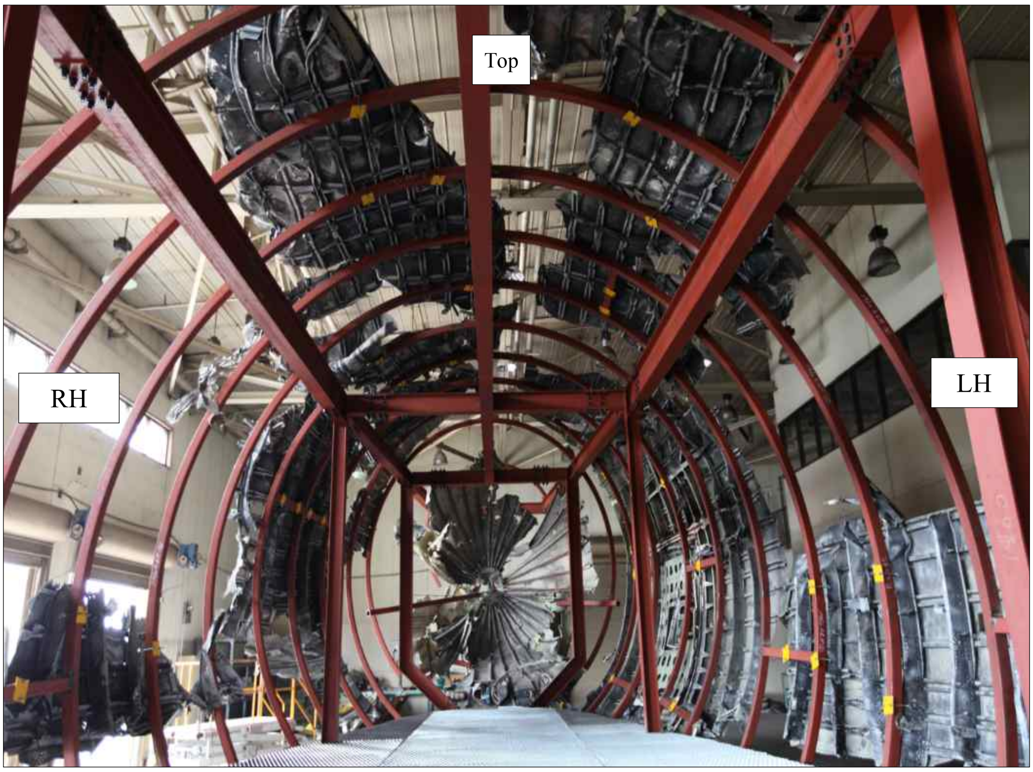
Meanwhile, the heat release from burning about 793 kg of photo-resist in position PR is about 19,032 MJ or 18.04 mega BTU. At position PR were also loaded 22 kg of paint, the heat release from which is estimated at about 1 mega BTU and thus, the total is 19 mega BTU for cargo position PR.

The ARAIB concludes that a rapid increase in thermal energy caused some portions of the fuselage to separate from the airplane, evidenced by the fact that shipments loaded inside the main deck cargo compartment were imbedded on the exterior surface of the wing.

2.4.5 Analysis of an In-flight Breakup Through 3D Wreckage Reconstruction

As shown in [Figure 71], the ARAIB carried out 3D wreckage reconstruction. The aircraft-shaped framework was made between FS1741 and FS2658, about 1/3 the length of the fuselage, and the selected pieces of the wreckage were attached to the framework.

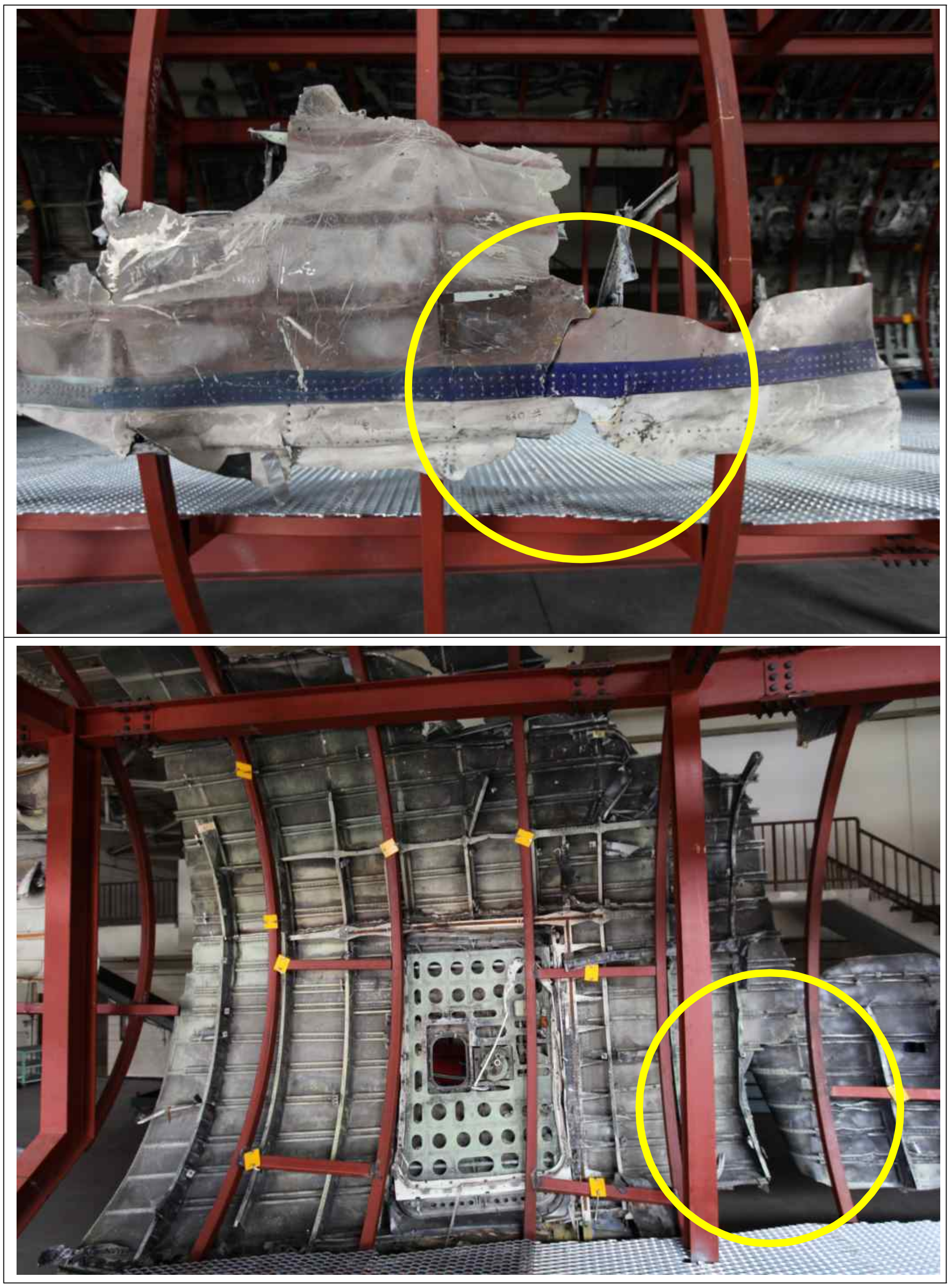
151) The British Thermal Unit (BTU) is the amount of energy needed to cool or heat one pound of water by one degree Fahrenheit. 1 kcal = 3.968 BTU.



[Figure 71] 3D Wreckage Reconstruction

[Figure 72] shows certain portions of the reconstructed wreckage. The upper image in [Figure 72] contains a yellow circle in which there is a fracture line between two pieces of the wreckage. Color on both sides of the line that should have been the same is apparently different. The left piece of the wreckage is heavily sooted, whereas the right one does not exhibit sooting, which indicates that a fire lasted even after the separation of the wreckage. In other words, the left piece of the wreckage was attached to the fuselage while the fire progressed, whereas the right one separated from the fuselage.

The bottom image in [Figure 72] shows a yellow circle in which stress is observed along a fracture line between two pieces of the wreckage at FS2180. The left piece of the wreckage could stand outward force because it was attached to the fuselage frame, whereas the skin of the right piece was bent outward due to energy on the inside. In other words, the skin along the wreckage sheared off in midair due to energy on the inside of the airplane.



[Figure 72] In-flight Breakup Evidence

2.5 Survival Aspects

2.5.1 Rescue and Search

On 28 July 2011, about 03:54, AAR991's pilots reported a cargo fire to SHI

ACC, and 4 minutes later, about 03:59, the ACARS message "ELT ON" was transmitted, but the distress signal was not received by the authorities concerned. According to Section 2.1 ACARS CMC Messages, the message "ELT ON" is generated when the pilots turn on the ELT or when it automatically activates with the impact of 5G and more.

Although AAR991 flew for more than 10 minutes after the message was generated, however, its distress signal was not received by the ground stations. Thus, it is assumed that the message did not likely mirror an actual situation, and when AAR991 crashed into the international waters about 130 km west of Jeju Airport, the signal was not also received. The ELT installed on AAR991 is inoperable in the water.

Therefore, the ARAIB concludes that a current ELT installed on airplanes flying over maritime areas needs to be newly improved to float to the surface and operate, be operable in the water or broadcast the GPS location so that the location of missing pilots and airplanes can be rapidly and accurately identified.

Agencies concerned including the Coast Guard conducted large-scale search and rescue operations to find missing pilots for about 3 months with the focus on the estimated crash site, an area 17 km in width by 13.5 km in length, but to no avail. On 29 October 2011, a Korean salvage company that was carrying out wreckage recovery operations at the accident site, using one-boat trawling, recovered a portion of the cockpit. On 30 October, when the interior of the cockpit was examined, the bodies of the captain and the FO were found.

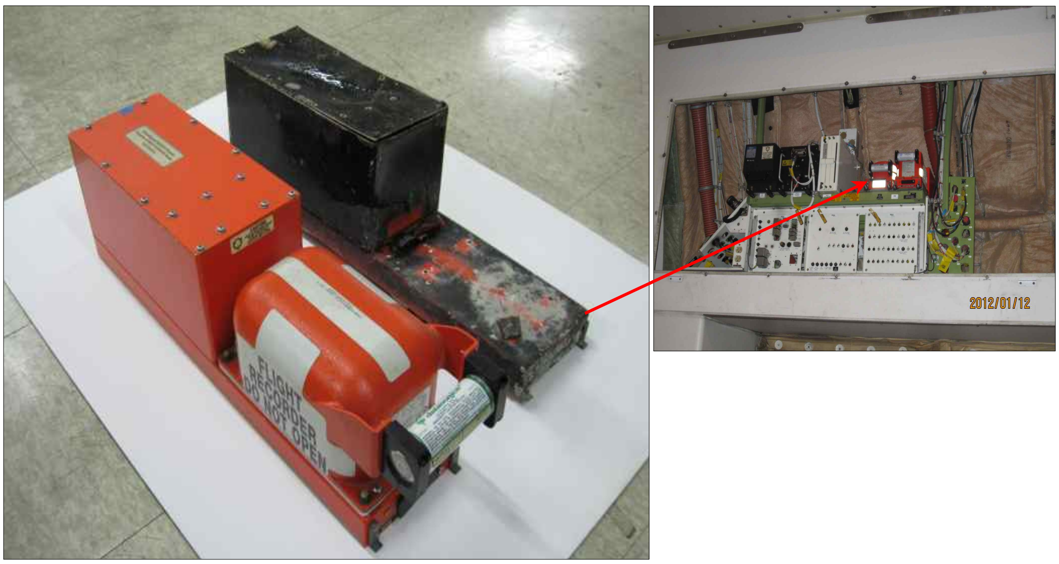
2.5.2 Search for FDR and CVR

Investigators from the ARAIB and Taiwanese and Singaporean investigation authorities, and agencies concerned (Asiana Airlines, Korean Navy and Coast

Guard) together used their sonars to listen for the unltrasonic signal emitted by the FDR in order to recover the FDR and CVR throughout four phases of search operations from the time of the crash until 28 August 2011 but to no avail.

To ensure a thorough accident investigation, the FDR and CVR should be retrieved, but as the airplane crashed into the sea, it could not be located although a lot of personnel, equipment, time, and costs (approximately $14 million) were injected.

From 18 to 25 April 2012, the ARAIB in cooperation with the former Ministry of Land, Transport and Maritime Affairs and the Navy checked the movement of the underwater wreckage to pinpoint their exact locations at the accident site, and as a result, added new wreckage coordinates to search for the FDR and CVR. From 10 May until 10 June 2012, a private salvage company carried out a second-phase search operation using a pair trawling method, and on 16 May, recovered the chassis with a severe fire damage, as shown in [Figure 73].



[Figure 73] FDR's Chassis

According to the results of fire damage analysis, the location where the FDR and CVR were installed (FS2300, aft of L5 door) sustained a level 2 fire damage (minor charring and/or paint discoloration from heat).

The flight data recorder rack was separated from the frame aft of the upper portion of the L5 door. The upper portion of the frame was thermally damaged, and its interior surface was heavily sooted. Judging by this evidence and the chassis' fire damage including sooting, the ARAIB assumes that the ULB fitted to the CSMU must have exceeded its operable temperature between -2.2 and 37.8°C or must have been burned in a fire, thereby becoming inoperable.

In addition, the depth of the sea where AAR991 had crashed was estimated at 81 to 87 meters. The sea floor, generally flat, consisted of mud and sand about 60 cm thick, but the currents flowed fast, at 2 - 4 m/sec, and the average visibility at the sea floor was just 0.5 meters. If the CSMU is buried here, it will be all the more difficult for a diver to find it with the naked eye, and the ULB signal will be much weaker.

On 1 June 2009, Air France flight 447, an Airbus A330-200, crashed into the Atlantic Ocean while flying en route from Brazil to France. After this accident, the difficulties of retrieving the flight recorders (costly and long lasting search) were encountered, and thus, the ICAO Flight Data Recovery Working Group is looking into new technology to safeguard flight data and/or to facilitate the localization and recovery of on-board recorders. The Working Group has studied the feasibility of the following measures, some of which were incorporated in Annex 6: ① extend from 30 to 90 days the regulatory transmission time for ULBs installed on flight recorders on airplanes; ② make it mandatory for airplanes to be equipped with an additional ULB capable of transmitting on a low frequency (between 8.5 and 9.5 kHz); ③ make it mandatory for airplanes to regularly transmit basic flight parameters via ACARS; and ④ implement deployable recorders.

Therefore, the ARAIB concludes that based on new technologies currently studied, technological research and development should be carried out to resolve problems with aircraft location tracking for identifying the location of the crashed aircraft and rescuing missing pilots because the ULB and chassis, vulnerable to heat and impact, can be easily separated from the CSMU and because the ULB signal will get much weaker if the sea floor consists of thick mud and sand like AAR991's accident site.

2.6 Cargo

2.6.1 Cargo Loading

From 01:00 to 02:02 on 28 July 2011, 58,265.8 kg of cargo (30 pallets, 5 containers), which is 60 cases by master airwaybill, was loaded at Incheon Airport, and 35 positions including 24 in the main deck (Class E) and 11 in the lower cargo (Class C) compartments were used. At positions of main deck assumed to be the origin of a fire, CL, CR, DL, DR, EL, ER, FL, FR, GL, GR, HL, HR, JL, JR, KL, KR, LR, ML, MR, PR, RR, SL and SR were loaded Code M (318 cm × 244 cm) pallets, and at position LL was loaded a Code M container. Positions A1, A2, B1, PL, RL and T were empty.

The total weight of Incheon departing cargo was 39,331 kg by 48 AWBs, and the cargo acceptance time at Asiana Airlines' export storage area was from 27 July at 10:11 through 28 July at 00:06. For security check during acceptance, X-ray screening and explosive trace detection were conducted. The total weight of cargo transshipped to AAR991 at Incheon Airport was 18,934 kg by 12 AWBs, and departure points were eight airports abroad.

Asiana Airlines classified cargo according to the assigned master airwaybill numbers and loaded it on the ULDs (pallets and containers). When loading the ULDs on the aircraft, the company matched the serial number assigned to each ULD with the applicable position in the cargo compartments according to its load plan. The ARAIB concludes that although all the dangerous goods were loaded together on two pallets for convenience in transportation, regulations on DG segregation was not violated, and found no evidence that Asiana Airlines' cargo loading was carried out in violation of the company's current regulations.

2.6.2 Dangerous Goods Acceptance

Cargo agents intending to transport the dangerous goods by air through Asiana Cargo's Incheon facility are required to register with the air carrier as a "Dangerous Goods Handling Agent." For registration, the Agent should submit certificates of DG Category 6 qualification and employment held by one of its personnel to Asiana Airlines and get its permission, thereby obtaining qualifications for offering the dangerous goods. This Dangerous Goods Handling Agent certification system requiring a certified DG handling employee was adopted only by Asiana Airlines at the time of the accident in 2011. To meet the requirements specified in "MOLIT Regulation for Dangerous Goods by Air Transport, Article 12 (Training Syllabus, etc.)," Dangerous Goods Handling Agents shall hire an employee who received DG training (including radioactive substance training) at least for more than 40 hours in the DG training institutions approved by the Minister of MOLIT and obtained a certificate.

The dangerous goods reserved only by a bonded goods caretaker (holder of a DG Category 6 qualification certificate) from the office separately located inside a cargo warehouse are accepted and inspected. Specifically, they were accepted only after master airwaybills prepared by shipper, shipper's DG declaration, packaging, marking and labelling were inspected according to the latest checklist attached to the newest DGR Appendix issued by IATA. The ARAIB found no evidence that Asiana Airlines accepted the dangerous goods in violation of the company's current regulations.

Also, it is concluded that Asiana Airlines has adequately managed the dangerous goods at airports in that, apart from the checklist attached to the IATA DGR Appendix, a loadmaster and a checker separately ran their own dangerous goods field checklist so that marking, labelling, external conditions of the packaging, compliance with This Side Up label, proper fixing, and conditions of DG labels affixed to ULDs could be reinspected.

2.6.3 Dangerous Goods Storage

The dangerous goods waiting to be loaded for air transportation are stored in a temporary DG storage area prepared separately in a cargo warehouse and exclusively managed by employees (holder of a DG Category 6 qualification certificate) of Asiana Airport, a company offering cargo handling services to Asiana Airlines. In other words, the dangerous goods waiting to be loaded on aircraft are always stored in a temporary DG storage area in isolation from other general cargo.

Asiana Airport employees store the dangerous goods in accordance with marking, labelling, and regulations on DG segregation (MOLIT Regulation for Dangerous Goods by Air Transport, Article 177) prescribing that the dangerous goods that have a dangerous chemical reaction to each other should be segregated.

The ARAIB found no evidence that the dangerous goods were stored in violation of Asiana Airlines' current regulations since the temporary DG storage area was furnished with DG-related agencies' latest contact information, DG labelling chart, DG segregation chart, dangerous area warning markings, disposable gloves, steel drum, protective gloves, waste plastic bags, power absorbent, detergent, plastic shovels, and first-aid kit, in accordance with MOLIT Regulation for Dangerous Goods by Air Transport, Appendix 23.

2.6.4 Lithium-ion Battery Build-up and Loading

Lithium-ion batteries shipped onboard the accident airplane were regulated as Class 9 UN3480, Packing Group Ⅱ, dangerous goods. They were in either a 6-cell or 12-cell configuration for use in hybrid electric vehicles. The individual cells were rated at 24.4 - 24.8 Ah at 3.65 volts and 89.1 - 90.5 Wh. The shipment contained a total of 18 lithium-ion batteries, including 15 of the 12-cell configuration and 3 of the 6-cell one.

According to the statement of the dangerous goods handling agent, fifteen 12-cell batteries were packed 1 per box in 15 fiberboard boxes, whereas three 6-cell batteries in 2 fiberboard boxes, with 2 per box and the remaining one per box. The batteries have the terminals covered with insulating material to prevent external short-circuit in transit, and they are wrapped with polyethylene that has a melting point of 122℃ and secured with fiberboard inner packaging material fit for the shape of the battery. A sheet of impact-resistant bubble wrap was placed in the top of the box and closed to complete the packaging.

One box can be packed with two 6-cell batteries or one 12-cell battery. Since the weight of two 6-cell batteries and one 12-cell battery is approximately 16 kg and 14 kg, respectively, the ratio of 14 - 16 kg of the battery weight to 40 kg of the box's packing weight limit as a percentage is 40% or less.

The manufacturer's testing of lithium-ion batteries met the method and standards prescribed in the UN Manual of Tests and Criteria, Part III, subsection

38.3 of "UN Recommendations for Transport of Dangerous Goods." The batteries were shipped in appropriate packing materials that were manufactured to the UN standard for Packing Group Ⅱ.

DG loading was performed in accordance with "MOLIT Regulation for Dangerous Goods by Air Transport, Article 180," IATA DGR, and ICAO T.I. MOLIT Regulation for Dangerous Goods by Air Transport, Article 180 (Loading and Fixing) specifies that DG packages and overpacks bearing the "Cargo Aircraft Only" label should be loaded according to one of the following methods: ① loaded in a Class C cargo compartment; ② loaded on ULDs equipped with the fire detection and extinguishing system approved by the Minister of MOLIT and in compliance with certification requirements of a Class C cargo compartment; and ③ easily confirmed and accessed by crewmembers, related personnel or authorized personnel during flight or in case of emergency, and segregated from other shipments if the dangerous goods' size and weight are within the allowable range. The ARAIB found no evidence that the dangerous goods were loaded in violation of Asiana Airlines' current regulations since the dangerous goods in a Class E cargo compartment were located near the aisle of the main deck cargo compartment accessible by the flight crew in accordance with the current laws and regulations.

Yet the ARAIB recommends that, for safer transportation of dangerous goods, flammable dangerous goods (Class 3) and lithium batteries (Class 9) bearing the "Cargo Aircraft Only" label be loaded and transported only in a Class C cargo compartment equipped with a separate smoke detector or fire detection system and with an approved built-in fire extinguishing or suppression system controllable from the cockpit, and that lithium batteries (Class 9) be loaded in a separate ULD and segregated from other flammable dangerous goods (Class 3).

2.6.5 Flammable Liquid Build-up and Loading

2.6.5.1 Photo-Resist/IC

This product is regulated as Class 3 UN1993, Packing Group III, flammable liquid. Transparent photo-resist solution in either a purple- or yellow-labeled glass container was loaded on pallets at positions ML and PR. Packaging was in accordance with ICAO TI Packing Instruction 366. The safety of the product is not affected by temperatures that exceed 10℃, but its marketability is negatively affected since its quality is compromised. The manufacturer in charge of product packaging enclosed the containers completely in clear and black plastic bags, respectively. Four of these glass containers were placed in one UN specification fiberboard box with 10 blue ice packs weighing 0.5 kg each and two digital temperature recorders, which, the ARAIB concludes, is suitable for air transportation.

The manufacturer handled the process from packaging to loading the product onto a transport vehicle. Yet its person in charge of DG packaging was not aware of the DG handling procedures and just understood that the product should be safely handled in a special custom-made durable box (UN specification) to be protected from damage in transit. The ARAIB recommends that, in accordance with Table 1-1 "Training Syllabus by Trainees" and Table 1-2 "Minimum Training Hours by Duty Categories" under MOLIT Regulation for Dangerous Goods by Air Transport, Article 14 (Training), the manufacturer's personnel who are delegated a packaging task by a dangerous goods handling agent receive the minimum DG-related training, i.e. Duty Category 2[152) DG training.

2.6.5.2 Photo-Resist/LCD

This product is a highly flammable liquid and is regulated as Class 3

152) Duty Category 2: 16-hour training for employees in charge of DG packaging, consisting of 8 subjects in relation to DG handling (MOLIT Regulation for Dangerous Goods by Air Transport).

UN1866, Packing Group Ⅲ, flammable liquid. Packaging was in accordance with ICAO TI Packing Instruction 355. The MSDS indicates that the flash point of the product is 41 - 47℃, and that the product may explode when heated. Photo-resist is used for LCD manufacturing, and it is either a bright blue or bright red liquid, designated by the "B" or the "R" in the product name. The integrity of the product is sensitive to temperature and light.

The product was contained in 53 brown plastic 10-liter containers, each of which was filled with 9 liters of a blue or red liquid. The containers were each enclosed in clear plastic bags and were packed 2 per 1 fiberboard box inside Styrofoam inserts with blue ice that keeps the product cold.

This product is stored at 5℃ in the manufacturer's facility and transported in a refrigerated truck to a dangerous goods handling agent. The safety of this product is not affected by temperatures that exceed 5℃, but it is no longer marketable since the quality of the product is compromised. The dangerous goods handling agent repackaged the product by placing it inside Styrofoam inserts with 10 blue ice packs and 2 digital temperature recorders provided by the manufacturer. The ARAIB concludes that, apart from the basic DG packaging, the product was more safely repackaged to maintain its quality.

2.6.5.3 Paint

According to packaging for liquids specified in IATA DGR 55th edition, 5.0.2.7.1 and 5.0.2.7.2, the body and the closure of any packaging must be so constructed as to be able to adequately resist the effects of temperature and vibration occurring in normal conditions of transport. The closure device must be so designed that it can be completely closed and remains closed during transport. In addition, for the inner packaging containing liquids, closures must be held securely, tightly and effectively in place by secondary means. Examples of such methods include: adhesive tape, friction sleeves, welding or soldering, positive locking wires, induction heat seals and child-resistant closures. When secondary means of closure cannot be applied, the inner packaging must be securely closed and placed in a leakproof liner and then placed in an outer packaging.

Flammable liquids (paint) loaded on the accident airplane were packaged by good-quality durable packaging materials that could endure impact during transport, and were sealed to prevent the contents from spilling due to a change of vibration, temperature, humidity, and pressure in normal conditions of transport, in compliance with the information provided by the manufacturer. Packaging materials were manufactured after tested by a specialized inspection agency, conformed to the tested design format, and were free from corrosion, contamination, and other damage prior to transportation.

The ARAIB found no evidence that paint was packaged in violation of Asiana Airlines' current regulations since the product was packaged in accordance with the current dangerous goods handling regulations, judging by the fact that paint containers were closed initially by a plastic lid and then by a metal screw cap, although not closed exactly by a secondary closure device mentioned above, and were placed in fiberboard boxes with Styrofoam inserts to prevent leakage.

2.6.5.4 Flammable Liquid Loading

Beginning January 2014, Asiana Airlines required that a copy of NOTOC listing the details of dangerous goods, specified in ICAO T.I Doc 9284, 7.4.1 and delivered to the captain, also be delivered to a flight dispatcher or a designated ground personnel responsible for flight operations, and then they examine the loaded status of the dangerous goods. Yet the ARAIB concludes that, in the case of AAR991, dangerous goods were loaded in accordance with more strict DG loading procedures than the requirement above since the dangerous goods on board were photographed, and their photos were stored.

Also, the ARAIB concludes that DG checks before and after loading were appropriately conducted, judging by the fact that the loadmaster responsible for loading, together with the captain, personally inspected the locations and loaded status of the dangerous goods in the main deck cargo compartment when he provided NOTOC to the captain.

The ARAIB concludes that flammable dangerous goods loaded in a Class E cargo compartment were located near the aisle of the main deck cargo compartment accessible by the flight crew in accordance with MOLIT Regulation for Dangerous Goods by Air Transport, Article 180 (Loading and Fixing), paragraph 3 stating that "during operation or in case of emergency, crewmembers and relevant employees should easily check and access dangerous goods."

Yet the ARAIB recommends that, for safer transportation of dangerous goods, flammable dangerous goods (Class 3) bearing the "Cargo Aircraft Only" label be loaded and transported only in a Class C cargo compartment equipped with a separate smoke detector or fire detection system and with an approved built-in fire extinguishing or suppression system controllable from the cockpit.

3. Conclusions

3.1 Findings

1. The aircraft, HL7604, was manufactured by the Boeing Company on 15 February 2006. On 22 February 2006, it was delivered to Asiana Airlines and registered under the Korean Airworthiness Authority. The aircraft held a valid airworthiness certificate issued on 24 February 2006.

2. The flight crew of AAR991 held a valid airman certificate proper for operation and an airman medical certificate in accordance with the Aviation Act of the Republic of Korea.

3. Review of the maintenance history of the five months before the accident confirms that there were no faults and corrective actions in relation to this accident on the aircraft journey log.

4. The center of gravity (CG) in accordance with a flight plan was within the approved range of CG in accordance with a flight manual and the operating range of CG in accordance with company rules.

5. The weather conditions over Jeju Island and the accident site indicate that a southwest current of air and a westerly current of air flowed in at the middle and upper levels, respectively. Also, there were no convective cloud or other unusual weather phenomena.

6. On 28 July 2011, about 04:11, Asiana Airlines flight 991, a B747-400F airplane, crashed into the international waters about 130 km west of Jeju Airport after the flight crew reported a cargo fire to SHI ACC near a reporting point SADLI on airway A593 about 03:54 and attempted to divert

to Jeju Airport.

7. At 03:52:39, SHI ACC instructed AAR991, "AAR991 radar contact, off-set 5 miles right of track," and at 03:52:51, the flight crew acknowledged this instruction without mentioning a cargo fire.

8. At 03:54:23, the FO declared an emergency to SHI ACC due to a main deck cargo fire and requested a descent to 10,000 ft.

9. At 04:03:01, the FO called SHI ACC and stated that AAR991 was unable to contact FUK ACC. Consequently, SHI ACC instructed AAR991 to pass information to KAL886 and let KAL886 relay the information to FUK ACC and ICN ACC.

10. From 03:53 to 04:00, FDE messages were transmitted via ACARS. At 03:53, ACARS messages "CGO DET 11 MN DK" and "EQUIPMENT SMOKE" were first transmitted, followed by many other messages between 03:56 and 04:00, after which ACARS messages were not transmitted any more.

11. AAR991 had to exchange flight information via HUK ACC since there was no direct telephone line between SHI ACC and ICN ACC. As a result, a more rapid exchange of information on its emergency could not be made.

12. After the occurrence of an emergency, AAR991 attempted to communicate with ICN ACC on 124.525 MHz around 10,000 ft but to no avail, and thus, KAL886 flying at a higher altitude had to relay the information between AAR991 and ICN ACC.

13. AAR991 entered a communication dead zone while descending from 34,000 ft to 10,000 ft because of the location of the 124.525 MHz transceiver

antennas used for communication, thereby failing to communicate directly with ICN ACC.

14. Korea's AIP valid at the time of the accident did not contain frequency 128.375 MHz as an ATC frequency for airways A593 and B576, and the frequency was not used when AAR991 in an emergency situation was flying around 10,000 ft.

15. Immediately after being notified of AAR991's accident, the ARAIB conducted search operations in four phases to locate the crash site and retrieve flight recorders. The Board recovered the chassis of the FDR but failed to locate its CSMU and the CVR.

16. The wreckage of AAR991 was distributed in the underwater area 3 km by 4 km, 130 km west of Jeju Airport, in southwest-northeast direction.

17. From 28 July 2011 to 10 June 2012, three times of wreckage recovery operations yielded about 40% of aircraft skin and about 15% of cargo.

18. According to wreckage examination results, blue photo-resist and electronic components loaded in the main deck cargo compartment were found on the top surface of the right wing.

19. The wreckage between FS1700 and APB, under which the pallets at positions ML and PR were located, sustained the most severe fire damage, and the evidence that smoke entered the flight deck was found.

20. Four out of the six riser ducts on AAR991 were recovered. All three left riser ducts sustained fire damage which was consistently more severe along the upper glass fiber portions and tapered off towards the bottom.

21. The ACARS message "ELT ON" was transmitted, but the distress signal was not received by any authorities concerned. The ELT installed on AAR991 is inoperable in the water.

22. The ARAIB awarded a contract to conduct "a study on wreckage reconstruction, and testing and analysis in relation to Asiana Airlines' crash accident," which dealt mainly with wreckage reconstruction, fire simulation, testing for determining the cause of a fire, etc.

23. As Asiana Airlines' simulator was a passenger configuration unable to support a full Fire Main Deck training for B747 freighters, pilots imagined that the simulator was a freighter and performed its non-normal procedures in the Fire Main Deck checklist.

24. AAR991 did not maintain 25,000 ft specified in the QRH's Fire Main Deck non-normal checklist. Judging from the size and condition of AAR991's fire, there is a possibility that, even if AAR991 had maintained 25,000 ft, the fire would not have been extinguished until the TOD point for Jeju Airport, and that, in this case, as an increase in oxygen during the descent had resulted in the spread of fire, the outcome of this accident would not have changed.

25. The flight crew failed to implement a procedure of operating the supernumerary oxygen switch, which was specified in the QRH's Fire Main Deck non-normal checklist.

26. It seems that the flight crew's implementation of the QRH's Fire Main Deck non-normal procedures was delayed.

27. The QRH available to the flight crew on AAR991 contained all procedures

applicable to Asiana Airlines' entire 747-400 fleet. This included two significantly different Fire Main Deck procedures, one unique to the 747-400 Combi and the other unique to the 747-400F.

28. There is a possibility that the flight crew implemented the Combi Fire Main Deck non-normal procedure instead of the Freighter one.

29. The QRH's non-normal procedures in relation to AAR991's fire situation were as follows: FIRE MAIN DECK; EQUIP COOLING; FIRE APU; Smoke Fire or Fumes; Smoke or Fumes Removal; and Ditching.

30. About 03:53, a fire was detected, and about 03:56, ACARS messages influencing flight control started to be generated.

31. Turbulence data from the ACMS was transmitted four times, about 03:57:23 03:57:43, 03:58:47, and 03:59:29, while the aircraft was descending from 22,700 ft to 13,400 ft.

32. It is possible that the flight crew intentionally did not stay at 25,000 ft, fire suppression altitude, because they may have regarded their situation as serious, needing to make a ditching.

33. Boeing's B747 manuals for the flight crew failed to specify the basis for the 25,000 ft requirement, the effect and concept of fire suppression at 25,000 ft, and when to descend from 25,000 ft.

34. At 04:06:32, at 9,900 ft, the captain reported the loss of rudder control, and 04:09:47, at 12,800 ft, reported the loss of all flight controls, including rudder control, to ATCs. At 04:10:15, when the aircraft was flying at 423 kt at an altitude of 11,300 ft on a heading of 004°, the FO reported the loss

of altitude control and the impending ditching.

35. After notified of the recurrent simulation training syllabus and evaluation items in advance, the flight crew receive the training, and this kind of pre-notification compromises the flight crew's ability to judge and respond to unexpected situations and the effect of the CRM training. Therefore, it is necessary to improve Asiana Airlines' method of recurrent training and evaluation.

36. As the subject of Fire Main Deck that cannot be simulated as the same as on a B747 freighter is difficult to be selected as a recurrent training subject and thus less trained, the flight crew usually can possibly neglect the study of this subject.

37. As the captain in a B747 freighter's cockpit could not accurately check the size and the condition of a cargo fire, including whether it was suppressed, extinguished, or spread, it may have been difficult for him to determine whether a fire could be suppressed and how serious it was.

38. In the process of Asiana Airlines' acceptance, storage, and loading of dangerous goods in accordance with its current dangerous goods handling regulations and procedures, the ARAIB found no evidence that the company violated its current regulations and procedures.

39. The ARAIB visited the manufacturer of lithium-ion batteries and examined their safety, but failed to acquire the data that could prove the self-ignition possibility of the batteries.

40. Paint manufactured by a Japanese company provides moisture-proof insulating coating used for manufacturing mobile phones. It has a flash point of -1℃.

After a container of the product, tightly closed by internal and external closure devices and inserted in the enclosed plastic bag, was left for 2 hours at room temperature of 18℃, its volatile organic compound (VOC) emissions were measured, then detected, but when tested in the air transport environment (at a cabin altitude), were not detected. Also, it could not be proven whether internal and external closure devices of the product failed to function properly during AAR991's flight.

41. Analysis of the ATC/pilot communications transcript and ACARS messages reveals that a fire occurred first in the aft fire zones rather than others. Thus, the ARAIB concludes that smoke was initially detected in fire zones 11 or 13.

42. When the FO communicated with SHI ACC at 03:52:51, he did not mention a fire, and the ARAIB thus concludes that a fire was initially detected between 03:52:51 and the time when "CGO DET 11 MN DK" was generated (03:53 - 03:54).

43. Review of the accident airplane's maintenance history revealed that no defect was caused by short-circuited wires.

44. The ARAIB assumes that a fire likely broke out first on or near the pallets containing dangerous goods, but physical evidence of the cause of the fire was not found.

45. After boarding the freighter with a similar flight pattern to that of the accident airplane, the ARAIB measured the amount of electrostatic energy accumulated in the plastic wrap used for cargo on the pallets, on one of which electrostatic energy measuring 0.23 mJ was found. Although this amount of energy was bigger than the MIE of a certain gas (methanol, one

of the molecules of paint, flammable material), it is difficult to conclude that electrostatic energy acted as an ignition source since flammable gas leakage tests revealed that VOCs were not detected at a cabin altitude (8,000 ft), same environment where the fire occurred on the accident airplane.

46. The ARAIB failed to acquire the data that could prove the self-ignition possibility of lithium-ion batteries in normal conditions of transport, but when they are heated externally, they can go into thermal runaway. The battery manufacturer argues that lithium-ion batteries are safe, but recalls have been issued because lithium-ion battery-operated computers caught on fire.

47. About 3 to 4 minutes after smoke detection, smoke spread rapidly throughout the main deck cargo compartment. Judging by the fact that a well defined soot trail was discovered on the exterior skin of the cockpit smoke evacuation shutter, smoke entered the flight deck. A fire did not spread beyond the APB.

48. The ARAIB concludes that powerful fire energy was produced to the extent that photo-resist/LCD and paint in position PR splattered on the top surface of the right wing, about 30 meters away from PR, that electronic components in position MR were imbedded in the composite wing upper surfaces, and that some portions of the fuselage separated from the airplane in midair.

49. Examination of two pieces of the reconstructed wreckage at FS2180 revealed that one piece of the wreckage could stand outward force because it was attached to the fuselage frame, whereas the skin of the other piece was bent outward due to energy on the inside. This indicates that the skin along the

wreckage sheared off in midair due to energy on the inside of the airplane.

50. The heat release from burning photo-resist in position ML is about 22.9 mega BTU. The total heat release from burning paint and photo-resist in position PR is about 19 mega BTU. A rapid increase in this thermal energy caused some portions of the fuselage to separate from the airplane in midair.

3.2 Causes

The Aviation and Railway Accident Investigation Board (ARAIB) determines the cause of this accident as follows:

A fire developed on or near the pallets containing dangerous goods but no physical evidence of the cause of the fire was found. The fire rapidly escalated into a large uncontained fire, and this caused some portions of the fuselage to separate from the aircraft in midair, thereby resulting in the crash.

3.3 Contributing Factors

1. Flammable materials like photo-resist (Class 3) were loaded in position ML, and flammable materials like paint, photo-resist, corrosive liquid, and lithium-ion batteries (Class 9) were loaded on one pallet in position PR.

2. It was difficult to contain a large scale of fire only by the fire suppression system of a Class E cargo compartment that was not equipped with an active fire suppression system.

4. Safety Recommendations

To Asiana Airlines

1. Ensure that flammable liquid dangerous goods (Class 3) and lithium batteries (Section 1, 1A)[153] which are bearing the "Cargo Aircraft Only (CAO)" label are segregated and loaded on separate ULDs.

2. Load lithium batteries classified as dangerous goods (Section 1, 1A) in a Class C cargo compartment.

3. Produce and equip your aircraft with a QRH that contains only the procedures required for the operation of that specifically configured aircraft.

4. Operate your simulators in such a way that your flight crew can be realistically trained on non-normal procedures of a passenger, cargo or combi plane.

5. Add and run a recurrent simulation training program whose syllabus is not notified in advance to your flight crew to improve their ability to respond to unexpected non-normal situations, and give your flight crew more intensive training on non-normal situations.

To MOLIT (Office of Civil Aviation)

1. Develop relevant standards for ensuring that flammable liquid dangerous goods (Class 3) and lithium batteries (Section 1, 1A) which are bearing the "Cargo Aircraft Only (CAO)" label are segregated and loaded on

153) This refers to ICAO TI Packaging Instructions 965-967, Section 1, 1A.

separate ULDs (pallets, etc.).

2. Develop loading standards for ensuring that various kinds of flammable dangerous goods (Class 3) are not concentrated in a single ULD within an aircraft.

3. Develop loading standards for ensuring that flammable dangerous goods (Class 3) and lithium batteries classified as dangerous goods (Section 1, 1A) are loaded in a Class C cargo compartment or that they are loaded on ULDs equipped with a fire extinguishing system or made of fire-resistant materials.

4. Develop a Technical Standard Order (TSO) for ULDs to ensure that ULDs used for loading flammable dangerous goods or lithium batteries classified as dangerous goods (Section 1, 1A) are equipped with a fire extinguishing system or made of fire-resistant materials.

5. Prepare monitoring measures to ensure that manufacturers' personnel in charge of packaging dangerous goods perform their duty only after receiving dangerous goods-related training in accordance with Table 1-1 "Training Syllabus by Trainees" and Table 1-2 "Minimum Training Hours by Duty Categories" under MOLIT Regulation for Dangerous Goods by Air Transport, Article 14 (Training).

6. Revise related regulations to require Korean operators to produce a QRH that contains only the procedures required for the operation of each specifically configured aircraft (i.e. passenger, cargo or combi configuration).

7. Revise regulations related to simulation training to ensure that the flight

crew can be realistically trained on non-normal procedures of a passenger, cargo or combi plane.

8. Monitor whether Korean operators add and run their recurrent simulation training program whose syllabus is not notified in advance to the flight crew to improve their ability to respond to unexpected non-normal situations.

9. Study the correlation of fire with electrostatic energy that can be accumulated in the plastic wrap used for pallets on the ground and during flight, and develop standards for the use of the plastic wrap.

10. Establish a communications network between ICN ACC and SHI ACC so that they can exchange flight information directly.

11. Contain the use of frequency 128.375 MHz in the AIP so that airplanes on airways A593 and B576 can communicate with ATCs on that frequency.

To the Boeing Company

1. Seek feasible measures to improve a B747 freighter system, including development of a visual means for helping pilots in the cockpit check the condition of a cargo fire, including whether it is suppressed, extinguished, or spread, and determine whether a fire can be contained.

2. Conduct research that seeks measures to equip a freighter's Class E cargo compartment with an active fire extinguishing or suppression system controllable from the cockpit, like that of a Class C cargo compartment.

3. Ensure that its B747-400 Flight Crew Operations manuals (FCOM or equivalent) contain specific information on the basis for the 25,000 ft requirement, the effect of the fire suppression complying with the 25,000 ft requirement, and strategies to be considered for when to begin a descent to land from that altitude.

To ICAO

Recommend your Flight Data Recovery Working Group[154)] to deal with the following issues:

1. Address the ULB's weakness of being vulnerable to heat.

2. Resolve problems facing when the ULB is buried under the sea floor consisting of thick mud and sand.

3. Ensure that the chassis will not be separated from the CSMU.

4. Seek ways to install an ELT that can float to the water surface and operate, or be operable in the water.

5. Develop a deployable ELT broadcasting a GPS position.

154) An international working group created to resolve technical problems about the recovery of recorders in the three following areas: flight data transmission; new flight recorder technology; and wreckage localization technology.

APPENDIXES

1. ACARS CMC Data Interpretation
2. Time-Based Aircraft Status and Events
3. Incheon Area Control Center's Radar Data
4. ATC Communication Transcript
5. Search Operations for Flight Recorders
6. Aircraft Cockpit Examination
7. AAR991's Flight Documents
8. 2011 Recurrent Training and Evaluation for B747-400 Flight Crew
9. QRH Procedures in Relation to AAR991's Fire
10. Results of Tests and Research

APPENDIX 1: ACRAS CMC Data Interpretation

Time CMC msg first became active	Mx M #	Maintenance Message	Intermittence	Activity	Flight Deck Effect	FDE #	FDE Level
18:53	**26330**	**CARGO FIRE MAIN DECK ZONE-11 LOOP-A FAIL**	**Intermittent**	**Inactive**	**CGO DET 11 MN DK**	**261 458 00**	**STATUS**

The Zone 11A detector was in alarm for at least 8 seconds without the Zone 11B detector being in alarm or the 11A detector failed to pass a "disagree" test from the zone 11 AFOLTS card or the wire from the zone 11A detector to the AFOLTS was open circuit when a "disagree" test was performed. Because this fault was correlated to "CGO DET 11 MN DK" and not to "MD CGO 11 LP A", the Zone 11B detector was in alarm or faulted within 20 seconds of the Zone 11A detector. The above message would be consistent with Zone 11A and Zone 11B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

18:53	**21422**	**E/E COOLING SMOKE DETECTED**	**Intermittent**	**Inactive**	**EQUIP COOLING**	**215 005 00**	**CAUTION**

The Forward Equipment Cooling System includes a flow-through photoelectric type smoke detector in the exhaust (ventilation) portion of the system. Airflow from the main E/E bay ventilation hoods and the flight deck exhaust piccolo ducts is drawn-through the system by the exhaust fan, and a small portion of the fan outlet air is routed to the smoke detector for sampling. When smoke is detected by this smoke detector, a discrete electrical ground signal from the smoke detector will be output and sensed as an input to the EIUs. The EICAS Caution level message EQUIP COOLING and Status level message EQUIPMENT SMOKE will be displayed immediately by the EIUs. The EIUs will send the smoke detected signal to the CMC via the ARINC 429 digital bus. The CMC message 21422 E/E COOLING SMOKE DETECTED will be set by the CMC when it sees the E/E Cooling Smoke Detected ARINC 429 signal for 3 continuous seconds. The EICAS Caution level message EQUIP COOLING will go away if the smoke detector is no longer providing the discrete electrical ground signal (smoke is no longer being detected by the smoke detector). If the aircraft is in the air, the EICAS Status level message EQUIPMENT SMOKE will be latched in the Non-Volatile Memory (NVM) of the EIUs . All three messages (the two EICAS messages and the one CMC message) will be inhibited (by the use of relays to break the electrical ground signal from the smoke detector to the EIUs) for any of the following conditions: 1) Main Deck Cargo Compartment is ARMED, 2) Either the Forward or Aft Lower Lobe Cargo Compartment is ARMED, or 3) the Equipment Cooling System is in a Self-Test Mode (which normally occurs 30 secs after landing after 10 flight legs).

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5/11/2015

18:53	21422	E/E COOLING SMOKE DETECTED	Intermittent	Inactive	EQUIPMENT SMOKE	215 010 00	STATUS

The Forward Equipment Cooling System includes a flow-through photoelectric type smoke detector in the exhaust (ventilation) portion of the system. Airflow from the main E/E bay ventilation hoods and the flight deck exhaust piccolo ducts is drawn-through the system by the exhaust fan, and a small portion of the fan outlet air is routed to the smoke detector for sampling. When smoke is detected by this smoke detector, a discrete electrical ground signal from the smoke detector will be output and sensed as an input to the EIUs. The EICAS Caution level message EQUIP COOLING and Status level message EQUIPMENT SMOKE will be displayed immediately by the EIUs. The EIUs will send the smoke detected signal to the CMC via the ARINC 429 digital bus. The CMC message 21422 E/E COOLING SMOKE DETECTED will be set by the CMC when it sees the E/E Cooling Smoke Detected ARINC 429 signal for 3 continuous seconds. The EICAS Caution level message EQUIP COOLING will go away if the smoke detector is no longer providing the discrete electrical ground signal (smoke is no longer being detected by the smoke detector). If the aircraft is in the air, the EICAS Status level message EQUIPMENT SMOKE will be latched in the Non-Volatile Memory (NVM) of the EIUs . All three messages (the two EICAS messages and the one CMC message) will be inhibited (by the use of relays to break the electrical ground signal from the smoke detector to the EIUs) for any of the following conditions: 1) Main Deck Cargo Compartment is ARMED, 2) Either the Forward or Aft Lower Lobe Cargo Compartment is ARMED, or 3) the Equipment Cooling System is in a Self-Test Mode (which normally occurs 30 seconds after landing after 10 flight legs).

18:54	26328	CARGO FIRE MAIN DECK ZONE-10 LOOP-A FAIL	Intermittent	Inactive	CGO DET 10 MN DK	261 457 00	STATUS

The Zone 10A detector was in alarm for at least 8 seconds without the Zone 10B detector being in alarm or the 10A detector failed to pass a "disagree" test from the zone 10 AFOLTS card or the wire from the zone 10A detector to the AFOLTS was open circuit when a "disagree" test was performed. Because this fault was correlated to "CGO DET 10 MN DK" and not to "MD CGO 10 LP A", the Zone 10B detector was in alarm or faulted within 20 seconds of the Zone 10A detector. The above message would be consistent with Zone 10A and Zone 10B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

18:54	26320	CARGO FIRE MAIN DECK ZONE-6 LOOP-A FAIL	Intermittent	Inactive	CGO DET 6 MN DK	261 426 00	STATUS

The Zone 6A detector was in alarm for at least 8 seconds without the Zone 6B detector being in alarm or the 6A detector failed to pass a "disagree" test from the zone 6 AFOLTS card or the wire from the zone 6A detector to the AFOLTS was open circuit when a "disagree" test was performed. Because this fault was correlated to "CGO DET 6 MN DK" and not to "MD CGO 6 LP A", the Zone 6B detector was in alarm or faulted within 20 seconds of the Zone 6A detector. The above message would be consistent with Zone 6A and Zone 6B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

		CARGO FIRE MAIN DECK ZONE-7 LOOP-A			**CGO DET 7 MN**		
18:55	**26322**	**FAIL**	**Intermittent**	**Inactive**	**DK**	**261 454 00**	**STATUS**

The Zone 7A detector was in alarm for at least 8 seconds without the Zone 7B detector being in alarm or the 7A detector failed to pass a "disagree" test from the zone 7 AFOLTS card or the wire from the zone 7A detector to the AFOLTS was open circuit when a "disagree" test was performed. Because this fault was correlated to "CGO DET 7 MN DK" and not to "MD CGO 7 LP A", the Zone 7B detector was in alarm or faulted within 20 seconds of the Zone 7A detector. The above message would be consistent with Zone 7A and Zone 7B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

		CARGO FIRE MAIN DECK ZONE-3 LOOP-A			**CGO DET 3 MN**		
18:55	**26314**	**FAIL**	**Intermittent**	**Inactive**	**DK**	**261 423 00**	**STATUS**

The Zone 3A detector was in alarm for at least 8 seconds without the Zone 3B detector being in alarm or the 3A detector failed to pass a "disagree" test from the zone 3 AFOLTS card or the wire from the zone 3A detector to the AFOLTS was open circuit when a "disagree" test was performed. Because this fault was correlated to "CGO DET 3 MN DK" and not to "MD CGO 3 LP A", the Zone 3B detector was in alarm or faulted within 20 seconds of the Zone 3A detector. The above message would be consistent with Zone 3A and Zone 3B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

		CARGO FIRE MAIN DECK ZONE-8 LOOP-A			**CGO DET 8 MN**		
18:55	**26324**	**FAIL**	**Intermittent**	**Inactive**	**DK**	**261 455 00**	**STATUS**

The Zone 8A detector was in alarm for at least 8 seconds without the Zone 8B detector being in alarm or the 8A detector failed to pass a "disagree" test from the zone 8 AFOLTS card or the wire from the zone 8A detector to the AFOLTS was open circuit when a "disagree" test was performed. Because this fault was correlated to "CGO DET 8 MN DK" and not to "MD CGO 8 LP A", the Zone 8B detector was in alarm or faulted within 20 seconds of the Zone 8A detector. The above message would be consistent with Zone 8A and Zone 8B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

		CARGO FIRE MAIN DECK ZONE-4 LOOP-A			**CGO DET 4 MN**		
18:55	**26316**	**FAIL**	**Intermittent**	**Inactive**	**DK**	**261 424 00**	**STATUS**

The Zone 4A detector was in alarm for at least 8 seconds without the Zone 4B detector being in alarm or the 4A detector failed to pass a "disagree" test from the zone 4 AFOLTS card or the wire from the zone 4A detector to the AFOLTS was open circuit when a "disagree" test was performed. Because this fault was correlated to "CGO DET 4 MN DK" and not to "MD CGO 4 LP A", the Zone 4B detector was in alarm or faulted within 20 seconds of the Zone 4A detector. The above message would be consistent with Zone 4A and Zone 4B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

Time	Code	Message	Type	State	Flight Deck Effect	ATA	Class
18:55	**26319**	**CARGO FIRE MAIN DECK ZONE-5 LOOP-B FAIL**	**Intermittent**	**Inactive**	**CGO DET 5 MN DK**	**261 425 00**	**STATUS**

The Zone 5B detector was in alarm for at least 8 seconds without the Zone 5A detector being in alarm or the 5B detector failed to pass a “disagree” test from the zone 5 AFOLTS card or the wire from the zone 5B detector to the AFOLTS was open circuit when a “disagree” test was performed. Because this fault was correlated to “CGO DET 5 MN DK” and not to “MD CGO 5 LP B”, the Zone 5A detector was in alarm or faulted within 20 seconds of the Zone 5B detector. The above message would be consistent with Zone 5B and Zone 5A detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

Time	Code	Message	Type	State	Flight Deck Effect	ATA	Class
18:55	**26340**	**CARGO FIRE MAIN DECK ZONE-16 LOOP-A FAIL**	**Intermittent**	**Inactive**	**CGO DET 16 MN DK**	**261 463 00**	**STATUS**

The Zone 16A detector was in alarm for at least 8 seconds without the Zone 16B detector being in alarm or the 16A detector failed to pass a “disagree” test from the zone 16 AFOLTS card or the wire from the zone 16A detector to the AFOLTS was open circuit when a “disagree” test was performed. Because this fault was correlated to “CGO DET 16 MN DK” and not to “MD CGO 16 LP A”, the Zone 16B detector was in alarm or faulted within 20 seconds of the Zone 16A detector. The above message would be consistent with Zone 16A and Zone 16B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

Time	Code	Message	Type	State	Flight Deck Effect	ATA	Class
18:57	**27201**	**SRM-R FAIL (SRM-R)**	**Hard**	**Active**	**>STAB TRIM 2**	**274 005 00**	**STATUS**

The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

Time	Code	Message	Type	State	Flight Deck Effect	ATA	Class
18:56	**27292**	**HYD-2 STAB TRIM ACT BRAKE RELEASE SW FAIL (SRM-R)**	**Hard**	**Active**	**>STAB TRIM 2**	**274 005 00**	**STATUS**

The STCM secondary brake released for at least 2 seconds without either a vaild SRM outupt trim command or an alternate electric trim command or the STCM secondary brake did not release within 2 seconds of a valid trim command when the stabilizer is within electric operating range, hydraulic pressure is high and STAB TRIM CONT 28 volts is present.

18:56 27503 FLIGHT CONTROLS PSM RIGHT 1 FAIL Hard Active F/D BAR BIAS 221 077 00 ADVISORY
The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 1 is missing (not connected).

18:57 22989 FCC-R FAIL (NO BUS OUTPUTS) Hard Active F/D BAR BIAS 221 077 00 ADVISORY
Several systems reported failure of FCC-R. The Central Maintenance Computers, EFIS/EICAS Interface Units, Stabilizer Trim/Rudder Ratio Changer Modules, and/or cross-channel FCCs may have reported this problem. The cause could be an actual failure of FCC-R, or of the output bus interface from the FCC to one or more of the other systems.

18:58 34012 FMC-R TO FMC-L RESYNC (FMC-R) Hard Active F/D BAR BIAS 221 077 00 ADVISORY
indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active F/D BAR BIAS 221 077 00 ADVISORY
The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:58 34737 FMC-L FAIL (NO BUS OUTPUTS) Intermittent Inactive F/D BAR BIAS 221 077 00 ADVISORY
EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:57 27001 SRM-L FAIL (SRM-L) Hard Active STAB TRIM 274 004 00 STATUS
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:57 27201 SRM-R FAIL (SRM-R) Hard Active STAB TRIM 274 004 00 STATUS
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of

the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:56 27292 HYD-2 STAB TRIM ACT BRAKE RELEASE SW FAIL (SRM-R) Hard Active STAB TRIM 274 004 00 STATUS

The STCM secondary brake released for at least 2 seconds without either a vaild SRM outupt trim command or an alternate electric trim command or the STCM secondary brake did not release within 2 seconds of a valid trim command when the stabilizer is within electric operating range, hydraulic pressure is high and STAB TRIM CONT 28 volts is present.

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active STAB TRIM 274 004 00 STATUS

The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:57 22651 YDM-LWR FAIL Hard Active YAW DAMPER LWR 222 102 00 STATUS

The lower yaw damper has detected a fault with the auto disengage relay, or a modal suppression accelerometer input is less than -0.425 g or greater than 0.425 g for 1 second, or the CONTROL or MONITOR channel has detected a rudder command difference of 0.35 Vrms for more than 0.5 seconds, or an internal yaw damper module fault has been detected.

18:56 22679 EXCITATION FAIL (YDM-LWR) Hard Active YAW DAMPER LWR 222 102 00 STATUS

The Lower YDM CONTROL processor has detected that the AC reference voltage output to the upper yaw damper servo LVDT has dropped below 18 vrms for more than 1.5 seconds.

18:56 27503 FLIGHT CONTROLS PSM RIGHT 1 FAIL Hard Active YAW DAMPER LWR 222 102 00 STATUS

The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 1 is missing (not connected).

18:56 27970 AFT SPD CARD FAIL OR AFT SPD CARD OUTPUT BUS FAIL Hard Active YAW DAMPER LWR 222 102 00 STATUS

The aft Surface Position Digitizer card has detected an internal fault, or the EIU has no input from the aft Surface Position Digitizer card.

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active A/P SINGLE SYS 221 084 00 STATUS
The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:56 27503 FLIGHT CONTROLS PSM RIGHT 1 FAIL Hard Active A/P SINGLE SYS 221 084 00 STATUS
The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 1 is missing (not connected).

18:56 27503 FLIGHT CONTROLS PSM RIGHT 1 FAIL Hard Active FLAP SYS MONITOR 275 002 00 STATUS
The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 1 is missing (not connected).

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active FLAP SYS MONITOR 275 002 00 STATUS
The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:57 16006 FLAP 26 VAC 2 INTERFACE 1 FAIL Hard Active FLAP SYS MONITOR 275 002 00 STATUS
FCUs C & R report: 26 VAC 2 FAIL (26 VAC 2 comes from M7360 FCE POWER SUPPLY-1 RIGHT)

18:57 27746 FLAP 26 VAC-3 > FCU-R INTERFACE FAIL Hard Active FLAP SYS MONITOR 275 002 00 STATUS
FCU R reports: 26 VAC 3 FAIL (26 VAC 3 comes from M7361 FCE POWER SUPPLY-2 RIGHT)

18:57 22989 FCC-R FAIL (NO BUS OUTPUTS) Hard Active NO AUTOLAND 221 083 00 STATUS
Several systems reported failure of FCC-R. The Central Maintenance Computers, EFIS/EICAS Interface Units, Stabilizer Trim/Rudder Ratio Changer Modules, and/or cross-channel FCCs may have reported this problem. The cause could be an actual failure of FCC-R, or of the output bus interface from the FCC to one or more of the other systems.

18:57 27001 SRM-L FAIL (SRM-L) Hard Active NO AUTOLAND 221 083 00 STATUS
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values

published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:57 27201 SRM-R FAIL (SRM-R) Hard Active NO AUTOLAND 221 083 00 STATUS
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:56 27503 FLIGHT CONTROLS PSM RIGHT 1 FAIL Hard Active NO AUTOLAND 221 083 00 STATUS
The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 1 is missing (not connected).

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active NO AUTOLAND 221 083 00 STATUS
The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:58 34012 FMC-R TO FMC-L RESYNC (FMC-R) Intermittent Inactive NO AUTOLAND 221 083 00 STATUS
indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:58 34737 FMC-L FAIL (NO BUS OUTPUTS) Intermittent Inactive NO AUTOLAND 221 083 00 STATUS
EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:59 22943 ELEVATOR SERVO-C/FCC-C FAIL Intermittent Inactive NO AUTOLAND 221 083 00 STATUS
A fault was detected in the actuator control loop between FCC-C and the center elevator autopilot servo. Elevator servo or force link common mode monitors may have detected shorted/broken wires or loss of LVDT excitation or the elevator servo command/response monitor may have detected a failure of the servo to move when commanded. The underlying failure may be in the FCC, the servo, the interface wiring, or the hydraulic supply to the servo.

18:59	**22501**	**RUDDER SERVO-C/FCC-C FAIL**	**Intermittent**	**Inactive**	**NO AUTOLAND**	**221 083 00**	**STATUS**

A fault was detected in the actuator control loop between FCC-C and the center rudder autopilot servo. Rudder servo or force link common mode monitors may have detected shorted/broken wires or loss of LVDT excitation or the rudder servo command/response monitor may have detected a failure of the servo to move when commanded. The underlying failure may be in the FCC, the servo, the interface wiring, or the hydraulic supply to the servo.

19:00	**22494**	**AILERON SERVO-C/FCC-C FAIL**	**Hard**	**Active**	**NO AUTOLAND**	**221 083 00**	**STATUS**

A fault was detected in the actuator control loop between FCC-C and the center aileron autopilot servo. Aileron servo or force link common mode monitors may have detected shorted/broken wires or loss of LVDT excitation or the aileron servo command/response monitor may have detected a failure of the servo to move when commanded. The underlying failure may be in the FCC, the servo, the interface wiring, or the hydraulic supply to the servo.

19:01	**22540**	**FCC-L~FCC-C INTERFACE FAIL**	**Hard**	**Active**	**NO AUTOLAND**	**221 083 00**	**STATUS**

A failure in the cross-channel data bus transmitting from FCC-L to FCC-C was detected by the FCC cross-channel test word monitor. FCC-L may have lost power or shut down, or wiring may have failed between the FCC-L CROSS CHANNEL RIGHT output and the FCC-C CROSS CHANNEL LEFT input.

18:56	**26177**	**CARGO FIRE EXTINGUISHER ARMED 'NO ACTION REQUIRED'**	**Hard**	**Active**	**PACK 2**	**215 018 00**	**ADVISORY**

The "CARGO FIRE EXTINGUISHER ARMED 'NO ACTION REQUIRED' " message can be set by either pushing the Fwd, Aft or Main Deck Cargo Fire Arm switch. Arming the cargo fire extinguishing system will automatically shutdown Pack 2 and Pack 3 during normal operations (all Packs operational). The PACK 1, PACK 2 or PACK 3 advisory message will be set when the pack is commanded on but is detected off e.g. the Pack 2 selector switch is in the NORM position while PACK 2 is commanded off due to a cargo compartment being ARMed).

18:56	**26177**	**CARGO FIRE EXTINGUISHER ARMED 'NO ACTION REQUIRED'**	**Hard**	**Active**	**PACK 3**	**215 020 00**	**ADVISORY**

The "CARGO FIRE EXTINGUISHER ARMED 'NO ACTION REQUIRED' " message can be set by either pushing the Fwd, Aft or Main Deck Cargo Fire Arm switch. Arming the cargo fire extinguishing system will automatically shutdown Pack 2 and Pack 3 during normal operations (all Packs operational). The PACK 1, PACK 2 or PACK 3 advisory message will be set when the pack is commanded on but is detected off e.g. the Pack 2 selector switch is in the NORM position while PACK 2 is commanded off due to a cargo compartment being ARMed).

19:00 21138 PACK 3 AIR FLOW SENSOR/WIRE FAIL Hard Active PACK 3 215 020 00 ADVISORY
The Pack Air Flow Sensor failure message will be set if the Flow Control Valve (FCV) is detected NOT closed and measured flow is lower than 100 CFM for 75 seconds or the FCV is commanded closed and measured flow is greater than 3400 CFM for 75 seconds. The Pack Air Flow Sensor failure message is inhibited if the FCV failure message is already set.

19:02 21135 FLOW CONTROL VALVE-3/WIRING FAIL Hard Active PACK 3 215 020 00 ADVISORY
The Pack Flow Control Valve (FCV) fault message will be set if the FCV is commanded close and the FCV is detected not closed for 60 seconds. The FCS is detected closed by a position switch which sends a ground analog discrete to the PTC.

18:56 23204 SATCOM SDU FAIL (NO BUS OUTPUTS) Hard Active SATCOM SYSTEM 232 521 00 STATUS
CMC, MCDU and SCID-3 systems indicating they were not receiving the expected labels from SDU.
This is a Consolidated Message (CMC AND (CDU-L OR -C OR -R) AND ((SCID-3 AND OPTION SELECTED) OR OPTION NOT SELECTED) REPORT FAILURE.

18:56 23204 SATCOM SDU FAIL (NO BUS OUTPUTS) Hard Active >SATCOM 232 501 00 STATUS
CMC, MCDU and SCID-3 systems indicating they were not receiving the expected labels from SDU.
This is a Consolidated Message (CMC AND (CDU-L OR -C OR -R) AND ((SCID-3 AND OPTION SELECTED) OR OPTION NOT SELECTED) REPORT FAILURE.

18:57 22989 FCC-R FAIL (NO BUS OUTPUTS) Hard Active >NO LAND 3 221 006 00 ADVISORY
Several systems reported failure of FCC-R. The Central Maintenance Computers, EFIS/EICAS Interface Units, Stabilizer Trim/Rudder Ratio Changer Modules, and/or cross-channel FCCs may have reported this problem. The cause could be an actual failure of FCC-R, or of the output bus interface from the FCC to one or more of the other systems.

18:57 27001 SRM-L FAIL (SRM-L) Hard Active >NO LAND 3 221 006 00 ADVISORY
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:57 27201 SRM-R FAIL (SRM-R) Hard Active >NO LAND 3 221 006 00 ADVISORY
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:56 27503 FLIGHT CONTROLS PSM RIGHT 1 FAIL Hard Active >NO LAND 3 221 006 00 ADVISORY
The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 1 is missing (not connected).

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active >NO LAND 3 221 006 00 ADVISORY
The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:58 34012 FMC-R TO FMC-L RESYNC (FMC-R) Intermittent Inactive >NO LAND 3 221 006 00 ADVISORY
indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:58 34737 FMC-L FAIL (NO BUS OUTPUTS) Intermittent Inactive >NO LAND 3 221 006 00 ADVISORY
EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:57 22989 FCC-R FAIL (NO BUS OUTPUTS) Hard Active >NO AUTOLAND 221 004 00 ADVISORY
Several systems reported failure of FCC-R. The Central Maintenance Computers, EFIS/EICAS Interface Units, Stabilizer Trim/Rudder Ratio Changer Modules, and/or cross-channel FCCs may have reported this problem. The cause could be an actual failure of FCC-R, or of the output bus interface from the FCC to one or more of the other systems.

18:57 27001 SRM-L FAIL (SRM-L) Hard Active >NO AUTOLAND 221 004 00 ADVISORY
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:57 27201 SRM-R FAIL (SRM-R) Hard Active >NO AUTOLAND 221 004 00 ADVISORY
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM posn.

18:56 27503 FLIGHT CONTROLS PSM RIGHT 1 FAIL Hard Active >NO AUTOLAND 221 004 00 ADVISORY
The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 1 is missing (not connected).

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active >NO AUTOLAND 221 004 00 ADVISORY
The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:58 34012 FMC-R TO FMC-L RESYNC (FMC-R) Intermittent Inactive >NO AUTOLAND 221 004 00 ADVISORY
indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:58 34737 FMC-L FAIL (NO BUS OUTPUTS) Intermittent Inactive >NO AUTOLAND 221 004 00 ADVISORY
EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:59 22943 ELEVATOR SERVO-C/FCC-C FAIL Intermittent Inactive >NO AUTOLAND 221 004 00 ADVISORY
A fault was detected in the actuator control loop between FCC-C and the center elevator autopilot servo. Elevator servo or force link common mode monitors may have detected shorted/broken wires or loss of LVDT excitation or the elevator servo command/response monitor may have detected a failure of the servo to move when commanded. The underlying failure may be in the FCC, the servo, the interface wiring, or hydraulic supply to the

servo.

18:59 22501 RUDDER SERVO-C/FCC-C FAIL Intermittent Inactive >NO AUTOLAND 221 004 00 ADVISORY
A fault was detected in the actuator control loop between FCC-C and the center rudder autopilot servo. Rudder servo or force link common mode monitors may have detected shorted/broken wires or loss of LVDT excitation or the rudder servo command/response monitor may have detected a failure of the servo to move when commanded. The underlying failure may be in the FCC, the servo, the interface wiring, or the hydraulic supply to the servo.

19:00 22494 AILERON SERVO-C/FCC-C FAIL Hard Active >NO AUTOLAND 221 004 00 ADVISORY
A fault was detected in the actuator control loop between FCC-C and the center aileron autopilot servo. Aileron servo or force link common mode monitors may have detected shorted/broken wires or loss of LVDT excitation or the aileron servo command/response monitor may have detected a failure of the servo to move when commanded. The underlying failure may be in the FCC, the servo, the interface wiring, or the hydraulic supply to the servo.

19:01 22540 FCC-L~FCC-C INTERFACE FAIL Hard Active >NO AUTOLAND 221 004 00 ADVISORY
A failure in the cross-channel data bus transmitting from FCC-L to FCC-C was detected by the FCC cross-channel test word monitor. FCC-L may have lost power or shut down, or wiring may have failed between the FCC-L CROSS CHANNEL RIGHT output and the FCC-C CROSS CHANNEL LEFT input.

18:57 22651 YDM-LWR FAIL Hard Active >YAW DAMPER LWR 222 101 00 ADVISORY
The lower yaw damper has detected a fault with the auto disengage relay, or a modal suppression accelerometer input is less than -0.425 g or greater than 0.425 g for 1 second, or the CONTROL or MONITOR channel has detected a rudder command difference of 0.35 Vrms for more than 0.5 seconds, or an internal yaw damper module fault has been detected.

18:56 22679 EXCITATION FAIL (YDM-LWR) Hard Active >YAW DAMPER LWR 222 101 00 ADVISORY
The Lower YDM CONTROL processor has detected that the AC reference voltage output to the upper yaw damper servo LVDT has dropped below 18 vrms for more than 1.5 seconds.

18:56 27970 AFT SPD CARD FAIL OR AFT SPD CARD OUTPUT BUS FAIL Hard Active >YAW DAMPER LWR 222 101 00 ADVISORY
The aft Surface Position Digitizer card has detected an internal fault, or the EIU has no input from the aft Surface Position Digitizer card.

18:57 22989 FCC-R FAIL (NO BUS OUTPUTS) Hard Active >AUTOPILOT DISC 221 002 00 WARNING
Several systems reported failure of FCC-R. The Central Maintenance Computers, EFIS/EICAS Interface Units, Stabilizer Trim/Rudder Ratio Changer

Modules, and/or cross-channel FCCs may have reported this problem. The cause could be an actual failure of FCC-R, or of the output bus interface from the FCC to one or more of the other systems.

18:57 27001 SRM-L FAIL (SRM-L) Hard Active >AUTOPILOT DISC 221 002 00 WARNING
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:57 27201 SRM-R FAIL (SRM-R) Hard Active >AUTOPILOT DISC 221 002 00 WARNING
The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:56 27503 FLIGHT CONTROLS PSM RIGHT 1 FAIL Hard Active >AUTOPILOT DISC 221 002 00 WARNING
The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 1 is missing (not connected).

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active >AUTOPILOT DISC 221 002 00 WARNING
The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:58 34012 FMC-R TO FMC-L RESYNC (FMC-R) Intermittent Inactive >AUTOPILOT DISC 221 002 00 WARNING
indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:58 34737 FMC-L FAIL (NO BUS OUTPUTS) Intermittent Inactive >AUTOPILOT DISC 221 002 00 WARNING
EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:58 34737 FMC-L FAIL (NO BUS OUTPUTS) Intermittent Inactive FMC LEFT 346 107 00 ADVISORY

EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:57 34338 FMC-L>EIU-R BUS FAIL Intermittent Active FMC LEFT 346 107 00 ADVISORY

indicates the EIUs are OK, and the EIU-R has detected the FMC-L output buses failed for 40 seconds.

18:58 34012 FMC-R TO FMC-L RESYNC (FMC-R) Intermittent Inactive FMC LEFT 346 107 00 ADVISORY

indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:57 26043 APU BOTTLE LOW PRESSURE Hard Active >BOTTLE LOW APU 262 201 00 ADVISORY

APU fire extinguishing bottle pressure is low (@ 200-250 psig). Bottle has either been discharged, or may have discharged through pressure relief valve, or leaked through a crack somewhere in the bottle, or the pressure switch on the bottle may not be connected properly, or a ground or open circuit between the pressure switch and EIU has occurred.

18:57 26037 APU FIRE LOOP-B Hard Active >DET FIRE APU 261 504 00 ADVISORY

If the CMCS message 26036 also is shown, then both loops are faulted. Fault correlated to “DET FIRE APU” indicates both loops faulted.

18:57 26036 APU FIRE LOOP-A Hard Active >DET FIRE APU 261 504 00 ADVISORY

If the CMCS message 26037 also is shown, then both loops are faulted. Fault correlated to “DET FIRE APU” indicates both loops faulted.

18:57 26043 APU BOTTLE LOW PRESSURE Hard Active BOTTLE LOW APU 262 202 00 STATUS

APU fire extinguishing bottle pressure is low (@ 200-250 psig). Bottle has either been discharged, or may have discharged through pressure relief valve, or leaked through a crack somewhere in the bottle, or the pressure switch on the bottle may not be connected properly, or a ground or open circuit between the pressure switch and EIU has occurred

18:57 26037 APU FIRE LOOP-B Hard Active APU FIRE LOOP-B 261 502 00 STATUS

If the CMCS message 26036 also is shown, then both loops are faulted. Fault correlated to “DET FIRE APU” indicates both loops faulted.

18:57	**26036**	**APU FIRE LOOP-A**	**Hard**	**Active**	**APU FIRE LOOP-A**	**261 501 00**	**STATUS**

If the CMCS message 26037 also is shown, then both loops are faulted. Fault correlated to "DET FIRE APU" indicates both loops faulted.

18:57	**27001**	**SRM-L FAIL (SRM-L)**	**Hard**	**Active**	**NO LAND 3**	**221 082 00**	**STATUS**

The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:58	**34012**	**FMC-R TO FMC-L RESYNC (FMC-R)**	**Intermittent**	**Inactive**	**NO LAND 3**	**221 082 00**	**STATUS**

indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:58	**34737**	**FMC-L FAIL (NO BUS OUTPUTS)**	**Intermittent**	**Inactive**	**NO LAND 3**	**221 082 00**	**STATUS**

EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:57	**22989**	**FCC-R FAIL (NO BUS OUTPUTS)**	**Hard**	**Active**	**NO LAND 3**	**221 082 00**	**STATUS**

Several systems reported failure of FCC-R. The Central Maintenance Computers, EFIS/EICAS Interface Units, Stabilizer Trim/Rudder Ratio Changer Modules, and/or cross-channel FCCs may have reported this problem. The cause could be an actual failure of FCC-R, or of the output bus interface from the FCC to one or more of the other systems.

18:57	**27201**	**SRM-R FAIL (SRM-R)**	**Hard**	**Active**	**NO LAND 3**	**221 082 00**	**STATUS**

The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:56	**27503**	**FLIGHT CONTROLS PSM RIGHT 1 FAIL**	**Hard**	**Active**	**NO LAND 3**	**221 082 00**	**STATUS**

The Flight Controls Electronics Power Supply Module Right 2 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26

Vac) or Power Supply Module Right 1 is missing (not connected).

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active NO LAND 3 221 082 00 STATUS
The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:57 31308 FLIGHT RECORDER FAIL Hard Active FLIGHT RCDR SYS 313 101 00 STATUS
Boeing records indicate DFDAC P/N 285U0071-207 and SSFDR 980-4700-042 were installed on RM863 at delivery.
CMC Fault message #31308 (FLIGHT RECORDER FAIL) is reported by the DFDAC (Digital Flight Data Acquisition Card) on the status of the SSFDR (Solid State Flight Data Recorder). The DFDAC monitors the FDR "Status" analog discrete signal and FDR "Maintenance" analog discrete signal from the SSFDR. The FDR "Status" discrete is set to OK (28 VDC) when the FDR acquires the correct sync words from the acquisition unit at the correct rate. If the sync words are not available or the transmission rate is incorrect, the FDR "Status" is set to FAIL (Ground, 0 VDC). The FDR "Maintenance" discrete is set to OK (Ground, 0 VDC) when the FDR internal BITE is OK. If the FDR has an internal fault, the FDR "Maintenance" discrete is set to FAIL (OPEN).

For CMC message #31308, the following items must be TRUE:
AC BUS #3 is OK
DC BUS #3 is OK
MAWEA/DFDAC Relay for FDR Power is ON

If the FDR "Status" or FDR "Maintenance" discrete signals indicate FAIL for 55 seconds and items above are true, CMC message #31308 is set.

If the FDR "Status" wire was broken/gone and FDR "Maintenance" was still OK, the message would NOT be set. OPEN state for FDR "Status" would not indicate FAIL to the DFDAC.

If the FDR "Maintenance" wire was broken/gone, this CMC message would be set.

The CMC does report DFDAC faults and failures. However, the PLF report provided to Boeing did not list any DFDAC faults.

The EICAS FDE "FLIGHT RECORDER SYS" is a status message (message # L31603) to indicate to the crew the FDRS (Flight Data Recorder System) has fail or is off while engines are running. The EIU monitors an analog discrete signal from the DFDAC. The EICAS message is annunciated when the DFDAC reports a FDRS failure for 60 continuous seconds and at least one engine is running. The DFDAC will indicate a FDRS failure when:
a. FDR "Status" discrete input indicates FAIL (Ground, 0 VDC); or

b. FDR “Maintenance” discrete input indicates FAIL (open); or
c. A DFDAC internal fault is detected.

18:57	**27001**	**SRM-L FAIL (SRM-L)**	**Hard**	**Active**	**STAB AUTO CUTOUT**	**274 001 00**	**STATUS**

The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:57	**27201**	**SRM-R FAIL (SRM-R)**	**Hard**	**Active**	**STAB AUTO CUTOUT**	**274 001 00**	**STATUS**

The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:56	**27292**	**HYD-2 STAB TRIM ACT BRAKE RELEASE SW FAIL (SRM-R)**	**Hard**	**Active**	**STAB AUTO CUTOUT**	**274 001 00**	**STATUS**

The STCM secondary brake released for at least 2 seconds without either a vaild SRM outupt trim command or an alternate electric trim command or the STCM secondary brake did not release within 2 seconds of a valid trim command when the stabilizer is within electric operating range, hydraulic pressure is high and STAB TRIM CONT 28 volts is present.

18:57	**27504**	**FLIGHT CONTROLS PSM RIGHT 2 FAIL**	**Hard**	**Active**	**STAB AUTO CUTOUT**	**274 001 00**	**STATUS**

The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:57	**22989**	**FCC-R FAIL (NO BUS OUTPUTS)**	**Hard**	**Active**	**STAB AUTO TRIM**	**274 022 00**	**STATUS**

Several systems reported failure of FCC-R. The Central Maintenance Computers, EFIS/EICAS Interface Units, Stabilizer Trim/Rudder Ratio Changer Modules, and/or cross-channel FCCs may have reported this problem. The cause could be an actual failure of FCC-R, or of the output bus interface from the FCC to one or more of the other systems.

18:57	**27001**	**SRM-L FAIL (SRM-L)**	**Hard**	**Active**	**STAB AUTO TRIM**	**274 022 00**	**STATUS**

The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:57 27201 SRM-R FAIL (SRM-R) Hard Active STAB AUTO TRIM 274 022 00 STATUS

The SRM has experienced a non-recoverable failure. All discrete outputs are set to invalid, all ARINC 429 output labels have their SSM set to FAIL. All engaged relays are disengaged. Cyclic Redundancy Check failures of the Read Only Memory, the absence of subroutine activity, loss of the other channel (ARM or CONTROL) funciton for 3 seconds, changes in software iteration rate of the other channel (+150 % or -75%) and erroneous values published by the background monitor in the other channel all could cause the SRM FAIL message. Left or Right SRM is determined by the EIU based on SRM position.

18:57 27504 FLIGHT CONTROLS PSM RIGHT 2 FAIL Hard Active STAB AUTO TRIM 274 022 00 STATUS

The Flight Controls Electronics Power Supply Module Right 1 has detected a fault with one of the four power supplies (+15 Vdc, +5 Vdc, -15 Vdc or 26 Vac) or Power Supply Module Right 2 is missing (not connected).

18:57 27153 HYD-2 STAB TRIM ACT 'SHUTOFF VALVE CLOSED FAIL [SRM'S] Hard Active STAB AUTO TRIM 274 022 00 STATUS

The Motor Operated Valve position feedback signal has not become positive more than 5 seconds after the command signal became positive.

18:57 31454 RIGHT EIU INPUT DISAGREE WITH EIU L&C Intermittent Active EIU DISAGREE 316 108 00 STATUS

This would be related to the FMC-L to EIU R bus fail. The EIU cross compares all of the input signals between EIUs. This message is simply telling you the R EIU is missing ARINC bus activity that the other 2 EIUs have. In this case of the FMC bus missing from the R EIU (34338 FMC-L>EIU-R BUS FAIL) , the CMC message text actually tells you which EIU (FMC L to R EIU) so this message is just redundant and does not provide any additional information.

18:58 34338 FMC-L>EIU-R BUS FAIL Intermittent Active EIU DISAGREE 316 108 00 STATUS

indicates the EIUs are OK, and the EIU-R has detected the FMC-L output buses failed for 40 seconds.

18:57 52104 DOOR L 5 SWITCH FAIL Hard Active DOOR ENTRY L 5 527 109 00 ADVISORY

The EICAS FDE "DOOR ENTRY L 5" is an advisory message (message # L52306) to indicate to the crew that the L5 Door is not latched. The EIU monitors an analog discrete signal from Door sensor. Not Latched = Ground ; Latched = Open CMC message # 52104 (DOOR ENTRY L 5 SWITCH FAIL) is the Flight Deck Effect (FDE). CMC will indicate fault if FDE has been set for 5 seconds.

18:58 34012 FMC-R TO FMC-L RESYNC (FMC-R) Intermittent Inactive >AUTOTHROT DISC 346 101 00 CAUTION
indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:58 34737 FMC-L FAIL (NO BUS OUTPUTS) Intermittent Inactive >AUTOTHROT DISC 346 101 00 CAUTION
EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:58 26169 CARGO BOTTLE A LOW PRESSURE Hard Active >CGO BTL DISCH 262 409 00 ADVISORY
The bottle A Temperature Compensated Pressure Sensor (TCPS) has detected a low bottle pressure. When the bottle pressure drops below 300 +/- 30 psig (@ 70F), the TCPS closes, and provides a 28 VDC analog signal. The TCPS has a normally closed failure mode, so a failed TCPS will also produce this message.

18:58 26170 CARGO BOTTLE B LOW PRESSURE Hard Active >CGO BTL DISCH 262 409 00 ADVISORY
The bottle A and B Temperature Compensated Pressure Sensors [TCPSs] (each bottle has its one independent TCPS) have detected a low bottle pressure. When the bottle pressure drops below 300 +/- 30 psig (@70F), the TCPS closes, and provides a 28 VDC analog signal. The TCPS has a normally closed failure mode, so a failed TCPS will also produce this maintenance message. In flight, the >CGO BTL DISCH advisory message is triggered when both the CARGO BOTTLE A & B LOWER PRESSURE maintenance messages are true.

18:58 27401 ELEVATOR FEEL COMPUTER FAIL Hard Active ELEVATOR FEEL 273 001 00 STATUS
Excessive pressure difference between metered pressure inputs or airspeed inputs. Inhibited by hydraulic system 2 or 3 pressure less than 1200 PSI.

18:58 26169 CARGO BOTTLE A LOW PRESSURE Hard Active BTL LOW CARGO A 262 302 00 STATUS
The bottle A Temperature Compensated Pressure Sensor (TCPS) has detected a low bottle pressure. When the bottle pressure drops below 300 +/- 30 psig (@ 70F), the TCPS closes, and provides a 28 VDC analog signal. The TCPS has a normally closed failure mode, so a failed TCPS will also produce this message.

18:58 26165 CARGO AFT-4 LOOP-A FAIL Intermittent Inactive CGO DET AFT 4 261 627 00 STATUS

The Aft lower lobe Zone 4A detector was in alarm for at least 8 seconds without the Zone 4B detector being in alarm or the 4A detector failed to pass a “disagree” test from the zone 4 AFOLTS card or the wire from the zone 4A detector to the AFOLTS was open circuit when a “disagree” test was performed. Because this fault was correlated to “CGO DET AFT 4” and not to “AFT CGO 16 LP A”, the Zone 4B detector was in alarm or faulted within 20 seconds of the Zone 4A detector. The above message would be consistent with Zone 4A and Zone 4B detectors being in alarm (detecting smoke) more than 8 second but less than 20 seconds apart.

18:58 34012 FMC-R TO FMC-L RESYNC (FMC-R) Intermittent Inactive >FMC MESSAGE 346 109 00 ADVISORY

indicates that the Right FMC has detected that the left FMC is master, but the intersystem bus from the Left FMC to the right FMC is failed or inactive. The signal is held up for at least 60 seconds after the R FMC starts to report that the intersystem bus from the L FMC is failed or inactive.

18:58 34737 FMC-L FAIL (NO BUS OUTPUTS) Intermittent Inactive >FMC MESSAGE 346 109 00 ADVISORY

EIUs are all valid and OK, the FMC power is OK, and all three EIUs and any MCDU report the L-FMC output buses failed for 5 seconds and the FMC is not in ground test.

18:59 23600 EMERGENCY LOCATOR TRANSMITTER ON Hard Active >ELT ON 232 401 00 ADVISORY

The "ELT ON" ACARS message indicates that the automatic-fixed ELT has been activated (turned on) either by the flight crew via the ELT control panel in the flight deck, or it has been automatically activated by g-forces.

Note: The source of the ACARS message is the "ELT ON" EICAS message via the CMC. The source of the "ELT ON" EICAS message is an analog discrete from the ELT to the EIUs via a MAWEA SCID card.

18:59 35006 SUPERNUMERARY OXYGEN ON Hard Active SUPRNMRY OXY ON 352 109 00 ADVISORY

The EICAS Flight Deck Effect (FDE) "SUPRNMRY OXY ON" is an advisory message (message # L35306) to indicate to the crew that the supernumerary oxygen flow control unit is actuated. The EIU monitors an analog discrete signal from Supernumerary Oxygen system.

CMC message #35006 (SUPERNUMERARY OXYGEN ON) echoes the Flight Deck Effect (FDE) message #L35360. CMC will indicate fault if FDE has been set for 55 seconds.

This message can be triggered manually through a switch in the flight deck overhead P5 panel (labeled SUPRNMRY OXY) or pneumatically when the cabin altitude exceeds 8.7 ± .2 psia. It is a open/ground discrete. The discrete set to ground indicates SUPRNMRY OXY ON.

Source of the signal is the Oxygen Flow-Surge Control Unit (equipment number M101) located at STA 770 WL160 RBL105.

747-400F airplanes were delivered with an Electro-Pneumatic Flow Control Unit (FCU). In case of decompression, the system is actuated automatically at cabin altitude of approx 8.7 ± .2 psia which is equivalent to a value in the range of 13,250 to 14,400 feet or may be activated by means of a switch on the overhead panel in the flight deck. The nominal activation altitude value is approximately 13,800 feet.

It is possible that the message is related to the fire suppression procedure. The third step of the main deck cargo fire checklist directs crew to turn the SUPERNMRY OXY switch to the ON position. Immediately after this step the crew is directed to ARM the Main Deck Cargo Fire Arm switch. However, the timing on the ACARS data is inconsistent with the checklist sequence. The PACK 2 and PACK 3 advisory messages occur at 18:56:xx whereas the SUPRNMRY OXY ON message occurs at 18:59:xx whereas. Once we have DFDR data we may be able to see if the SUPRNMRY OXY message was triggered due to the cabin altitude exceeding the trigger altitude due to the aircraft being depressurized per procedure.

18:59	**24098**	**DC CURRENT SENSOR-6 FAIL (BCU-2)**	**Intermittent**	**Inactive**	**>BAT DISCH APU**	**243 005 00**	**ADVISORY**

The CMC message "DC CURRENT SENSOR-6 FAIL" indicated that the APU Battery Current Sensor has failed and this failure caused the EICAS Advisory message >BAT DISCH APU displayed. The EICAS Advisory message >BAT DISCH APU will display whenever the APU Battery current is sensed less than 0 amps for 3 minutes or less than 6 amps

18:59	**36301**	**APU DUCT FAIL**	**Hard**	**Active**	**APU**	**491 101 00**	**ADVISORY**

The APU DUCT FAIL message is set by an overheat being sensed in the vicinity of the APU duct when the battery bus is energized (which is normally the case). Both the overheat condition and energized battery bus criteria must persist for 10 or more seconds for the CMC message to be set. The APU duct runs from the APU in the tail cone, through the bottom of the rear pressure dome and then along the left cheek adjacent to the aft lower cargo compartment until it reaches the wheel well. There are 20 thermal switches, 15 are located along the duct adjacent to the aft lower cargo compartment, and 5 are located along the duct in the area aft of the bulk cargo compartment. 7 more switches are located between the APU isolation valve and APU check valve near the wheel well. When the local air temperature exceeds 250 F, the thermal switches close triggering a ground analog discrete into the EIU on pin C15. The EIU then passes a discrete to the CMC indicating the overheat. Note: the system has no self-test capability.

19:00	**27664**	**FLAP LEVER RVDT FAIL (FCU' S)**	**Hard**	**Active**	**FLAPS CONTROL**	**275 003 00**	**CAUTION**

All 3 FCUs report: 2 out of the 3 Flap Lever RVDTs have failed or 2 out of the 3 26VAC excitation inputs have failed.

19:00	**22607**	**UPPER YAW DAMPER ACTUATOR LVDT FAIL (YDM-UPR)**	**Intermittent**	**Inactive**	**YAW DAMPER UPR**	**222 104 00**	**STATUS**

As seen by the Upper YDM CONTROL processor, the sum of the voltages of the two upper rudder yaw damper servo LVDT windings has dropped below 7 vrms for more than 2 seconds, or the voltage of one individual winding has dropped below 2 vrms for more than 2 seconds, in the presence of a nominal 26 vrms excitation reference.

19:00	**22629**	**EXCITATION FAIL (YDM-UPR)**	**Hard**	**Active**	**YAW DAMPER UPR**	**222 104 00**	**STATUS**

The Upper YDM CONTROL processor has detected that the AC reference voltage output to the upper yaw damper servo LVDT has dropped below 18 vrms for more than 1.5 seconds.

19:00	**22607**	**UPPER YAW DAMPER ACTUATOR LVDT FAIL (YDM-UPR)**	**Intermittent**	**Inactive**	**>YAW DAMPER UPR**	**222 103 00**	**ADVISORY**

As seen by the Upper YDM CONTROL processor, the sum of the voltages of the two upper rudder yaw damper servo LVDT windings has dropped below 7 vrms for more than 2 seconds, or the voltage of one individual winding has dropped below 2 vrms for more than 2 seconds, in the presence of a nominal 26 vrms excitation reference.

19:00	**22629**	**EXCITATION FAIL (YDM-UPR)**	**Hard**	**Active**	**>YAW DAMPER UPR**	**222 103 00**	**ADVISORY**

The Upper YDM CONTROL processor has detected that the AC reference voltage output to the upper yaw damper servo LVDT has dropped below 18 vrms for more than 1.5 seconds.

19:00	**27108**	**UPR RUDDER RATIO ACTUATOR FEEDBACK FAIL (SRM-L)**	**Intermittent**	**Active**	**RUD RATIO DUAL**	**272 021 00**	**ADVISORY**

The upper rudder ratio changer actuator feedback signal to the SRM has been less than .35 Vdc for 0.75 seconds.

19:00	**27158**	**UPR RUDDER RATIO CHANGER 115 VAC FAIL (SRM' S)**	**Hard**	**Active**	**RUD RATIO DUAL**	**272 021 00**	**ADVISORY**

The SRM has determined that the upper rudder ratio changer has lost 115 Vac power for at least 2 seconds.

19:00	**27160**	**UPR RUDDER RATIO CHANGER 28 VDC FAIL (SRM' S)**	**Hard**	**Active**	**RUD RATIO DUAL**	**272 021 00**	**ADVISORY**

The SRM has determined that the upper rudder ratio changer has lost 28 Vdc power for at least 2 seconds.

19:00	**27308**	**UPR RUDDER RATIO ACTUATOR FEEDBACK FAIL (SRM-R)**	**Intermittent**	**Active**	**RUD RATIO DUAL**	**272 021 00**	**ADVISORY**

The upper rudder ratio changer actuator feedback signal to the SRM has been less than .35 Vdc for 0.75 seconds.

APPENDIX 2: Time-based Aircraft Status and Events

ACARS (GMT) (Capt Clock)	ATC (GMT)	Airplane Altitude (ft)	Airspeed (kts)	Lat	Long	Event	Message Type	FDE Code	Mx Message Code	Activity	Intermittence
18:04:49		211	97	N37°28.7'	E126°26.7'	Turbulence report	ACMS				
18:05:09		331	172	N37°28.2'	E126°27.2'	Turbulence report	ACMS				
18:05:32		1,413	170			Takeoff	FMC → ACMS				
18:07:58		6,521		N37°21.3'	E126°36.9'	Position 1	FMC → ACMS				
	18:12:35	18,000				Incheon, Good morning AAR991, Now passing 180 for 340. (captain)	ATC & Radar				
18:14:26		21,881		N36°43.9'	E126°36.9'	Position2	FMC → ACMS				
18:17:27		30,269		N36°23.7'	E126°34.5'	Position3	FMC → ACMS				
18:21:27		33,983		N35°55.6'	E126°31.2'	Position4	FMC → ACMS				
18:24:20		33,995		N35°33.0'	E126°28.5'	Position5	FMC → ACMS				
18:26:38		33,999		N35°15.3'	E126°26.4'	Position6	FMC → ACMS				
	18:51:04	34,000				"134.0, AAR991 see you later" (FO)	ATC & Radar				
	18:51:15	34,000				Shanghai control, good morning, AAR991 direct SADLI maintain level 340. (FO)	ATC & Radar				
	18:52:51	34,000				"Ok, 5 miles romeo side AAR991, thank you" (FO)	ATC & Radar				
18:53:xx						CGO DET 11 MN DK	Status	261 458 00		Active	n/a
18:53:xx						CARGO FIRE MAIN DECK ZONE-11 LOOP-A FAIL	Mx Message		26330	Inactive	Intermittent
18:53:xx						EQUIP COOLING	Caution	215 005 00		Inactive	n/a
18:53:xx						E/E COOLING SMOKE DETECTED	Mx Message		21422	Inactive	Intermittent
18:53:xx						EQUIPMENT SMOKE	Status	215 010 00		Active	n/a
18:53:xx						E/E COOLING SMOKE DETECTED	Mx Message		21422	Inactive	Intermittent
18:53:49		34,003		N31°53.3'	E124°58.8'	Position7	FMC → ACMS				
	18:54:23	34,000				"shanghai control, shanghai control, AAR991 request emergency descent, emergency, declare emergency due to fire main deck. request descent, and descent to one-zero-thousand" (FO)	ATC & Radar				
18:54:xx						CGO DET 10 MN DK	Status	261 457 00		Active	n/a
18:54:xx						CARGO FIRE MAIN DECK ZONE-10 LOOP-A FAIL	Mx Message		26328	Inactive	Intermittent
18:54:xx						CGO DET 6 MN DK	Status	261 426 00		Active	n/a
18:54:xx						CARGO FIRE MAIN DECK ZONE-6 LOOP-A FAIL	Mx Message		26320	Inactive	Intermittent
	18:54:42	34,000				Maintain...descend one-zero thousand on own discretion, AAR991. (FO)	ATC & Radar				
	18:55:08	33,900				We have fire main deck, AAR991. return to Jeju, AAR991. (FO)	ATC & Radar				
18:55:xx						CGO DET 7 MN DK	Status	261 454 00		Active	n/a
18:55:xx						CARGO FIRE MAIN DECK ZONE-7 LOOP-A FAIL	Mx Message		26332	Inactive	Intermittent
18:55:xx						CGO DET 3 MN DK	Status	261 423 00		Active	n/a
18:55:xx						CARGO FIRE MAIN DECK ZONE-3 LOOP-A FAIL	Mx Message		26314	Inactive	Intermittent
18:55:xx						CGO DET 8 MN DK	Status	261 455 00		Active	n/a
18:55:xx						CARGO FIRE MAIN DECK ZONE-8 LOOP-A FAIL	Mx Message		26324	Inactive	Intermittent
18:55:xx						CGO DET 4 MN DK	Status	261 424 00		Active	n/a
18:55:xx						CARGO FIRE MAIN DECK ZONE-4 LOOP-A FAIL	Mx Message		26316	Inactive	Intermittent
18:55:xx						CGO DET 5 MN DK	Status	261 425 00		Active	n/a
18:55:xx						CARGO FIRE MAIN DECK ZONE-5 LOOP-B FAIL	Mx Message		26319	Inactive	Intermittent
18:55:xx						CGO DET 16 MN DK	Status	261 463 00		Inactive	n/a
18:55:xx						CARGO FIRE MAIN DECK ZONE-16 LOOP-A FAIL	Mx Message		26340	Inactive	Intermittent
	18:55:58	29,000				Request divert to Jeju. (Captain)	ATC & Radar				
18:56:xx						>STAB TRIM 2	Advisory	274 005 00		Active	n/a
18:56:xx						HYD-2 STAB TRIM ACT BRAKE RELEASE SW FAIL (SRM-R)	Mx Message		27292	Active	Hard
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard
18:56:xx						F/D BAR BIAS	NMFDE	221 077 00		Active	n/a
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard
18:57:xx						FCC-R FAIL (NO BUS OUTPUTS)	Mx Message		22989	Active	Hard
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Inactive	Intermittent
18:58:xx							Mx Message		34737	Inactive	Intermittent Added
18:56:xx						SATCOM DATA	Status	232 530 00		Active	n/a
18:56:xx						SATCOM SDU FAIL (NO BUS OUTPUTS)	Mx Message		23204	Active	Hard
18:56:xx						STAB TRIM	Status	274 004 00		Active	n/a
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard

ACARS (GMT) (Capt Clock)	ATC (GMT)	Airplane Altitude (ft)	Airspeed (kts)	Lat	Long	Event	Message Type	FDE Code	Mx Message Code	Activity	Intermittence	
18:57:xx → 18:56:xx						HYD-2 STAB TRIM ACT 'SHUTOFF VALVE CLOSED FAIL (SRM'S)	Mx Message		27292	Active	Hard	
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard	
18:57:xx						SRM-L FAIL (SRM-L)	Mx Message		27001	Active	Hard	
18:56:xx						YAW DAMPER LWR	Status	222 102 00		Active	n/a	
18:56:xx						AFT SPD CARD FAIL OR AFT SPD CARD OUTPUT BUS FAIL	Mx Message		27970	Inactive	Intermittent	
18:56:xx						EXCITATION FAIL (YDM-LWR)	Mx Message		22679	Active	Hard	
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard	
18:57:xx						YDM-LWR FAIL	Mx Message		22651	Active	Hard	
18:56:xx						A/P SINGLE SYS	Status	221 084 00		Active	n/a	
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard	
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard	
18:56:xx						FLAP SYS MONITOR	Status	275 002 00		Active	n/a	
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard	
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard	
18:57:xx						FLAP 26 VAC 2 INTERFACE 1 FAIL	Mx Message		16006	Active	Hard	
18:57:xx						FLAP 26 VAC 3 ~ FCU-R INTERFACE FAIL	Mx Message		27746	Active	Hard	
18:56:xx						NO AUTOLAND	Status	221 083 00		Active	n/a	in 18:59 FDE changes to
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard	
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard	
18:57:xx						FCC-R FAIL (NO BUS OUTPUTS)	Mx Message		22989	Active	Hard	
18:57:xx						SRM-L FAIL (SRM-L)	Mx Message		27001	Active	Hard	
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard	
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent	
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Active → Inactive	Hard → Intermittent	in 19:02 → 18:58 PLF changes to Inactive / Intermittent
18:59:xx						ELEVATOR SERVO-C/FCC-C FAIL	Mx Message		22943	Inactive	Intermittent	
18:59:xx → No Inform						RUDDER SERVO-C/FCC-C FAIL	Mx Message		22501	Inactive → No Inform	Intermittent → No Inform	
19:00:xx						AILERON SERVO-C/FCC-C FAIL	Mx Message		22494	Active	Hard	
19:01:xx						FCC-L~FCC-C INTERFACE FAIL	Mx Message		22540	Active	Hard	
18:56:xx						PACK 3	Advisory	215 020 00		Inactive	n/a	
18:56:xx						CARGO FIRE EXTINGUISHER ARMED 'NO ACTION REQUIRED'	Mx Message		26177	Active	Hard	
19:00:xx						PACK 3 AIR FLOW SENSOR/WIRE FAIL	Mx Message		21138	Active	Hard	
19:02:xx						FLOW CONTROL VALVE-3/WIRING FAIL	Mx Message		21135	Active	Hard	
18:56:xx						PACK 2	Advisory	215 018 00		Inactive	n/a	
18:56:xx						CARGO FIRE EXTINGUISHER ARMED 'NO ACTION REQUIRED'	Mx Message		26177	Active	Hard	
18:56:xx						SATCOM SYSTEM	Status	232 521 00		Active	n/a	
18:56:xx						SATCOM SDU FAIL (NO BUS OUTPUTS)	Mx Message		23204	Active	Hard	
18:56:xx						>SATCOM	Advisory	232 501 00		Active	n/a	
18:56:xx						SATCOM SDU FAIL (NO BUS OUTPUTS)	Mx Message		23204	Active	Hard	
18:56:xx						>NO LAND 3	Advisory	221 006 00		Inactive	n/a	
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard	
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard	
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard	
18:57:xx						SRM-L FAIL (SRM-L)	Mx Message		27001	Active	Hard	
18:57:xx						FCC-R FAIL (NO BUS OUTPUTS)	Mx Message		22989	Active	Hard	
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Active	Hard	in 19:02 → 18:58 PLF changes
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent	
18:56:xx						>NO AUTOLAND	Advisory	221 004 00		Active	n/a	
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard	
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard	
18:57:xx						FCC-R FAIL (NO BUS OUTPUTS)	Mx Message		22989	Active	Hard	
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard	
18:57:xx						SRM-L FAIL (SRM-L)	Mx Message		27001	Active	Hard	
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent	
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Active	Hard	in 19:02 → 18:58 PLF changes

ACARS (GMT) (Capt Clock)	ATC (GMT)	Airplane Altitude (ft)	Airspeed (kts)	Lat	Long	Event	Message Type	FDE Code	Mx Message Code	Activity	Intermittence
18:59:xx						ELEVATOR SERVO-C/FCC-C FAIL	Mx Message		22943	Inactive	Intermittent
18:59:xx						RUDDER SERVO-C/FCC-C FAIL	Mx Message		22501	Inactive	Intermittent
19:00:xx						AILERON SERVO-C/FCC-C FAIL	Mx Message		22494	Active	Hard
19:01:xx						FCC-L~FCC-C INTERFACE FAIL	Mx Message		22540	Active	Hard
18:56:xx						>YAW DAMPER LWR	Advisory	222 101 00		Active	n/a
18:56:xx						AFT SPD CARD FAIL OR AFT SPD CARD OUTPUT BUS FAIL	Mx Message		27970	Inactive	Intermittent
18:56:xx						EXCITATION FAIL (YDM-LWR)	Mx Message		22679	Active	Hard
18:57:xx						YDM-LWR FAIL	Mx Message		22651	Active	Hard
18:56:xx						>AUTOPILOT DISC	Warning	221 002 00		Inactive	n/a
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard
18:57:xx						SRM-L FAIL (SRM-L)	Mx Message		27001	Active	Hard
18:57:xx						FCC-R FAIL (NO BUS OUTPUTS)	Mx Message		22989	Active	Hard
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Inactive	Intermittent
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent
18:56:58		23,724		N31°51.4'	E124°29.9'	Position8	FMC → ACMS				
	18:57:00	24,000					Radar				
18:57:03		23,478	337	N31°51.6'	E124°29.2'	Turbulence2	ACMS				
18:57:xx						FMC LEFT	Advisory	346 107 00		Active	n/a
18:57:xx						FMC-L>EIU-R BUS FAIL	Mx Message		34338	Active	Intermittent
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Inactive	Intermittent
18:57:xx						FMC LEFT	Status	346 108 00		Active	n/a
18:57:xx						FMC-L>EIU-R BUS FAIL	Mx Message		34338	Active	Intermittent
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Inactive	Intermittent
18:57:xx						>BOTTLE LOW APU	Advisory	262 201 00		Active	n/a
18:57:xx						APU BOTTLE LOW PRESSURE	Mx Message		26043	Active	Hard
18:57:xx						>DET FIRE APU	Advisory	261 504 00		Active	n/a
18:57:xx						APU FIRE LOOP-A	Mx Message		26036	Active	Hard
18:57:xx						APU FIRE LOOP-B	Mx Message		26037	Active	Hard
18:57:xx						BOTTLE LOW APU	Status	262 202 00		Active	n/a
18:57:xx						APU BOTTLE LOW PRESSURE	Mx Message		26043	Active	Hard
18:57:xx						APU FIRE LOOP B	Status	261 502 00		Active	n/a
18:57:xx						APU FIRE LOOP-B	Mx Message		26037	Active	Hard
18:57:xx						APU FIRE LOOP A	Status	261 501 00		Active	n/a
18:57:xx						APU FIRE LOOP-A	Mx Message		26036	Active	Hard
18:57:xx						NO LAND 3	Status	221 082 00		Inactive	n/a
18:56:xx						FLIGHT CONTROLS PSM RIGHT 1 FAIL	Mx Message		27503	Active	Hard
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard
18:57:xx						FCC-R FAIL (NO BUS OUTPUTS)	Mx Message		22989	Active	Hard
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard
18:57:xx						SRM-L FAIL (SRM-L)	Mx Message		27001	Active	Hard
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Active → Inactive	Hard → Intermittent
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent
18:57:xx						FLIGHT RCDR SYS	Status	313 101 00		Active	n/a
18:57:xx						FLIGHT RECORDER FAIL	Mx Message		31308	Active	Hard
18:57:xx						STAB AUTO CUTOUT	Status	274 001 00		Active	n/a
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard
18:57:xx						HYD-2 STAB TRIM ACT 'SHUTOFF VALVE CLOSED FAIL (SRM'S)	Mx Message		27153	Active	Hard
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard
18:57:xx						SRM-L FAIL (SRM-L)	Mx Message		27001	Active	Hard
18:57:xx						STAB AUTO TRIM	Status	274 022 00		Active	n/a
18:57:xx						FLIGHT CONTROLS PSM RIGHT 2 FAIL	Mx Message		27504	Active	Hard
18:57:xx						FCC-R FAIL (NO BUS OUTPUTS)	Mx Message		22989	Active	Hard
18:57:xx						SRM-R FAIL (SRM-R)	Mx Message		27201	Active	Hard
18:57:xx						SRM-L FAIL (SRM-L)	Mx Message		27001	Active	Hard

ACARS (GMT) (Capt Clock)	ATC (GMT)	Airplane Altitude (ft)	Airspeed (kts)	Lat	Long	Event	Message Type	FDE Code	Mx Message Code	Activity	Intermittence
18:57:xx						EIU DISAGREE	Status	316 108 00		Active	n/a
18:57:xx						FMC-L>EIU-R BUS FAIL	Mx Message		34338	Active	Intermittent
18:57:xx						RIGHT EIU INPUT DISAGREE WITH EIU L&C	Mx Message		31454	Active	Intermittent
18:57:xx						DOOR ENTRY L5	Advisory	527 109 00		Active	n/a
18:57:xx						DOOR L 5 SWITCH FAIL	Mx Message		52104	Active	Hard
18:57:23		22,333	336	N31°52.9'	E124°26.5'	Turbulence2	ACMS				
18:57:43		20,697	345	N31°54.7'	E124°24.3'	Turbulence3	ACMS				
	18:58:00	19,000					Radar				
18:58:xx						>AUTOTHROT DISC	Caution	346 101 00		Active	n/a
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Inactive	Intermittent
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent
18:58:xx						>CGO BTL DISCH	Advisory	262 409 00		Active	n/a
18:58:xx						CARGO BOTTLE A LOW PRESSURE	Mx Message		26169	Active	Hard
18:58:xx						CARGO BOTTLE B LOW PRESSURE	Mx Message		26170	Active	Hard
18:58:xx						ELEVATOR FEEL	Status	273 001 00		Active	n/a
18:58:xx						ELEVATOR FEEL COMPUTER FAIL	Mx Message		27401	Active	Hard
18:58:xx						BTL LOW CARGO A	Status	262 302 00		Active	n/a
18:58:xx						CARGO BOTTLE A LOW PRESSURE	Mx Message		26169	Active	Hard
18:58:xx						CARGO DET AFT 4	Status	261 627 00		Active	n/a
18:58:xx						CARGO AFT-4 LOOP-A FAIL	Mx Message		26165	Inactive	Intermittent
18:58:xx						>FMC MESSAGE	Advisory	346 109 00		Inactive	
18:58:xx						FMC-R TO FMC-L RESYNC (FMC-R)	Mx Message		34012	Inactive	Intermittent
18:58:xx						FMC-L FAIL (NO BUS OUTPUTS)	Mx Message		34737	Inactive	Intermittent
18:58:25		17,690	348	N31°59.7'	E124°21.6'	Turbulence4	ACMS				
18:58:47		15,490	363	N32°2.5'	E124°21.0'	Turbulence4	ACMS				
	18:59:00	15,000					Radar				
18:59:09		14,045	358	N32°5.2'	E124°21.7'	Turbulence5	ACMS				
18:59:29		13,294	351	N32°7.6'	E124°22.6'	Turbulence5	ACMS				
18:59:xx						>ELT ON	Advisory	232 401 00		Active	n/a
18:59:xx						EMERGENCY LOCATOR TRANSMITTER ON	Mx Message		23600	Active	Hard
18:59:xx						SUPRNMRY OXY ON	Advisory	352 109 00		Active	n/a
18:59:xx						SUPERNUMERARY OXYGEN ON	Mx Message		35006	Active	Hard
18:59:xx						>BAT DISCH APU	Advisory	243 005 00		Active	n/a
18:59:xx						DC CURRENT SENSOR-6 FAIL (BCU-2)	Mx Message		24098	Inactive	Intermittent
	18:59:26	13,600				Roger, AAR991 we have rear, after cargo, fire after cargo, descend	ATC & Radar				
18:59:xx						APU	Advisory	491 101 00		Active	n/a
18:59:xx						APU DUCT FAIL	Mx Message		36301	Active	Hard
	19:00:00	12,000					Radar				
19:00:xx						FLAPS CONTROL	Caution	275 003 00		Active	n/a
19:00:xx						FLAP LEVER RVDT FAIL (FCU' S)	Mx Message		27664	Active	Hard
19:00:xx						>YAW DAMPER UPR	Advisory	222 103 00		Active	n/a
19:00:xx						UPPER YAW DAMPER ACTUATOR LVDT FAIL (YDM-UPR)	Mx Message		22607	Inactive	Intermittent
19:00:xx						EXCITATION FAIL (YDM-UPR)	Mx Message		22629	Active	Hard
19:00:xx						YAW DAMPER UPR	Status	222 104 00		Active	n/a
19:00:xx						UPPER YAW DAMPER ACTUATOR LVDT FAIL (YDM-UPR)	Mx Message		22607	Inactive	Intermittent
19:00:xx						EXCITATION FAIL (YDM-UPR)	Mx Message		22629	Active	Hard
19:00:xx						RUD RATIO DUAL	Advisory	272 021 00		Active	n/a
19:00:xx						UPR RUDDER RATIO ACTUATOR FEEDBACK FAIL (SRM-L)	Mx Message		27108	Active	Intermittent
19:00:xx						UPR RUDDER RATIO CHANGER 115 VAC FAIL (SRM' S)	Mx Message		27158	Active	Hard
19:00:xx						UPR RUDDER RATIO CHANGER 28 VDC FAIL (SRM' S)	Mx Message		27160	Active	Hard
19:00:xx						UPR RUDDER RATIO ACTUATOR FEEDBACK FAIL (SRM-R)	Mx Message		27308	Active	Intermittent
	19:01:00	9,800					Radar				
	19:01:18	9,250				Unable contact Jeju 124.52. (Captain)	ATC & Radar				
	19:02:22	8,500				Fukuoka AAR991 mayday mayday mayday, we have cargo fire,	ATC & Radar				
	19:03:05	8,500				Unable contact at fukuoka. (FO)	ATC & Radar				
	19:03:07	8,750				AAR991 now you relay inform.. pass information to the Korean Air	ATC & Radar				
	19:06:05	10,900				Descend seven thousand feet. (Captain)	ATC & Radar				
	19:06:32	10,000				Ah.. we are now that rudder control is not working and seems to be jammed by	ATC & Radar				
	19:07:34	10,500				(In Korean) "We have to open the hatch, hatch" (Captain)	ATC & Radar				

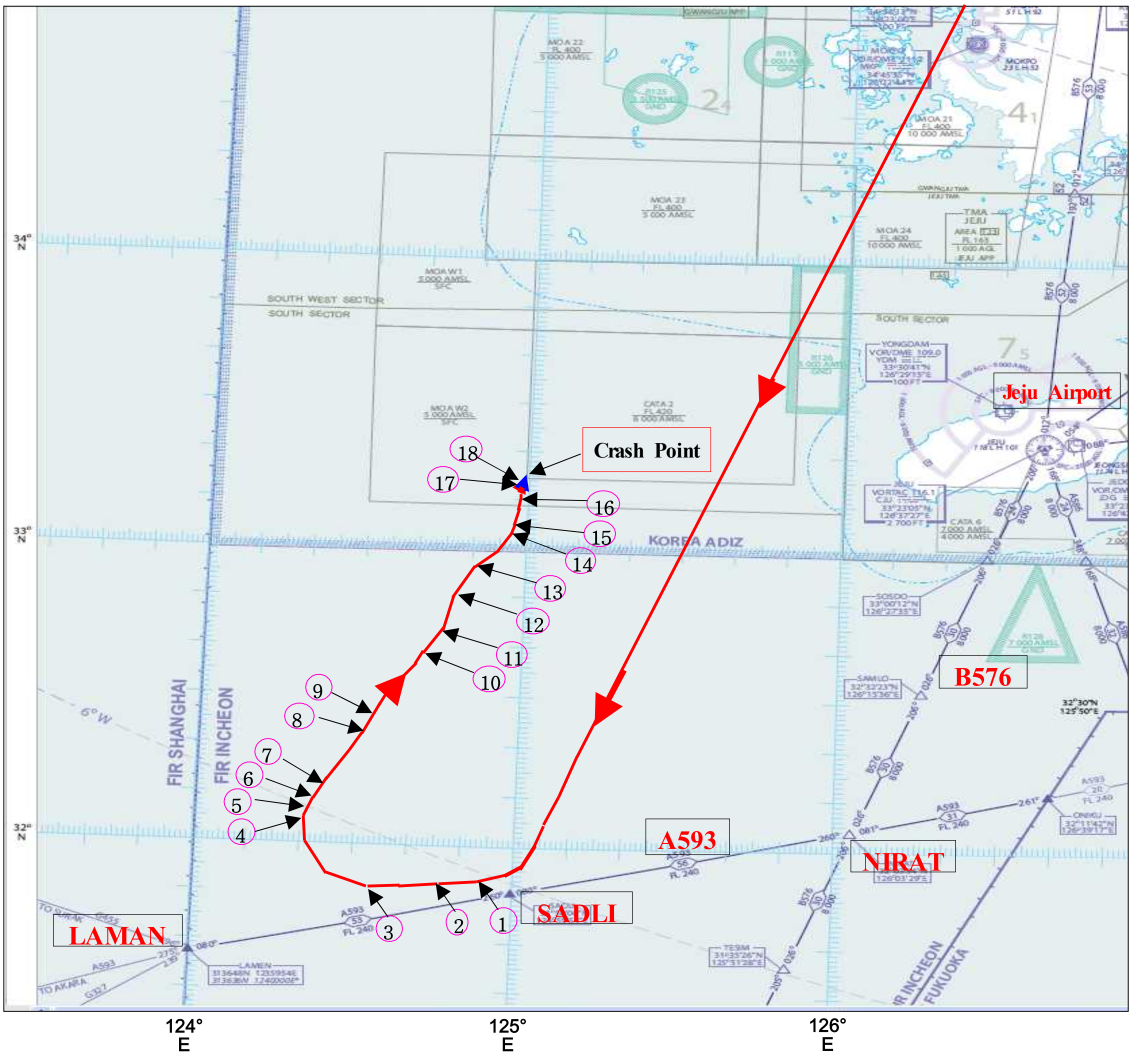
ACARS (GMT) (Capt Clock)	ATC (GMT)	Airplane Altitude (ft)	Airspeed (kts)	Lat	Long	Event	Message Type	FDE Code	Mx Message Code	Activity	Intermittence
	19:09:47	12,900				(In Korean) "rudder control... flight control, all are not working" (Captain)	ATC & Radar				
	19:09:56	11,800				(In Korean, to Jeju Appr) "Do you have a contact with us now" (FO)	ATC & Radar				
	19:10:06	11,600				(In Korean) "Since the airplane is shaking too violently, we may have	ATC & Radar				
	19:10:15	11,200				(In Korean) Can not maintain the altitude due to heavy vibration, going to ditch.... ah	ATC & Radar				
	19:10:50	9,600				AAR991 AAR991, this is Jeju approach, guard out if you hear me, squawk ident.	ATC & Radar				

APPENDIX 3: Incheon Area Control Center's Radar Data

Incheon Area Control Center's Radar Data (28 July 2011)								
Detection	Radar-based Position		Altitude		Speed	Heading	A/C position	
Time(UTC)	X	Y	Feet	Type	Knots	Degrees	LAT	LONG
0354:23.435	-137.37	-248.72	34000	LEVEL	461.43	252.75	N315228	E245346
0354:35.480	-138.94	-248.72	34000	LEVEL	466.26	261.55	N315226	E245156
0354:47.550	-140.41	-248.84	34000	LEVEL	464.94	265.77	N315216	E245013
0354:59.577	-142.06	-248.91	33900	DSCND	473.29	268.02	N315209	E244817
0355:11.540	-143.62	-249.06	33300	DSCND	474.83	267.93	N315158	E244627
0355:23.573	-145.22	-249.22	32400	DSCND	476.37	266.85	N315146	E244435
0355:35.633	-146.75	-249.56	31400	DSCND	473.95	264.14	N315123	E244248
0355:47.607	-148.31	-249.87	30300	DSCND	472.63	261.64	N315101	E244059
0355:59.648	-149.91	-250.19	29300	DSCND	476.37	259.76	N315040	E243907
0356:12.405	-151.34	-250.59	28200	DSCND	470.00	257.70	N315013	E243727
0356:24.367	-153.06	-250.50	27000	DSCND	475.93	261.28	N315015	E243526
0356:36.002	-154.62	-250.44	25800	DSCND	475.27	265.37	N315016	E243336
0356:48.391	-156.19	-250.12	24700	DSCND	472.63	271.39	N315033	E243145
0357:00.087	-157.75	-249.53	23900	DSCND	478.12	278.89	N315105	E242954
0357:12.067	-159.22	-248.84	23300	DSCND	482.52	286.12	N315144	E242809
0357:24.119	-160.44	-248.12	22800	DSCND	468.24	292.36	N315225	E242642
0357:36.138	-161.75	-247.00	21900	DSCND	473.07	300.13	N315330	E242508
0357:48.175	-162.81	-245.91	20800	DSCND	471.09	306.99	N315433	E242351
0358:05.769	-163.66	-244.56	19100	DSCND	480.98	328.05	N315553	E242248
0358:12.211	-164.19	-242.91	18800	DSCND	484.06	330.53	N315731	E242207
0358:29.850	-164.69	-241.37	18000	DSCND	494.17	341.34	N315902	E242128
0358:36.310	-165.19	-239.94	17100	DSCND	486.69	341.26	N320027	E242050
0358:48.283	-165.28	-238.59	15900	DSCND	451.76	345.00	N320148	E242041
0359:00.647	-165.12	-236.91	14900	DSCND	450.88	352.28	N320329	E242048
0359:12.258	-164.69	-235.50	14200	DSCND	445.17	1.59	N320455	E242115
0359:24.313	-164.19	-234.06	13600	DSCND	446.92	9.98	N320622	E242147
0359:36.305	-163.75	-232.47	13100	DSCND	461.87	14.63	N320758	E242215
0359:48.676	-163.12	-231.22	12400	DSCND	454.39	19.28	N320915	E242257
0400:00.671	-162.22	-230.22	11900	DSCND	437.04	26.86	N321016	E242358
0400:12.672	-161.59	-228.78	11400	DSCND	439.89	28.93	N321144	E242439
0400:24.728	-161.03	-227.41	11100	DSCND	441.43	28.07	N321307	E242516
0400:42.353	-160.28	-226.12	10800	DSCND	444.95	29.62	N321426	E242606
0400:48.746	-159.66	-225.16	10300	DSCND	428.25	30.17	N321525	E242648
0401:00.756	-158.97	-223.97	9800	DSCND	412.65	30.53	N321638	E242734
0401:12.810	-158.19	-222.94	9300	DSCND	400.78	32.25	N321741	E242827
0401:24.879	-157.47	-221.75	8800	DSCND	398.14	32.61	N321854	E242915
0401:42.519	-156.75	-220.62	8200	DSCND	404.52	33.41	N322003	E243004
0401:48.889	-156.06	-219.28	8600	CLIMB	411.77	32.23	N322125	E243050
0402:00.930	-155.34	-218.16	9200	CLIMB	412.87	31.51	N322233	E243138
0402:18.583	-154.69	-216.97	8600	DSCND	408.25	28.97	N322346	E243222
0402:24.388	-154.25	-215.97	8500	DSCND	406.27	28.21	N322446	E243251
0402:36.146	-153.66	-214.75	8700	CLIMB	408.03	26.95	N322601	E243330
0402:47.920	-153.06	-213.59	8600	LEVEL	407.59	26.77	N322712	E243410
0403:00.808	-152.44	-212.34	8500	LEVEL	410.01	26.55	N322828	E243451
0403:12.595	-151.81	-211.22	8800	CLIMB	407.81	26.91	N322936	E243533
0403:24.343	-151.22	-210.03	9100	CLIMB	405.62	27.22	N323049	E243613
0403:36.176	-150.41	-209.25	9200	CLIMB	384.30	31.86	N323137	E243709

0403:47.897	-150.03	-207.56	9500	CLIMB	407.15	27.16	N323319	E243732
0403:59.698	-149.31	-206.44	9600	CLIMB	418.14	26.73	N323427	E243821
0404:11.475	-148.53	-205.16	9800	CLIMB	430.66	27.89	N323546	E243914
0404:23.282	-147.59	-204.16	9600	DSCND	430.44	32.13	N323647	E244018
0404:35.078	-146.56	-203.19	9400	DSCND	429.35	37.53	N323747	E244129
0404:46.823	-145.56	-202.25	9500	LEVEL	426.93	42.15	N323845	E244238
0404:58.614	-144.66	-201.19	9500	LEVEL	426.05	43.48	N323951	E244340
0405:10.367	-143.87	-200.00	9700	CLIMB	426.71	41.38	N324103	E244434
0405:22.166	-143.53	-198.12	9900	CLIMB	452.86	30.81	N324257	E244454
0405:33.945	-142.75	-197.59	10400	CLIMB	417.70	30.83	N324330	E244549
0405:45.709	-142.31	-196.44	10700	CLIMB	391.77	28.31	N324440	E244618
0405:57.804	-142.06	-195.03	11000	CLIMB	388.48	21.94	N324605	E244633
0406:09.570	-141.84	-193.78	10800	DSCND	386.28	16.09	N324720	E244646
0406:21.358	-141.66	-192.47	10400	DSCND	392.87	11.92	N324839	E244656
0406:33.147	-141.37	-191.06	9800	DSCND	406.27	10.06	N325004	E244714
0406:44.927	-140.97	-189.72	9500	DSCND	417.26	11.12	N325126	E244740
0406:56.715	-140.37	-188.47	9300	DSCND	421.87	15.10	N325242	E244820
0407:08.438	-139.72	-187.06	9400	LEVEL	435.72	19.64	N325407	E244904
0407:20.202	-138.75	-186.28	9900	CLIMB	418.80	28.72	N325456	E245011
0407:32.000	-137.78	-185.25	10500	CLIMB	416.38	36.35	N325559	E245118
0407:43.741	-136.84	-184.37	11400	CLIMB	410.23	41.93	N325654	E245224
0407:55.481	-135.97	-183.50	11700	CLIMB	401.88	45.05	N325747	E245324
0408:07.273	-135.12	-182.47	11600	LEVEL	398.80	44.73	N325851	E245423
0408:19.003	-134.31	-181.41	11300	DSCND	399.24	42.84	N325955	E245518
0408:30.785	-133.53	-180.22	11300	LEVEL	408.47	39.13	N330108	E245612
0408:42.596	-132.87	-178.97	12000	CLIMB	417.26	34.71	N330224	E245656
0408:54.415	-132.34	-177.84	13100	CLIMB	410.89	30.66	N330333	E245732
0409:06.515	-132.00	-176.44	13900	CLIMB	413.53	24.60	N330458	E245754
0409:18.305	-131.75	-175.19	14600	CLIMB	409.35	18.85	N330613	E245809
0409:30.061	-131.62	-173.91	14400	DSCND	401.88	13.20	N330730	E245816
0409:41.828	-131.53	-172.66	13400	DSCND	395.51	8.46	N330845	E245820
0409:53.592	-131.47	-171.22	12200	DSCND	404.74	4.89	N331012	E245822
0410:05.405	-131.34	-169.87	11600	DSCND	411.33	3.80	N331133	E245829
0410:17.146	-131.09	-168.41	11200	DSCND	424.07	4.97	N331301	E245844
0410:25.000	**MCRC**	**SSR+SR**	**9600**			**20**	**N331412**	**E245912**
0410:28.993	**-130.72**	**-167.03**	**9600**	**DSCND**	**429.57**	**8.03**	**N331425**	**E245908**
0410:34.000	**MCRC**	**SR**	**6500**			**19**	**N331459**	**E245926**
0410:50.000	**MCRC**	**SR**	**4000**			**42**	**N331512**	**E245934**
				NTSB	**SUGGESTED**	**IMPACT PT**	**N331532**	**E245942**

- AAR991's Flight Track Based on ICN ACC's Radar Data



- Major Events Based on Radar Flight Track Data

Track No	Time	Position	Alt	Speed	Heading	Major Events
1	18:54:23	N315228 E245346	340	461	252	AAR991 declared an emergency due to a main deck fire and requested SHI ACC to allow emergency descent to 10,000 ft.
2	18:55:08	N315158 E244627	339	473	268	AAR991 requested SHI ACC to allow a diversion to Jeju Airport.
3	18:56:32	N315016 E243336	258	475	265	SHI ACC instructed AAR991 to turn right.
4	18:59:13	N320455 E242115	142	445	001	AAR991 requested a radar vector to Jeju.
5	18:59:26	N320622 E242147	136	446	010	AAR991 reported a rear cargo fire to SHI ACC.
6	18:59:50	N320915 E242257	124	454	019	SHI ACC instructed AAR991 to fly heading 045.
7	19:00:23	N321307 E242516	111	441	028	AAR991 attempted to contact ICN ACC on 124.52 but to no avail.
8	19:02:00	N322233 E242138	092	412	032	AAR991 attempted to contact SHI ACC on 133.6 but to no avail.
9	19:03:07	N322936 E243533	088	407	027	KAL886 started to relay information between AAR991 and ICN ACC.
10	19:04:48	N323845 E244238	095	426	042	ICN ACC instructed KA886 to relay the message to AAR991 that AAR991 should maintain heading 060 and descend to 8,000 or 7,000 ft.
11	19:05:32	N324330 E244549	104	417	031	KAL886 relayed ICN ACC's instruction to AAR991.
12	19:06:32	N325004 E244714	098	406	010	The captain stated, "Ah... we are now that rudder control is not working and seems to be fired... (jamming)."
13	19:07:34	N325559 E245118	105	416	036	The captain stated, "We have to open the hatch, hatch."
14	19:08:52	N330333 E245732	131	411	031	ICN ACC instructed KAL886 to relay the message to AAR991 that JEJ APP established radar contact with AAR991 and that AAR991 should contact JEJ APP on 121.2.
15	19:09:08	N330458 E245754	139	414	025	KAL886 relayed ICN ACC's instruction to AAR991.
16	19:09:47	N331010 E245822	134	396	008	When AAR991 made first contact with JEJ ACC, the captain stated, "Rudder control... flight control, all are not working."
17	19:10:15	N331301 E245844	112	424	005	The FO stated, "Altitude control is not available due to heavy vibration, going to ditch... ah."
18	19:10:29	N331425 E245908	096	433	011	The last location detected by ICN ACC's secondary air route surveillance radar (ARSR).

APPENDIX 4: ATC Communication Transcript

ATC communication transcript

Between aircraft and ATC facilities

Legend

AAR991: Asiana flight 991
AAR724: Asiana flight 724
CES2015: China Eastern flight 2015
FO: Co-pilot
CDITW: Clearance Delivery in Incheon ATC Tower
RCICA: Ramp Control in Incheon airport
ICTOW: Incheon ATC Tower
SLDEC: Seoul Departure Control
ICNACC: Incheon Area Control Center
JEJAPP: Jeju Approach Control
KAL886: Korean Air flight 886
SHIACC: Shanghai Area Control Center

Note: All the times in the table are Korean standard time

Transmi-ssion time	Transmi-tter	Contents of transmission
Communication under the Clearance Delivery in Incheon ATC Tower		
02:42:27	AAR991	Incheon delivery, good morning, AAR991. (FO)
02:42:31	CDITW	Good morning, AAR991.Delivery, go ahead..
02:42:34	AAR991	Request ATC clearance to Pudong, proposing FL340, stand 624, information Lima. (FO)
02:42:41	CDITW	AAR991, Cleared to Shanghai Pudong runway 15L MALPA 1R departure via Y51 RINBO B576, maintain FL340, departure frequency 125.15, squawk 7163.
02:42:56	AAR991	Cleared to Pudong runway 15L MALPA 1R departure. Y51 RINBO B576 maintain FL340, 125.15, squawking 7163, AAR991. (FO)
02:43:10	CDITW	AAR991, read back is correct, contact ramp 121.87.
02:43:14	AAR991	121.87 AAR991, 수고하십시오(good bye). (FO)
02:43:18	CDITW	수고하십시오(good bye).
Communication under the Ramp Control in Incheon airport		
02:47:49	AAR991	Ramp control AAR991, request push back and start, stand 624. (FO)

02:47:55	RCICA	AAR991 push back and start approved, good morning.
02:47:59	AAR991	Push back and start AAR991, good morning. (FO)
02:53:52	AAR991	Ramp control AAR991 request taxi. (FO)
02:53:57	RCICA	AAR991 taxi to delta, contact tower 118.2, good day.
02:54:03	AAR991	Taxi to delta, tower 118.2, AAR991, good day, 수고하십시오(good bye). (FO)
Communication under the Incheon ATC Tower		
02:54:25	AAR991	Incheon tower, good morning AAR991 approaching 4Y. (FO)
02:54:30	ICTOW	AAR991, good morning, taxi to runway 15L via Delta then Lima.
02:54:36	AAR991	15L, Delta then Lima, AAR991. (FO)
03:01:14	ICTOW	AAR991 confirm ready for departure.
03:01:19	AAR991	Ready for departure, AAR991. (FO)
03:01:22	ICTOW	AAR991, wind 190 at 20 knots, cleared for takeoff runway 15L.
03:01:28	AAR991	Cleared for takeoff runway 15L, AAR991. (FO)
03:04:28	AAR991	AAR991 rolling. (Captain)
03:04:30	ICTOW	Roger.
03:05:35	ICTOW	AAR991 contact departure 125.15, 수고하세요(good bye).
03:05:39	AAR991	125.15 AAR991, 수고하세요(good bye). (Captain)
Communication under the Seoul Departure Control		
03:05:48	AAR991	Departure, good morning, AAR991 now passing 1,800. (Captain)
03:05:54	SLDEC	AAR991 Seoul departure radar contact, climb to FL340, no altitude restriction.
03:06:02	AAR991	Climb 340, no altitude restriction, AAR991, thank you. (Captain)
03:07:45	SLDEC	AAR991 direct MALPA then Y51.

03:07:49	AAR991	MALPA then Y51, AAR991, thank you. (Captain)
03:12:19	SLDEC	AAR991 contact Incheon control 128.3, good day.
03:12:24	AAR991	128.3, 수고하세요(good bye). (Captain)
Communication under the Incheon Area Control Center		
03:12:35	AAR991	Incheon, Good morning AAR991, Now passing 180 for 340. (captain)
03:12:43	ICNACC	AAR991, Incheon ... AAR991, Incheon control, Climb to FL340.
03:12:52	AAR991	Climb 340, AAR991. (captain)
03:13:05	ICNACC	AAR991, clear direct NIRAT.
03:13:08	AAR991	Direct NIRAT, AAR991, thank you. (captain)
03:26:05	ICNACC	AAR991, change to my frequency 124.52.
03:26:11	AAR991	124.52, AAR991. (FO)
03:26:18	AAR991	Incheon control, AAR991 with you. (FO)
03:26:21	ICNACC	AAR991, Incheon control, clear direct SADLI.
03:26:26	AAR991	Direct SADLI. 감사합니다(thank you). (FO)
03:50:46	ICNACC	AAR991, radar service terminated, contact Shanghai control 134.0.
03:50:55	AAR991	134.7, AAR991. (FO)
03:50:58	ICNACC	AAR991, negative, frequency 134.0.
03:51:04	AAR991	134.0, AAR991. 수고하십시오(see you later). (FO)
03:51:08	ICNACC	수고하십시오(see you later).
04:04:18	KAL886	Incheon control, KAL886.
04:04:22	ICNACC	KAL886, Incheon control, radio check, how do you read me?
04:04:25	KAL886	KAL886, Relay for AAR991, AAR991, diverting to Jeju due to cargo fire, emergency, they descent emergency, ah, and they request radar vector to Jeju. Request radar contact with AAR991.
04:04:48	ICNACC	Okay KAL886, please delivery my message to AAR991. Fly heading, fly heading 060 vector for final approach and maintain, pilot discretion maintain 8,000 or 7,000 approved.

04:05:10	KAL886	Roger, Stand by.
04:05:52	ICNACC	KAL886, Incheon.
04:07:55	ICNACC	AAR991, AAR991, this is Incheon on guard, if you hear me contact Jeju Approach 121.2, 121.2, acknowledge by IDENT.
04:08:23	KAL886	AAR991, KAL886, radio check.
04:08:28	ICNACC	AAR991, this is Incheon control, loud and clear. How do you read?
04:08:34	KAL886	Incheon control, stand by, stand by, KAL886. AAR991, Do you read KAL886?
04:08:45	ICNACC	Roger, stand by.
04:08:47	KAL886	Incheon control, this is KAL886. Has any message for Asiana?
04:08:52	ICNACC	Okay. Please delivery my message. Jeju Approach rad.. rad.. radar contact AAR991. At this time contact Jeju Approach 1212, 1212.
04:09:06	KAL886	Roger, Stand by.
04:09:08	KAL886	AAR991, this is KAL886. Relay message from Incheon. Jeju Approach has radar contact to you. Jeju Approach has radar contact to you. Please try to contact Jeju on 121.2, 121.2.
04:09:34	KAL886	Affirmative, affirmative. Try to contact Jeju 121.2, They request radar contact with you.
04:09:46	KAL886	Ah, unable to control?
04:09:49	KAL886	아, control이 안 되신다 구요?(ah, did you say that control is not working?)
04:09:55	KAL886	아...(ah)
04:09:58	KAL886	Asiana, KAL886.
04:10:08	AAR724	Incheon control, AAR724.
04:10:13	ICNACC	AAR724, go ahead.
04:10:15	AAR724	예. 지금 현재 그 AAR991 바로 들리는 거로는 control이 안됩니다. control이 안 된다고 잠깐 조종사가 말이 나왔습니다(yes, I heard at a moment, AAR991 says that control is not working).

04:10:23	ICNACC	일단 Jeju Approach contact하라고 좀 전해주십시오, 121.2 (please let him contact Jeju approach however, 121.2).
04:10:28	AAR724	Okay. AAR991, AAR724.
04:10:48	AAR724	AAR991, 혹시 들리시면 Jeju Approach 1212로 contact하시기 바랍니다(AAR991, if you hear me, contact Jeju approach).
Communication under the Shanghai Area Control Center		
03:51:15	AAR991	Shanghai control, good morning, AAR991 direct SADLI maintain level 340. (FO)
03:51:21	SHIACC	AAR991 Shanghai, squawk 6353.
03:51:25	AAR991	Squawking 6353, AA991. (FO)
03:52:39	SHIACC	AAR991 radar contact, off-set 5 miles right of track.
03:52:43	AAR991	Offset 5 miles romeo side, AAR991, confirm? (FO)
03:52:48	SHIACC	Affirm, 5 miles right side.
03:52:51	AAR991	Ok, 5 miles romeo side AAR991, thank you. (FO)
03:54:23	AAR991	Shanghai control, shanghai control, AAR991 request emergency descent, Emergency, declare emergency due to fire main deck. Request descent, and descent to one-zero thousand. (FO)
03:54:37	SHIACC	AAR991 cleared to descend and turn at own discretion.
03:54:42	AAR991	Maintain...descend one-zero thousand on own discretion, AAR991. (FO)
03:54:47	SHIACC	东方2015雷达引导右转30度由于间隔,避让 (Eastern 2015 radar vector right turn heading 030 due to separation, avoidance)
03:54:51	CES2015	雷达引导右转30度，东方2015 (Radar vector right turn 030, eastern 2015)
03:55:05	SHIACC	AAR991 say again emergency.
03:55:08	AAR991	We have fire main deck, AAR991. Return to Jeju, AAR991. (FO)

03:55:29	SHIACC	AAR991 confirm fire in the cabin?
03:55:54	AAR991	Shanghai AAR991. (captain)
03:55:57	SHIACC	Go ahead.
03:55:58	AAR991	Request divert to Jeju. (captain)
03:56:02	SHIACC	AAR991 do you need to turn right back to..eoh.. ..do you need to turn right immediately?
03:56:13	AAR991	Right turn immediately AAR991. (captain)
03:56:15	SHIACC	approved.
03:56:25	SHIACC	AAR991 confirm request divert to romeo-kilo-papa-charlie?
03:56:30	AAR991	Affirmative. (captain)
03:56:32	SHIACC	Roger, you may turn right, turn right now.
03:57:19	SHIACC	AAR991 confirm you need to descend and maintain flight level 030?
03:57:36	SHIACC	AAR991 shanghai confirm you need to descend and maintain three thousand feet, meter?
03:57:43	AAR991	One zero thousand, return to Jeju. (FO)
03:57:48	SHIACC	Oh, roger, stand by.
03:58:03	SHIACC	AAR991, roger, maintain one-zero thousand feet.
03:58:25	SHIACC	KAL886 shanghai.
03:58:27	KAL886	Shanghai KAL886, go ahead sir.
03:58:32	SHIACC	If you receive any information from the AAR991 and I didn't respond to him, please relay information to me, thank you.
03:58:41	KAL886	Roger, 886. they are descending one-zero thousand feet and now direct to Jeju.
03:58:48	SHIACC	Roger, thank you.
03:59:03	SHIACC	AAR991, do you have any other special request?

03:59:13	AAR991	Yeh, AAR991 request radar vector to Jeju please. (FO)
03:59:22	SHIACC	AAR991, do you have your own heading to Jeju?
03:59:26	AAR991	Roger, AAR991 we have rear, after cargo, fire after cargo, Descend to one-zero thousand and request radar vector to Jeju please. (FO)
03:59:40	KAL886	Shanghai 886, they request radar vector to Jeju.
03:59:50	SHIACC	AAR991 fly heading 045.
03:59:55	AAR991	Heading 045 AAR991. (FO)
04:00:23	SHIACC	AAR991 contact Incheon on 124.52 for vector to Jeju.
04:00:32	AAR991	Say again AAR991. (FO)
04:00:34	SHIACC	Contact frequency 124.52 for Jeju, correction, for Incheon.
04:00:39	AAR991	AAR991. (FO)
04:00:56	SHIACC	东方2015上海(Eastern 2015 shanghai)
04:00:58	CES2015	请讲2015(go ahead 2015)
04:01:02	SHIACC	你拿另外一部开一下124.52听一下韩亚991有没有过去叫 (Please tune another radio 124.52 and listen to Asiana 991 if calling you)
04:01:08	CES2015	好的 (roger)
04:01:15	AAR991	Shanghai AAR991. (FO)
04:01:17	SHIACC	Go ahead.
04:01:18	AAR991	Unable contact Jeju 124.52. (FO)
04:01:22	SHIACC	AAR991, initial monitor this frequency, monitor 134.0.
04:01:27	AAR991	Monitor one two, three four decimal zero(1234.0). (FO)
04:01:50	SHIACC	东方2015 你现在联系下。。。稍等 (Eastern 2015 you contact … wait a moment)

04:02:00	SHIACC	AAR991 contact Fukuoka on 133.6, if unable make establish contact, return to my frequency 133.6
04:02:10	AAR991	AAR991. (FO)
04:02:22	AAR991	Fukuoka AAR991 mayday mayday mayday, we have cargo fire, request direct to Jeju please. (FO)
04:02:35	SHIACC	东方2015你现在开一下1336看一下那边有没有韩亚991叫 (Eastern 2015 you tune 1336, check if any Asiana 991 calling)
04:02:40	CES2015	好的2015(roger 2015)
04:02:42	SHIACC	你在那边不要发话,你就听一下韩亚991有没有过去 (You do not need to transmit, just monitor radio if any Asiana 991 around there)
04:02:46	CES2015	好的(Roger)
04:03:01	AAR991	Shanghai control AAR991. (FO)
04:03:03	SHIACC	Go ahead.
04:03:05	AAR991	Unable contact at Fukuoka. (FO)
04:03:07	SHIACC	AAR991 now you relay inform.. pass information to the Korean Air 886 and let him relay information to Fukuoka and Incheon.
04:03:19	AAR991	Korean air, AAR991. (FO)
04:03:24	KAL886	Stand by 991, this is KAL886, I will relay to Incheon your message, stand by.
04:03:29	AAR991	예, 지금(Yes, now) direct Jeju heading 030. (FO)
04:03:34	KAL886	Shanghai gave you heading 045, 045, stand by, I will relay to Incheon.
04:03:44	AAR991	Heading 045. (FO)
04:04:14	SHIACC	KAL886 shanghai.
04:04:17	KAL886	Shanghai KAL886, go ahead sir.
04:04:20	SHIACC	You use another frequ.., another transmitter to contact Incheon on 124.52 and request heading to Jeju from your present position and tell me please.

04:04:34	KAL886	Roger we are contacting Incheon control.
04:05:30	AAR991	886, AAR991. (captain)
04:05:32	KAL886	AAR991, KAL886, relay from Incheon control, from Incheon control, maintain heading 060, radar vector for final, and you may descend to 7000 feet.
04:05:49	AAR991	Seven thousand. (captain)
04:05:52	KAL886	KAL886 relay for AAR991, maintain heading 060 radar vector for final, and descend to 7000 feet.
04:06:05	AAR991	Descend seven thousand feet. (captain)
04:06:07	KAL886	Affirmative, affirmative
04:06:25	AAR991	Korean Air, AAR991. (captain)
04:06:28	AAR991	Korean Air, AAR991. (captain)
04:06:30	KAL886	Stand by, stand by.
04:06:32	AAR991	아.. 우리 rudder control도 안 되고 fire가 지금... (jamming)...것 같아요 (Ah.. we are now that rudder control is not working and seems to be fired....). (captain)
04:06:41	SHIACC	KAL886 contact Inchon control 124.52.
04:07:06	AAR991	Korean Air, AAR991. (captain)
04:07:16	SHIACC	AAR991 call KAL886 on 124.52, please try.
04:07:25	AAR991	124.52. (captain)
04:07:28	SHI ACC	Confirm Korea air on 12452.
04:07:30	AAR991	12452. (captain)
04:07:34	AAR991	해치를 열어야 할 것 같아. 해치(we have to open the hatch, hatch). (captain)
04:07:40	KAL886	AAR991, this is KAL886.
04:07:44	AAR991	AAR991 go ahead. (captain)
04:07:47	KAL886	AAR991 please change frequency to 124.52, 12452. Incheon control I have relayed for you.
04:08:00	AAR991	12452. (captain)

04:08:01	KAL886	Affirmative, 124.52
Communication under the Jeju Approach Control		
04:09:47	AAR991	Rudder control... flight control이 다 안 되요(rudder control... flight control, all are not working). (captain)
04:09:50	AAR991	Jeju AAR991. (FO)
04:09:53	JEJAPP	AAR991 Jeju approach, go ahead.
04:09:56	AAR991	Did you contact? 어.. 저희들 contact 하고 있어요? (Do you contact with us?) (FO)
04:10:02	JEJAPP	AAR991.. 그,. 예 들립니다...(gue... yes I can hear you).
04:10:06	AAR991	저희들 항공기 진동이 너무 심해서 emergency landing, emergency ditching 해야 될 것 같아요... (We have heavy vibration on the airplane, may need to make emergency landing, emergency ditching) (FO)
04:10:13	JEJAPP	예... 다시 한 번 말씀해주십시오... (Yes.. say again please)
04:10:15	AAR991	항공기 진동이 너무 심해서 고도 control 이 안 돼........ 곧 ditching 할 것 같애... 아...... (altitude control is not available due to heavy vibration, going to ditch.... ah...) (FO)
04:10:26	JEJAPP	AAR991 제주 approach로 접근 가능하십니까? (can you make approach to Jeju?)
04:10:37	JEJAPP	AAR991 this is Jeju appoach, guard out, Jeju approach로 접근 가능하십니까?(Is it possible to approach to Jeju)
04:10:50	JEJAPP	AAR991 AAR991, this is Jeju approach, guard out if you hear me, squawk ident.
04:11:18	JEJAPP	AAR991 AAR991 Jeju approach, this is Jeju appoach, you are able to land at Jeju airport if you hear me direct da... direct MAMMY expect ILS/DME RWY 6 approach.

APPENDIX 5: Search Operations for Flight Recorders

☐ **The first-phase search operation** was conducted from 28 July until 4 August 2011, and the summary of the operation is as follows:

○ Participants
- ARAIB: 1 person (investigator specializing in flight recorders)
- Coast Guard: 2 persons (search support)
- Navy: 5 persons (search support)
- Asiana Airlines: 1 person (search support)

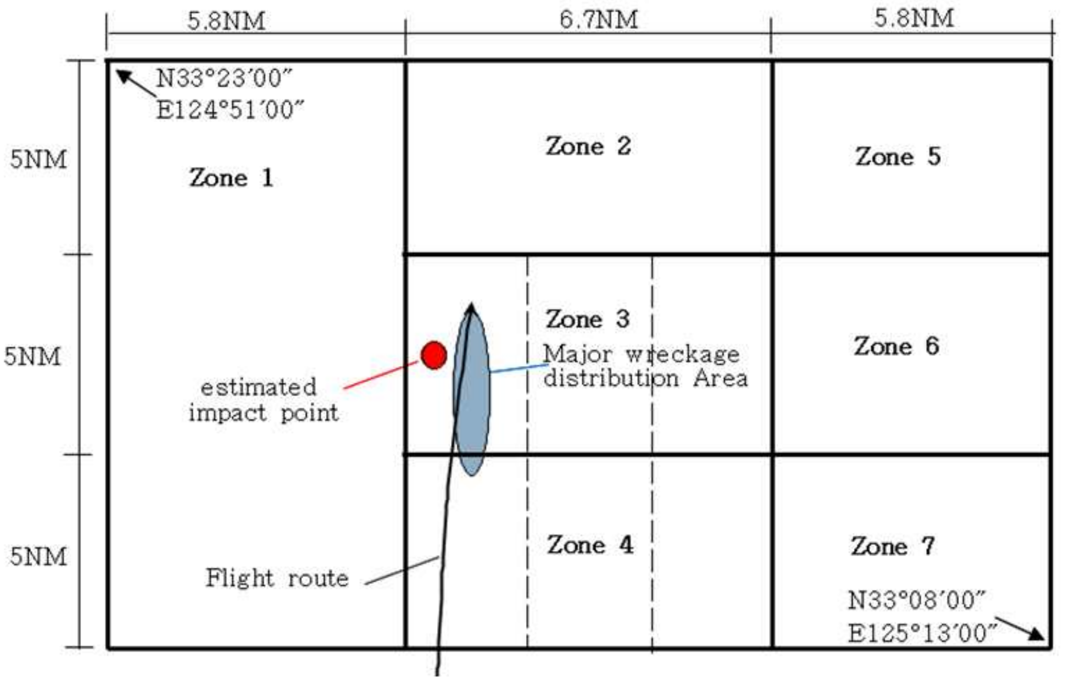
○ Search Equipment
- Portable Pinger Receiver: 1 set (ARAIB)
- Pinger Location Sonar: 1 set (fitted to the Navy vessel)

○ Search Area and Operation

The vessels of the Navy and the Coast Guard searched for wreckage by dividing the area into seven zones as shown in [Figure 1]. For the flight recorders, the naval vessels searched Zones 3 and 4 at intervals of 2 km (radius: 1 km), and for the wreckage, the naval boats searched Zones 1, 2, 5, 6, and 7 at random intervals.

☐ **The second-phase search operation** was conducted from 10 August until 14 August 2011, and the summary of the operation is as follows:

○ Participants
- ARAIB: 2 persons (investigators specializing in ATC & flight recorders)
- Coast Guard: Crew aboard the Coast Guard ship (search support)
- Singapore AAIB: 2 persons (participation in search)
- Asiana Airlines: 6 persons (participation in search)



[Figure 1] First-Phase Search Area for Wreckage and Flight Recorders

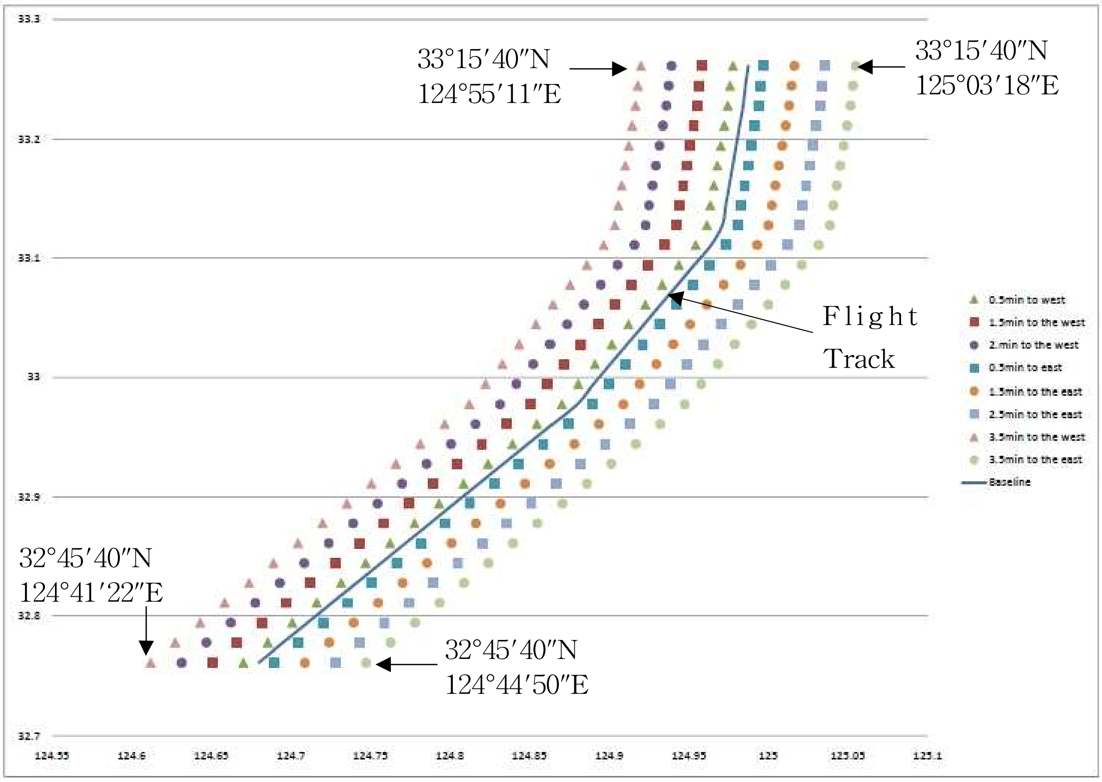
○ Search Equipment

- Portable Pinger Receiver: 5 sets (ARAIB: 1/Benthos 275, AAIB: 2/RJE 275, ASC: 1/RJE 275, Boeing Company: 1/Dukane N30A5B)
- Coast Guard Boat: 4 boats

○ Search Area and Operation

The second-phase search area is shown in [Figure 2], and it was decided to be 14.4 km in width by 66 km in length so that the area could incorporate points between where the aircraft passed one minute before the pilot said that the rudder control was lost and where the northeastern end of the wreckage distribution area was.

On the site, pinger receivers were tested to measure their effective distance. As a result, in consideration of the shortest effective distance (1,000 m), the receivers were dropped at 256 points in the area at intervals of 1,800 m (radius: 900 m) to carry out search operations.



[Figure 2] Second-Phase Search Area for Flight Recorders

☐ **The third-phase search operation** was conducted from 16 August until 20 August 2011, and the summary of the operation is as follows:

○ Participants

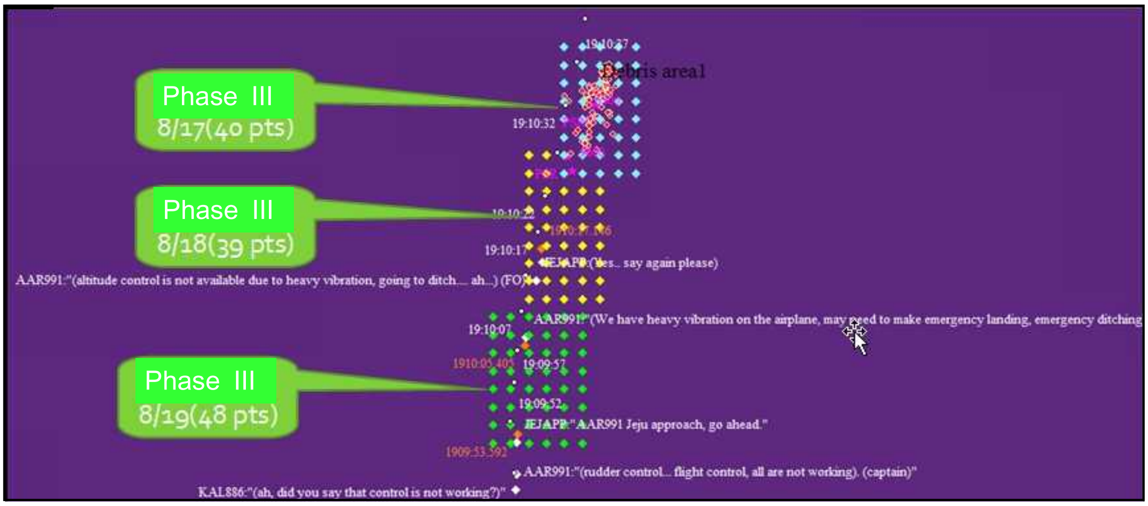
- ARAIB: 1 person (investigator specializing in ATC)
- Coast Guard: all crew aboard the Coast Guard ship (search support)
- Taiwan ASC: 1 person (participation in search)
- Asiana Airlines: 3 persons (participation in search)

○ Search Equipment

- Portable Pinger Receiver: 3 sets (ARAIB: 1/Benthos 275, ASC: 1/RJE 275, Boeing Company: 1/Dukane N30A5B)
- Coast Guard Boat: 3 boats

○ Search Area and Operation

The third-phase search area is shown in [Figure 3], and it was decided to cover the area from the whole wreckage distribution area located by a side scan sonar to the point where AAR991 had the last communication. The area was more closely searched at 127 points at intervals of 500 m (radius: 250 m) than in the second-phase operation.



[Figure 3] Third-Phase Search Area for Flight Recorders

☐ **The fourth-phase search operation** was conducted from 21 August until 27 August 2011, and the summary of the operation is as follows:

○ Participants

- ARAIB: 1 person (investigator specializing in flight recorders)
- Coast Guard: all crew aboard the Coast Guard ship (search support except for 1 person participating in search)
- Asiana Airlines: 4 persons (participation in search)

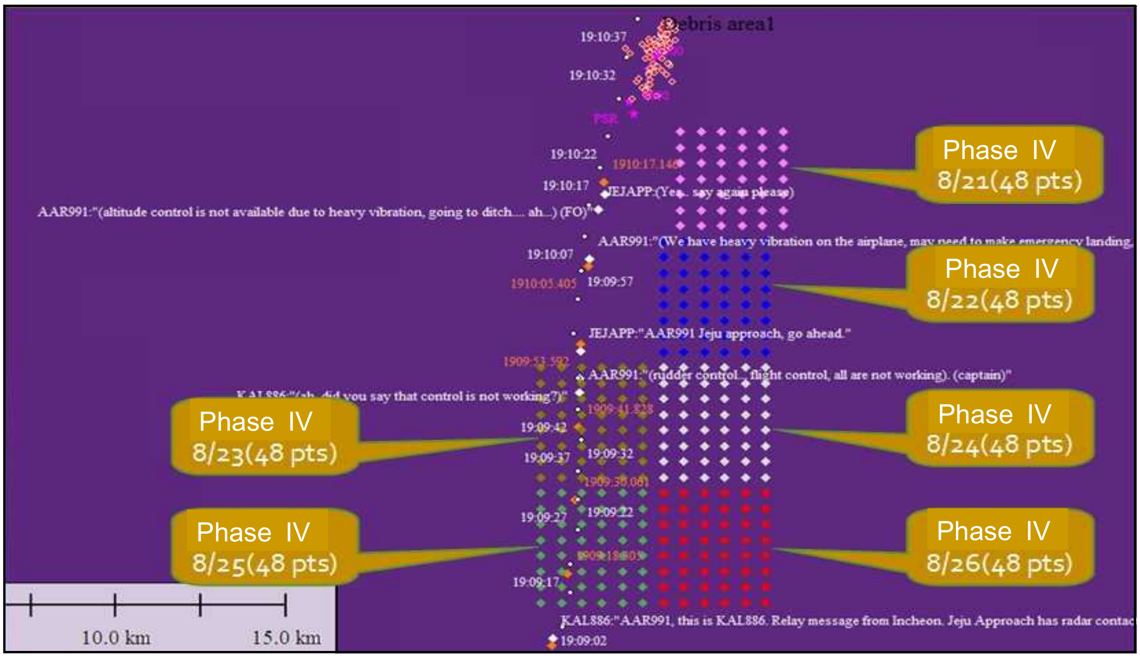
○ Search Equipment

- Portable Pinger Receiver: 2 sets (ARAIB: 1/Benthos 275, Boeing Company: 1/Dukane N30A5B)

- Coast Guard Boat: 2 boats

○ Search Area and Operation

The fourth-phase search area is shown in [Figure 4], and it was decided to cover the area from the point where AAR991 was flying at 14,600 ft to the southern part of the third-phase search area. In consideration of the strong southwest wind at the time of the accident, the area along a 5km band east of the flight track was also searched.



[Figure 4] Fourth-Phase Search Area for Flight Recorders

APPENDIX 6: Aircraft Cockpit Examination

January 18, 2012

A. ACCIDENT ID (NTSB #): DCA11RA087

LOCATION: Near Jeju Island, Korea

DATE/TIME: Juy 28, 2011

AIRCRAFT: Boeing 747-400, Asiana Airlines flight 911, registered as HL7604

B. GROUP:

Technical Advisor: Robert L. Swaim

National Transportation Safety Board (NTSB)

Washington, DC

C. SUMMARY:

Only July 28, 2011, about 04:12 am local Korean time (July 27, 2011 at 1912 UTC), Asiana Airlines flight 991, a Boeing 747-400F cargo airplane (HL7604), disappeared from air traffic control radar and crashed into the East China Sea, approximately 70 miles west of Jeju Island, Republic of Korea, shortly after the flight crew reported a main cargo deck fire. The two flight crew members were fatally injured.

The airplane was being operated as a scheduled cargo flight from Incheon International Airport, Seoul, Korea, to Pudong, China.

D. DETAILS OF THE INVESTIGATION:

STRUCTURE:

The overall cockpit section extended from about fuselage station 200 to almost station 400 and the roof of the cab had been cut away prior to arrival of the group. The roof structure had generally been removed near the windows on the side of the first officer and the windshield frame structures have been cut between the windshield panes on the side of the captain.

A crush line extended from about STA 200, two frames forward of the top of the nose door, to the top of the fuselage at about fuselage station 400. The captain's side of the roof was crushed into the flight deck more than the side of the first officer. The exterior of the cockpit roof skins were extensively pressure formed to the contours of the interior frames and stringers. The aft of the cockpit roof was found twisted to the right. The heavy structures that had been the frames of the windshield were found deformed downward. The lower windshield frame collapsed downward with a sharp bend directly in front of the captains seat.

The upper deck skins and underlying structure had different types of damage on the left and right sides of the cockpit. The skins on the captain''s side were flat. Little existed of the skins from the side of the first officer and the underlying structure was buckled vertically.

Forward of the cockpit, the upper portion of the nose cargo door remained with the cockpit. The left side separated below the upper deck floor (separated about 7 stringers beneath the hinge) and the right side separated roughly at the level of the cockpit floor. The nose door remained closed with the cockpit portion of the fuselage and with a separate fragment of the left fuselage. The right pivot of the nose door had been displaced upward, the right side of the door had torn so that it was missing at three to four stringers beneath the hinge.

The center pedestal had been displaced left to the midpoint of the captains Multi Function display. The seat of the first officer had also displaced left to contact the displaced center pedestal.

The main deck hand fire extinguisher was found protruding upward through the cockpit floor between the FSTA frames 330 and 340, at the airplane centerline. The bottom of the fire extinguisher was to the right and the hose was caught on structure further to the right. The pin was in place and the indicator showed a full charge.

The overhead hatch remained in the closed position, with the handle at the mid-point of the range of travel. The range of travel is normally 180 degrees and the handle was found immovable at about 90 degrees from the stowed position. The exterior surface of the hatch had been pressure formed.

All of the cockpit emergency descent devices were found with the cockpit roof and all were partially extended, not in normal storage positions.

All of the cockpit windshields were accounted for, mostly in the frames and displaced inward.

SEATS

The captain seat was found detached from the cockpit. The floor in the vicinity of the captain seat tracks was gouged consistent with spacing of the seat attachments, such that the marks were less than three inches from full forward. The gouges were to the right and forward.

The complete seat of the captain was found with the back broken aft. The seat retained three of the four mounts and the forward right floor track remained with the seat. All four mounting points were oriented so that the rear of the seat was displaced to the

right, which corresponded with the structural intrusion into the seat space.
The captain seat pan had no hydroform type of downward damage. The cushions had no thermal damage and were not blackened in color. Both lap belts had been cleanly cut and the buckle was not with the seat, when observed. The lower strap and shoulder straps remained with the seat.
The captains seatbelt buckle was found and matched to the lap straps. Both of the captain lap belt straps had been cleanly cut. The lower (crotch) and shoulder belts were found intact.
The first officer seat was found immovable on the seat rails at 8 to 9 inches from the forward stop. The seat pan is not displaced or hydroformed downward. The seat back is broken aftward to the level of the glareshield.
The first officer shoulder harness straps are both in the stowed positions. The left and crotch straps are both complete with metal tangs that would engage with the buckle mechanism. The remaining right strap has a ragged tension separation in the middle of the strap that matches the portion remaining attached to the buckle..
The two cockpit observer seats were found complete, with the back assembly of each broken aft. The lap belts had damage similar to that seen at the first officer seat.

OXYGEN SYSTEM

The supplies for the oxygen system were not seen and this section only describes the cockpit portions found.
The captains stowage box for the normal oxygen mask had been partially crushed, with the top of the control yoke found in the box. The supply hose was complete to the fitting where the mask assembly had connected. The captains oxygen mask was not seen.
Found with the seat of the captain was an empty oxygen mask box from the cockpit, marked EROS by Intertechnique, P/N MXP147-3, S/N SE09373. The mask box was deformed in a way that captured two laminated NORMAL PROCEDURES checklists. In another Asiana 747, the checklists were found in a pocket on top of the glareshield.
Two oxygen masks of the observer type were found. The mask found near the first officer seat was complete with the head bands and a selector on the bridge of the nose (goggle vent) was initially found at a mid position, closer to the marking “"KEEP CLOSED WITHOUT GOGGLES.”"
The smoke mask of the first officer was found on floor next to the F/O seat, attached to a supply hose.

The stowage area for the mask had been disrupted and the mask had extensively more damage than the observer masks, including a broken lens, headbands separated from one end, and extensive damage was found to the microphone/valve area.

None of the masks were darkened internally or externally with soot-like deposits.

FORWARD INSTRUMENT PANELS AND PEDESTAL

Notes:

1. Nearly all of the annunciator lights were seized and could not be opened normally to check the bulbs. The mechanisms had to be soaked and then pried open.
2. Lightbulbs were examined with a 10X glass on-site and then separately under magnification of 50-200X with a digital microscope.
3. Two types of annunciator lights were found. Typical of the larger was model OL387 and AS150. Typical of the smaller bulb was stamped model OL-685-15.
4. The following references were used for the light bulb examination:

Guide to the Impact Behaviour of Aircraft Instrument Panel Lamp Filaments, Australian Department of Defense Report DSTO-TR-2217, October 2008, by B. Grigson.

A Guide to Light Bulb filament Analsys In Support Of Aircraft Accident Investigation, Transportation Safety Board of Canada Report TP6255E, Rev 1991, M.R. Poole & M. Vermij.

Light Bulb Filament Impact Dynamics Study, published in 16 ISASI 1985, by M.R. Poole, M. Vermij, and T. W. Heaslip.

5. As noted in the studies pertaining to incandescent light bulbs, tungsten achieves white luminosity at about 3000-5000 degrees F and becomes ductile at about 480 F. Variables involved in the stretch of filaments include temperature, impact load, and filament age.

At the left edge of the forward instrument panel, the captains SOURCE SELECT switches were found with the FLT DIR selected to Left, NAV to FMC Left, EIU to Auto, IRS to Left, and Air Data selected to Left.

The captain shoulder heater was at low, the foot hear at high, and windshield heater at high.

The captains clock was missing the glass and sweep needle. The captains RMI had intact facial glass that was not completely clear. Two orange INOP flags could be seen

through the glass. Both external knobs were oriented upward.
The faces were shattered on the captains Primary Flight Display (PFD) and the Multi Function Display (MFD) units.
The top of the captains control column had been broken downward by the downward displacement of the glareshield. Most of the control yoke was in the oxygen mask box, without the right handle.
Beneath the PFD, the HYD BRAKE PRESS gauge was obscured by the captains right grab handle / foot rest. The AUTOBRAKES selector was folded into a damaged area ahead of the displaced throttle pedestal.
Above the captain PFD, the panel was bent and the display selector knobs were missing. The shaft flats for the knobs were configured for the INBD CRT to display the PFD and the LWR CRT to display EICAS PRI.
The standby attitude indicator was partially crushed and the face had been contacted by the left Multifunction Control Display Unit (MCDU, shown in some documents as CDU). In areas of disruption were the EIU SEL assembly, the FMC selector, as well as the selectors for the first officer LWR CRT and INBD CRT.
The captains stabilizer trim indicator shows OFF. The speed brake control handle is 1.1 inches aft of the flight detent, with the autopilot Mode Control Panel (MCP) resting against it. The parking brake lever was found extended.
The MCP was also resting against the remnants of all four thrust levers, which were found at the aft edges of travel. Each of the four thrust levers were missing the top knob and all four were bent to the right. All four thrust reverser levers were found in the stowed positions.
Both EICAS display units had crushed facial glass and the lower unit had been twisted by the displaced pedestal.
The landing gear handle was found past the up position, bending the top of the handle box, with the frame of the right MCDU resting against the bottom of the handle.
The panel for alternate flap and alternate landing gear selection and annunciator assemblies was crushed into a disrupted area. The only remaining light bulb was of the small type from the NOSE/BODY switch light and under magnification, the filament had a fracture at one end. The filament had not stretched in general form or in individual coils.
On the right side of the pedestal, the stabilizer trim indicator displayed the word OFF.
A crease line extended from the right edge of the throttles diagonally aft, folding the

set of stabilizer trim switches to the right.

The faces were shattered on the first officer Primary Flight Display (PFD) and the Multi Function Display (MFD) units. The first officer clock facial glass was missing and the sweep needle was at the parked position (up). The top of the first officer control column had been crushed downward, separating the control yoke, which had the right handle broken off.

The first officer master caution warning annunciator was not seen. At the right edge of the forward instrument panel, the first officer SOURCE SELECT switches were found with the FLT DIR knob missing and the flat of the shaft selected to Right, NAV to FMC Right, EIU to Auto, IRS to Right, and Air Data selected to Right.

The first officer shoulder heater was at high, the foot hear at low, and windshield heater at high.

The components mounted on the glareshield had been crushed and twisted. The captains electronic flight instrument control (EFIS) control was selected to MAP with a range of 320 miles. The captain flight director was to OFF. The FMC control panel was broken across the vertical speed selector. The selected speed was 239 knots, the heading selection was in an indented area and closest to the display of 143 degrees. The autopilot disengage switch was in a bent area of the panel. The first officer flight director was at OFF, the EFIS control panel was selected to MAP with a range of 160 miles.

Aft of the pedestal were the four fuel cutoff (FCO) switches that were documented in place, removed, rinsed in tap water to remove salt deposits, and under magnification.

FUEL CUTOFF SWITCH #1

When removed from the pedestal, the plastic body of the switch was found cracked. Found with the toggle in the ON position and with corresponding microscopic marks on the gate and finger of the latching mechanism. Under magnification, the lock/latch mechanism was found unremarkable and no metal smears or deformation was noted. The red plastic cap was removed to access a lightbulb. The glass of the bulb was found in fragments and the filament was not found.

FUEL CUTOFF SWITCH #2 When removed from the pedestal, the plastic body of the switch was found cracked.

Found with the toggle in the ON position and with corresponding microscopic marks on the gate and finger of the latching mechanism. Under magnification, the lock/latch mechanism was found past the spring loaded locking feature and twisted, so that the left finger was on top of the locking gate and the right finger was a full finger-width past the gate. The ON side of the left finger had a strike and rust mark corresponding with the ON side of the gate. The ON side of the left gate had a smear toward the OFF side. The top of the right gate (ON position) had a strike mark and a corresponding mark was on the finger.

The red plastic cap containing a bulb was not present when the switch was first found.

FUEL CUTOFF SWITCH #3 When removed from the pedestal, the body of the switch was found intact.

Found with the toggle in the OFF position, with microscopic markings at the ON position on the gate and finger of the latching mechanism. Under magnification, the ON side of the left finger had a single strike mark at the edge, consistent with the toggle displaced to the right and fully seated on the gate. The bottom/ON side of the right finger had a set of diagonal contact marks that were out of plane with normal operation. The direction for the top of the diagonal was consistent with displacement to the right. The OFF sides of the left and right fingers had significant rust deposits and wear spots. What was visible of the surfaces did not have strike marks or metal displaced.

The red plastic cap was removed to access a light bulb. The glass of the bulb was found intact and the filament had broken into multiple small fragments with no stretching of the coils.

FUEL CUTOFF SWITCH #4 When removed from the pedestal, the plastic body of the switch was found intact.

Found with the toggle in the OFF position, with microscopic markings at the ON position on the gate and finger of the latching mechanism. Under magnification, the top sides of both gates had marks in the metal and the right gate had smeared metal at the top corner. The ON side of the left finger had minor marks, the right finger had no visible marks. The OFF sides of the gates were partially obscured by rust, the visible metal was not damaged.

The red plastic cap of FCO #4 was removed to access a lightbulb. The glass of the bulb was found intact and the filament had broken into multiple small fragments with no stretching of the coils.

The captains audio panel selections were for Left VOR and Center MKR.

The NO SMOKING selector was at AUTO, the SEATBELTS selector was at OFF. The rudder trim indicator was found with the OFF flag showing at 8 units left of center.

The AUTOBRAKES rotary selector was found at DISARM.

OVERHEAD PANELS

All overhead panels have extensive evidence of contact, impact damage, and deformation. Many had to
be extensively cut into smaller pieces to extricate annunciator and switch assemblies. The luminescent
panels had broken and exposed the underlying tracks were black and missing the normal copper color.
Forward of the overhead luminescent panels was a black residue on the plastic panels that had been
above the forward windshields.

The **lighting control panel** from the captain side has 2 of 4 knobs broken away at the panel.
The circuit breaker and glareshield lighting control knobs were found deformed. The AISLE
STAND PANEL FLOOD knob was at full on.
Other than the OUTBD LEFT (on), the landing lights were found at OFF. The RWY TURNOFF
left switch had been broken and the right had been bent. The taxi light switch was found at OFF.
Of the lighting switches on the side of the first officer, none had an intact toggle and shaft.

The **hydraulic control panel** had grossly deformed facial features.
The #1 system knob was missing and the knob flat was at AUTO.
The two large style **PRESS** annunciator bulbs were found broken into smaller sections and
neither had stretching in general form or of the individual coils. One smaller ON bulb had a
single filament break and the other had a fragment break free; no stretching in form or of
individual coils was seen in either filament.
The two large style **SYS FAULT 1** annunciator bulbs both had the filaments fracture into
multiple small parts with no stretch observed.

The #2 system knob was between AUTO and ON.
The filaments of the two large style **PRESS** annunciator bulbs were found broken into smaller
fragments and none had stretching in general form or of the individual coils. Both smaller ON
bulbs had a section of the filament separate and neither had stretching in form or of individual
coils.
The two large style **SYS FAULT 2** annunciator bulbs each had the filament break and stretching was found in some of the fragments. The right bulb had fragments appear to adhere
to the inside of the glass.
The #3 system knob was at AUTO.
The filaments of the two large style **PRESS** annunciator bulbs were found broken into smaller
fragments and none had stretching in general form or of the individual coils. Both smaller ON
bulbs had the filament break into small fragments and none had stretching in form or of
individual coils.
The two large style SYS FAULT 3 annunciator bulbs had a difference in appearance of the
filaments, although both had broken into smaller portions. In one the portions were small and
brittle looking. Some of the fragments of the second filament had extensive amounts of stretch
and some had no stretch.
The #4 system knob was between AUTO and ON.
The filaments of the two large style **PRESS** annunciator bulbs were found broken into smaller
fragments and none had stretching in general form or of the individual coils. Both smaller ON
bulbs had the filament break into small fragments and none had stretching in form or of

individual coils.

The **electrical control panel** was extensively disrupted and deformed. The following items were observed:

The switch mechanism for the Standby Power rotary knob had separated from the back of the panel and no clear alignment characteristics were found.

UTILITY LEFT,

The left filament from the OFF annunciation had broken into fragments with extensive stretching to the general form and individual coils of two fragments. The glass enclosure of the second OFF bulb was found fragmented and no filament was seen. The left ON filament had broken into small fragments and individual coils, with no stretching characteristics. The right ON filament had broken, with fragments adhered to the glass and a two exhibiting gross stretching.

UTILITY RIGHT,

Both ON filaments had broken into numerous small fragments and no stretching was seen. Both OFF bulb glass enclosures had broken and the filaments were not seen.

The APU selector on the electrical control panel was found at OFF and the STDBY selector was missing.

BATTERY ANNUNCIATOR BULBS,

The ON left bulb filament had broken into smaller fragments, with at least two individual coils.

No distortion of the major features or of more than a single localized coil was seen. The ON right bulb filament had broken into small fragments with no distortion of the major features or of the single localized coils.

The battery annunciator OFF left bulb filament had two loose fragments. One filament fragment

had a sharp bend and minor coil stretches. The second fragment had distortion of the major
features and of single localized coils. The OFF right bulb filament had a single break with
stretched coils near the break and in at least two other locations, as well as a sharp bend in the
coil.

BUS TIE #2

The filament from one of the smaller bulbs that had been behind the AUTO legend had broken in
one location and an indefinite amount of mild stretched across the mid portion, with tight coils
near the posts. The second filament had not broken and was unremarkable. Two large style bulbs
were behind the legend ISLN. One ISLN filament had a slightly opaque glass and the visible
filament had a section fractured from the middle, with no visible stretching. The second ISLN
filament had a sagging filament that had broken between the posts.

BUS TIE #3

The filaments of the smaller bulbs that had been behind the AUTO legend had both broken
without stretching. The two large style bulbs were behind the legend ISLN and both had broken
into small fragments. The two small style bulbs had broken filaments that exhibited no stretching
in form or of the individual coils.

The IRS panel was found with all three selectors at NAV.

The Digital Electronic Engine Control (DEEC) annunciators had two smaller bulbs behind the NORM
legend and two larger bulbs behind the ALTN legend. The DEEC #1 ALTN filaments had both broken
and no stretching was noted. One had a long single portion separate and the second filament broke into

numerous small fragments. The two small style NORM filaments had broken into filaments that
exhibited no stretching in form or of the individual coils.
The DEEC #2 ALTN filaments had both broken into smaller fragments and no stretching was noted.
One of the two NORM bulb filaments was intact and the other had a break; neither had stretching in
form or of the individual coils.
One of the DEEC #3 ALTN filaments had broken in a single location and the second into smaller
fragments; no stretching was noted in either. Both of the NORM bulb filaments broke into small
fragments and neither had stretching in form or of the individual coils.
The DEEC #4 ALTN filaments had both broken into smaller fragments and no stretching was noted.
Both of the two NORM bulb filaments had broken and neither had stretching in form or of the
individual coils.
At the forward center of the overhead panel, the window heat panel left wiper switch was at low and
the right was at high.
The **fuel control panel** was grossly distorted.
The start panel had the left STDBY igniter knob missing, the AUTO knob to SINGLE, and the
fuel jettison knob at OFF.
The **fire control panel** contained a pull handle for each of the four engines and one for the APU.
None of the engine or APU handles had been turned to the discharge positions. An apparent
difference in extensions of the handles observed was subsequently found to be displacement of
the handle bodies that were located behind the panels. Once the displacement was accounted for,
all of the extension measurements equated to the stowed positions.

ENGINE #1 Fire Handle

Of the four bulbs, one bulb had broken and was missing the filament and a second bulb was filled with fluid. The filaments in each glass had broken and no stretch in general form or individual coils was observed.

ENGINE #2 Fire Handle

Of the four bulbs, one bulb glass was missing and two had holes in the glass. The filament in the complete bulb had broken into small fragments and no stretch in general form or individual coils was observed. One of the bulbs with a hole had about a third of the filament remain and no stretch in general form or individual coils was observed.

ENGINE #3 Fire Handle

Of the four bulbs, one bulb had broken and was missing the filament. The filaments in each glass had broken and no stretch in general form or individual coils was observed.

ENGINE #4 Fire Handle

Of the four bulbs, two bulbs were missing the glass, with filament fragments remaining in the base. The filaments in each and the intact bulbs (each contained filament fragments) had no stretch in general form or individual coils.

APU Fire Handle

Bulbs #1-#4: Two of the four bulbs had broken glass and retained filament fragments within the base areas. All four bulb filaments had broken and no stretch in general form or individual coils was observed.

APU BTL DISCH

One of the two bulbs contained a broken filament and neither of the filaments had stretch in general form or stretching of the individual coils.

BTL A DISCH, Engines 3 and 4,
The left and right bulb filaments had each broken into multiple fragments with no distortion of
the major features or of the single localized coils.
BTL B DISCH, Engines 3 and 4,
The left and right bulb filaments had each broken into multiple fragments with no distortion of
the major features or of the single localized coils.
The EMER LIGHTS toggle was found at the ARMED position with the guard broken away.
The OBServer AUDIO SYSTEM lift/latch switch was found at NORM. The CAPT AUDIO SYSTEM
toggle was found bent upward past NORM. The INTERPHONE SERVICE TOGGLE was found at ON
and the CARGO/CABIN switch was found at OFF.
The Smoke Evac handle was found in the stowed position with a coiled microphone type of cord
wrapped around the T, which could not be freed without extending the handle. The Teleflex cable
attached to the back of the handle was found to retain a broken arm from the valve assembly at the
opposite end of the cable and the arm had been caught by the edge of the overhead hatch. The teleflex
cable was found extended to the full length, past the sliding extension at the end, so that about 4 inches
of the flexible cable was exposed. The shutter for the valve was found closed.
The **pneumatic control panel** contained the following items:
The left isolation valve annunicator had two types of bulb. The larger bulbs were behind the
legend **VALVE** and the smaller were behind a horizontal **line** that could be illuminated to
complete a flow path. None of the filaments exhibited stretch in general form or of individual
coils.

The right isolation valve annunicator had two types of bulb and the glass enclosures had
separated from the two larger bulbs with more than half of the filaments remaining. None of the
filaments exhibited stretch in general form or of individual coils.
The APU pneumatic supply annunciator had two types of bulb. The larger bulbs were behind the
legend VALVE. The smaller bulbs were behind the word ON. Both ON bulb filaments had
broken at the ends of indefinite stretched areas between the posts. Both VALVE bulb filaments
had broken into many small fragments with no stretching in general or of individual coils.
The #1 pack selector was at NORM on January 9, 2012, as it was observed in Korean notes of
August 11, 2011. The body of the switch assembly had not rotated in the mount.
The #2 pack selector was missing the knob and the shaft flat was at NORM on January 9, 2012,
as it was observed in Korean notes of August 11, 2011. The body of the switch assembly had not
rotated in the mount.
The #3 selector was at OFF on January 9, 2012, as it was observed in Korean notes of August 11,
2011. The body of the switch assembly had not rotated in the mount.
The two #1 SYS FAULT light bulbs were intact and the filaments exhibited no stretching of the
general form or of the individual coils.
The two #2 SYS FAULT light bulbs were intact and the filaments exhibited no stretching of the
general form or of the individual coils.
The two #3 SYS FAULT bulbs had extensive amounts of filament stretch between the tops of the
posts.
The two #4 SYS FAULT bulbs had some sag and minor amounts of filament stretch in

localized
areas.

The **Environmental Control System (ECS) control panels** contained the following items:
Both outflow valves indicators were found at the full open positions.

MANUAL OUTFLOW VALVE ANNUNCIATOR, LEFT (MAN L)

The assembly contained two bulbs and two blanking plugs. Neither bulb had a filament stretched
in general form or with stretching of the individual coils.

MANUAL OUTFLOW VALVE ANNUNCIATOR, RIGHT (MAN R)

The assembly contained two bulbs and two blanking plugs. Neither bulb had a filament stretched
in general form or with stretching of the individual coils.

FAN

Neither bulb had a filament stretched in general form or with stretching of the individual coils.

ZONE RST

The left SYS FAULT bulb was found broken into small fragments with no distortion of the major
features or of the localized coils. The right bulb had a single break and indefinite minor stretching
of the general features. The upper two bulb positions were filled with plastic plugs.

TRIM AIR

The filaments of the two bulbs each had one major portion loose within the glass enclosure. No distortion of the major features or of the localized coils was seen. The lower two positions had plastic plugs installed.

HI FLOW

The assembly contained moist dirt, both bulbs had broken, and the filaments could not be
examined.

PACK RST

The left SYS FAULT filament had a separated section and a short area of one had minor stretched
beyond normal, with none of the coils clearly stretched. The right SYS FAULT bulb had two

filament fragments that had clearly been stretched. The upper two holes were filled with plastic
blanking plugs.
AFT CARGO HT, ON and TEMP
The four filaments within the AFT CARGO HT annunciator had each broken into small fragments with no distortion of the major features or of the localized coils.
The temperature control panel had the following control positions:
flight deck knob at AUTO,
the MAIN DECK FWD at about 2 o''clock,
the MAIN DECK AFT shaft flat (no knob) near AUTO,
the LOWER LOBE FWD TEMP knob missing and the shaft flat at about 9 o''clock,
the LOWER LOBE AFT TEMP knob missing and the shaft flat at about 3 o''clock,
CARGO FIRE PANEL
MAIN DECK
The lower two bulbs in the annunciator were behind a red caption that was labeled
MAIN DECK.
The left filament had major distortion and distortion of the localized coils. The right filament had
a single large central section separate and major distortion or distortion of the localized coils was
not visible. Both ARMED bulb filaments were intact and unstretched.
FWD CARGO
The lower two bulbs in the annunciator were behind a red caption that was labeled
FWD. The left
FWD filament had broken into separate pieces, one of which adhered to the glass at least two
exhibited both stretching in general form and of individual coils. The right FWD bulb filament
had two fragments separate, one of which was grossly stretched toward one end. Additional
stretching was seen in a fragment remaining attached to the base. The left ARMED filament was
found with a single break and no distortions of the general form or individual coils. The right

ARMED filament was found intact.
AFT CARGO
The lower two bulbs in the annunciator were behind a red caption that was labeled AFT. The left filament had sag and a single break, with no distortion of the major features or of the single localized coils. The right bulb for the red AFT annunciation had at least four loose fragments within the glass and no distortion of the major features or of the single localized coils was seen.
Both ARMED bulb filaments were intact and unstretched.
CARGO FIRE DEPRESS/DISCH
The upper two bulbs were behind a caption DEPRESS and the lower two bulbs were behind the caption DISCH. The left DEPRESS filament had broken into a large section and at least two smaller fragments. The general filament did not exhibit generalized stretching; some individual coils had stretched near a post. The right DEPRESS filament was intact with some sag and minor individualized coil stretches near one post. The filament of the left DISCH bulb exhibited stretching of the general form and individual coils near both posts and down one side. The filament of the right DISCH bulb exhibited gross stretching of the general form and individual coils, with one break of the filament.
The supernumerary passenger oxygen switch guard was safety wired (frangible wire) in the closed and OFF position.
The yaw damp annunciators had two types of bulb. The larger bulbs were behind the legend INOP and the smaller were behind the word ON.
The left yaw damp annunciator INOP bulbs had broken filaments, combined with areas

of
stretching the general form. Both of the smaller filaments had no stretching and brittle types of
breakage.
The right yaw damp annunciator and the smaller were behind the word. The larger INOP bulbs
had broken filaments and areas of stretching the general form. Both of the smaller ON filaments
had no stretching and brittle types of breakage.

AFT OVERHEAD PANELS

An unlabeled switch (seen as the ELT switch in another airplane) that had been located aft of the
Digital Electronic Engine Control (DEEC) panel was in an impacted area and labeled ON ARMED
RESET. The heavily damaged switch was missing the guard and the damaged toggle was found at
RESET.
The GND TESTS switch at the aft left corner of the overhead panels was found extensively impact
damaged.
The FLT CONTROL HYD switches were all found in the closed (guarded) positions, with damage to
the guards.
An extensively damaged area contained remnants of guarded toggle switches labeled GEN FIELD
MAN RESET and SPLIT SYSTEM BREAKER.
The LOWER LOBE CARGO CONDITIONED AIR FLOW RATE rotary selector was found to the left
of OFF.
List of removed parts
Asiana 911 -- HL7604
Note that most of the following parts were removed to access other components. The NVM items were
removed for preservation.

1. No Smoking / Seatbelt Panel with two switches:
1A. No Smoking Rotary Switch
Janco
P/N: AC45-0008-2
S/N: 8592
Date: 05 09
1B. Seatbelt Rotary Switch
Janco
P/N: AC45-0008-2
S/N: 8588
Date: 05 09
2. Rudder/Aileron Trim Module
233T6201-21
233T6201-324
S/N: D02592
3. Call Light Panel
BAE Systems
P/N: 285U1004-1
S/N: D00137
4. Autobrake Panel-Autobrake Selector Switch
Janco
Boeing P/N: S283T022-3
Janco P/N: AC30-0003-3
S/N: 2903
Date Code: 9649
5. CON-4B Control Unit (Radar)
Honeywell
SER CON 4B-05338
DMF: 082005
MFR: 97896
S/N: 0543
6. TCAS Panel
P/N: G6992-03
S/N: 4310

7. Chronometer -- Labeled “"F/O Side”"
Smiths
PNR: 2510-08-1
SER: CL5080
Boeing P/N: 60800303-107
Software P/N: S00076-SW-04
8. Audio Control Panel -- Labeled “"Pedestal Observer Seat”"
Hughes/Avicom
Hughes P/N: 1167015-141
Boeing P/N: S220U000-203
S/N: D-9103000783
NVM Note: No NVM
9. Audio Control Panel -- Labeled “"Captain”"
Hughes/Avicom
Hughes P/N: 1167015-141
Boeing P/N: S220U000-203
S/N: 9502040340
NVM Note: No NVM
10. Audio Control Panel -- Labeled “"F/O”"
Hughes/Avicom
Hughes P/N: 1167015-141
Boeing P/N: S220U000-203
S/N: D-9102000737
NVM Note: No NVM
11. Multi Input Printer
Matsushita
MFR P/N: RD-AC1203-5B3
S/N: 200341
Date: 02 97
12. MCDU
Honeywell
Honeywell P/N: 4058650
Boeing P/N: S242T102-152
S/N: 91091428

NVM Note: No Aircraft Status recorded, only hardware faults and software exceptions with
no time tags.
13. Radio Communication Panel — Labeled “"Captain”"
BAE Systems
P/N: 285U0037-613
S/N: D03188
NVM Note: Records frequencies, modes, BITE status.
14. Radio Communication Panel — Labeled “"Copilot”"
BAE Systems
P/N: 285U0037-613
S/N: D01980
NVM Note: Records frequencies, modes, BITE status.
15. Radio Communication Panel — Labeled “"Captain”"
BAE Systems
P/N: 285U0037-613
S/N: D03214
NVM Note: Records frequencies, modes, BITE status.
16. Mode Control Panel
NVM Note: Records last selections, such as crew section of airspeed, selected altitude, and
selected heading. Does not record system failures.
17. MCDU –- Labeled “"Captain CDU”"
Honeywell
P/N: 4077880-998
S/N: 31804106
NVM Note: No Aircraft Status recorded, only hardware faults and software exceptions with no
time tags.
18. Brake Pressure Indicator
P/N: 162LCP639
S/N: 05105424
19. Integrated Standby Flight Display (ISFD)
Thales Avionics

P/N: C16221LA03

S/N: C16221005129

NVM Note: No Aircraft Status recorded, only hardware faults and software exceptions.

20. RMI

Collins

P/N: 203

S/N: 1R951

21. Chronometer

Smiths

P/N: 2610-08-1

S/N: CL6225

22. MCDU Keyboard

Honeywell

P/N: MS90451-7132

S/N: 2595

23. Display Unit — Labeled “"Upper EICAS”"

Rockwell/Collins

P/N: 4V792

S/N: 160TG0

NVM Note: Records internal fault status only.

24. Display Unit — Labeled “"Capt (Left) PFD

Rockwell/Collins

P/N: 4V792

S/N: 1RLHV

NVM Note: Records internal fault status only.

25. Display Unit — Labeled “"Copilot Left”"

Rockwell/Collins

P/N: 4V792

S/N: 160TG1

NVM Note: Records internal fault status only.

26. Display Unit — Labeled “"Copilot RT”"

Rockwell/Collins

P/N: 4V792

S/N: 160TG5

NVM Note: Records internal fault status only.

27. Display Unit –- Labeled “"Capt MFD”"

Rockwell/Collins

P/N: 4V792

S/N: 1RL2B

NVM Note: Records internal fault status only.

28. Display Unit –- Labeled “"EICAS Lower”"

Rockwell/Collins

P/N: 4V792

S/N: 1RMLY

NVM Note: Records internal fault status only.

29. MCDU –- Labeled “"Copilot CDU”"

Honeywell

P/N: 4058650-90

S/N: 94062367

NVM Note: No Aircraft Status recorded, only hardware faults and software exceptions with no time tags.

APPENDIX 7: AAR991's Flight Documents

● Flight Plan (5/5)

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OZ991   RKSI/ZSPD   27/JUL/2011      OFP 2:1510Z       PAGE  1/4
--------- -------- --------- --------- --------- --------- ---------

AAR991     27/JUL/2011 HL7604 B747-400CGO GQLM  APMS/2.4
WIND/TEMP M009/M24     DIST     613/628      SPD:  340.M84-CI040-M84.290

PAX :  0F- 0C- 0Y    TTL 0     CGO 73 TONS                TKOF ALTN:....
ICN/RKSI  P0900 : STD/ 17.45Z ETD/17.45    ATD-      /
PVG/ZSPD  P0800 : STA/ 19.40Z ETA/19.23    ATA-      /

SPOT NR/COORD:

ICN.MALPA.Y51.RINBO.B576.NIRAT.A593.DUMET.DUMET22.PVG : ICNPVG1
ICN/0340/LAMEN/0321/
---------- ---------- ---------- ---------- ----------- -----------

              FUEL    TIME            PLAN      ACTL               UNIT:100LBS

TRIP          0332    01.28           SOW 3504
CONT          0040    00.12 / 10%     PLD 1630      MTOW                  8700
ALTN/RKPC     0188    00.51           ZFW 5134      MZFW 6100 TOF 1071 7171
HOLDING       0085    00.30           TOF 1071      MLDW 6660 TIF 0332 6992
                                      TOW 6205
RQRD          0646    03.01           TIF 0332
EXTRA         0425    01.53 RSN/TKG LDW 5873      AGTOW                 6992
PAD           0000    00.00
TKOF          1071    04.54                               EXTRA FUEL(U): 0000
TAXI          0015
RAMP          1086    04.54 TCAP: 3594 / 6.7   TIF ADJ 0203/PLD 5000 LBS
                                  *********  TANKERING INFO  *********
TTL  RSV      0739    03.26       * TANKERING SECTOR                     *
                                  * GAIN(P): 1001 USD (042500 LBS)       *
                                  * DISPATCH DEFINED                     *
ALTN SUMMARY:                     ******** ******** ******** *********
 ALTN        DIST   FL    TIME   WIND   FUEL   RTE
 RKPC/06     335    331   00.51  P13    0188   DCT PUD A593 NIRAT DCT
 ZSHC/25     145    217   00.29  M04    0109   DCT PUD A599 JTN G204 AND
                                               AND11A
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Flight Plan 1/5

OZ 991/27 JUL/ICN-PVG Page 3

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OZ991  RKSI/ZSPD  27/JUL/2011      OFP 2:1510Z       PAGE  2/4
                                 MAX SR/01/CJU      MIN OAT/M37/CJU
--------- -------- --------- --------- --------- --------- ---------
DST POINT     FL   MC LAT       ETO REM  OT WIND - COMP SR TAS ZT/ACTM
FREQ   AWY    MORA TC LONGI     ATO ACTL AT ACTL - WIND TP G/S TIF/ACTF
--------- -------- --------- --------- --------- --------- ---------
RKSI   TAXI            N037 27.8    1071
 ELEV 0023FT           E126 26.4
--------- --------- --------- --------- --------- --------- ---------
108 TOC       CL  175 N036 06.7...0927 34 25/025 M004         16/00.16
              036 167 E126 50.1                        52 396 144/0144
/MALPA1B
--------- --------- --------- --------- --------- --------- ---------
017 RINBO     340 174 N035 53.9...0921 37 25/024 M004 00 492 02/00.18
              036 167 E126 53.8                        52 471 007/0150
RINBO/MALPA1B
--------- --------- --------- --------- --------- --------- ---------
023 LINTA     340 193 N035 31.3...0911 37 25/023 M011 01 492 03/00.21
              038 185 E126 51.3                        52 470 010/0160
LINTA/B576
--------- --------- --------- --------- --------- --------- ---------
024 KWA       340 192 N035 07.6...0900 37 24/022 M011 01 492 03/00.24
114.40        049 185 E126 48.7                        52 473 010/0171
GWANGJU/B576
--------- --------- --------- --------- --------- --------- ---------
053 IPDAS     340 192 N034 15.3...0878 37 25/019 M009 01 492 07/00.31
              049 185 E126 43.0                        52 475 023/0193
IPDAS/B576
--------- --------- --------- --------- --------- --------- ---------
052 CJU       340 192 N033 23.1...0855 37 26/015 M005 01 492 06/00.37
116.10        074 185 E126 37.5                        53 480 023/0216
JEJU/B576
--------- --------- --------- --------- --------- --------- ---------
024 SOSDO     340 206 N033 00.2...0845 37 26/013 M006 01 490 03/00.40
              074 200 E126 27.6                        53 481 010/0226
SOSDO/B576
--------- --------- --------- --------- --------- --------- ---------
030 SAMLO     340 207 N032 32.4...0832 37 27/012 M004 01 490 04/00.44
              010 200 E126 15.6                        53 481 013/0239
SAMLO/B576
--------- --------- --------- --------- --------- --------- ---------
030 NIRAT     340 206 N032 03.9...0819 37 28/009 M001 01 490 04/00.48
         -CCRP 010 200 E126 03.5                       52 485 013/0252
NIRAT/B576
--------- --------- --------- --------- --------- --------- ---------
056 SADLI     340 262 N031 49.8...0795 37 27/013 M012 01 490 07/00.55
              010 256 E125 00.0                        52 479 024/0276
SADLI/A593
--------- --------- --------- --------- --------- --------- ---------
053 LAMEN     340 262 N031 36.6...0772 37 26/015 M015 01 490 06/01.01
              013 256 E124 00.0                        52 475 023/0299
LAMEN/A593                                                       -ZSHA
--------- --------- --------- --------- --------- --------- ---------
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Flight Plan 2/5

OZ 991/27 JUL/ICN-PVG Page 4

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OZ991  RKSI/ZSPD  27/JUL/2011     OFP 2:1510Z      PAGE  3/4
--------- -------- --------- --------- --------- --------- ---------
DST POINT    FL   MC LAT      ETO REM  OT WIND - COMP SR TAS ZT/ACTM
FREQ   AWY   MORA TC LONGI    ATO ACTL AT ACTL - WIND TP G/S TIF/ACTF
--------- -------- --------- --------- --------- --------- ---------
023 TOD      321 262 N031 30.8...0764 32 25/017 M017     484 03/01.04
             013 256 E123 33.4                        53 470 008/0307
/A593
--------- --------- --------- --------- --------- --------- --------
003 AKARA    DC  262 N031 30.0...0764 31 25/017 M016         01/01.05
             013 256 E123 30.0                        53 457 000/0307
AKARA/A593
--------- --------- --------- --------- --------- --------- --------
038 DUMET    DC  263 N031 21.7...0760 17 23/010 M012         05/01.10
             013 258 E122 46.5                        53 410 003/0311
DUMET/A593
--------- --------- --------- --------- --------- --------- --------
ZSPD   TAXI          N031 08.5   0739                        18/01.28
079 ELEV 0011FT      E121 47.4                               021/0332
--------- -------- --------- --------- --------- --------- ---------

ONE FL BLW.  TIF 0336  TIME 01.29  WIND/M010
RKSI/0320/LAMEN/0302/
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Flight Plan 3/5

OZ 991/27 JUL/ICN-PVG Page 5

OZ991 RKSI/ZSPD 27/JUL/2011 OFP 2:1510Z PAGE 4/4

ADV CFP VALID UNTIL:2345Z 27/JUL/2011

THIS FLIGHT IS RELEASED IN ACCORDANCE WITH APPLICABLE REGULATIONS.

DISP OR AGENT LEE SANG GOOK . . . .

PILOT IN COMMAND CHOI . SANG KI . . . .

UPPER WIND/TEMP DATA: PROG 2712 2718 2800

WPT	WIND/OAT 10000	15000	20000	31000	35000
CLB	24028P10	24027P02	24026M07	25025M29	25023M39

	(25000)	(28000)	(31000)	(34000)	(37000)	(40000)
TOC	25024M16	25024M23	25025M29	25024M37	25020M45	26019M52
RINBO	25023M16	25024M23	25024M29	25024M37	25019M45	26018M52
LINTA	25021M16	25022M23	25022M29	25023M37	25017M45	26016M52
KWA	25019M16	25020M23	25019M29	24022M37	25016M45	26014M52
IPDAS	24015M16	25017M22	25018M29	25019M37	26014M45	27012M52
CJU	24012M16	25015M22	25016M29	26015M37	27012M45	28010M52
SOSDO	24010M16	25013M22	26015M29	26013M37	27011M45	28010M53
SAMLO	24009M16	25012M22	26014M29	27012M37	27011M45	28009M53
NIRAT	23008M16	26010M23	27012M29	28009M37	29009M45	31009M53
SADLI	23010M16	25012M22	26013M29	27013M37	29011M45	31012M53
LAMEN	23011M16	24014M22	25016M29	26015M36	27014M45	28012M52
TOD	23012M16	24015M22	25017M29	25017M36	26015M44	28013M52

	39000	35000	31000	20000	10000
DSC	27014M50	25016M39	25017M29	22010M07	20016P12

Flight Plan 4/5

OZ 991/27 JUL/ICN-PVG Page 6

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[ ATC Flight Plan ]
-----------------------------------------------------------------------
FF RKSIZPZX RKSIZTZX RKRRZQZX RKRRYFYX RKSSZTZX RJTGYJYX RJJJZQZX
ZSJNZRZX ZSSSZBZX ZSOFZRZX ZSCNZRZX ZSAMZRZX ZSSSZRZX ZSPDZPZX
ZSQDZXZX ZSJNZXZX ZBBBZGZX ZSAMZXZX ZSPDZXZX ZSACZQZX ZSSSZXZX
271509 RKSSAARO
(FPL-AAR991-IS
-B744/H-SDHIJPRXWYZ/SD
-RKSI1745
-N0491F340 MALPA Y51 RINBO B576 NIRAT A593 LAMEN/K0896S0980 A593
 DUMET DUMET22
-ZSPD0128 RKPC
-EET/ZSHA0101 REG/HL7604 SEL/GQLM OPR/AAR DOF/110727 RMK/ADSB TCAS
 II EQUIPPED NAV/RNAV1 RNAV5 DAT/SHVM CODE/71BE04 STS/CARGO)
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Flight Plan 5/5

● Load Sheet

```
L O A D   S H E E T    B747-400F              ALL WEIGHTS IN LBS
FLT NR   DATE   FROM/TO REG NR  VERSION      CREW     PRINT      EDNR
OZ0991   28JUL ICN/PVG HL7604               2/ 0/ 0 28JUL/0112   01
---------------------------------------------------------------------
                              WEIGHT          DISTRIBUTION
LOAD IN COMPARTMENTS          145368    1/  9103   2/ 10124   3/  9535
                                        4/  8413   5/     0   A/     0
                                        B/     0   C/  5093   D/  5412
                                        E/  7441   F/  8697   G/  9361
                                        H/  9037   J/  9762   K/ 13173
                                        L/ 13501   M/ 11649   P/  3672
                                        R/  2778   S/  8818   T/     0
---------------------------------------------------------------------
PASSENGER/CABIN BAG            0  A/  0 C/  0 I/  0 TTL  0 CAB     0
BAG PC/WT    0/     0             PAX BY CLASS  F/  0  C/  0  Y/   0
           CABIN-AREA TRIM    A/ 0
---------------------------------------------------------------------
 WEIGHT    I.U.     C.G.
 350433   84.11                DRY OPERATING WT.      L  RTOW  620500
 145368                        TOTAL PAYLOAD
 495801   81.57    27.31 ZFW CG ZERO FUEL WT.            MZFW  610000
 107100                        TAKE OFF FUEL
 602901   81.45    25.98 T/O   TAKE OFF WT.              MTOW  870000
- 33200                        TRIP FUEL
 569701                        LANDING WT.            L  MLDW  666000
                               ALLOWABLE GROSS WT.A     AGTOW  620500
---------------------------------------------------------------------
STAB TAKE-OFF  4.2
TAXI FUEL 1500   TAXI WGT 604401   MRMW 873000
---------------------------------------------------------------------
UNDERLOAD BEFORE LMC 17599
LAST MINUTE CHANGES
DEST  SPEC     CL/CPT      - WEIGHT


SI

PANTRY CODE A
---------------------------------------------------------------------
PREPARED BY LOADMASTER OR AGENT  SIGN    108965
                                 ------------------------------------
APPROVED BY CAPTAIN              SIGN
                                 ------------------------------------
```

● Flight and Maintenance Log

ASIANA AIRLINES | LOG PAGE 941639 | FLIGHT & MAINTENANCE LOG | HL 7604 | DAY(DD) 26 MON(MMM) JUL YEAR(YY) 11

NO	CREW NAME	EMP. NO	DUTY CODE 1	2	3	4	5	6	NO	CREW NAME	EMP. NO	DUTY CODE 1	2	3	4	5	6	NO	CREW NAME	EMP. NO	DUTY CODE 1	2	3	4	5	6
1	김정수	701097	C	C					5	[illegible]	702347			2C				9	[illegible]	[illegible]				2C	2C	
2	이창준	714433	F	F					6	[illegible]	715814			2F				10	[illegible]	[illegible]				[illegible]	2F	
3	임근하	707791			2C				7	김봉관	[illegible]				2C	2C		11								
4	[illegible]	715613			2F				8	[illegible]	[illegible]				2F	2F		12								

TRAINING FLIGHT RECORD: NAME | LOCAL TIME | T/O | L/D

LEG NO	FLT NO	STATION FROM	TO	IRR	BLOCK TIME R/O	R/I	B/T	TIME IN SERVICE T/O	L/D	T/S	NIGHT FLT TIME	INST FLT TIME	FUEL STATUS (Q'TY LBS) RAMP OUT	REMAIN	USED	CREW T/O	L/D	LDT	CAPT'S SIGN
1	997	ICN	TSN		0504	0714	2+10	0543	0706	1+23		1+23	87.900	49.300	38.600	1	2	A	김정수
2	998	TSN	ICN		0900	1105	2+05	0929	1044	1+15		1+15	55.800	26.300	29.500	2	1	A	김정수
3	785	ICN	VIE		1303	2347	10+44	1327	2334	10+07	10+07	10+07	283.300	38.600	244.700	4	5	M	[illegible]
4	785	VIE	FRA		0140	0316	1+36	0200	0307	1+07	1+07	1+07	55.300	32.100	23.200	7	7	A	김봉관
5	786	FRA	ICN		0508	1515	10+07	0531	1511	9+40	5+00	9+40	287.800	46.400	241.400	10	8	A	김봉관
6																			

PART CHANGE

ITEM NO	NOMENCLATURE	POSITION	PART NO (ON)	PART NO (OFF)	SERIAL NO (ON)	SERIAL NO (OFF)

	A/C TIME	A/C CYCLE	APU TIME	APU CYCLE
PREV	28728:28	4794	1916	2155
TODAY	23:32	5	7	9
TOTAL	28752:00	4799	1923	2164

LEG NO	ENG & APU OIL(QT) 1	2	3	4	APU	IDG/CSD OIL(QT) 1	2	3	4	HYD (GAL) 1	2	3	4	ACCOMPLISHED CHECK TYPE	STATION	BY
1	3.0	3.0	3.0	2	0	0	0	0	0	0	0	0	0	TR	ICN	122903
2	0	0	0	0	0	0	0	0	0	0	0	0	0	TR	ICN	123128 김용만
3	0	0	0	0	0	0	0	0	0	0	0	0	0	LS	ICN	153934
4	0	0	0	0	0	0	0	0	0	0	0	0	0	TR	VIE	06351
5	0	0	0	0	0	0	0	0	0	0	0	0	0	TR	FRA	MAY 031080

LEG NO	FUEL SERVICE RECORD (Q'TY LBS) GRADE	SPEC	ORDER	REMAIN	SERVICE	DIFF(±)	REF D,C,M	ON BOARD	RETURN TO SERVICE DAY / TIME	LICENCE NO	BY	CAPT'S ACCEPT
1	JETA1	6.66	86500	30900	56.600	1000	M	87.500	26/1231	3991	136687	[illegible]
2	JETA1	6.66	51900	49300	7200	4600	C	56500	26/1641	4761	123128 김용만	김정수
3	JETA1	6.56	283500	26300	257900	+700	M	284200	26/2200	5562	153934	[illegible]
4	Jet A1	6.56	55300	38600	16400	+700	M	55000	27/0305	06351	[illegible]	김봉관
5	JetA1	6.68	288600	32,100	256900	+400		289000	27/0635	AAR 0007	031080	[illegible]

LEG NO	ITEM NO	MALFUNCTION	ITEM NO	CORRECTIVE ACTION	STATION	DATE	BY	INSPECTOR

REV.3 2011.03.01 LOG PAGE 941639 AAR MQ 506 01

● Fuel Information

icnod

보낸 사람: gmpow@asianamsg.com
보낸 날짜: 2011년 7월 28일 목요일 오후 1:19
받는 사람: icnod
제목: [QD] MVT

중요도: 높음

```
QD ICNODOZ
.GMPOWOZ 041828JUL 023DC4
MVT
OZ0991/27.HL7604 .ICN
AD1747/1805 EA1933 PVG
DLSG/0002
PX000/000/000
SI RMPF/0108600 APLD/0145368
```

● NOTOC

C/F 3002

Notification to Captain for Special Load

Page 1 of 2 ASIANA CARGO

7

SPECIAL LOAD - NOTIFICATION TO CAPTAIN

Station of Loading	Flight Number	Date	Aircraft Reg.	Prepared by:	Emergency Contact point(Telephone number of Origin station):
ICN	OZ 991	28 Jul 2011	HL7604	kim yong	82 32 744 2807

DANGEROUS_GOODS

Station of Unloading	Air Waybill Number	Proper Shipping Name	Class or Division. For Class 1, compat. Grp.	UN or ID Number	Sub Risk	Nbr. of Pkgs.	Net Qty or Trans. Index per Pkg.	Radio-active Material Category	Pack-ing Group	IMP Code	ERG Code	CAO (X)	Loaded ULD ID	Loaded POSN	Loaded Moved to POSN
PVG	988-63857393	LITHIUM ION BATTERIES	9	UN3480		15	14.5KGG		II	RLI	9F	X	PMC13389OZ	PR	
		LITHIUM ION BATTERIES	9	UN3480		1	16.4KGG		II	RLI	9F	X			
		LITHIUM ION BATTERIES	9	UN3480		1	9.7KGG		II	RLI	9F	X			
					// OVERPACK USED X 1 //										
	988-68019571	PAINT	3	UN1263		1	.236L		III	RFL	3L				
					(OVERPACK USED) LTD,QTY										
	988-68119586	AMINES, LIQUID,CORROSIVE,N.O.S	8	UN2735		1	5L		III	RCM	8L	X			
		.,(ETHOXYLATED ALKYLAMINES)													
	988-68527056	PAINT	3	UN1263		1	12L		II	RFL	3L	X			
					OVERPACK USED										
	988-68693542	RESIN SOLUTION	3	UN1866		10	18L		III	RFL	3L				
					OVERPACK USED*2										
		RESIN SOLUTION	3	UN1866		6	18L		III	RFL	3L				
		RESIN SOLUTION	3	UN1866		1	9L		III	RFL	3L				
					OVERPACK USED*1										
	988-68738110	FLAMMABLE LIQUID N.O.S (PROPYL	3	UN1993		8	15.12L		III	RFL	3L	X	PMC11978OZ	HL	
		ENE GLYCOL MONO METHYL ETHER A			OVERPACK USED*1										
		CETATE SOLUTION)													
		FLAMMABLE LIQUID N.O.S (PROPYL	3	UN1993		3	15.12L		III	RFL	3L	X			
		ENE GLYCOL MONO METHYL ETHER A			OVERPACK USED*1										
		CETATE SOLUTION)													
	988-68738121	FLAMMABLE LIQUID N.O.S (PROPYL	3	UN1993		2	15.12L		III	RFL	3L	X	PMC13389OZ	PR	
		ENE GLYCOL MONO METHYL ETHER A													
		CETATE SOLUTION)													
		FLAMMABLE LIQUID N.O.S (PROPYL	3	UN1993		1	11.34L		III	RFL	3L	X			
		ENE GLYCOL MONO METHYL ETHER A			OVERPACK USED*1										
		CETATE SOLUTION)													

http://www.asianacargo.com

● CJU Chart

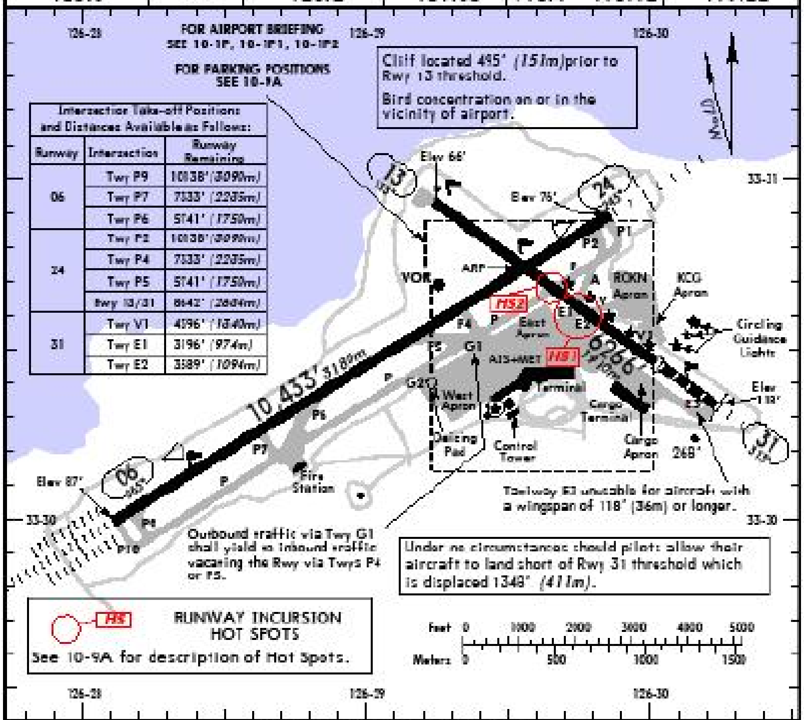
- Airport Chart

RKPC/CJU
Apt Elev 119'
N33 30.7 E126 29.6

JEPPESEN
13 MAY 11 (10-9)

JEJU, KOREA
JEJU INTL

*D-ATIS	ACARS: D-ATIS PDC	JEJU Clearance	Ground	Tower	JEJU Departure (R)
126.8		126.2	121.65	118.1 118.12	119.22



ADDITIONAL RUNWAY INFORMATION

RWY		Landing Beyond Threshold	Landing Beyond Glide Slope	Take-Off	Width
06	(1) HIRL (2) CL ALSF-II TDZ (3) PAPI-L (5) grooved RVR		9272' 2826m		148' 45m
24	(1) HIRL (2) CL SSALF (3) PAPI-L (6) grooved RVR		9482' 2890m		
13	(1) HIRL (7) grooved				148' 45m
(8) 31	(1) HIRL SSALF (4) PAPI Circling guidance lights.	4918' 1499m			

(1) (197' 60m spacing)
(2) (49' 15m spacing)
(3) (angle 3.0°)
(4) (angle 3.5°)
(5) First 738' (225m) not grooved.
(6) First 656' (200m) not grooved.
(7) First 1988' (606m) not grooved.
(8) Grooved, first 984' (300m) not grooved.

TAKE-OFF

	Rwys 06, 24, 31 HIRL & CL or RCLM	Rwys 06, 24, 31 Other	Rwy 13
2 Eng	500m	[1] 1600m	NA
3 & 4 Eng	500m	800m	NA

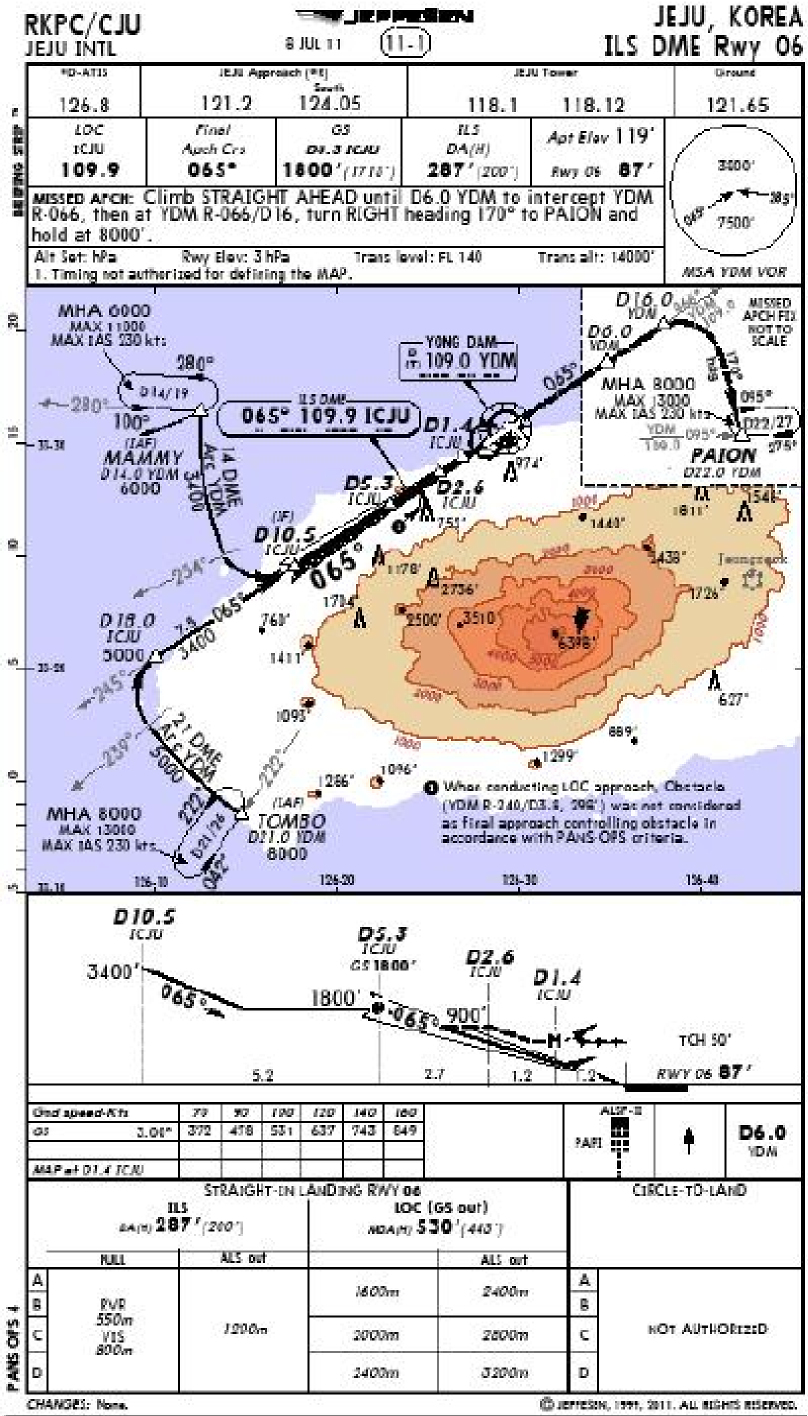
[1] 1 & 2 Eng

FOR FILING AS ALTERNATE

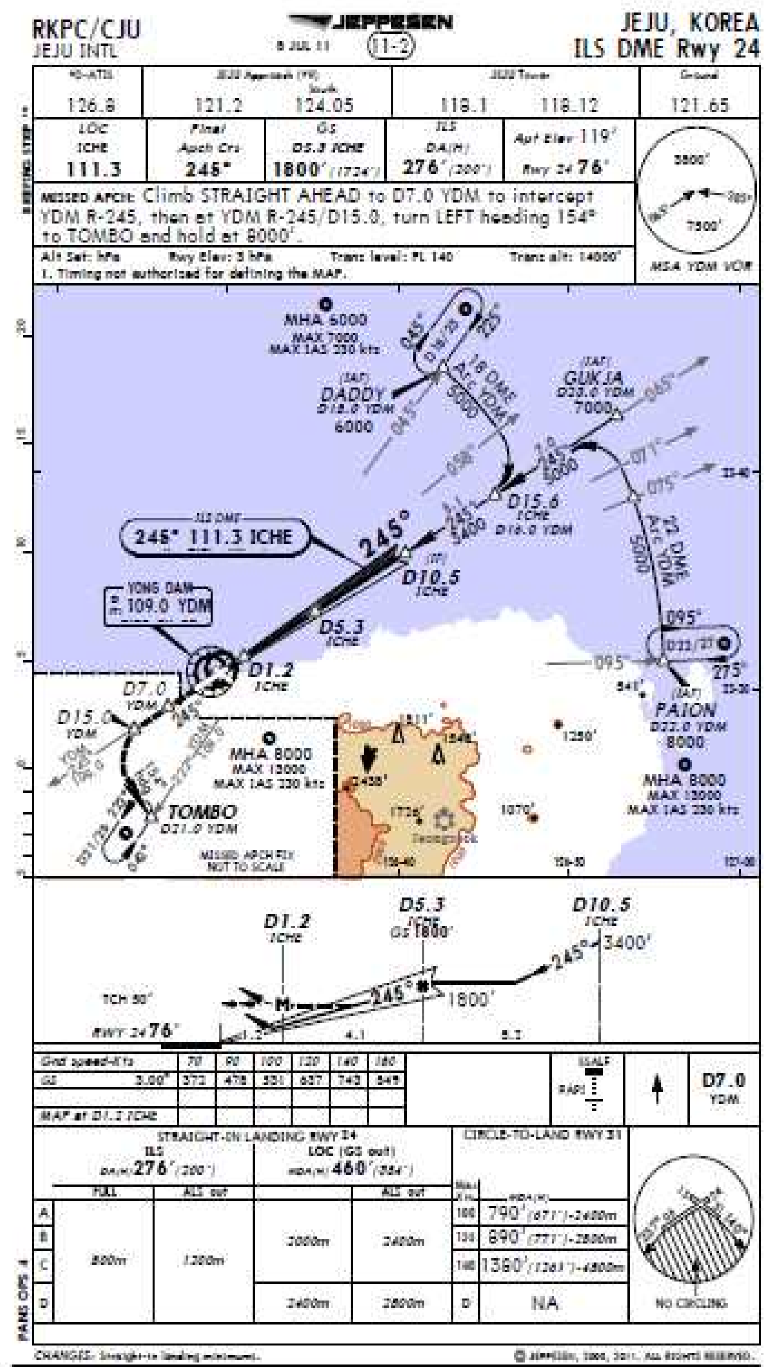
	Precision	Non-Precision
A B C D	600'-3200m	800'-3200m

CHANGES: Rwy 06/24 grooving.

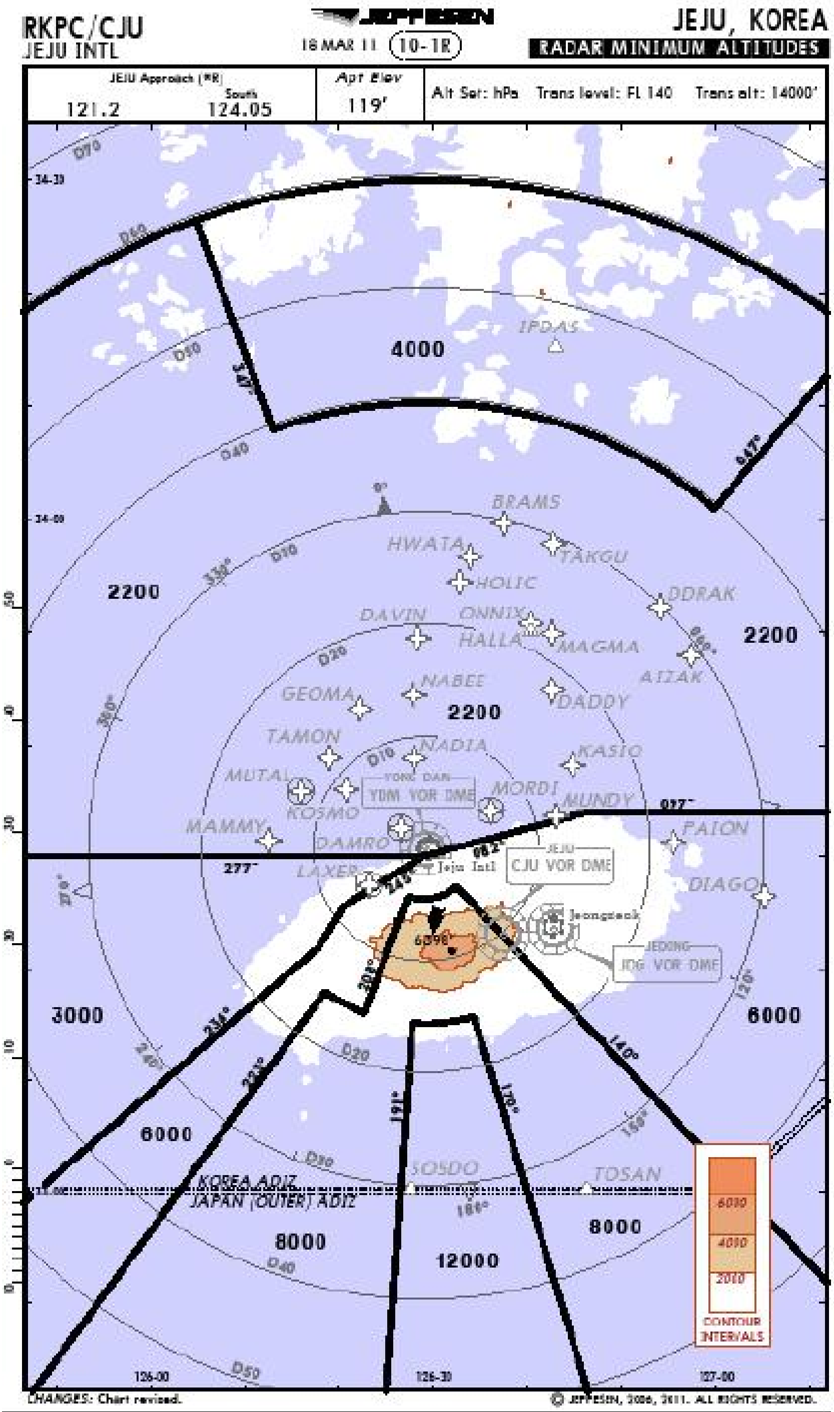
- Runway 06 ILS Procedure



- Runway 24 ILS Procedure



- Radar Minimum Altitude



● CJU Upper Wind Information

2011.07.27 12:00 Z		
Altitude	Wind Direction	Wind Speed
(km)	(deg)	(kt)
0	110	15
0.3	150	18
0.6	190	27
0.9	190	29
1.2	195	30
2.1	210	25
3.3	210	25
4.2	255	11
4.5	220	9
5.4	230	15
5.7	200	15
6.6	235	20
7.2	230	18
7.5	250	22
7.8	240	18
8.1	265	18
9	240	8
9.3	170	6
9.6	205	10
11.1	195	17
11.7	235	10
12.3	320	12
14.1	350	12
15	315	14
15.3	340	17
15.6	15	16
15.9	45	11
16.5	25	18
16.8	50	20
17.4	45	27
18	80	23
18.6	60	24
19.2	90	27
20.4	75	26
20.7	90	25
21	65	25
22.2	90	35
23.4	65	31
24.6	90	35
25.5	70	26
26.4	100	26
29.1	90	47
29.7	100	36
30.6	70	37
31.5	95	39
32.4	85	30

2011.07.28 00:00 Z		
Altitude	Wind Direction	Wind Speed
(km)	(deg)	(kt)
0	140	13
0.3	180	16
0.6	195	22
0.9	200	28
1.2	205	28
2.1	210	24
4.2	210	18
4.5	220	18
5.1	190	13
5.7	210	12
7.5	190	14
8.1	215	10
8.4	190	15
9	240	19
10.5	295	12
11.4	240	16
12.3	290	15
14.7	310	24
15.3	350	22
15.6	5	23
15.9	35	20
16.2	20	19
16.8	45	24
17.4	80	21
18	60	21
19.2	55	30
21.6	105	30
21.9	85	36
23.4	100	28
24.3	70	27
25.2	95	34
26.7	90	43
27.9	105	41
29.4	65	31
30	95	30
30.6	60	38
31.5	80	41

● Illuminated Friction of the Moon's Disk

Date		Illuminated Friction of the Moon's Disk [%]														
YY YY	MM/ DD	hh														
		00	01	02	03	04	05	06	07	17	18	19	20	21	22	23
2011	7/27	16.2	15.8	15.5	15.2	14.9	14.6	14.3	14.0	11.1	10.8	10.6	10.3	10.0	9.8	9.5
2011	7/28	9.2	9.0	8.7	8.5	8.2	8.0	7.8	7.5	5.3	5.1	4.9	4.7	4.6	4.4	4.2

● Civil Twilight

Date		Sun			Moon			Civil Twilight	
YY YY	MM/DD	Rise	Meri. Pass	Set	Rise	Meri. Pass	Set	Begin	End
2011	7/27	05:49	12:47	19:44	02:04	09:24	16:45	05:21	20:11
2011	7/28	05:50	12:47	19:43	02:58	10:19	17:37	05:22	20:10

● Surface Illumination (N33°15'12" E124°59'34")

YY YY	MM/ DD	Time	Sun		Moon		Illum.	Surface Illumination			
			a	A	a	A	Frac.	Clear	Thin Cloudy	Cloudy	Thick Cloudy
			°	°	°	°	%	mlux	mlux	mlux	mlux
2011	7.28	03:00	-28.8	36.0	.7	62.1	10.0	1.35	.67	.45	.13
2011	7.28	04:00	-20.4	48.5	11.2	69.6	10.5	11.02	5.51	3.67	1.10
2011	7.28	05:00	-10.3	58.8	22.7	76.6	10.3	58.04	29.02	19.35	5.80
2011	7.28	06:00	1.3	67.5	34.6	83.4	10.0	1404 596.1	7022 98.05	4681 98.70	1404 59.61

APPENDIX 8: 2011 Recurrent Training and Evaluation for B747-400 Flight Crew

● B747-400 Type Transition Training, Recurrent Training and Evaluation for AAR991 Flight Crew

Category			Training & Evaluation Date	
			CAP	F/O
B747-400 Training	Acquisition of Type Rating		1994. 07. 23.	2010. 08. 31.
	Completion of Type Transition		2001. 06. 22.	2010. 11. 02.
B747-400 Recurrent Training	Common Subjects	Ground School	2011. 02. 25.	2011. 02. 10.
		DG Training	2010. 07. 22.	2010. 10. 28.
		Emergency Equipment Training	2010. 07. 22.	2010. 10. 28.
		CRM	2010. 12. 17.	2011. 02. 10.
	Type Training		2011. 04. 19.	2011. 01. 25.
	Simulator Training		2011. 03. 02.	2011. 02. 25.
B747-400 Line Qualification Check	Proficiency Check		2011. 03. 03.	2011. 02. 26.
	Route Check		2011. 06. 02.	2010. 11. 02.

● Fire-related Ground and Simulator Training for AAR991 Flight Crew

Category	Training Contents	Training Date	
		Ground	Simulator
CAP	CARGO FIRE	2009. 10. 20.	2009. 10. 22.
	ENGINE FIRE	2011. 02. 25.	2011. 03. 02.
	SMOKE, FIRE or FUMES	2007. 09. 04.	2007. 09. 18.
	DITCHING	2009. 03. 11.	2009. 04. 16.
F/O (B744 Transition 2010.06.14.~ 2010.11.2)	CARGO FIRE	2010. 07. 01.	2010. 08. 01.
	ENGINE FIRE	2011. 01. 25.	2011. 02. 25.
	SMOKE, FIRE or FUMES	2009. 08. 14.	2009. 09. 20.
	DITCHING	2009. 02. 06.	2009. 04. 18.

● Recurrent Training for B747-400 Flight Crew in the 1st Half of 2011

- CAP

ASIANA AIRLINES

B747-400

RECURRENT TRAINING (CAPT with CAT II/III) THE 1ST HALF OF 2011

CIG VIS	WIND	GW CG	BRAKE ACT	OZ 222 CLEARED TO JFK AIRPORT SEL1B DEP G597 AS FILED CLIMB MAINTAIN FL 290 DEP FREQ 125.15 SQ 4001	RKSI GATE:17 (N3727.2E12627.1) QNH 1013/2992 OAT: 0°C / 25°C
				ALT : X 1000 FT 10 20 30	
RVR 150m	X-WIND 10K	870.0 25%	RKSI 33L DRY	▲COCKPIT PREPARATION & MANAGEMENT ▲ PUSH BACK & ENGINE START (only ONE ENG NON-NORMAL) ▲SLIPPERY& LOW VISIBILITY TAXI USE SMGCS on snow Twy (FCTM 2.7 -2.14) 10 ▲ REJECT T/O (LOW or HIGH SPEED) 20 ▲ ENGINE FAILURE after V1 (severe damage) ▲SID ▲ HOLDING & FUEL JETTISON (580.000 lbs by IP & Restart by IP) 30 ▲AIR WORK (STEEP TURN, APP&L/D STALL) 40 ▲KGN 8 ARR' (ALT 10M')	
OVC 1000' VIS 10KM	X-WIND 15K	580.0 23%	KJFK 13L WET	▲ FLAPS CONTROL Direct ASALT 50 ▲ VOR RWY 13L APP with FLAPS CONTROL	
RVR 700ft (200M) CAT II (CAT I)	X-WIND 10K ↓	580.0 23% ↓	KJFK 04R WET ↓	1+00 ▲ENGINE FIRE after V1 <<CAT I/ II /III OPERATION>> (CAT I : NO CAT II/III CAPT) ▲ILS RWY 04R CAT II (CAT I) APP 10 ▲MSD APP with ONE ENG INOP RELOCATED 6NM ON FINAL LEG by IP ▲ILS RWY 04R CAT II (CAT I)APP then MAN LAND for NO AUTO LAND 20	
RVR 700ft (200M) CATIII (CAT I)	X-WIND 10K ↓	580.0 23% ↓	KJFK 04R WET ↓	▲ INSTRUMENT TAKE OFF (Kennedy one Departure) ▲ ILS RWY 04R CATIII (CAT I) APP 30 ▲REJECTED LAND below AH for LOC DEVIATION RELOCATED 6NM ON FINAL LEG by IP ▲ILS RWY 04R CATIII (CAT I) APP & AUTO LAND 40	
CAVOK	X-WIND 10K ↓	580.0 23% ↓	KJFK 04R GOOD ↓	▲ENGINE FIRE after V1 (TWO BOTTLE) ▲ ENGINE FUELFILT or OIL FILT MSG (SAME SIDE) 50 ▲ILS or VISUAL RWY 04R APP & LAND with TWO ENGINE INOP ▲ PAX EVACUATION (R/W EXCURSION or FIRE) 2+00	
REMARK				① "▲" RECURRENT & CAT II / III TRAINING ITEMS. ② RKSI FUEL DUMP AREA..NCN R264/D22, SEL R278/D45, ALTITUDE 6000 FEET OR ABOVE ③ IF THE CAPT. TRAINING TIME IS NOT COMPLETED 2 HOURS, IT CAN BE EXTENDED 2 HRS(BY TAKING F/O TRAINING TIME). BUT TRAINING TIME OF TWO PILOTS SHOULD NOT BE EXTENDED BEYOND 4 HOURS	

2011.04.11 REV 03 - 1- FLIGHT CREW TRAINING TEAM

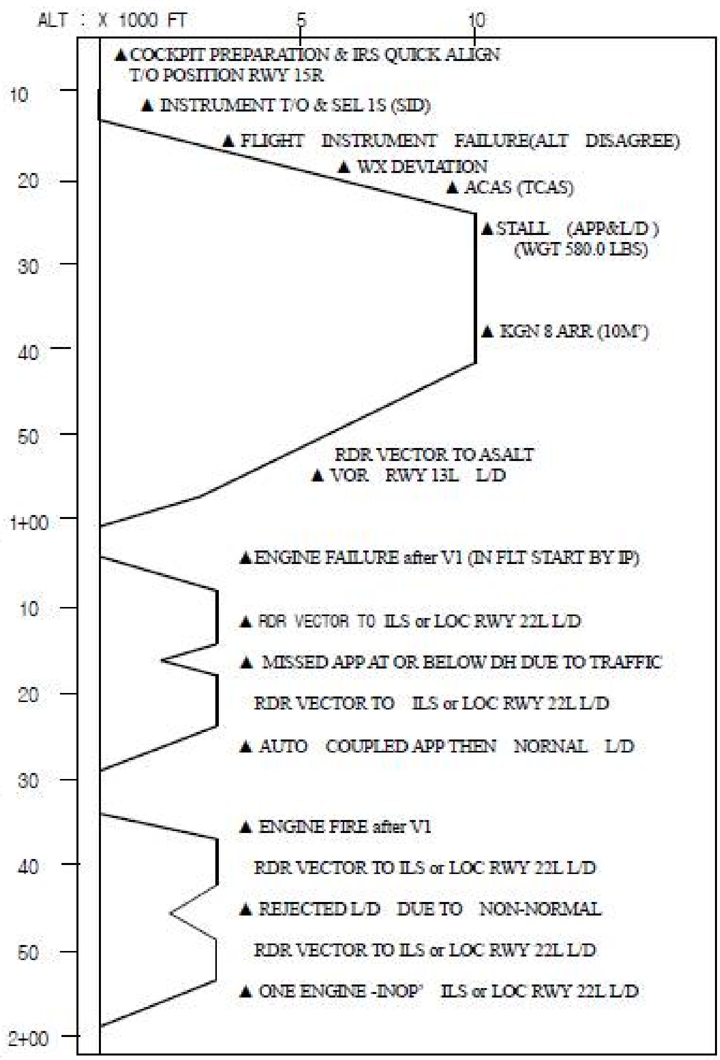
- F/O

ASIANA AIRLINES

B747-400

RECURRENT TRAINING (Co-pilot(F/O)) THE 1[ST] HALF OF 2011

CIG VIS	WIND	GW CG	RWY COND	OZ 222 CLEARED TO JFK AIRPORT SEL1S DEP THEN AS FILED MAINTAIN 10000'DEP FREQ 125.15 SQ 4001	RKSI GATE:17 KJFK(N4038.5 W07347.1) QNH 1013 /29.92 OAT: 0 ℃ / 25℃
R550M ↓	X-WIND 15K	870.0 25%	RKSI 15R DRY		
OVC 1000' 10KM ↓	X-WIND 15K ↓	580.0 23% ↓	KJFK 13L WET		
OVC 500' 1SM CAT I	X-WIND 10K	580.0 23%	KJFK 22L WET		
OVC 500' 1SM CAT- I	X-WIND 10K	580.0 23%	KJFK 22L WET		



REMARK	① "▲"RECURRENT TRAINING ITEMS. ② AFTER MSD APP,INSTRUCTOR CAN BE RELOCATED ON BASE LEG or FINAL LEG FOR SAVING TIME. ③ PM should not take over PF's flight control.

2011.04.11 REV O3 -2- FLIGHT CREW TRAINING TEAM

● Proficiency Check for B747-400 Flight Crew in the 1st Half of 2011

- CAP

ASIANA AIRLINES

B747-400 FLIGHT CREW CHECK GUIDE

PERIODIC PROFICIENCY CHECK PROFILE (for Captain)

CIG RVR	CROSS WIND	WT (LBS)	RWY COND	ATC CLR : OZ222 CLEARED TO SEL 1B DEP THEN AS FILED FL290 DEP FREQ 125.15 SQ 4001	IRS DATA (GATE17) RKSI N3727.2 E12627.1 KJFK N4038.5 W0734.7
				0 5 10 30	(ALT. X1000FT)
RVR150M	10KTS	870 25%	RKSI33L DRY	10	- COCKPIT PREPARATION - IRS QUICK ALIGN ▲ NON-NORMAL ENG START ONLY ONE ENG - LOW VISIBILITY TAXI (SMGCS) ◎ REJECTED T/O (LOW OR HIGH SPEED)
				20	◎ ENG FAILURE AFTER V1 SEL 1B DEP (RESTART ENG BY CHECKER)
				30 40	- AIRWORK : APP STALL (WT:580)
OVC 1000FT 10KM	15KTS	600 23%	KJFK VOR 13L	50	▲ FLAPS CONTROL - RADAR VETCOR TO ASALT - VOR 13L APP & L/D
RVR5	10KTS	600 23%	KJFK 04R WET	1+00 10	◎ ENG FAILURE AFTER V1 (UNABLE INFLIGHT START) - RADAR VECTOR TO ILS RWY 04R ◎ MISSED APP AT OR BELOW DH (BY CHECKER)
CAT-II	10KTS			20	- RADAR VECTOR TO ILS RWY 04R ◎ MAN L/D DUE TO NO AUTOLAND
RVR5	10KTS	600 23%	KJFK 04R WET	30	X WIND T/O RWY04R - RADAR VECTOR TO ILS RWY 04R ◎ MISSED APP AT 50FT RA (LOC DEVIATION)
CAT-III	10KTS			40	- RADAR VECTOR TO ILS RWY 04R ◎ AUTO COUPLED APP & AUTO L/D
CAVOK	10KTS	600 23%	KJFK 04R WET	50 2+00	▲ ENG FIRE AFTER V1 ▲ ENG FLAMEOUT/STALL SAME SIDE ENG - TWO ENG INOP ILS APP 04R APP ▲ PASSENGER/SUPERNUMERY EVACUATION
REMARK	(1) "▲" NON-NORMAL EVENTS (2) "◎" All Weather Operation Requirements (CAT-II & CAT-III) (3) Checker can give variable wind conditions, but MAX steady crosswind component is 15KTS. (CAT-II/III : MAX 10KTS)				

REVISION NO : 0 (JAN 01 2011) 4/5 FLIGHT CREW EVALUATION

- F/O

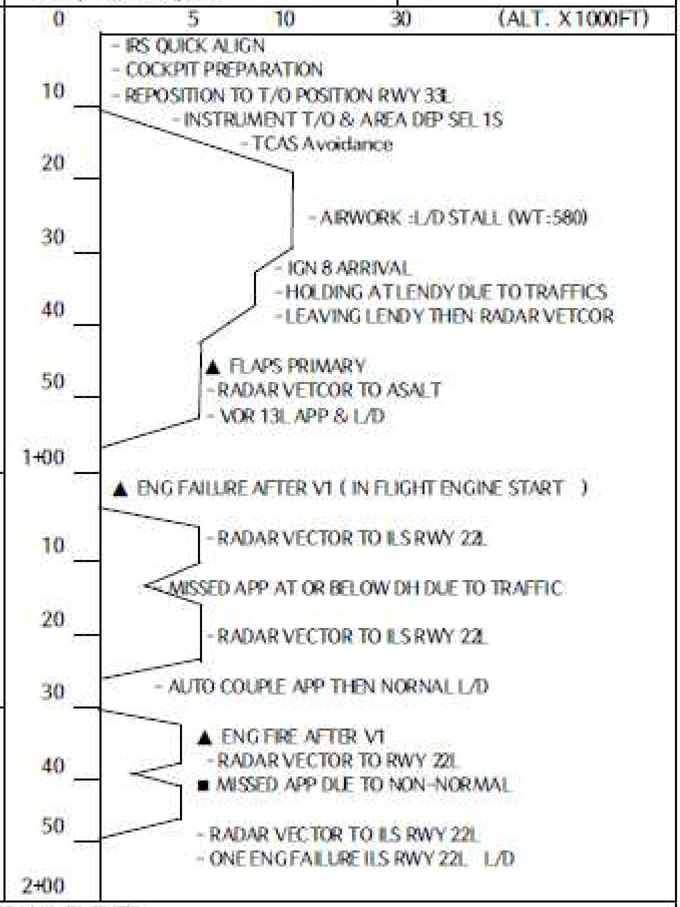
ASIANA AIRLINES

B747-400 FLIGHT CREW CHECK GUIDE

PERIODIC PROFICIENCY CHECK PROFILE (for Co-pilot(F/O))

CIG RVR VIS	CROSS WIND	WT (LBS)	RWY COND	ATC CLR	IRS DATA (GATE 17)
				: OZ222 CLEARED TO JFK SEL 1S DEP THEN AS FILED FL290 DEP FREQ 125.15 SQ 4001	RKSI N3727.2 E12627.0 KJFK N4038.5 W0734.7

CIG RVR VIS	CROSS WIND	WT (LBS)	RWY COND
R300M OVC 1000FT 10KM	15KTS 15KTS	870 25% 600 23%	RKSI 15R DRY KJFK 13L DRY
RVR18 CAT-I	10KTS	600 23%	KJFK 22L WET
RVR18 CAT-I	10KTS	600 23%	KJFK 22L WET



REMARK	
	(1) "▲" NON-NORMAL EVENTS (2) Checker can give variable wind conditions, but MAX steady crosswind component is 15KTS. (CAT-II/III/MAX 10KTS) (3) If the CAPT check time isn't completed within 2HRS, it could be extended 2HRS (by taking Co-pilot(F/O) check time). But total check time for 2Pilots shouldn't exceed 4HRS (4) In the event non-normal conditions occur while Co-pilot(F/O) takes off after V1 speed. Co-pilot(F/O) shall play a role as a PF.

● Recurrent Training for B747-400 Flight Crew in the 2nd Half of 2011

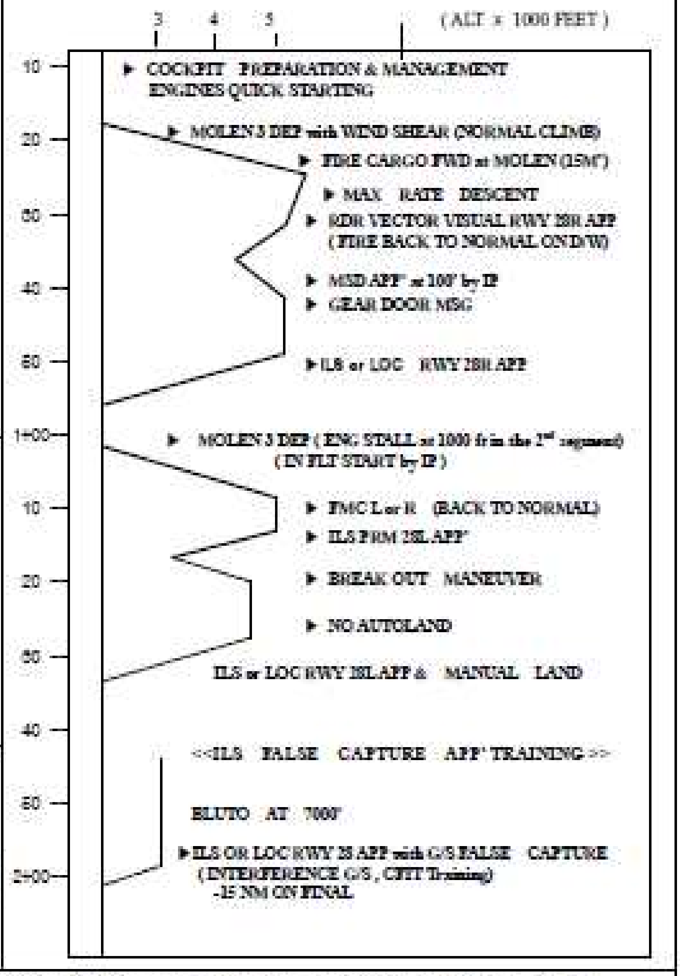
- CAP

ASIANA AIRLINES

B747-400

RECURRENT TRAINING (CAPT) **THE 2ND HALF OF 2011**

FCIG VIS	X-WIND	GW CG ×1000	RWY COND.	OZ 283 CLEARED TO ANC A/P MOLEN 3 DEP' AS FILED FL330 INITIALLY 15M' DEP FRQ 120.15 SQ 4025	KSFO T/O POSN / QNH 29.92, OAT: 25 °C / 5 °C
CAVOK (Night time)	15k G 5k 10k	650.0 25% HL7420 ↓	KSFO 28R wet		
OVC 1500' RVR 5 (150m) ↓ CAT-I	10k	600.0 24% ↓	KSFO 28R wet 28L wet		
OVC 8000' 10km	10k ↓	600.0 24%	KORD 28 wet or snow (-5 °C)		



REMARK	(1) "▶" RECURRENT TRAINING ITEMs (FIRE CARGO FWD REPLACES SMOKE or FUME) (2) ALL RWY BRAKE ACTIONS ARE WET IN SUMMER and SNOW IN WINTER.

2011. 7. 1 REV 00 - 1 - FLIGHT CREW TRAINING TEAM

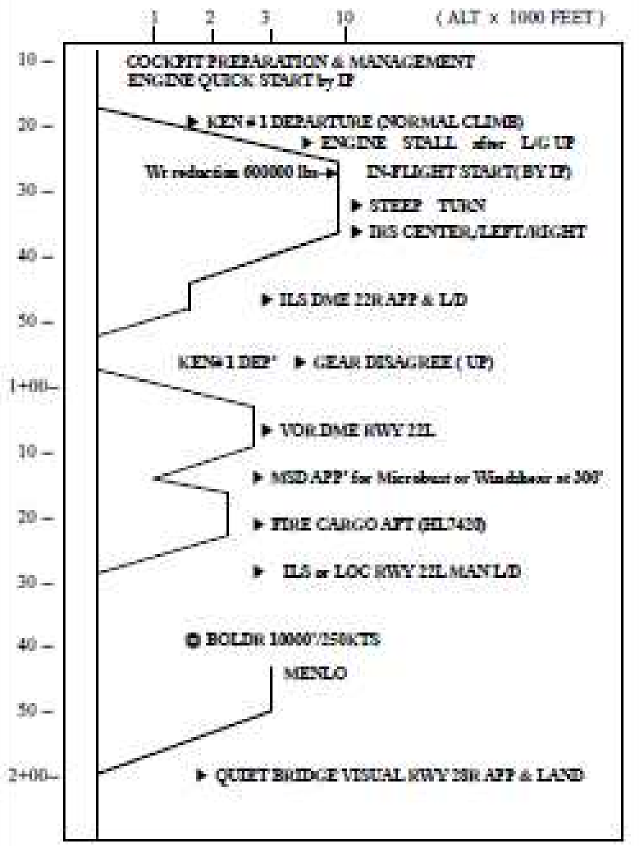
- F/O

ASIANA AIRLINES

B747-400

RECURRENT TRAINING (CO-pilot(F/O)) **THE 2ND HALF OF 2011**

FCKI VIS	X-WIND	GW CG x 1000	RWY COND	OZ 297, CLEARED TO ANC A/P KE# 1 DEP' AS FILED FL 120 10MIN AFT DEP' MAINTAIN 10M DEP FRQ 125.2 SQ 4025	KJFK T/O PSN QNH 29.92 OAT 25℃ / -5℃
OVC 3000 RVR18	10K	800.0 25%	KJFK 22R wet or snow		
CAT-I	10K	600.0 24%	KJFK 22R wet or snow		
CAVOK	10k	600.0 24%	KJFK 22R dry		
↓	10k GUST 5 K	↓	22L dry		
CAVOK (NIGHT TIME) ↓	10K ↓	600.0 24% ↓	KSFO 28R dry ↓		



REMARK	(1) "▶" RECURRENT TRAINING ITEMS(FIRE CARGO FWD REPLACES SMOKE or FUME) (2) ALL RWY BRAKE ACTIONS ARE WET IN SUMMER AND SNOW IN WINTER.

2011. 7. 1 REV 00 - 2 - **FLIGHT CREW TRAINING TEAM**

● Post-LOFT Training for B747-400 Flight Crew in the 2nd Half of 2011

- CAP & F/O

ASIANA AIRLINES
B747-400

POST LOFT TRAINING CAPT/ Co-pilot(FO) THE 2ND HALF OF 2011

SIG VIS	WIND	G/W CG x 1000	BRAKE ACT	OZ 108 CLEARED TO NGT AIRPORT SEL1B DEP CLIMB MAINTAIN 6000' DEP FREQ 126.15 SQ 2008	RKSI T/O P507 QNH 1018 OAT: 25 ℃ / -6℃
					ALT : X 1000 FT (2, 3, 4)
CAVOK	X-WIND 10 K	600.0 24%	RKSI 15L WET	0+05	▲ << CAPTAIN R/H SEAT TRAINING>> ENGINE FAILURE after V1 (T/O FLAP 10)
					ILS DME RWY 15L with ONE ENG INOP
CAVOK		600.0 24%		0+30	MISSED APPROACH by IP 6NM ON FINAL
					ILS DME RWY 15L
					▲ ONE ENG' SHUT DOWN TAXI INTO GATE 17
				0+45	<< X-WIND LANDING TRAINING>> - USE CO-PILOT(FO)
CAVOK	X-WIND 25 K	600.0 24%	RKSI 33R DRY		- IDLE REVERSE ON LANDING
				1+00	<< CDO-continuous descent operation >> (JEPP 20-1P) -USE CO-PILOT(FO)
CAVOK	X-WIND 10 K	600.0 24 %	RKSI 33R WET		-PSN at KARBU (20M FT) or JINBU - JINBU 1M RNAV Arrival - ILS DME RWY 33R
				1+15	<< HIGH ALTITUDE G/A TRAINING>> -High FLT PATH OVER G/S at Intermediate Approach Segment(SPD*2) -GO-AROUND AT 2000' (M/A ALT 3000')
				1+30	
REMARK		(1) INSTRUCTOR PILOTS DO NOT HAVE TO DO R/H SIDE RECURRENT TRAINING (2) PRE-BRIEFING FOR CDO IS REQUIRED BEFORE SIM TRAINING (JEPP 20-1P CDO Procedure) (3) ▲ ONE ENGINE SHUT DOWN TAXI IN PROCEDURE(GATE 17) : #3 ENGINE CUT OFF 3MIN AFT T/D			

2011.07.01. REV 00 1 FLIGHT CREW TRAINING TEAM

● **Post-LOFT Training for B747-400 Flight Crew in the 2nd Half of 2011 (after 2011.08.05.)**

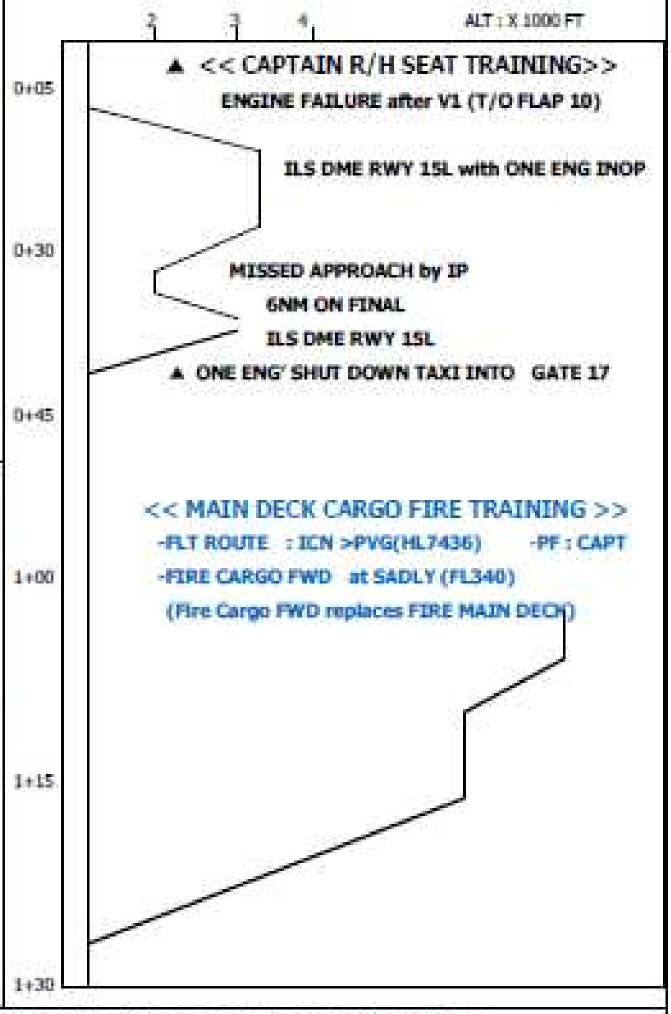
- CAP & F/O

ASIANA AIRLINES

B747-400

POST LOFT TRAINING CAPT/ Co-pilot(FO) THE 2ND HALF OF 2011

SIG VIS	WIND	G/W CG x 1000	BRAKE AUT	OZ 108 CLEARED TO NRT AIRPORT SEL1B DEP CLIMB MAINTAIN 6000' DEP FREQ 125.15 SQ 4006	RKSI T/O PSN QNH 1019 OAT: 25 °C / -6 °C
CAVOK	X-WIND 10 K	600.0 24%	RKSI 15L WET		
CAVOK		600.0 24%			
CAVOK	X-WIND 25 K	600.0 24%	RKSI 15L DRY		
CAVOK	X-WIND 10 K	600.0 24 %	RKPC 06		



REMARK	(1) INSTRUCTOR PILOTS DO NOT HAVE TO DO R/H SIDE RECURRENT TRAINING (2) ▲ ONE ENGINE SHUT DOWN TAXI IN PROCEDURE(GATE 17) : #3 ENGINE CUT OFF 3MIN AFT T/D

2011.08.05. REV 01 1 **FLIGHT CREW TRAINING TEAM**

● AAR991 Flight Crew's Monthly Schedule for July 2011

ASIANA AIRLINES 11/07/28
COCKPIT CREW MONTHLY SCHEDULE

EMPNO : 702402 NAME : 최상기 EFFECTIVE : 110701 - 110731
POSITION : B744-CAP CHOI SANG KI Mail Box :

DATE	SHOWUP	근무구분 (DUTY)	근무구간(SECTOR)	ETD - ETA
1 FR		DAY OFF		
2 SA		298 /298	ICN/ ANC/ ORD	07/02-23:05 07/02-23:25
3 SU		ORD		
4 MO		ORD		
5 TU		298	ORD/ JFK	07/05-23:50 07/06-02:55
6 WE		297	JFK/ ANC	07/06-04:55 07/06-07:55
7 TH		2831	ANC/ ICN	07/07-06:30 07/08-07:50
8 FR				
9 SA		DAY OFF		
10 SU		DAY OFF		
11 MO	06:00	standby		
12 TU		785	ICN/ VIE	07/12-22:15 07/13-01:45
13 WE		VIE		
14 TH		775	VIE/ MXP	07/14-22:45 07/15-00:05
15 FR		776	MXP/ ICN	07/15-02:35 07/15-19:55
16 SA		DAY OFF		
17 SU		DAY OFF		
18 MO		DAY OFF		
19 TU	06:00	standby		
20 WE	06:00	standby		
21 TH		202	ICN/ LAX	07/21-16:30 07/21-12:00
22 FR		965	LAX/ PEK	07/22-20:05 07/24-00:20
23 SA		PEK		
24 SU		965	PEK/ ICN	07/24-02:20 07/24-05:25
25 MO		DAY OFF		
26 TU		DAY OFF		
27 WE	00:00	다음날 새벽 비행		
	00:00	DAY OFF		
28 TH		991 /992	ICN/ PVG/ ICN	07/28-02:45 07/28-08:30
29 FR	06:00	standby		
30 SA		DAY OFF		
31 SU		DAY OFF		

ASIANA AIRLINES 11/07/28

COCKPIT CREW MONTHLY SCHEDULE

EMPNO : 716465 NAME : 이정웅 EFFECTIVE : 110701 - 110731

POSITION : B744-F/O LEE JEONGWOONG Mail Box :

DATE	SHOWUP	근무구분 (DUTY)	근무구간(SECTOR)	ETD - ETA
1 FR		DAY OFF		
2 SA		DAY OFF		
3 SU		DAY OFF		
4 MO	06:00	standby		
5 TU		785	ICN/ VIE	07/05-22:15 07/06-01:45
6 WE		VIE		
7 TH		775	VIE/ MXP	07/07-22:45 07/08-00:05
8 FR		776	MXP/ ICN	07/08-02:35 07/08-19:55
9 SA		DAY OFF		
10 SU		DAY OFF RQST		
11 MO		DAY OFF		
12 TU		DAY OFF		
13 WE		723	ICN/ HKG	07/13-19:50 07/13-22:40
14 TH		HKG		
15 FR		724	HKG/ ICN	07/15-00:30 07/15-05:00
16 SA		DAY OFF		
17 SU	06:00	standby		
18 MO		995 /995	ICN/ ANC/ JFK	07/18-23:05 07/19-01:25
19 TU		JFK		
20 WE		JFK		
21 TH		587	JFK/ BRU	07/21-03:45 07/21-16:35
22 FR		BRU		
23 SA		588	BRU/ ICN	07/23-17:55 07/24-11:30
24 SU				
25 MO		DAY OFF		
26 TU	08:00	RECURRENT GRND (기종교육)		
27 WE	00:00	다음날 새벽 비행		
	00:00	DAY OFF		
28 TH		991 /992	ICN/ PVG/ ICN	07/28-02:45 07/28-08:30
29 FR	06:00	standby		
30 SA	06:00	standby		
31 SU	06:00	standby		

APPENDIX 9: QRH Procedures in Relation to AAR991's Fire

● COMBI - FIRE MAIN DECK (April 1, 2011)

8.29

ASIANA AIRLINES
747 Flight Crew Operations Manual

MAIN DECK

FIRE MAIN DECK

HL7417, HL7421, HL7423

Condition: Smoke is detected in the main deck cargo area.

1 Instruct the designated crewmember to verify presence of smoke or fire.

2 Choose one:

◆Presence of smoke or fire is **verified**:

►►**Go to step 3**

◆Presence of smoke or fire is **not** verified:

A crewmember must monitor the cargo compartment for the rest of the flight.

■ ■ ■ ■

3 MAIN Deck CARGO FIRE ARM switch . . . . Confirm . . . . ARMED

Pack 3 will shut down.

4 PACK 3 control selector . . . . OFF

5 PACK 1 and 2 control selectors. . . . .One pack on, one pack OFF

6 CARGO FIRE DISCH switch . . . . . . Push and hold for 1 second

90 minutes of fire suppression are available.

7 TRIM AIR switch. . . . . Off

▼ Continued on next page ▼

FIRE MAIN DECK (April 1, 2011-COMBI) 1/3

▼FIRE MAIN DECK continued▼

8 Choose one:

◆Airplane is **at or below** 8,000 feet:

►►**Go to step 11**

◆Airplane is **above** 8,000 feet:

►►**Go to step 9**

9 LDG ALT switch . . . . .MAN

10 LDG ALT selector . . . . Set between 8000 8500

11 Plan to land at the nearest suitable airport

12 Do **not** accomplish the following checklists:

LANDING ALT

TEMP ZONE

TRIM AIR OFF

13 Checklist Complete Except Deferred Items

Deferred Items

Before descent

LDG ALT switch. . . . . AUTO

Descent Checklist

Recall . . . . .Checked

Autobrake . . . . ___

Landing data . . . . .VREF___, Minimums___

▼ Continued on next page ▼

FIRE MAIN DECK (April 1, 2011-COMBI) 2/3

▼FIRE MAIN DECK continued▼

Approach briefing . . . . Completed

Approach Checklist

Altimeters . . . . ___

Warning! Inform ground personnel not to open the cargo door until all passengers and crew have exited the airplane and fire fighting equipment is nearby.

Landing Checklist

Speedbrake . . . . Armed

Landing gear . . . . DOWN

Flaps . . . . ___

■ ■ ■ ■

FIRE MAIN DECK (April 1, 2011-COMBI) 3/3

● FREIGHTER - FIRE MAIN DECK (April 1, 2011)

MAIN DECK

FIRE MAIN DECK
FIRE MN DK AFT, FWD, MID

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

Condition: Smoke is detected in the main deck cargo area(s).

1 Don the oxygen masks.

2 Establish crew communications.

3 SUPRNMRY OXY switch . . . . .ON

4 MAIN Deck CARGO FIRE
ARM switch . . . . .Confirm . . . . ARMED

HL7436 - HL7616
SATCOM will shut down to prevent overheating.

Two packs are automatically shut down and the associated PACK messages are shown.

Select the pack control selectors that have the PACK messages shown.

5 PACK control selectors . . . . One pack on, two packs **OFF**

Warning! Either pack 1 or 3 must be operating to prevent excessive smoke accumulation on the flight deck.

6 CARGO FIRE
DEPRES/DISCH switch . . . . Push and hold for 1 second

▼ Continued on next page ▼

FIRE MAIN DECK (April 1, 2011-FREIGHTER) 1/3

▼FIRE MAIN DECK continued▼

7 Climb or descend to 25,000 feet when conditions and terrain allow.

8 Plan to land at the nearest suitable airport.

9 Do **not** accomplish the following checklists:

CABIN ALTITUDE or Rapid Depressurization

TEMP ZONE

TRIM AIR OFF

10 Checklist Complete Except Deferred Items

▼ Continued on next page ▼

FIRE MAIN DECK (April 1, 2011-FREIGHTER) 2/3

▼FIRE MAIN DECK continued▼

Deferred Items

Descent Checklist

Recall . . . . Checked

Autobrake . . . . ___

Landing data . . . . .VREF___, Minimums___

Approach briefing . . . . Completed

Approach Checklist

Altimeters . . . . ___

Warning! Inform ground personnel not to open the cargo door until all supernumeraries and crew have exited the airplane and fire fighting equipment is nearby.

Landing Checklist

Speedbrake . . . . Armed

Landing gear . . . . DOWN

Flaps . . . . ___

■ ■ ■ ■

FIRE MAIN DECK (April 1, 2011-FREIGHTER) 3/3

● **FREIGHTER - FIRE MAIN DECK (May 10, 2011)**

MAIN DECK

FIRE MAIN DECK
FIRE MN DK AFT, FWD, MID

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

Condition: Smoke is detected in the main deck cargo area(s).

1 Don the oxygen masks.

2 Establish crew communications.

3 SUPRNMRY OXY switch . . . . .ON

4 MAIN Deck CARGO FIRE
ARM switch . . . . .Confirm . . . . ARMED

HL7436 - HL7616
SATCOM will shut down to prevent overheating.

Two packs are automatically shut down and the associated PACK messages are shown.

5 PACK 2 control selector . . . . OFF

Warning! Either pack 1 or 3 must be operating to prevent excessive smoke accumulation on the flight deck.

6 CARGO FIRE
DEPRES/DISCH switch . . . . Push and hold for 1 second

7 Expedite a climb or descent to 25,000 feet when conditions and terrain allow. Plan to stay at 25,000 feet as long as possible. After the descent has been started, do not delay the approach and landing.

▼ Continued on next page ▼

FIRE MAIN DECK (May 10, 2011-FREIGHTER) 1/3

▼FIRE MAIN DECK continued▼

8 Plan to land at the nearest suitable airport.

9 Do **not** accomplish the following checklists:

CABIN ALTITUDE or Rapid Depressurization

PACK

TEMP ZONE

TRIM AIR OFF

10 Checklist Complete Except Deferred Items

Deferred Items

Descent Checklist

Recall . . . . Checked

Autobrake . . . . ___

Landing data . . . . VREF___, Minimums___

Approach briefing . . . . Completed

Approach Checklist

Altimeters . . . . ___

Warning! Inform ground personnel not to open the cargo door until all supernumeraries and crew have exited the airplane and fire fighting equipment is nearby.

▼ Continued on next page ▼

FIRE MAIN DECK (May 10, 2011-FREIGHTER) 2/3

8.34

ASIANA AIRLINES
747 Flight Crew Operations Manual

▼FIRE MAIN DECK continued▼

Landing Checklist

Speedbrake . . . . Armed

Landing gear . . . . DOWN

Flaps . . . . ___

■ ■ ■ ■

8.34 D6-30151-423(AAR) May 10, 2011

FIRE MAIN DECK (May 10, 2011-FREIGHTER) 3/3

● FREIGHTER- EQUIP COOLING (April 1, 2011)

EQUIP COOLING

Condition: One of these occurs:
- On the ground, the ground exhaust valve is not in the commanded position
- With Equipment Cooling selector in NORM or STBY, one or more of these occur:
  - Airflow is insufficient
  - An overheat is sensed
  - Smoke is sensed
- With Equipment Cooling selector in OVRD, differential pressure for reverse flow cooling is not sufficient.

1 Avionics/electronic equipment and displays may become unreliable or fail.

2 Choose one:

◆On the **ground**:

EQUIP COOLING selector . . . . STBY

■ ■ ■ ■

◆In **flight**:

►►**Go to step 3**

3 EQUIP COOLING selector. . . . . .OVRD

▼ **Continued on next page** ▼

EQUIP COOLING (April 1, 2011) 1/2

▼EQUIP COOLING continued▼

4 Choose one:

◆EQUIP COOLING message **stays blank**:

■ ■ ■ ■

◆EQUIP COOLING message **stays shown or shows again**:

Plan to land at the nearest suitable airport.

■ ■ ■ ■

EQUIP COOLING (April 1, 2011) 2/2

● **FREIGHTER - FIRE APU (April 1, 2011)**

8.1

ASIANA AIRLINES
747 Flight Crew Operations Manual

APU

FIRE APU

Condition: Fire is detected in the APU.

1 APU fire switch . . . . Confirm . . . . Pull, rotate to the stop and hold for 1 second

2 Choose one:

◆FIRE APU message **stays shown:**

Plan to land at the nearest suitable airport.

►►**Go to step 3**

◆FIRE APU message **blanks:**

►►**Go to step 3**

3 Do **not** accomplish the following checklist:

APU

■ ■ ■ ■

April 1, 2009 D6-30151-423(AAR) 8.1

FIRE APU (April 1, 2011)

● FREIGHTER - FIRE CARGO AFT (April 1, 2011)

AFT

FIRE CARGO AFT

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

Condition: Smoke is detected in the aft lower cargo compartment.

1 AFT CARGO FIRE
ARM switch . . . . Confirm. . . . . ARMED

HL7436 - HL7616
SATCOM will shut down to prevent overheating.

Two packs are automatically shut down and the associated PACK messages are shown.

Select the pack control selectors that have the PACK messages shown.

2 ⚠ PACK control selectors . . . . One pack on, two packs OFF

3 CARGO FIRE DEPRESS/
DISCH switch . . . . Push and hold for 1 second

HL7413 - HL7415
195 minutes of fire suppression are available.

HL7419, HL7420, HL7436 - HL7616
210 minutes of fire suppression are available.

▼ Continued on next page ▼

FIRE CARGO AFT (April 1, 2011) 1/3

▼FIRE CARGO AFT continued▼

4 Choose one:

◆Airplane is **at or below** 8,000 feet:

►►**Go to step 8**

◆Airplane is **above** 8,000 feet:

►►**Go to step 5**

5 LDG ALT switch . . . . .MAN

6 LDG ALT selector . . . . Set between 8000 and 8500

HL7413 - HL7415

7 **If** airplane is above 25,000 ft descend to 25,000 ft.

8 Plan to land at the nearest suitable airport

9 Do **not** accomplish the following checklist:

LANDING ALT

10 Checklist Complete Except Deferred Items

▼ Continued on next page ▼

FIRE CARGO AFT (April 1, 2011) 2/3

8.22

ASIANA AIRLINES
747 Flight Crew Operations Manual

▼FIRE CARGO AFT continued▼

Deferred Items

Before descent

LDG ALT switch . . . . AUTO

Descent Checklist

Recall . . . . Checked

Autobrake . . . . ___

Landing data . . . . VREF___, Minimums___

Approach briefing . . . . Completed

Approach Checklist

Altimeters . . . . ___

Warning! Inform ground personnel not to open the cargo door until all supernumeraries and crew have exited the airplane and fire fighting equipment is nearby.

Landing Checklist

Speedbrake . . . . Armed

Landing gear . . . . DOWN

Flaps . . . . ___

■ ■ ■ ■

8.22 D6-30151-423(AAR) October 1, 2008

FIRE CARGO AFT (April 1, 2011) 3/3

● **FREIGHTER - CABIN ALTITUDE or Rapid Depressurization (April 1, 2011)**

**CABIN ALTITUDE
or
Rapid Depressurization**

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

Condition: A cabin altitude exceedance occurs.

1 Don the oxygen masks.

2 Establish crew communications.

3 Check the cabin altitude and rate. Verify packs are on and outflow valves are closed.

HL7413 - HL7415

4 In case of decompression, an aural warning will be given automatically for 30 seconds.

SEATBELTS selector . . . . ON

5 **If** the cabin altitude is uncontrollable:

SUPRNMRY OXY switch . . . . ON

Without delay, descend to the lowest safe altitude or 14,000 feet, whichever is higher.

To descend:

Move the thrust levers to idle.

Extend the speedbrakes.

If structural integrity is in doubt, limit airspeed and avoid high maneuvering loads.

Descend at VMO/MMO.

▼ Continued on next page ▼

CABIN ALTITUDE or Rapid Depressurization 1/2

2.2

ASIANA AIRLINES
747 Flight Crew Operations Manual

▼CABIN ALTITUDE or Rapid Depressurization continued▼

6 **If** OUTFLOW VLV L, OUTFLOW VLV R, **and** CABIN ALT AUTO messages are shown:

Do **not** accomplish the following checklists:

CABIN ALT AUTO

OUTFLOW VLV L, R

■ ■ ■ ■

CABIN ALTITUDE or Rapid Depressurization 2/2

● **FREIGHTER - Smoke Fire or Fumes (April 1, 2011)**

Smoke, Fire or Fumes

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

Condition: Smoke, fire or fumes occur.

1 Diversion may be needed.

2 Don the oxygen masks, if needed.

3 Establish crew communications.

4 Instruct the supernumeraries to turn on the upper deck reading lights.

5 UTILITY power switches (both) . . . . Off

6 FLT DECK FAN switch . . . . Off

7 APU selector . . . . OFF

8 Passenger signs . . . . ON

HL7604

9 MAIN DECK SIGNALING switch . . . . .Push

10 **Anytime** the smoke or fumes become the greatest threat:

► ►**Go to the Smoke or Fumes Removal checklist on page 8.44**

▼ Continued on next page ▼

Smoke Fire or Fumes (April 1, 2011) 1/5

▼Smoke, Fire or Fumes continued▼

11 Choose one:

◆Source of the smoke, fire or fumes **is** obvious **and can** be extinguished quickly:

Isolate and extinguish the source of the smoke, fire or fumes.

If possible, remove power from the affected equipment by switch or circuit breaker in the flight deck or upper deck.

►►**Go to step 12**

◆Source of the smoke, fire or fumes is **not** obvious **or can not** be extinguished quickly:

►►**Go to step 13**

12 Choose one:

◆Source **is** visually confirmed to be extinguished **and** smoke or fumes are **decreasing**:

Continue the flight at the captain's discretion.

Restore unpowered items at the captain's discretion.

►►**Go to step 24**

◆Source **is not** visually confirmed extinguished **or** smoke or fumes **continue**:

►►**Go to step 13**

▼ Continued on next page ▼

Smoke Fire or Fumes (April 1, 2011) 2/5

▼Smoke, Fire or Fumes continued▼

13 Divert to the nearest suitable airport while continuing the checklist.

14 Consider an immediate landing if the smoke, fire or fumes situation becomes uncontrollable.

15 Do not delay landing in an attempt to complete the following steps.

16 ISLN valve switches (both) . . . . Off

This isolates the left and right sides of the bleed air system.

17 PACK 2 control selector . . . . OFF

18 **Wait** 2 minutes unless the smoke or fumes are increasing. This allows time for the smoke or fumes to clear.

19 Choose one:

◆Smoke or fumes **continue or are increasing**:

PACK 3 control selector . . . . OFF

Wait 2 minutes unless the smoke or fumes are increasing. This allows time for the smoke or fumes to clear.

►►**Go to step 20**

◆Smoke or fumes are **decreasing**:

►►**Go to step 24**

▼ Continued on next page ▼

Smoke Fire or Fumes (April 1, 2011) 3/5

8.14

ASIANA AIRLINES
747 Flight Crew Operations Manual

▼Smoke, Fire or Fumes continued▼

20 Choose one:

◆Smoke or fumes **continue or are increasing**:

PACK 3 control selector . . . . NORM

PACK 1 control selector . . . . OFF

R ISLN valve switch . . . . On

►►Go to step 21

◆Smoke or fumes are **decreasing**:

L ISLN valve switch . . . . On

►►Go to step 21

21 PACK 2 control selector . . . . .NORM

22 **Wait** 2 minutes unless the smoke or fumes are increasing. This allows time for the smoke or fumes to clear.

23 Choose one:

◆Smoke or fumes **continue or are increasing**:

ISLN valve switches (both) . . . . On

PACK 1 control selector . . . . NORM

Consider an immediate landing.

►►Go to step 24

◆Smoke or fumes are **decreasing**:

►►Go to step 24

▼ Continued on next page ▼

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Smoke Fire or Fumes (April 1, 2011) 4/5

▼Smoke, Fire or Fumes continued▼

24 Do **not** accomplish the following checklists:

HL7419, HL7420, HL7436 - HL7616
CARGO DET AIR

ELEC UTIL BUS L, R

FUEL OVRD 2, 3 FWD

FUEL PRESS CTR L

FUEL PUMP 2, 3 FWD

HL7616
HUMID FLT DK

TEMP ZONE

TRIM AIR OFF

►►Go to the Smoke or Fumes Removal checklist on page 8.44, if needed

■ ■ ■ ■

Smoke Fire or Fumes (April 1, 2011) 5/5

● **FREIGHTER - Smoke or Fumes Removal (April 1, 2011)**

Smoke or Fumes Removal

HL7413 - HL7415, HL7419, HL7420, HL7436 - HL7616

Condition: Smoke or fumes removal is needed.

Objective: To remove smoke or fumes through the smoke override valve, or the smoke evacuation port.

1 Do this checklist **only** when directed by the Smoke, Fire or Fumes checklist.

2 Do not delay landing in an attempt to complete the following steps.

3 EQUIP COOLING selector . . . . OVRD

This attempts to discharge the smoke or fumes overboard by using the equipment cooling override mode.

▼ Continued on next page ▼

Smoke or Fumes Removal (April 1, 2011) 1/3

▼Smoke or Fumes Removal continued▼

4 Choose one:

◆ Smoke or fumes does **not** continue and is **not** severe:

►►**Go to the Smoke, Fire or Fumes checklist on page 8.11 and do the remaining steps**

■ ■ ■ ■

◆ Smoke or fumes **continues or** is **severe** and the smoke or fumes source is determined to be on the **flight deck**:

Pull the smoke evacuation handle. Pulling the smoke evacuation handle when smoke or fumes source is not on the flight deck may bring the smoke or fumes into the flight deck.

►►**Go to the Smoke, Fire or Fumes checklist on page 8.11 and do the remaining steps**

■ ■ ■ ■

◆ Smoke or fumes **continues or** is **severe** and the smoke or fumes source is determined to be in the **cabin**:

►►**Go to step 5**

5 LDG ALT switch . . . . Push to MAN

MAN landing altitude mode shows on EICAS.

▼ Continued on next page ▼

Smoke or Fumes Removal (April 1, 2011) 2/3

▼Smoke or Fumes Removal continued▼

6 LDG ALT selector . . . . Set between 8000 and 8500

7 EQUIP COOLING selector . . . . .NORM

8 Start a descent. Level off at the lowest safe altitude or 8,500 feet, whichever is higher.

9 OUTFLOW VALVES MAN switches (both) . . . . . .ON

10 OUTFLOW VALVES manual control . . . . .Hold in OPEN until the outflow valve indications show fully open

11 Do **not** accomplish the following checklists:

CABIN ALT AUTO

LANDING ALT

OUTFLOW VLV L, R

►►**Go to the Smoke, Fire or Fumes checklist on page 8.11 and do the remaining steps**

■ ■ ■ ■

Smoke or Fumes Removal (April 1, 2011) 3/3

● **FREIGHTER - Ditching (April 1, 2011)**

Ditching

Condition: Airplane ditching and evacuation are needed.

1 Plan to jettison fuel as needed to reduce the VREF speed.

2 Do **not** arm the autobrakes.

3 Plan to ditch with the gear up.

4 Use flaps 30 and VREF 30.

5 Checklist Complete Except Deferred Items

Deferred Items

Descent Checklist

Recall . . . . Checked

Autobrake . . . . **OFF**

Landing data . . . . **VREF 30, Minimums**____

Approach briefing . . . . Completed

Approach Checklist

Altimeters . . . . ______

▼ Continued on next page ▼

Ditching (April 1, 2011) 1/3

▼Ditching continued▼

When below 5,000 feet:

GND PROX GEAR OVRD switch . . . . OVRD

GND PROX TERR OVRD switch . . . . OVRD

PACK control selectors (all) . . . . OFF

OUTFLOW VALVES MAN
switches (both) . . . . ON

OUTFLOW VALVES
manual control . . . . Hold in CLOSE
until outflow valve
indications show fully closed

Passenger signs . . . . ON

HL7604
MAIN DECK SIGNALING switch . . . . Push

When on final approach:

Omit the landing checklist.

Landing gear lever . . . . UP

FLAP lever 30

Advise the cabin of imminent touchdown.

Maintain airspeed at VREF 30.

Rotate to a touchdown attitude of 10 to 12 degrees.

After impact:

FUEL CONTROL switches (all). . . . . . . CUTOFF

Engine fire switches (all) . . . Pull, rotate to the
stop and hold for 1 second

▼ Continued on next page ▼

Ditching (April 1, 2011) 2/3

▼Ditching continued▼

Deploy the slide/rafts and evacuate the airplane.

■ ■ ■ ■

Ditching (April 1, 2011) 3/3

APPENDIX 10: Results of Tests and Research

1. 3D Hardware Wreckage Reconstruction

2. 3D Software Wreckage Reconstruction

3. Dangerous Goods Chemical Properties Test & Analysis

4. Dangerous Goods Leakage Test in Pressurized Environment

5. Measure the Electrostatic Energy of Packaging the Cargo

6. Test of the Flight Vibration Condition Using Tri-axis(X/Y/Z) Vibration Machine

7. Fire Dynamics Simulation

8. Additional Analysis & Tests

a. Dangerous Goods Packaging Materials Fusible Test

b. Paint Flammable Gas Leakage Check

c. Insulation Test

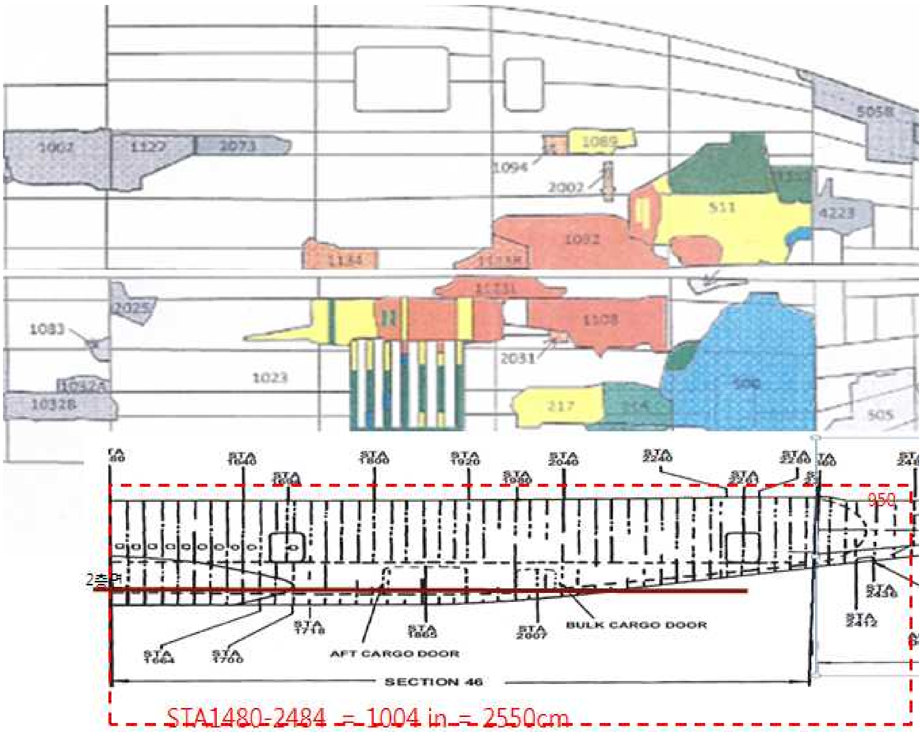
d. Chemical Reaction of Amines Liquid Corrosive N.O.S. & Lithium-ion Batteries

1. 3D Hardware Wreckage Reconstruction

☐ 3D reconstruction Procedures

- Phase 1 : Development procedure
- Phase 2 : Wreckage selected
- Phase 3 : Support structure design
- Phase 4 : Support structure Assembly
- Phase 5 : 3D scanning data decimate
- Phase 6 : Aligning of multiple Wreckage
- Phase 7: Wreckage 3D assembly
- Phase 8 : Analysis of Structures

☐ Support structure and mounting : Section 46 reorganization around a fire trail. From the STA 1480 is to the STA 2484 in the full length is 25.5m, 6.5m, and the largest width of the length of the structure of the whole fuselage. That the aircraft is on the second floor of the cargo compartment to 1m in height from the ground. To allow the attachment of the wreckage by placing a circular structure that is 1m intervals to maintain the elliptical shape of the aircraft.



<Fig.162> 3D reconstruction section and the wreckages

<Fig.163> mounted wreckages

- 3D H/W reconstructed wreckages analysis : STA 1700 ~ 2000 in the vicinity of some tearing and appears to the outside of the spout form below to receive a column as shown by the pressure and heat damage of the explosion in wreckages #1134 and #1123. This location is the main cargo compartment of the aircraft ML/MR, PL/PR area. Aluminum alloy fuselage was damaged by the heat was some melted Refine torn up due to the shape of the crown form of explosive Dangerous Goods.

<Fig.164> Shape of the upper airplane

- 3D H/W reconstructed wreckages analysis : Some of the wreckage #511 of STA 2205 melt a hole in the vicinity of the melting of the heat received and appears to down a cup shape, corresponding to RR area that 250 inches rearward from the main cargo compartment appeared PR area .

<Fig.165> Melted by heat of fire plane right outside

☐ 3D H/W reconstructed wreckages analysis : The state is heavily tanned inside of the top of the main cargo compartment with dangerous goods ML area wreckage #1134. Showed inside and outside that a colored state is loaded in the cargo hold PR area by Dangerous Goods of blue photoresist. This is thought to be the blue liquid flies in the plane ripped a hole in the state already has the upper body by the fire.

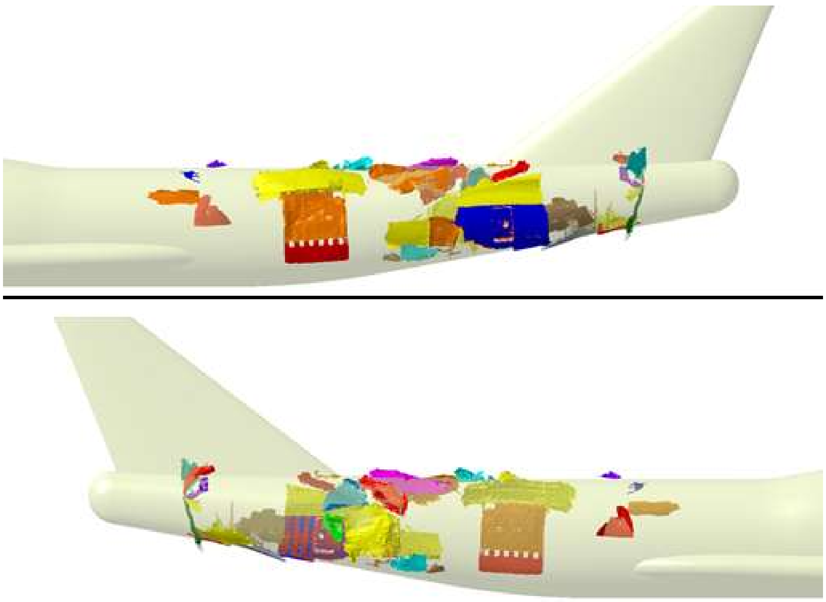
<Fig.166> Colored wreckage #1134, left)outside, right)inside

2. 3D Software Wreckage Reconstruction

□ 3D Software Wreckage Reconstruction Simulation Procedures

- Phase 1 : Development of 3D S/W procedure
- Phase 2 : modeling & data configuration
- Phase 3 : Wreckage selected
- Phase 4 : Wreckage 3D scanning
- Phase 5 : Wreckage 3D digitizing process
- Phase 6 : 3D scanning data decimate
- Phase 7 : Aligning of multiple datasets
- Phase 8 : 3D S/W reconstruction with reference frame
- Phase 9 : Wreckage 3D assembly
- Phase 10 : Analysis of results

□ Modeling and 3D Scan Data written : Guidelines for Reference Frame CAD Data written to the target, Use the "GSD Application" in the CATIA V5 model creation, Area division is divided into seven Area for the STA 1480 ~ STA 2436. Using 3D Scanning Camera TU-50, Scanning is complete, We make below Fig.



<Fig.167> S/W Reconstruction Result(1): Left View(Up), Right View(down)

3. Dangerous Goods Chemical Properties Test & Analysis

☐ Flash point test is applied to a total 7 Dangerous Goods

<tab.32> Flash point test results of 7 Dangerous Goods

Dangerous Goods	Test Result			Remarks
Photo-resist/IC 8132 (KUPR-A58-2.9cP)	47.5℃			
Photo-resist/IC 8110, 8121 (HIK-128C-1.7cP)	47℃			
Photo-resist/LCD R4650	1st	2nd	3rd	Repeat three times
	48℃	49℃	50℃	
Photo-resist/LCD B4650	45℃			
Photo-resist/LCD B5120	42℃			
Paint (TF-4200EB-451)	12℃			
Amines Liquid Corrosive N.O.S.	Does not Flash in more than 150℃			

☐ Ignition point test is applied to a total 2 Dangerous Goods

<tab.33> Ignition point test results

Dangerous Goods	Ignition point test result
Photo-resist/LCD	273℃
Paint(TF-4200EB-451)	264℃

☐ Spark Ignition test is applied to a total 7 Dangerous Goods

● Before Spark Ignition tests, Measurement of VOCs to a small amount of sample injected into 10ml transparent closed container results.

<tab.34> VOCs Measurement Results of Dangerous Goods

Dangerous Goods	VOCs Measurement Results
Photo-resist/IC 8132 (KUPR-A58-2.9cP)	VOCs Measured
Photo-resist/IC 8110, 8121 (HIK-128C-1.7cP)	VOCs Measured
Photo-resist/LCD R4650	VOCs Measured
Photo-resist/LCD B4650	VOCs Measured
Photo-resist/LCD B5120	VOCs Measured
Paint (TF-4200EB-451)	VOCs Measured
Amines Liquid Corrosive N.O.S.	VOCs Measured

□ Spark Ignition tests Results

<tab.35> Spark Ignition tests Results (after 2hr. rest)

Dangerous Goods	Spark Ignition tests Results	
	after 30min'	after 1hr
Photo-resist/IC 8132 (KUPR-A58-2.9cP)	Does not ignite	Does not ignite
Photo-resist/IC 8110, 8121 (HIK-128C-1.7cP)	Does not ignite	Does not ignite
Photo-resist/LCD R4650	Does not ignite	Does not ignite
Photo-resist/LCD B4650	Does not ignite	Does not ignite
Photo-resist/LCD B5120	Does not ignite	Does not ignite
Paint (TF-4200EB-451)	ignite	ignite
Amines Liquid Corrosive N.O.S.	Does not ignite	Does not ignite

● Additional testing of the paint on the spark ignited, rest times after 5min., 10min., 15min., 30min., after 1hr.,

<tab.36> tests Results of Additional testing of the paint.

Elapsed time	Whether the spark ignition
5min.	Does not ignite
10min.	ignite
15min.	ignite
30min.	ignite
after 1hr.	ignite

4. Dangerous Goods Leakage Test in Pressurized Environment

□ To confirm dangerous goods leakage for loaded Dangerous Goods Receptacles in pressurized environment.

- Implement a pressurized environment test equipment (chamber)

<Fig.168> pressurized environment test equipment

- Through Test Results, Confirmed that it does not leak flammable liquid or gas in air transport (pressurized environment, 8,000ft below) Dangerous Goods.

- Do check the possibility of Dangerous Goods leaks of flammable substances in the (32,000ft ~ 34,000ft) pressure of cruising altitude of cargo.

<tab.37> Flammable gas leaks of dangerous goods in air transport environment

Dangerous Goods	Pressure conditions	
	73~77kPa	below 30kPa
Photo-resist/LCD	No detect	Detected
Photo-resist/IC	No detect	Detected
Paint	No detect	Detected

5. Measure the Electrostatic Energy of Packaging the Cargo

☐ Measure the electrostatic energy of packaging the cargo package

- Date : 2014.January.10
- Site : Cargo Terminal
- Temperature and Humidity : 0.7℃~6℃, 52.5~68.3% RH

<tab.38> The actual measured temperature and humidity for electrostatic energy measurements

Type	Measured temperature	Measured humidity	Remarks
Type-A	6℃	52.2% RH	nonconductor
Type-B	1.4℃	65% RH	nonconductor
Type-C	0.7℃	68.3% RH	conductor

<Fig.169> Measured electrostatic to packaging material at Cargo Terminal

☐ The MIE values of the specific gas, which can cause dangerous goods. Can be compared to a standard to determine whether the electrostatic potential energy with MIE values of the specific gas is derived.

- Photo-resist/IC 8132

<tab.39> Minimum ignition Energy(MIE) value of Photo-resist/IC 8132 gas

molecule name	molecular formula	M I E (mJ)
ethly acetate	$CH_3COOC_2H_5$	1.42
Propylene	C_3H_6	0.28

- Photo-resist/IC 8110, 8121

<tab.40> Minimum ignition Energy(MIE) value of Photo-resist/IC 8110/8121 gas

molecule name	molecular formula	M I E (mJ)
ethly acetate	$CH_3COOC_2H_5$	1.42
Propylene	C_3H_6	0.28
cyclohexane	C_6H_{12}	0.22
methane	CH_4	0.28
carbon monoxide	CO	0.3

- Photo-resist/LCD R4650

<tab.41 > Minimum ignition Energy(MIE) value of Photo-resist/LCD R4650 gas

molecule name	molecular formula	M I E (mJ)
ethly acetate	$CH_3COOC_2H_5$	1.42
Propylene	C_3H_6	0.28
ether	$C_2H_5OC_2H_5$	0.19
ethylene	CH_2	0.07

- Photo-resist/LCD B4650

<tab.42> Minimum ignition Energy(MIE) value of Photo-resist/LCD B4650 gas

molecule name	molecular formula	M I E (mJ)
ethly acetate	$CH_3COOC_2H_5$	1.42
Propylene	C_3H_6	0.28
ether	$C_2H_5OC_2H_5$	0.19
ethylene	CH_2	0.07
cyclohexane	C_6H_{12}	0.22
methane	CH_4	0.28
carbon monoxide	CO	0.3

- Photo-resist/LCD B5120

<tab.43> Minimum ignition Energy(MIE) value of Photo-resist/LCD B5120 gas

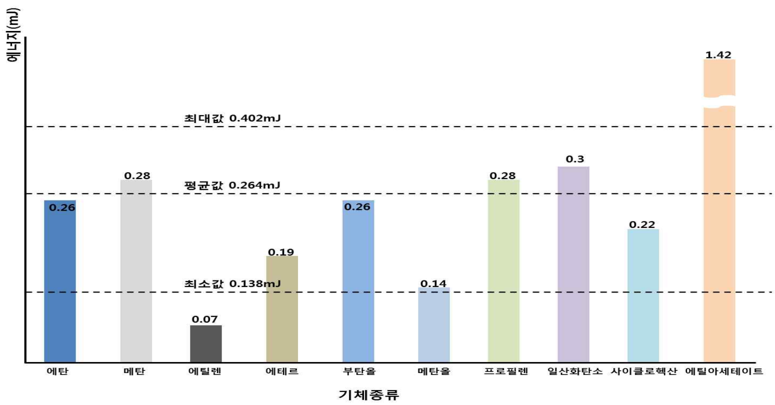
molecule name	molecular formula	M I E (mJ)
ethly acetate	$CH_3COOC_2H_5$	1.42
Propylene	C_3H_6	0.28
ether	$C_2H_5OC_2H_5$	0.19
ethylene	CH_2	0.07
cyclohexane	C_6H_{12}	0.22
methane	CH_4	0.28
carbon monoxide	CO	0.3

- Paint TF-4200EB-451

<tab.44> Minimum ignition Energy(MIE) value of Paint TF-4200EB-451 gas

molecule name	molecular formula	M I E (mJ)
butanol	$C_4H_{10}O$	0.26
methlycyclohexane	C_7H_{14}	0.27
methanol	CH_4O	0.14
methane	CH_4	0.28
ethane	C_2H_6	0.26

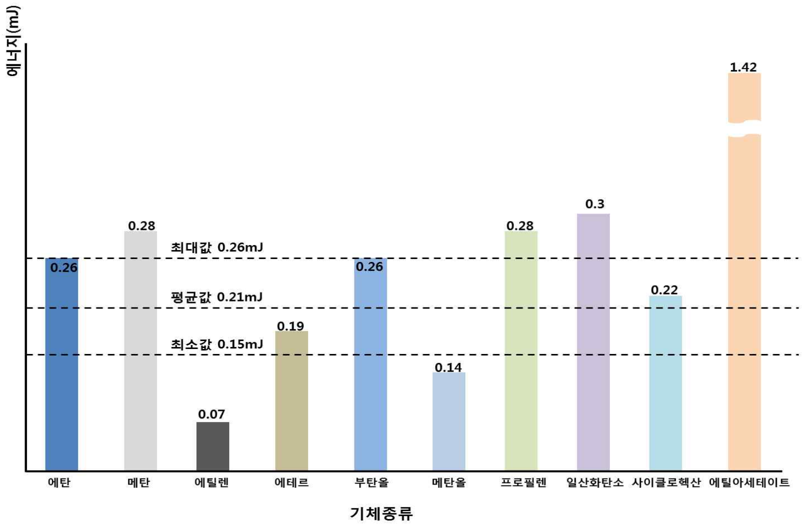
☐ Type-A : Analysis of the results of the Minimum ignition Energy(MIE) derived from the charged Dangerous Goods.



<Fig.170 > Type-A with MIE

- The minimum of the measured Type-A, which can be determined that the average, have at least one or more high electrostatic energy than the MIE of vaporized components from the maximum energy is dangerous goods.

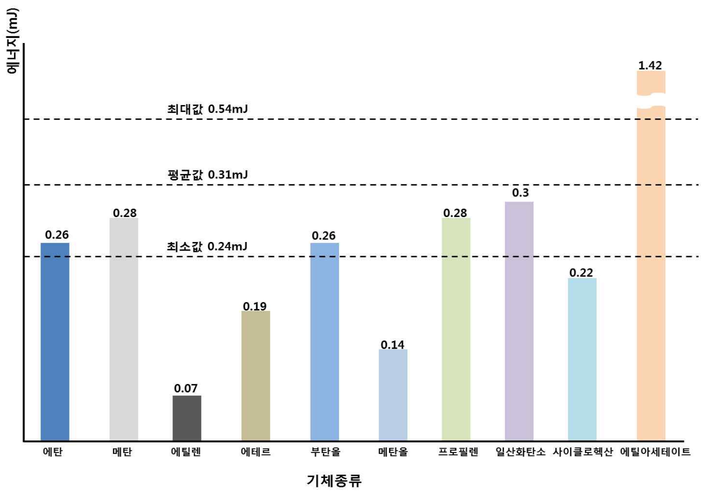
☐ Type-B : Analysis of the results of the Minimum ignition Energy(MIE) derived from the charged Dangerous Goods.



<Fig.171 > Type-B with MIE

● The minimum of the measured Type-B, which can be determined that the average, have at least 2 or more high electrostatic energy than the MIE of vaporized components from the maximum energy is dangerous goods.

☐ Type-C : Analysis of the results of the Minimum ignition Energy(MIE) derived from the charged Dangerous Goods.



<Fig.172 > Type-C with MIE

● The minimum of the measured Type-C, which can be determined that the average, have at least 4 or more high electrostatic energy than the MIE of vaporized components from the maximum energy is dangerous goods.

☐ 2nd Measure the electrostatic energy of packaging the cargo package

- Date : 2014.April.9-10
- Site : Cargo Terminal, Aircraft Cargo Compartment
- Cargo Terminal : after electrification elapsed time, after 15min., after 30min.
  - Ground test measurements

after electrification Elapsed time	goods	quantity of electric charge (nC)	electrostatic energy (mJ)	Temp. (℃)	Humidity (%)
Shortly after electrification	1	18.2	0.27	10.3	71.8
		11.3	0.17	10.5	71.7
		31.0	0.47	10.5	76.3
	2	16.2	0.24	11.1	68.5
		14.1	0.21	11.1	68.6
		15.9	0.24	11.2	68.4
	3	17.5	0.26	11.5	67.4
		11.3	0.17	11.3	67.4
		23.0	0.35	11.4	67.2
after 15 min.	1	×	×	10.5	74.5
		×	×	10.3	76.4
		×	×	10.6	75.3
	2	10	0.15	10.5	74.6
		×	×	10.4	75.5
		10.6	0.16	10.2	75.9
	3	×	×	10.5	74.3
		×	×	10.5	75.2
		×	×	10.4	75.8
after 30 min.	1	×	×	10.4	71.5
		×	×	10.6	72.8
		×	×	10.5	74.5
	2	×	×	11.5	64.9
		×	×	10.4	73.3
		×	×	10.5	74.3
	3	×	×	10.5	74.0
		16.5	0.25	10.1	74.2
		×	×	10.0	77.7

<Fig.173 > result of quantity of electric charge at Cargo Terminal

- 8 kinds of cargo loaded on aircraft, after electrification 35min. ~ 1hr 35min.

<Fig.174 > measurements of quantity of electric charge at Cargo Compartment

- Test measurements In Aircraft Cargo Compartment

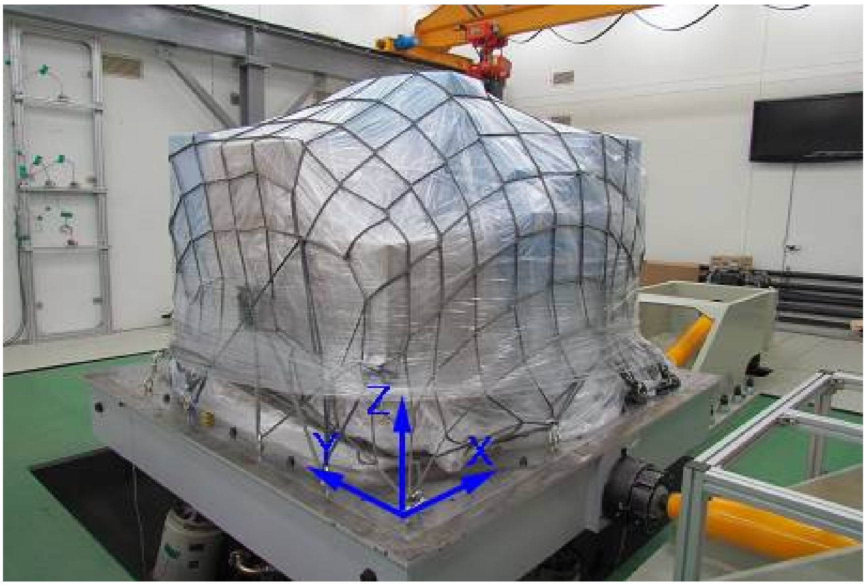
after electrification Elapsed time	goods	Packing	quantity of electric charge (nC)	electrostatic energy (mJ)	Temp. (℃)	Humidity (%)
35 min.	JR	Total Package	×	×	14.3	23.1
			×	×	14.2	23.2
1 hr. 20 min.	GR	Total Package	×	×	16.7	19.3
			×	×	16.7	19.3
1 hr. 35 min.	T	Total Package	×	×	10.7	15.5
			×	×	10.7	15.5
1 hr. 15 min.	SL	2nd Package	×	×	11.2	14.2
1 hr.	PR	Total Package	×	×	22.7	13.2
			×	×	21.3	11.1
1 hr.	ML	Total Package	×	×	22.7	15.0
			×	×	20.0	10.3
1 hr. 20 min.	RL	Total Package	×	×	18.7	9.6
			×	×	18.6	8.8
1 hr. 20 min.	GL	Total Package	15.4	0.23	17.8	8.0
			×	×	17.4	8.8

<Fig.175 > result of quantity of electric charge at Cargo Compartment

6. Test of the Flight Vibration Condition Using Tri-axis(X/Y/Z) Vibration Machine

☐ According to the data transmitted by the ACARS of AAR991 1.32G logged in Incheon airport runway shows a vertical takeoff airplane accelerometer. Typically, the B747 aircraft during take-off vertical acceleration is about 1.15G, 1.32G takeoff is recorded as G is estimated to be greater than normal operation.

☐ Charger and dangerous in a similar condition to determine the type of cargo loaded on the airplane. Performing the test by using the vertical acceleration whether or not the loaded condition and the motion of the cargo, such as the 3-axis vibration machine in a 1.3G or greater.



<Fig.176> the direction of specimen installed on the vibration machine

☐ Test conditions apply of vibration machine

- Waveform generation performed according to the Random-motion Test method.
- Table is also a 3-axis simultaneous excitation
- Tests once, The total test time is 30 seconds, Maintained for more than 25 seconds strong motation time.

☐ Test result : Confirmed that changes according to unverified very thin possibility of cargo loaded on the airplane to take off by the acceleration of the group is thinking of moving cargo is loaded on the 3-axis vibration machine.

7. Fire Dynamics Simulation

□ Should adopt the FDS_5(Fire Dynamics Simulator) model as an analysis tool for the fire simulation.

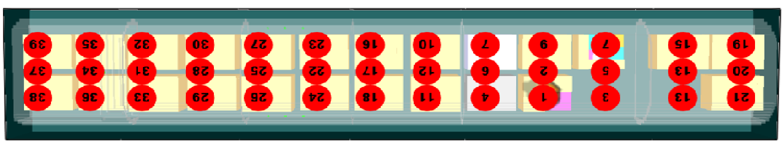
□ Fire simulation procedure

- Calculate the area and grid settings
- Cargo compartment and cargo geometric modeling
- Thermal boundary conditions set
- Ventilation settings
- Measurement equipment, control settings
- Set around like pressurization, the temperature in the hold, gravity environment conditions
- Ignition sources selected according to the scenario
- Simulation execution, and results analysis

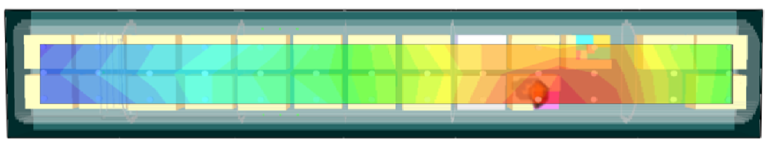
Scenario 1 : sources of ignition at position ML

- Represents the trend leaning towards the front, but the direction of movement of the flame. Scenario 2 less than the heat release rate of the overall size.

- Propagation delay progression of peripheral sources of ignition are also different scenario 2 depending on the ignition source location. The farther away from the source of ignition is showing similar progress.



(a) Smoke detector alarm sequence



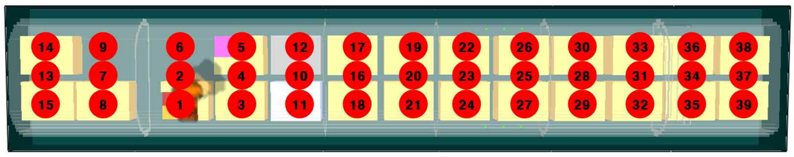
(b) Smoke propagation path (the more red the first detection)

<Fig.177> After the fire, the smoke spread in the ML area

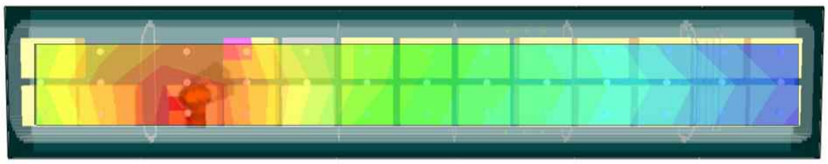
Scenario 2 : sources of ignition at position PR

- Check that the first smoke and flames spread to the front than the rear.

- Refine the first detection of smoke in the front side MR, ML section area than the PL and PR in the STA position as an ignition source.

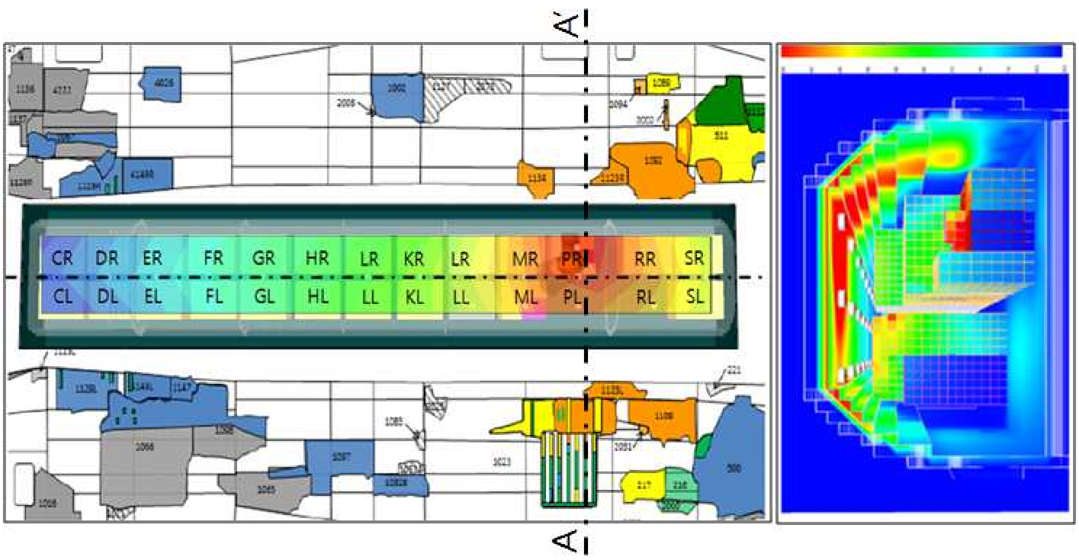


(a) Smoke detector alarm sequence



(b) Smoke propagation path (the more red the first detection)

<Fig.178> After the fire, the smoke spread in the PR area



<Fig.179> Left), the thermal distribution of heat in the body even if the PR section also ignite and damage, Right) Heat distribution in the section A-A' for PR area of main cargo compartment

8. Additional Analysis & Tests

a. Dangerous Goods Packaging Materials Fusible Test

□ Performing a test administered by the polystyrene form was used as packaging for liquid dangerous goods loaded on the airplane dangerous goods. Polystyrene form 990cm^3 (1.1cm×15cm×10cm×6pieces), addition liquid Dangerous Goods 40cc. Test Result : Paint, Photo-resist/IC, Photo-resist/LCD are chemical respond rapidly.

<Fig.180> give paint to a Packaging Materials

<Fig.181> give dangerous goods to a Packaging Materials Left) Photo-resist/LCD, Right) Photo-resist/IC

b. Paint Flammable Gas Leakage Check

□ Measured at the internal & external closure of the paint firmly locked state with the flammable gas leaks whether VOCs meter for the case was allowed to stand 2 hours, then kept at room temperature for 2 hours in a refrigerator, and if placed in a sealed plastic bag and the paint container.

<Fig.182> Ensure that you are ready to paint flammable gas leakage in closed closure, Left) In Refrigerator rest, 5℃, 2hrs, Right) At room temp. 18℃, after 2hrs, in Laboratory

□ VOCs (Volatile Organic Compounds) Test Result :

- At room temp. 18℃, after 2hrs, in Laboratory : Flammable gas(VOCs) Detect
- In Refrigerator rest, 5℃, after 2hrs : Flammable gas(VOCs) non-detect, Odor weakly detect.

c. Insulation Test

□ Dangerous Goods in the airplane is located on the same palette, lithium-ion battery with a liquid Dangerous Goods also tested for insulation and electrical conductivity of liquid Dangerous Goods.

<tap.45> Electro Insulation test Result for Dangerous Goods

Dangerous Goods	Isolated / non-isolated	Electrical conductivity
Photo-resist/IC 8132 (KUPR-A58-2.9cP)	non-isolated	Very weak (water level)
Photo-resist/IC 8110, 8121 (HIK-128C-1.7cP)	non-isolated	Very weak (water level)
Photo-resist/LCD R4650	non-isolated	Very weak (water level)
Photo-resist/LCD B4650	Isolated	Not at all
Photo-resist/LCD B5120	non-isolated	Very weak (water level)
Paint (TF-4200EB-451)	Isolated	Not at all
Amines Liquid Corrosive N.O.S.	non-isolated	Very weak (water level)

d. Chemical Reaction of Amines Liquid Corrosive N.O.S. & Lithium-ion Batteries

□ A lithium-ion battery for car completely soaked in Amines Liquid Corrosive N.O.S 30 minutes after checking in ambient temperature 18 ℃ environment of the lithium-ion battery damage result is not at all. Between the Amines Liquid Corrosive N.O.S with lithium-ion battery has not chemical and electrical reactions occur at all.

<Fig.183> A lithium-ion battery soaked in Amines Liquid Corrosive N.O.S