국토교통부

ARAIB/AIR1505

AIRCRAFT SERIOUS INCIDENT REPORT

Reentry to Runway after Runway Excursion on Landing

Korean Air

B737-800, HL8224

Guam International Airport, Runway 6R

5 July 2015

11 October 2016

국토교통부

항공철도사고조사위원회

Aviation 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 test shall prevail.

Aircraft Serious Incident Report

Aviation and Railway Accident Investigation Board. ***Reentry to Runway after Runway Excursion on Landing, Korean Air, B737-800, HL8224, Guam International Airport, Runway 6R, 5 July 2015.*** **Aircraft Serious Incident Report ARAIB/AAR-1505. 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.

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Contents

Reentry to Runway after Runway Excursion on Landing

- Operator: Korean Air
- Manufacturer: The Boeing Company
- Type: B737-800
- Registration Mark: HL8224
- Location: Guam International Airport, runway 6R
- Date & Time: 4 July 2015, approximately 17:06 UTC[1] (5 July 2015, approximately 03:06 local time)

Synopsis

On 4 July 2015, approximately 21:51 Korean Standard Time (KST), Korean Air flight 2115 (hereafter referred to as “HL8224”) took off from Gimhae International Airport (PUS) in Busan, Republic of Korea, bound for Guam International Airport (GUM) in Guam, United States. On 5 July 2015, at 03:06 local time, the aircraft was on an ILS approach to runway 6R at GUM when it touched down on the right hand edge of the runway about 2,000 feet (ft) past the runway threshold.

The aircraft started to veer right about 2,200 ft past the runway threshold and departed the paved surface of the runway. Both main landing gears were completely off the runway and ran through grass about 3,000 ft past the runway threshold before the aircraft reentered the runway abut 4,400 ft past the runway threshold and came to a stop.

As a result of this serious incident, there were no injuries to crew and passengers. The aircraft engine and part of the fuselage sustained damage, and two runway edge lights and two taxiway lights were damaged.

1) UTC: Universal Time Coordinated.

In accordance with the Annex 13 to the Convention on International Civil Aviation, Paragraph 5.1, the State of Occurrence, which is the United States in this case, shall institute an investigation into the circumstances of this serious incident and be responsible for the conduct of the investigation. For the safe of the investigation convenience, however, the National Transportation Safety Board (NTSB) of the United States decided to delegate the whole part of the conducting of such investigation to the Aviation and Railway Accident Investigation Board (ARAIB) of the Republic of Korea. The ARAIB, therefore, conducted the investigation and issued this final report.

The ARAIB determines that the probable cause of the serious incident was ① the captain's inappropriate judgement while landing on runway 6R at Guam International Airport at night with heavy rain under the influence of a typhoon, which led to a runway excursion; and ② the captain's decision to continue to land instead of executing a go-around although visual references were not established.

As a result of this investigation, the ARAIB makes two safety recommendations to Korean Air.

1. Factual Information

1.1 History of Flight

On 4 July 2015, approximately 21:51 KST, HL8224 took off from PUS, bound for GUM, with 7 crew and 75 passengers. The captain of HL8224 was the pilot flying (PF) during the whole flight.

The captain performed an ILS approach to runway 6R at GUM and, in compliance with the ban on auto landing at GUM, as specified in Korean Air's K-File, disengaged the autopilot and authothrottle at 600 ft at 16:48:22 UTC (hereafter all times stated in the report are UTC) and visually verified the runway approach lights at 500 ft.

According to the CVR data, the first officer (FO) stated that the aircraft was slightly to the right of the localizer at about 300 ft, and then, descending through 200 ft RA,[2] he said that the aircraft was slightly below glideslope, and that descending through 100 ft RA, the aircraft was slightly above glideslope.

HL8224 continued to descend until 30 ft at which point the captain initiated a go-around and climbed up to 3,000 ft. Then, he requested another ILS approach to runway 6R.

While climbing up to 3,000 ft, the captain said to the FO that he could not land because he was unable to visually verify the runway even with the windshield wipers at a maximum speed, immediately before landing.

While on the ILS approach, captain and the FO set V_{app} at 146 kts (V_{ref} 141 kts + 5 kts) and crosschecked it. In accordance with the descent and approach

2) RA is a radio altitude which is the height of the aircraft above terrain immediately below the aircraft.

checklist, they also set the flight management computer (FMC) to approach runway 6R and selected autobrake in MAX position.

At 16:57:50, Guam Departure Control relayed a pilot report to HL8224, stating "braking action FAIR,[3] on final heavy rain and no turbulence."

Later, Agana Tower also advised that Jeju Air flight 3154 which had landed at 17:02:46 reported "braking action FAIR, visibility 1 mile, runway visible at 600 ft, and heavy rain." The flight crew of HL8224 both confirmed the pilot reports of weather conditions.

The Tower gave HL8224 a landing clearance and a weather report of winds from 350° at 13 kts. When the FO called 500 ft, the captain called the runway in sight and disengaged autopilot and autothrottle.

When an electronic voice announced "minimum" at 17:04:55, the captain called the aircraft was stabilized. Descending through 150 ft RA, the FO called the aircraft was below glideslope, and descending through 100 ft RA, called out four reds.[4]

Just before touchdown, at 17:05:27, a sudden crosswind from the left caused HL8224 to veer right and touch down on the right hand edge of runway 6R about 2,000 ft past the threshold. The FO advised the captain twice to steer left.

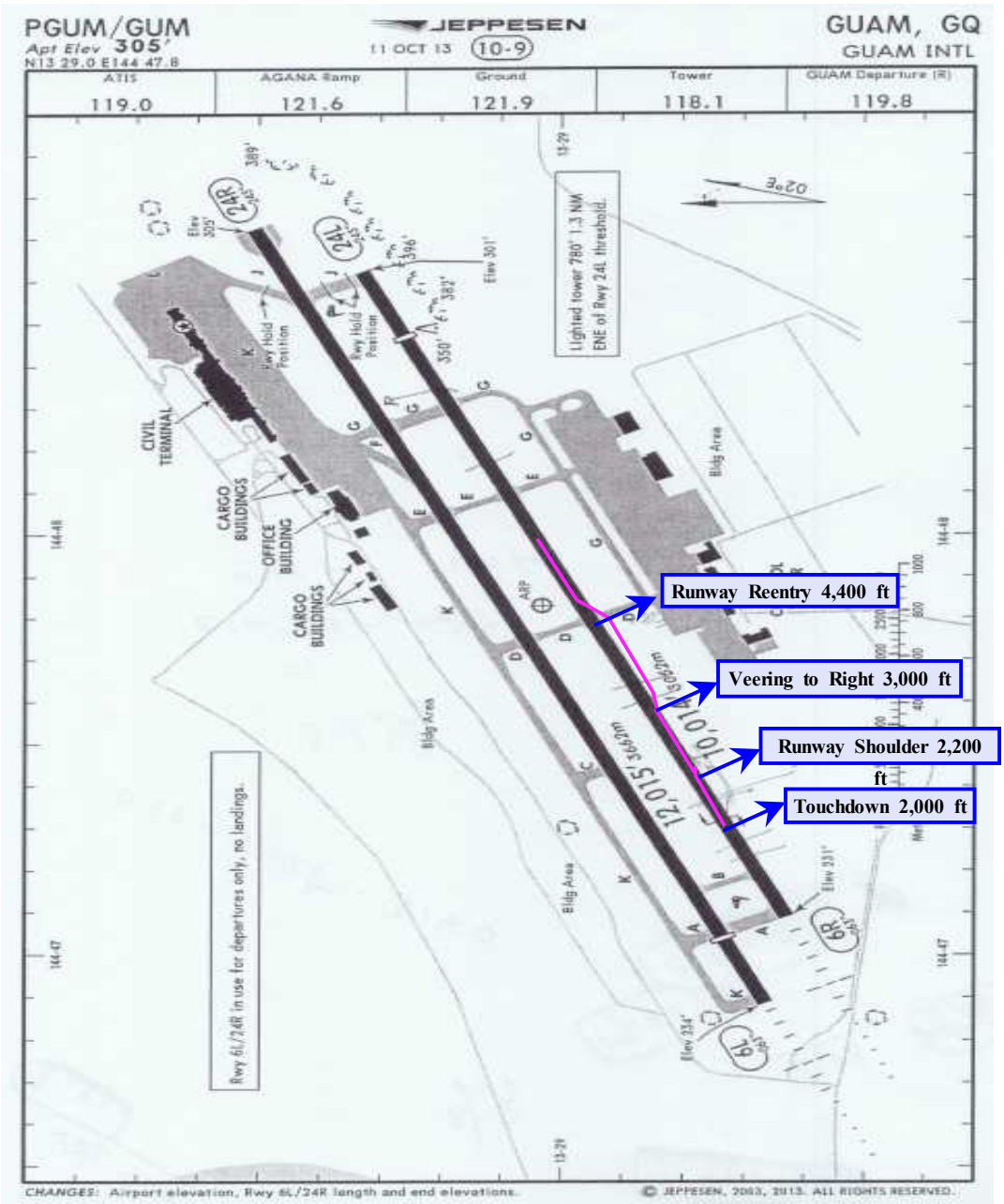
The aircraft started to veer right about 2,200 ft past the runway threshold and departed the paved surface of the runway. Then, both main landing gears were completely off the runway and ran through grass about 3,000 ft past the runway

3) Braking action is a description of how easily an aircraft can stop after landing on a runway. When reporting braking action according to the Federal Aviation Administration (FAA) of the United States, any of the following terms may be used: GOOD; FAIR (or MEDIUM); POOR; and NIL.

4) Four reds mean four PAPI (precision approach path indicator) lights are red, indicating the airplane's significantly below-glidepath position. Two white and two red lights indicate the airplane's on-glidepath position.

threshold before the aircraft reentered the runway abut 4,400 ft past the runway threshold and came to a stop.

The aircraft was inspected on the runway before #2 engine was shut down, and was towed to the ramp. HL8224's runway excursion and reentry are summarized in [Figure 1] and [Figure 2].



[Figure 1] Runway Excursion and Reentry Path

	
Skid Marks at 2,000 ft	Skid Marks at 2,000 ft
	
Runway Excursion at 3,000 ft	Runway Excursion at 3,000 ft
	
Reentry at 4,400 ft	Reentry at 4,400 ft

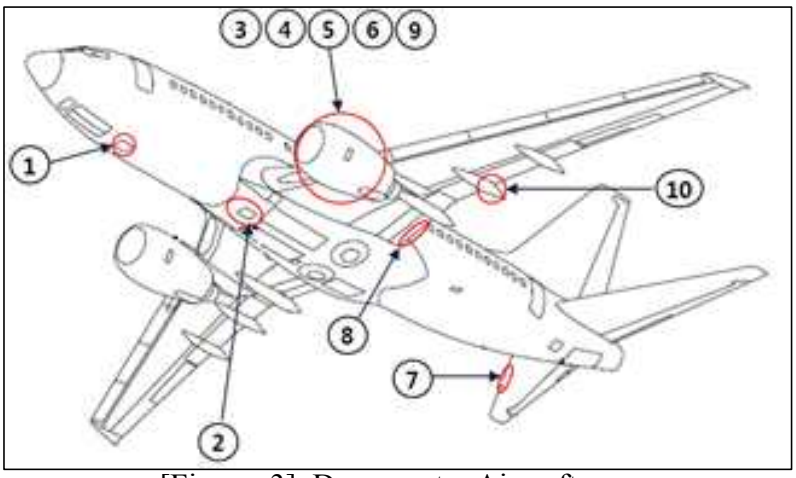
[Figure 2] Runway Excursion and Reentry Marks

1.2 Injuries to Persons

There were no personal injuries as a result of this serious incident.

1.3 Damage to Aircraft

As shown in [Figure 3], as the aircraft veered off the runway and ran through grass, #1 engine, electronic equipment (E/E) compartment access door, and wing-to-body faring sustained damage, about 1.4 billion KRW worth.



[Figure 3] Damage to Aircraft

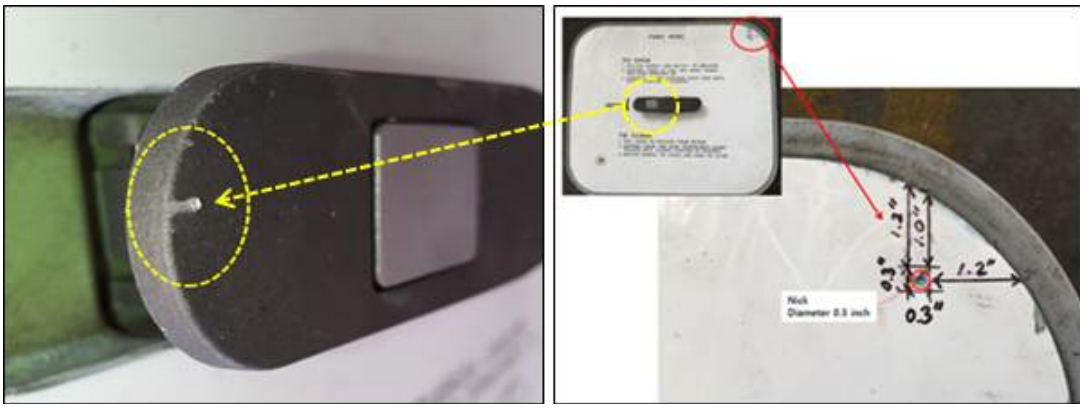
1.3.1 Damage to Fuselage

Damage to fuselage is summarized in [Table 1].

No.	Damage	Photo
①	Foreign objects (grass, soil) found lodged in E/E compartment	 E/E Access Door
②	Damage to wing-to-body fairing - Size: 17” × 8.5”	
⑦	Dent in RH horizontal stabilizer leading edge skin - Size: 0.8” in diameter, 0.2” in max. depth	 Wing-to-Body Fairing
⑧	Dent on the bottom skin of LH wing aft flap	
⑩	Crack in LH wing #2 flap support fairing tail cone	

[Table 1] Damage to Fuselage

As shown in [Figure 4], the E/E compartment access door opened because the door handle turned when the aircraft struck foreign objects during runway excursion, which caused grass and soil to ingest into the E/E compartment.



[Figure 4] Damage to E/E Compartment Access Door

1.3.2 Damage to Engine

Damage to engine is summarized in [Table 2].

No.	Damage	Photo
③	Damage to all 24 fan blades of #1 engine	 #1 Engine
④	Dent in #1 engine's inlet cowl lip skin - Size: 18" × 9", 1.5" in depth	
⑤	Delamination damage to #1 engine's RH reverser cowl	
⑥	Crack and dent in #1 engine's RH fan cowl - Crack: 2.0" - Dent: 2.0" × 0.3", 0.2" in depth	 #1 Inlet Cowl Lip
⑨	Rubbing damage to #1 engine's abradable shroud	

[Table 2] Damage to Engine

1.3.3 Aircraft Damage Repair

The E/E compartment access door was inspected and reinstalled, and the wing-to-body fairing was replaced. Dent in RH horizontal stabilizer leading edge skin was judged to be within the allowable range of damage in the manual, so left unrepaired. Dent on the bottom skin of LH wing aft flap and crack in LH wing #2 flap support fairing tail cone were temporarily[5] repaired to be closely examined at the company base.[6]

All tires, brake, #3 VHF[7] antenna, LH & RH landing retractable light and outflow valve[8] were replaced, and the main landing gear temperature sensor bracket was repaired.

All blades of #1 engine, engine inlet cowl, and RH thrust reverser cowl were replaced, and as a temporary repair,[9] a crack stop hole was drilled into #1 engine RH fan cowl. Also, #1 engine abradable shroud rubbing damage was deferred according to the maintenance manual, and #1 and #2 engines were on borescope inspection (BSI).

1.4 Other Damage

Apart from aircraft damage, two runway edge lights, two taxiway lights, and a taxiway D sign were damaged.

5) Temporary repair according to the manual and procedures, like application of speed tape.
6) The base is located in Incheon International Airport.
7) VHF: Very High Frequency.
8) The outflow valve regulates the airplane pressurization by discharging air outboard or stopping it.
9) Temporary Repair: crack stop hole drilling and speed tape application.

1.5 Personnel Information

1.5.1 The Captain

The captain (male, age 43) held a valid air transport pilot license,[10] B737 type rating,[11] first-class airman medical certificate,[12] aeronautical radio operator license,[13] and level 5 ICAO English proficiency certificate.

The captain had accumulated 7,933 total flight hours, including 1,884 hours in B737. He was appointed as a B737 captain on 18 April 2014 and had logged 749 hours in B737 as PIC. He had flown 163 hours and 40 hours in the last 90 and 30 days, respectively.

The captain passed his line check on 28 April 2015, received his B737 recurrent training from 17 to 18 June 2015, and passed his proficiency check on 20 June 2015.

In the 72 hours before the serious incident, the captain operated an international flight (Incheon-Sanya-Incheon) from 22:30 KST on 1 July to 07:52 KST on 2 July and had a day off on 3 July. On 4 July, he operated a domestic flight (Gimpo-Busan) from 17:59 KST to 19:03 KST and then, an international flight (Busan-Guam) from 21:15 KST. He stated that he did not drink any alcohol or take any illegal medication in the 24 hours before the flight and was in good health.

1.5.2 The First Officer

The FO (male, age 39) held a valid commercial pilot license,[14] B737 type

10) License No.: 11-003096 (issued on 4 Jan. 2011).
11) Acquired on 22 Aug. 2003.
12) Certificate No.: 185-00665 (valid until 31 May 2016).
13) License No.: 00-34-8-0002 (issued on 21 Apr. 2000).

rating,[15] first-class airman medical certificate,[16] aeronautical radio operator license,[17] and level 4 ICAO English proficiency certificate.

The FO had accumulated 2,865 total flight hours, including 205 hours in B737. He had flown 120 hours and 43 hours in the last 90 and 30 days, respectively.

He received his B737 recurrent training on 29 April 2015 and passed his proficiency check on 1 May 2015.

In the 72 hours before the serious incident, on 2 and 3 July, the FO had no flight. On 4 July, he operated a domestic flight (Gimpo-Busan) from 17:59 KST to 19:03 KST and then, an international flight (Busan-Guam) from 21:15 KST. He stated that he did not drink any alcohol or take any illegal medication in the 24 hours before the flight and was in good health.

1.6 Aircraft Information

1.6.1 General

HL8224 (Serial No. 38,822) was manufactured by the Boeing Company on 25 June 2011. It was delivered new to Korean Air on 17 July 2011 and registered[18] with the Ministry of Land, Infrastructure and Transport in Korea. It held a valid airworthiness certificate[19] and had accumulated 12,853 total hours and 5,913 total cycles, as of June 2015.

The aircraft was powered by two CFM56-7B turbofan engines manufactured

14) License No.: 12-004419 (issued on 25 Nov. 2014).
15) Acquired on 25 Nov. 2014.
16) Certificate No.: 105-03394 (valid until 29 Feb. 2016).
17) License No.: 01-34-1-0055 (issued on 3 Dec. 2013).
18) Registration No.: 2011-053.
19) Certificate No.: AB11034 (issued on 23 Jul. 2011).

by GE & SNECMA. The engines (#1 and #2) were installed during the manufacture of the aircraft and had since been operated.

- #1 and #2 Engines Part No.: CFM56-7B24E
- #1 and #2 Engines Serial No.: 960156/960166
- #1 and #2 Engines Manufacture Date: 5 Jun. 2011
- #1 and #2 Engines Installation Date: 25 Jun. 2011
- #1 and #2 Engines Service Hours: 12,853
- #1 and #2 Engines Cycles: 5,913

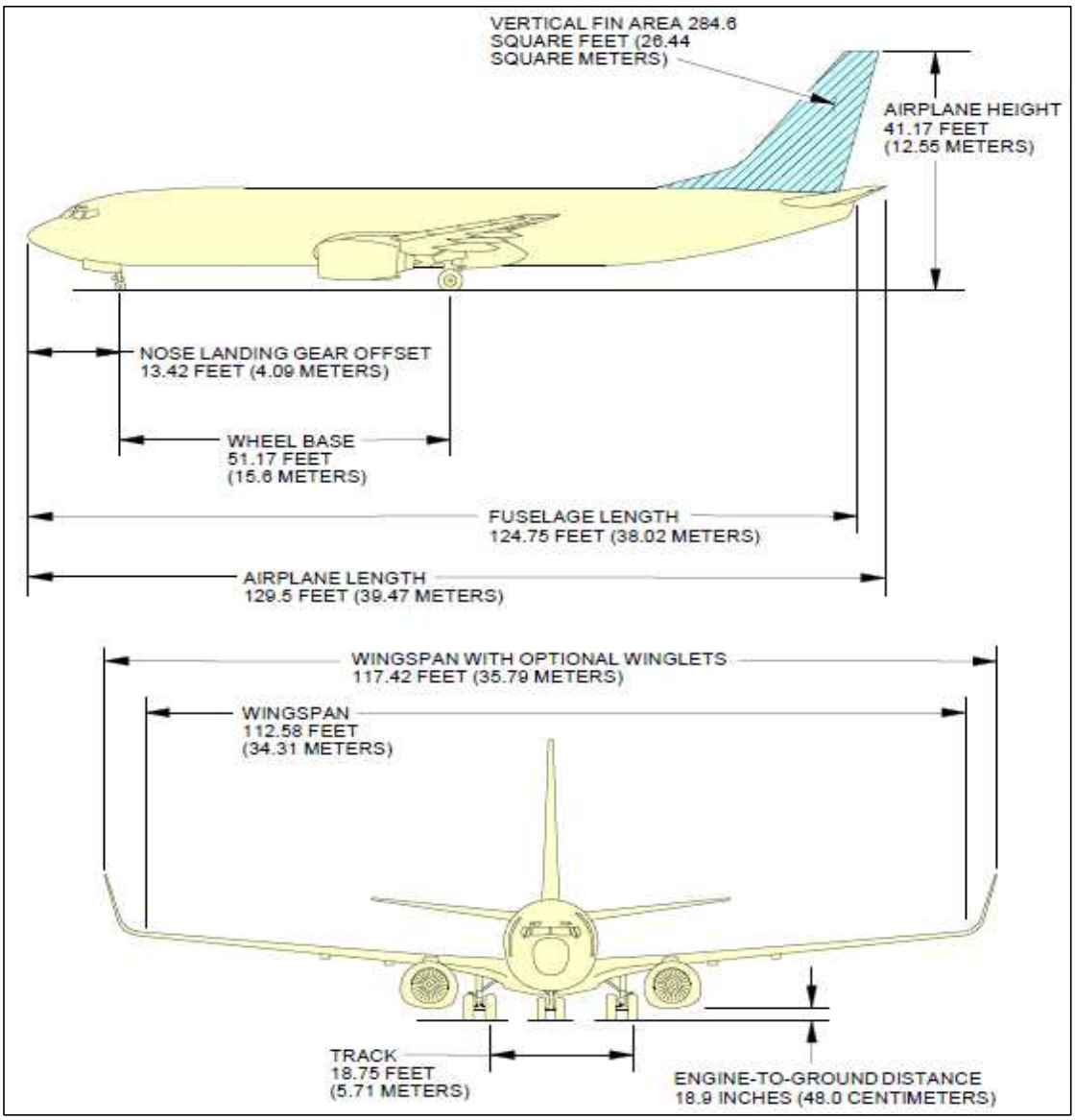
On the day of the serious incident, no defects were found in the aircraft not only during a preflight maintenance check by a Korean Air mechanic but also until the aircraft's arrival at GUM.

According to the in-house maintenance program, Korean Air performed the following scheduled maintenance in its maintenance facilities: IAA inspection[20] on 8 June 2015; ICD inspection[21] on 13 January 2015; and ICG inspection[22] on 9 May 2015.

1.6.2 Aircraft Specifications

General specifications of HL8224 are shown in [Figure 5].

20) IAA Inspection: maintenance activity conducted every 600 flight hours.
21) ICD Inspection: maintenance activity conducted every 6,000 flight hours.
22) ICG Inspection: maintenance activity conducted every 24 months/5,500 flight hours.



[Figure 5] Specifications of HL8224

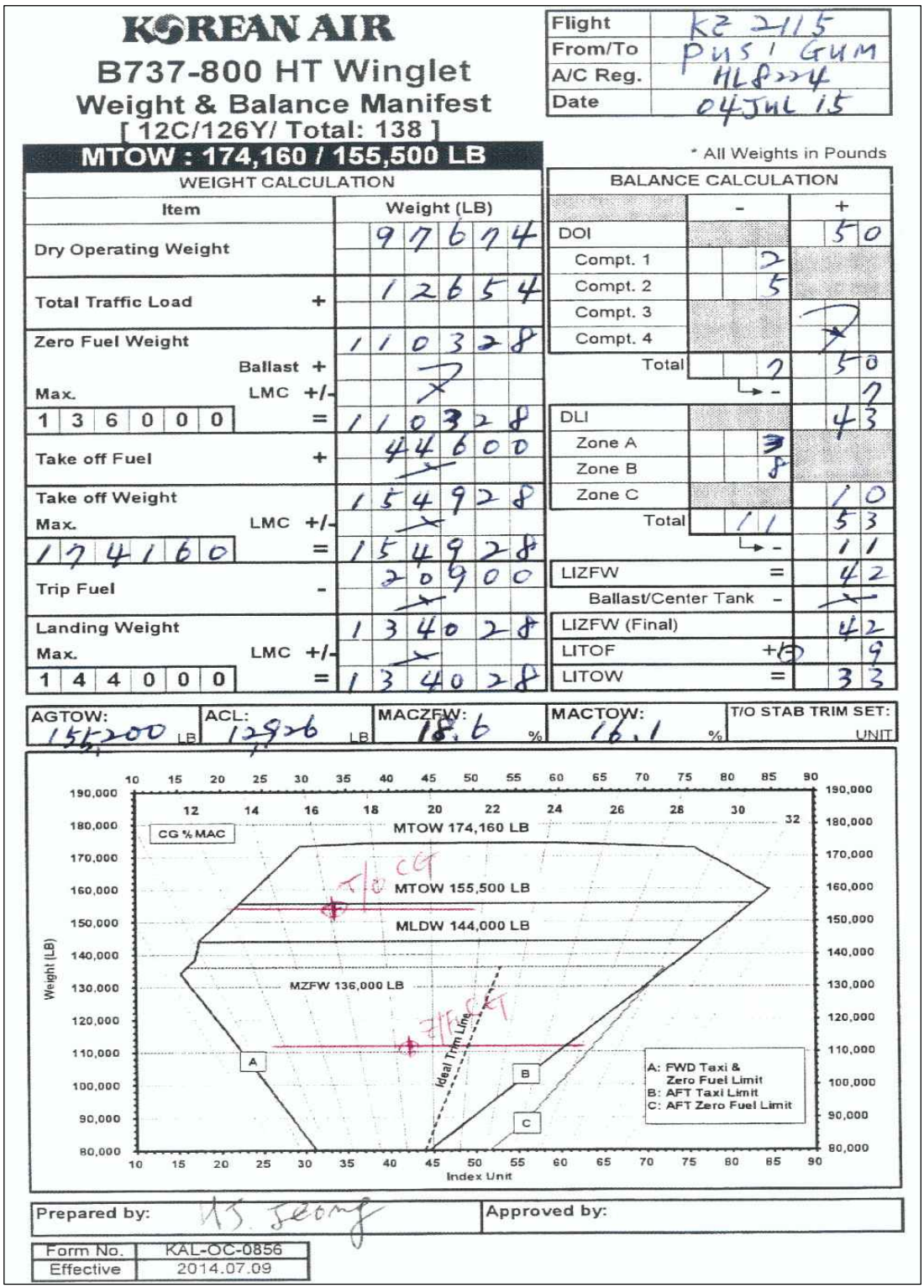
1.6.3 Weight and Balance

The weight and balance data of HL8224 is summarized in [Table 3]. HL8224's zero fuel weight (ZFW), takeoff weight (TOW), and landing weight (LDW) were within the allowable range of weight, and as shown in [Figure 6], the center of gravity of ZFW and TOW were also within the allowable limits.

[unit: kg]

Passenger & Baggage Weight	5,740	Cargo Weight	None
ZFW	50,045	Max. ZFW	61,688
Takeoff Fuel	20,231	Max. TOW	78,997
TOW	70,276	Max. LDW	65,317
Trip Fuel	9,480	Fuel for Go-around and Reapproach	689
Estimated LDW on First Landing	60,214	Estimated LDW on Second Landing	59,524

[Table 3] Weight and Balance Data



[Figure 6] Weight and Balance Manifest[23)]

23) At the request of the ARAIB, Korean Air prepared this manifest, and thus, there is no signature of the captain.

1.7 Meteorological Information

A METAR weather report filed when HL8224 landed at GUM about 17:05 was as follows:

METAR 041601 30009KT 2SM RA BR SCT004 BKN009 OVC014 25/25 A2949
METAR 041645 31009KT 1SM +RA BR VV008 25/25 A2949
METAR 051654 31009KT 1 1/4SM +RA BR OVC010 25/25 A2947
METAR 051719 30011KT 1SM +RA BR VV009 25/25 A2949

The weather information contained in the GUM Automatic Terminal Information Service (ATIS) "Foxtrot"[24] broadcast to which HL8224 listened about 16:02 (02:02 local time) is as follows: wind from 300° at 10 kts, gust 19 kts, visibility 3,000 meters, scattered at 400 ft, broken at 900 ft, overcast at 1,400 ft, temperature 25°C, altimeter setting 2949 inch.

When HL8224 was first cleared to land at runway 6R about 16:44 (02:44:51 local time), weather conditions at GUM were wind from 320° at 9 kts, gust 19 kts, and wind variable 320° to 360°. Later, Agana Tower reported, "We have heavy rain at the airport. This time runway wet, no brake action report."

About 16:57:50 (02:57:50 local time), Guam Departure Control advised HL8224 that another flight's pilot reported "braking action FAIR, on final heavy rain and no turbulence."

About 17:02:55 (03:02:55 local time), Agana Tower advised HL8224, "Runway 6R, wind 010° at 9 kts, gust 17 kts."

24) An ATIS broadcast is given a letter designation at the beginning and the end of it. The letter progresses through the alphabet with every update, starting at "alfa" and ending at "zulu."

About 17:03:03 (03:03:03 local time), the Tower gave HL8224 a landing clearance and a weather report of wind variable at 010° – 320°, wind 12 kts to 17 kts.

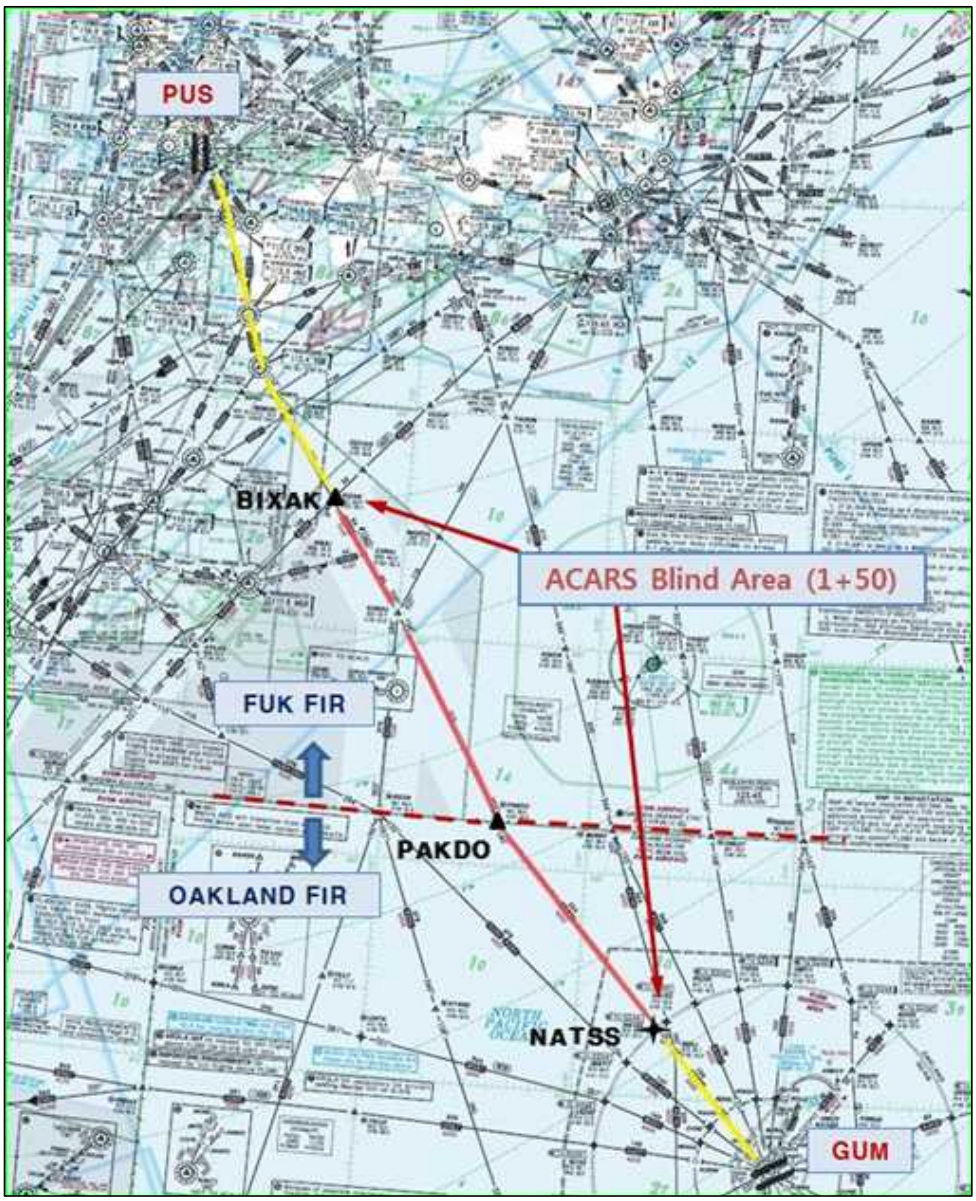
1.8 Aids to Navigation

When HL8224 on an ILS approach to runway 6R landed, the ILS was in normal operation, and GUM's approach lighting system, runway edge lights, and PAPI were illuminated, but runway centerline lights were not installed.

1.9 Communications

As HL8224 was equipped with VHF and HF communications equipment, the aircraft was able to communicate with ground stations during the over-water flight from PUS to GUM. When the typhoon changed its course, however, the aircraft was not able to check for the up-to-date weather conditions at GUM in a timely manner because it was flying in the VHF ACARS[25] blind area, as shown in [Figure 7].

25) The Aircraft Communications Addressing and Reporting System (ACARS) is a digital data-link system that provides data communication between an airplane and ground stations. ACARS transmits various data including flight information such as flight departure/arrival and boarding gate.



[Figure 7] VHF ACARS Blind Area

When HL8224 communicated with Guam Approach Control, Guam Departure Control, and Agana Tower to approach and land, no communication problems were noted. The transcript[26] from the recorded voice communications between HL8224 and ATCs is summarized in [Table 4].

26) Only the voice communications relevant to the determination of the probable cause are selected and contained in [Table 4].

Transmi-ssion Time	Trans-mitter	Contents of Transmission
16:28:14.2	F/O	GUAM center, KE2115. Request direct to MEMKE
16:28:19.7	APP	KE2115, turn left direct to MEMKE
16:28:22.1	F/O	Left turn direct to MEMKE, KE2115
16:33:35.3	APP	KE2115, cross MEMKE at or above 3000 clear straight in ILS RWY 6R approach
16:44:27.1	APP	KE2115, contact tower 118.1 good day
16:44:31.4	F/O	118.1, good day, KE2115
16:44:44.9	F/O	AGANA tower, KE2115. Established ILS 6R
16:44:51.5	TWR	KE2115, AGANA tower, RWY 6R wind 320 at 9 gust 19 and wind variable 320 to 360. RWY 6R cleared to land
16:45:08.8	F/O	Cleaed to land RWY 6R, KE2115
16:45:14.6	TWR	And we have heavy rain at the airport. This time RWY wet no brake action report
16:46:28.3	TWR	??? Wind 320 at 13
16:46:32.9	F/O	320 at 13, KE2115
16:47:47.2	TWR	Wind 350 at 10
16:47:50.9	F/O	KE2115
16:48:41.0	TWR	Wind 320 12
16:49:22.4	TWR	KE2115, RWY heading 2600 contact GUAM departure
16:49:27.2	F/O	RWY heading 2000 and contact AGANA departure?
16:49:32.8	TWR	??? Climb and maintain 2600
16:49:38.5	F/O	KE2115, going around, say again?
16:49:42.0	TWR	Contact GUAM departure 118.7
16:49:46.3	F/O	Roger, 118.7, KE2115
16:50:05.9	F/O	GUAM departure, KE2115. maintain RWY heading 2000
16:50:13.0	DEP	KE2115, GUAM departure. Radar contact climb and maintain 3000 when able turn right heading 150
16:50:21.6	F/O	Climb and maintain 3000 when able right turn, Confirm 350?
16:50:27.6	DEP	KE2115, negative. When able turn right heading 150
16:50:34.3	F/O	Roger, Climb 3000 when able right turn 150, KE2115
16:51:57.6	CAP	GUAM center uh departure, KE2115
16:52:01.6	DEP	KE2115, go ahead, sir
16:52:03.1	CAP	Execute missed approach due to RWY not in sight due to heavy rain, request another approach
16:52:09.4	DEP	KE2115, roger sir, turn right heading 240
16:52:13.7	CAP	Right turn heading 240, 3000, KE2115

Transmi-ssion Time	Trans-mitter	Contents of Transmission
16:57:50.2	DEP	KE2115 company B737 this time reporting braking action FAIR, on final heavy rain, and no turbulence
17:00:59.8	DEP	KE2115 6 miles from SEGMU turn right heading 035, maintain 2600 ?? Localizer cleared ILS RWY 6R approach
17:01:09.8	F/O	Right heading 035, 2600 cleared ILS RWY 6R approach KE2115
17:02:02.4	DEP	KE2115 roger, contact TWR 118.1, sir
17:02:06.5	F/O	118.1, KE2115
17:02:49.4	F/O	AGANA tower, KE2115, ILS 6R
17:02:55.4	TWR	KE2115, AGANA tower. RWY 6R, wind 010 at 9 gust 17
17:03:03.4	TWR	Cleared to land, braking action report is FAIR by B737. He broke out at one mile 600 feet
17:03:38.8	TWR	KE2115, wind variable at 010~320 12 knots to 17 knots
17:03:52.5	F/O	Roger, KE2115, confirm cleared to land?
17:03:57.9	F/O	AGANA tower, KE2115, confirm cleared to land?
17:04:00.9	TWR	Right, cleared to land
17:04:03.9	F/O	Roger, cleared to land 6R, KE2115
17:04:07.4	TWR	Wind now 350 at 8
17:04:13.2	F/O	Roger, KE2115
17:04:38.0	TWR	Wind 350 13
17:05:14.8	TWR	Wind 320 at 14
17:05:48.0	F/O	AGANA tower, KE2115, stop on the runway
17:05:53.4	TWR	You stopping on the runway, understand?
17:05:56.4	F/O	Roger
17:05:57.6	TWR	Uh, you need a assistance
17:06:01.9	F/O	Roger, okay, KE2215, request emergency equipment
17:06:09.5	TWR	2115, roger, stand by
17:06:11.9	F/O	Stand by
17:06:13.7	TWR	Say your nature of emergency, please?
17:06:16.5	CAP	Stand by
17:06:54.0	TWR	KE2115, Are you still on the runway?
17:06:58.2	CAP	Affirm. We are still on the runway request towing unable to taxi
17:07:04.2	TWR	I say again you need tow?
17:07:06.1	CAP	Affirm
17:07:07.5	TWR	Do you require any other assistance besides the tow?
17:07:10.7	CAP	Ah- right now is uh- just stand by for emergency equipment

Transmi-ssion Time	Trans-mitter	Contents of Transmission
17:08:01.3	TWR	KE2115, AGANA tower
17:08:03.1	CAP	Ah- just confirm towing and emergency equipment and check our aircraft, please
17:08:09.7	TWR	We have called them and we towing arrange right now and you want ??? check your aircraft, is that correct?
17:08:16.5	CAP	Yes sir, check our aircraft
17:08:19.1	TWR	Roger

※ F/O: first officer, CAP: captain, DEP: Guam Departure Control, TWR: Agana Tower

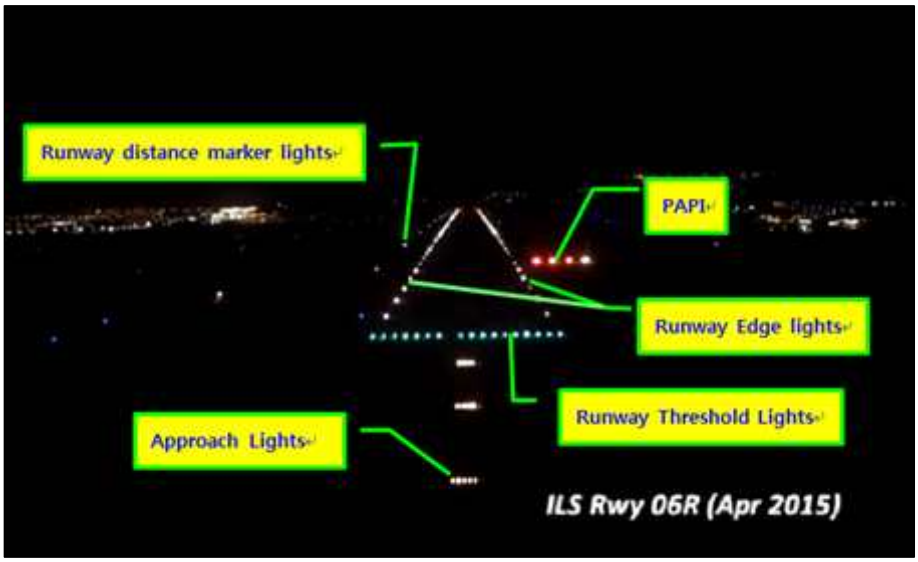
[Table 4] Voice Communications Between HL8224 and ATCs

1.10 Airport Information

The A.B. Won Pat Guam International Airport has two parallel runways: runway 6R/24L and runway 6L/24R. Runway 6R/24L is 3,052 meters long and 46 meters wide, and runway 6L/24R is 3,662 meters long and 46 meters wide. The threshold elevation of runway 6R is 231 ft but rises to 301 ft at the end of the runway, and the runway has a gradient of 0.7% up, paved with asphalt and concrete.

Runway 6R was not equipped with runway centerline lights, and other lighting system is shown in [Figure 9]. Runway 6R is mainly used for landing, whereas a longer runway 6L is mainly used for takeoff.

[Figure 8] Overview around GUM



[Figure 9] Runway 6R Lighting System

A Notice to Airmen (NOTAM) issued at a time when HL8224 was operated is shown in [Figure 10]. The NOTAM stated that the runway 6L ILS was unserviceable from 24 February to 31 December 2015, and that the runway 6L approach light system (ALS) was unserviceable from 2 to 6 July 2015.

■ RUNWAY
25JUN15 09:01 - 31AUG15 07:00 PGUM A0227/15
E) RWY 06L: TORA 11015FT TODA 11015FT ASDA 11015FT LDA 11015FT
RWY 24R: TORA 11015FT TODA 11015FT ASDA 11015FT LDA 11015FT)

■ APPROACH
26JUN15 03:19 - 23DEC15 03:19 PGUM A0235/15
E) ILS OR LOC RWY 6L, AMDT 4... PROCEDURE NOT AUTHORIZED.)

24FEB15 22:07 - 31DEC15 23:59 PGUM A0096/15
E) RWY 06L ILS U/S)

24AUG12 23:57 - UFN PGUM A0298/12
E) NAV ILS RWY 6R DME UNUSBL BYD 20 DEGREES RIGHT OF COURSE)

09APR12 20:33 - UFN PGUM A0156/12
E) ILS RWY 06L UNMONITORED)

■ APPROACH LIGHT
02JUL15 00:56 - 06JUL15 23:59 PGUM A0243/15
E) RWY 06L ALS U/S)

[Figure 10] GUM NOTAM

1.11 Flight Recorders

As shown in [Figure 11], HL8224 was equipped with flight recorders.

[Figure 11] FDR and CVR

1.11.1 Flight Data Recorder

Data retrieved from HL8224's FDR confirmed the following:

○ At 17:02:18 (3 minutes 8 seconds before landing), about 10.5 miles from runway 6R, HL8224 was flying at 3,020 ft at an airspeed of 183 kts, weighting about 60,237 kg.

○ At 17:02:30 (2 minutes 30 seconds before landing), about 9.75 miles from runway 6R, HL8224 was flying at 3,015 ft at an airspeed of 183 kts.

○ At 17:04:44 (42 seconds before landing), HL8224 with the autopilot disengaged was flying at 760 ft RA at an airspeed of 148 kts when V_{app} was 146 kts.

○ At 17:04:46 (40 seconds before landing), the autothrottle was disengaged, and wind was from 315° at 20 kts.

○ At 17:05:26 (landing), HL8224 was on a heading of 58° at an airspeed of 140 kts. The bank angle of HL8224 was at 3.2° to the right just before landing, then changed to 0.4° to the left on landing. As shown in [Figure 12], the aircraft touched down at E144°47'23.48" N13°28'45.10", 2,000 ft past the runway 6R threshold.

[Figure 12] HL8224 Touchdown Point

1.11.2 Cockpit Voice Recorder

HL8224 was equipped with the solid-state CVR that records the audio environment in the flight deck of an aircraft by digitally recording the signals of the microphones of the captain and the FO, and of an area microphone and a backup microphone in the cockpit. The ARAIB, using the manufacturer's equipment, retrieved 2 hours of audio information from 2 input channels, and 30 minutes from 4 input channels.

The CVR recorded the 120-minute data which started at 16:09:40, about 56 minutes and 10 seconds before HL8224's landing, and the ARAIB listened to the whole data and transcribed a segment necessary for investigation.

1.12 Wreckage and Impact Information

As HL8224 veered off the runway and ran through grass, the aircraft engine and part of the fuselage sustained damage, and two runway edge lights, two taxiway lights, and a taxiway D sign were damaged, as shown in [Figure 13].

[Figure 13] Airport Facilities Damage

1.13 Medical and Pathological Information

Medical and pathological aspects are not related to this serious incident.

1.14 Fire

As a result of this serious incident, no fire occurred.

1.15 Survival Aspects

After HL8224 managed to return to the runway centerline, the captain conducted a cabin inspection with the purser (or cabin manager) to prepare for a possible fire, and the Guam Airport Rescue and Firefighting (ARFF) personnel and Korean Air mechanics performed an exterior inspection. An evacuation was not initiated since there was no sign of fire as a result of runway excursion, and the aircraft was towed to the ramp in consideration of safety.

1.16 Tests and Research

No tests and research were conducted in relation to this serious incident.

1.17 Organizational and Management Information

1.17.1 Flight Plan

1.17.1.1 Fuel Plan

The flight and fuel plans of HL8224 which took off from PUS bound for GUM are summarized in [Table 5].

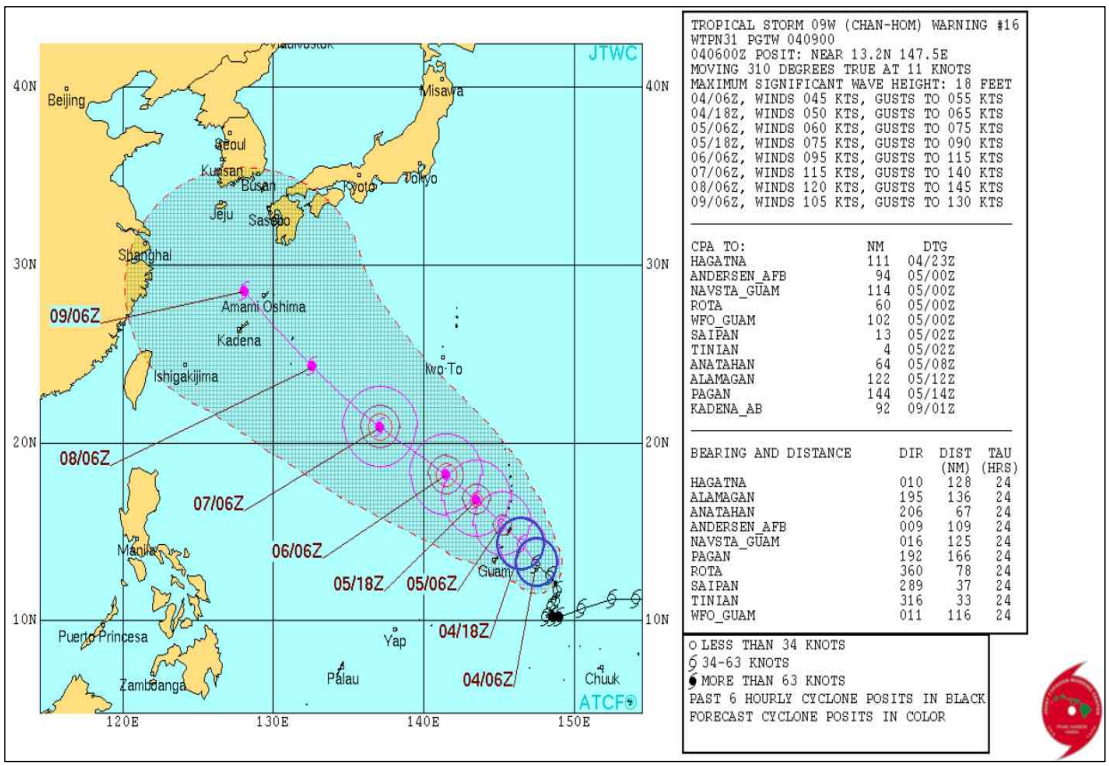
[unit: lbs]

Estimated Flight Time	3 hrs 39 min	Estimated Fuel Consumption	20,900
Flight Time to Alternate Airport	3 hrs 17 min	Estimated Fuel Consumption	16,400
Required Fuel Time	7 hrs 38 min	Required Fuel	40,600
Extra Fuel Time	48 min	Extra Fuel	4,000
Total Fuel Time	8 hrs 27 min	Total Fuel	44,600[27)]

[Table 5] Flight and Fuel Plans

At the time of the serious incident, Chan-Hom, the ninth typhoon of this year, was approaching GUM, as shown in [Figure 14].

27) Total fuel excluding taxi fuel of 500 lbs.



[Figure 14] Estimated Path of Chan-Hom

A person in charge of weather in Korean Air's Operations Control Center (OCC) expected that the typhoon would be located about 130 nautical mile (nm) eastnortheast of Guam on 5 July, approximately 03:00 local time, when HL8224 was expected to arrive at GUM. Therefore, the dispatcher in charge of HL8224's flight plan, taking into account the radius of maximum wind of 80 nm, expected that the typhoon would indirectly affect GUM and planned a normal operation.

Notwithstanding, as shown in [Figure 5], when fuel planning, he loaded about additional 4,000 lbs of fuel, including 500 lbs of CCF,[28] to prepare for adverse weather resulting from the typhoon.

28) Company Compensation Fuel (CCF) is fuel which the company additionally loads to compensate for repeatedly over-consumed fuel calculated as a result of analyzing a fuel consumption tendency for the last 45 days.

1.17.1.2 Alternate Airport

When flight planning, Korean Air's dispatcher normally assigns Saipan International Airport (SPN) as an alternate airport of GUM. The distance, flight time on a B737-800 airplane, and fuel consumption from GUM to SPN are 165 nm, 34 minutes, and 3,400 lbs, respectively.

However, the dispatcher not only assigned Kansai International Airport (KIX), 1,423 nm from GUM, as an alternate airport but also loaded additional fuel to prepare for unexpected adverse weather because SPN was expected to be indirectly affected by the typhoon on HL8224's arrival.

The reason for selecting KIX, which is farther from GUM than SPN, as an alternate airport was that the dispatcher considered SPN an unsuitable location for an alternate aircraft because it was expected to be affected by the approaching typhoon at the time.

1.17.1.3 Flight Crew Schedule

According to the flight crew schedule, the day before the event, the captain and the FO had a day off, and on the day of the event, they operated a domestic flight from Gimpo International Airport (GMP) to PUS, then an international flight from PUS to GUM. After the PUS-GUM flight, they were supposed to stay overnight in Guam and the next day, to operate an international flight from GUM to KIX to Jeju International Airport.

In the 90 days before the event, except for 75 flight hours in May, the captain had accumulated 50 flight hours or so per month, as other B737 captains had. The reason for a surge in May was that flights were unexpectedly added in the process of the air carrier's turning to smaller type airplanes due to a

decrease of passengers resulting from the outbreak of Middle East Respiratory Syndrome (MERS). In addition, the FO had accumulated 55 flight hours per month, slightly more than average monthly flight hours of other B737 FOs.

The captain and the FO conducted three flights and one flight to GUM in 2015, respectively. As GUM was designated as an airport with risk factors, Korean Air's B737 team put limitation on flight hours and gave a GUM flight only to the pilot-in-command (PIC) with more than 500 flight hours. In the case of the captain, he had logged 749 hours since his promotion to a B737 PIC.

1.17.2 Pilot Manuals on Crosswind Landing

Korean Air specified considerations according to runway braking action, wind limitations, and crosswind landing techniques in the Flight Operations Manual (FOM), Flight Crew Reference Manual (FCRM), and Flight Crew Training Manual (FCTM), and the flight crew have applied the relevant portions of the manuals to their flights.

1.17.2.1 Flight Operations Manual

Before landing, the PIC should consider the following to reduce the landing distance: make a firm landing in the touchdown zone, and immediately after touchdown, deploy the reverser and ground spoilers to the maximum.

The PIC should compare the braking action reported by ATC with those in [Figure 15], and for example, if the reported braking action is "Medium to Poor," the PIC should apply a worse braking action "Poor."

Estimaed Surface Friction Code(ICAO)	Runway Condition Description	Mu(μ)[1]	RCR[2]	Deceleration And Directional Control Observation	Reported Braking Action
6	• Dry				Dry
5	• - RA, • RA (Grooved or PFC Runway)[3] • Frost, • Damp, • Wet 3mm (1/8 inch) or less: • Water, Slush, Dry Snow, Wet Snow	0.4 or higher	At or above 13	Braking deceleration is normal for the wheel braking effort applied. Directional control is normal.	Good
4	At or below -15°C OAT • Compacted Snow	0.39 ~ 0.36	12	Brake deceleration and controllability is between Good and Medium.	Good to Medium
3	• RA (Smooth Runway) [4] • Slippery when Wet [5] Greater than 3mm (1/8 inch): • Dry Snow – max 100 mm (4 inch) [6] • Wet Snow – max 25 mm (1 inch) [6] Above -15°C OAT and at or below -3 °C OAT • Compacted Snow	0.35 ~ 0.30	11 ~ 10	Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be noticeably reduced.	Medium
2	• Heavy Rain Greater than 3 mm (1/8 inch): • Water or Slush – max 13 mm (1/2 inch) [6]	0.29 ~ 0.26	9 ~ 8	Brake deceleration and controllability is between Medium and Poor. Potential for hydroplaning exists.	Medium to Poor
1	• Ice Above -3 °C OAT • Compacted Snow	0.25 ~ 0.21	7	Braking deceleration is significantly reduced for the wheel braking effort applied. Directional control may be significantly reduced.	Poor

[Figure 15] Runway Conditions and Braking Actions

According to FOM, Chapter 4, Section 5, wind data provided by the control tower shall be used for landing, and if there is a gust wind, this shall be applied as the max wind. Wind limitations for takeoff and landing are shown in [Figure 16].

Braking Action			
Good (cross wind / tail wind)	**Medium (or fair) (cross wind / tail wind)**	**Poor (cross wind / tail wind)**	**Nil**
30 / 10 kts	20 / 5 kts	Takeoff: 8 kts / NA Landing: 10 kts / NA	NA

Note: The NA means Not Authorized.

- B737 is certified of tailwind 15kt for takeoff and landing in AFM. Tailwind 15kt limitation can be applied only to specified airports by company. Refer to FOM 5.8 - Airport Restrictions for the relevant information. <CLICK>
- For auto-landing wind limitations, refer to Autopilot/Flight Director System.

[Figure 16] Wind Limitations for Takeoff and Landing

According to FOM, Chapter 6, Section 8, although the PF has made a decision to land, the PF himself or PM, if "Go-around" is considered necessary, shall immediately make a callout "Go-around," and the PF shall immediately execute a go-around.

The PIC shall attempt a go-around in the following cases:

- if there is concern about the safety of landing for certain reasons including adverse weather;
- if stabilized approach requirements are not expected to be met or a continuous stabilized approach is considered impossible; and
- if a safe touchdown in the touchdown zone is impossible or a safe stop on the remaining runway after touchdown is doubtful.

Reapproach after a missed approach resulting from bad weather rests on the PIC's decision, and after a second missed approach, the PIC shall consider diverting. However, if weather conditions, according to the weather report, are expected to make a notably desirable change and if there is remaining fuel enough to make a safe landing possible, the PIC can attempt another approach.

1.17.2.2 Flight Crew Reference Manual

According to the FCRM, Chapter 3, Section 1, crosswind landing guidelines are as follows:

- Throughout the approach, flare, and touchdown, wings should be maintained level.
- Just before touchdown, downwind rudder should be applied to align the aircraft longitudinal axis with the runway centerline.
- The early application of the de-crab[29] technique may cause the aircraft to drift towards the downwind side due to an effect of crosswind.

29) The objective of de-crab is to align the aircraft longitudinal axis with the runway centerline by applying the downwind rudder.

- The change in the aircraft position resulting from the use of the rudder generates more lift on the upwind wing, developing roll to the downwind side. Thus, to keep the wings level, upwind aileron application should be utilized.
- The application of opposite rudder and aileron while de-crabbing may cause the aircraft to sink in proportion to the amount of de-crab.

Procedures of correcting for drift[30] at cross wind landing are as follows:

- First of all, rudder and aileron pressure should be corrected by a small amount to stop drift and align with the runway centerline.
- Insufficient aileron application while de-crabbing may cause the aircraft to drift towards the downwind side.
- De-crabbing should be stopped until touchdown, and take corrective actions by changing the aircraft's bank angle within 5°.
- Although the aircraft is not slightly aligned with the centerline, maintain the current longitudinal axis of the aircraft if a safe landing is considered possible.
- As a corrective action, a crab angle should not be increased to the downwind side.
- Immediately execute a go-around if drift is not corrected or a safe landing is considered impossible.

1.17.2.3 Flight Crew Training Manual

The B737 manufacturer's FCTM, Chapter 6, page 47, "De-crab During Flare," states as follows:

The objective of this technique is to maintain wings level throughout the approach, flare, and touchdown. On final approach, a crab angle is established

30) Drift is the lateral shift of the aircraft from the runway centerline caused by crosswind on landing.

with wings level to maintain the desired track. Just prior to touchdown while flaring the airplane, downwind rudder is applied to eliminate the crab and align the airplane with the runway centerline.

As rudder is applied, the upwind wind sweeps forward developing roll. Hold wings level with simultaneous application of aileron control into the wind. The touchdown is made with cross controls and both gear touching down simultaneously. Throughout the touchdown phase upwind aileron application is utilized to keep the wings level.

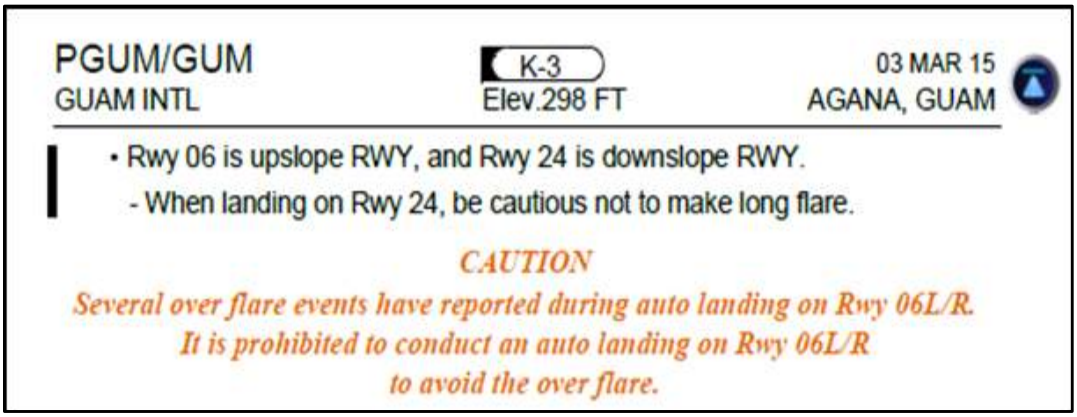
1.17.3 K-File's Prohibition of Auto Landing

The operations division of Korean Air produced a K-File, one of whose goals is to provide its flight crew with information on airports the company flies to. Through this K-File, the flight crew familiarize themselves with their destination airports.

According to the "CAUTION" specified in the K-File valid at the time of the serious incident, several over flare events have been reported during auto landing on runway 06L/R since runway 06 is an upslope runway, and thus, it is **prohibited** to conduct an auto landing on runway 06L/R to avoid the over flare.

The K-File in 2009 stated that several over flare events have been reported during auto landing on runway 06L/R, and thus, it is **not recommended** to conduct an auto landing on runway 06L/R to avoid the over flare.

Later, in the revised 2013 June edition, a previous passage "it is not recommended to conduct an auto landing" was revised to "it is prohibited to conduct an auto landing."



[Figure 17] Information on GUM

1.17.4 Flight Crew Training

The captain received his captain upgrade training on 10 April 2014 and his line check on 28 April 2015.

The evaluation results of the captain's upgrade training said that, on the final approach, the captain moved the thrust lever a bit excessively to maintain V_{app}, and the evaluation results of the captain's line check stated that he did not make a soft landing because he decreased power early when the aircraft was heavy in a crosswind situation.

1.18 Additional Information

Not applied.

2. Analysis

2.1 General

Analysis of this serious incident was carried out based on the following factual information: FDR data; flight plan provided to the captain; the captain's flight operation during landing; information on weather conditions at GUM; information on GUM; and flight crew training data.

2.2 Flight and Fuel Planning

The dispatcher in Korean Air's OCC expected that the typhoon, whose maximum wind radius is 80 nm, would be located about 130 nm eastnortheast of Guam by the time of HL8224's arrival, and therefore, planned a normal operation. Also, he assumed no problems with the flight operation because he expected that GUM would only be indirectly affected by the typhoon.

When planning, the dispatcher decided to load about additional 4,000 lbs of fuel to prepare for unexpected adverse weather resulting from the typhoon. The ARAIB concludes that this extra fuel was loaded to prepare for adverse weather because, in many cases, actual weather conditions have been different from weather forecasts due to the effect of a typhoon.

Normally, the dispatcher plans to load extra fuel in anticipation of the selection of an airport under the influence of the same adverse weather conditions as an alternate airport, of a possible change of a flight route due to en-route adverse weather, or of longer holding due to heavy air traffic. This extra fuel is an important determinant of whether the flight crew decide to proceed with the flight in an abnormal situation.

2.3 Effect of Changing an Alternate Airport

When a dispatcher prepares a flight plan for GUM, SPN is normally assigned as an alternate airport. The distance between GUM and SPN is 165 nm, which can be covered by B737-800 for about 34 minutes, with 3,400 lbs of fuel consumption.

The dispatcher of the event flight, when preparing HL8224's flight plan, assigned KIX as an alternate airport, instead of SPN. The ARAIB concludes that the reason why he selected KIX, 1,423 nm away from GUM, at the time is that he thought the approaching typhoon would affect SPN as well as GUM.

If HL8224 had diverted to KIX, about 16,400 lbs of fuel would have been consumed. If there had been no problem with the assignment of SPN as an alternate airport in spite of HL8224's possible holding or missed approach resulting from adverse weather, SPN would have been the alternate, meaning that HL8224 would have had 13,000 lbs of extra fuel.

On a first missed approach, HL8224 loaded with an additional 4,000 lbs of fuel consumed about 1,500 lbs of fuel, and under the circumstances, if the aircraft had missed a second approach, it might have diverted to KIX because of no possibility of reapproach or holding.

Although SPN was under the influence of the typhoon, the dispatcher should have prepared an alternative flight plan designating SPN as an alternate. In addition, the captain and the FO stated that they could not consider diverting to SPN, but if they had made more preparations for SPN diversion, including a check on weather conditions, they could have landed or executed a go-around, with no concern about holding because there was an additional 13,000 lbs of fuel.

2.4 Runway Condition and Crosswind Effect

During HL8224's landing on runway 6R, heavy rain was reported as shown in [Table 6].

METAR 041601 30009KT 2SM RA BR SCT004 BKN009 OVC014 25/25 A2949
METAR 041645 31009KT 1SM +RA BR VV008 25/25 A2949
METAR 051654 31009KT 1 1/4SM +RA BR OVC010 25/25 A2947
METAR 051719 30011KT 1SM +RA BR VV009 25/25 A2949

[Table 6] Weather Conditions During Landing at GUM

At the time, there were no runway braking coefficients which were actually measured, but as the runway was covered with a lot of water due to heavy rain, this report assumed the braking action to be "Poor," and based on this assumption, analyzed crosswind conditions on landing.

According to the B737 Pilot Operation Manual (POM), crosswind limitation for landing is 10 kts. As shown in [Table 6], winds, when HL8224 was landing on runway 6R, were from 310° at 9 kts and from 300° at 11 kts, and a 90-degree crosswind at about 8 to 9 kts. Therefore, although the braking action was assumed to be Poor, the crosswind was within its limitation of 10 kts.

2.5 Flight Crew Schedule

2.5.1 Monthly Flight Hours of the Flight Crew

According to the flight crew's schedule, the day before the event, the captain and the FO had a day off, and on the day of the event, operated a domestic flight from GMP to PUS, then an international flight from PUS to GUM.

In the 90 days before the event, except for 75 flight hours in May, the captain had accumulated 49 and 50 flight hours in June and July, respectively, which are the same as other B737 captains' average flight hours of 50 per month. The reason for a surge in May was that flights were unexpectedly added as the air carrier turned to smaller type airplanes with low fuel consumption and operational cost, including landing and ground handling fees, due to a decrease of passengers resulting from the outbreak of MERS.

In addition, in the 90 days before the event, the FO had accumulated about 55 to 57 flight hours on average, slightly more than other B737 FOs' average flight hours of 50 per month. Therefore, his flight schedule was not considered demanding or hectic.

2.5.2 Experience of Flying to GUM

The captain and the FO conducted three flights and one flight to GUM in 2015, respectively. As Korean Air's B737 team designated GUM as an airport with risk factors, the team put limitation on the flight crew's flight hours.

In this regard, the team has given a GUM flight only to the PIC with more than 500 flight hours to ensure the safety of operations. Likewise, flights to special airports like Da Nang and Langkawi International Airports have been also given to the PIC with more than 500 flight hours.

However, the reason why the B737 team autonomously put flight hours limitation on GUM which is not a special airport is that the team believes that it is more difficult to land at GUM than other airports.

Korean Air's flight crew scheduler has entered each type's flight hours limit per special airport into the Aircrew System[31] and prepared a monthly flight

31) A computer program designing monthly flight schedules of the flight and cabin crew members. If limits

crew schedule. The ARAIB concludes that this kind of scheduling aims to minimize the problems arising in the course of operations by assigning the flight crew with a lot of experience and flight hours to special airports.

2.6 Flight Maneuvers on Landing

During his landing briefing, the captain stated as follows: runway 6R is in use; moderate rain; wind from 300° at 9 kts and gust at 19 kts; runway 6R is not equipped with runway centerline lights; and due to the ban on auto landing, manual landing is performed.

According to the CVR recording, while on the initial ILS approach to runway 6R, the captain disengaged autopilot and autothrottle at about 600 ft and continued to approach after visually verifying the runway at about 500 ft.

Descending through 300 ft RA, the FO stated the aircraft was slightly to the right of the localizer, descending through 200 ft RA, the FO called the aircraft was slightly below glideslope, and descending through 100 ft RA, the FO advised the aircraft was slightly above glideslope. Judging by this fact, the ARAIB concludes that the captain was unable to maintain the airplane in the center of the flight director (F/D) until the end of the runway (at 50 ft RA) after visually verifying the runway on the initial approach.

HL8224 continued to descend, and descending through 30 ft RA, the captain performed go-around procedures normally, was given radar vector of Guam Departure Control, and requested an ILS approach to runway 6R again.

While climbing up to 3,000 ft, the captain said to the FO that he could not land because he was unable to visually verify the runway even with the windshield

by airport, route, and type are entered into the system, these limits are automatically applied when schedules are generated.

wipers at a maximum speed, immediately before landing. Judging by this fact, the ARAIB concludes that the captain was unable to align the aircraft with the runway centerline in heavy rain and that he executed a go-around at 30 ft RA because he probably believed landing was impossible.

While on the second approach, the captain found that Korean Air flight 733 (B737-800) had landed, and Guam Departure Control provided him with flight 733's pilot report on weather conditions.

According to the pilot report, weather conditions at the time of the event were as follows: runway visible at 600 ft; visibility 1 mile; braking action FAIR; and on final heavy rain and no turbulence. The captain and the FO both confirmed this report and prepared for approach in accordance with the landing checklist.

Agana Tower gave HL8224 a landing clearance and a weather report of winds from 350° at 13 kts. When the FO called 500 ft, the captain immediately called out the runway in sight and disengaged autopilot and autothrottle.

When an electronic voice announced "minimums," the captain decided to land, calling the aircraft was stabilized. Descending through 150 ft RA, the FO called the aircraft was below glideslope, and descending through 100 ft RA, called out four reds.

For landing, the captain paid a lot of attention to visual references outside and failed to maintain the aircraft in the center of the F/D. Descending through 100 ft RA, the FO called out four reds as he spotted PAPI outside. HL8224 crossed the runway threshold at 28 ft RA, and judging by the fact that the aircraft on glideslope normally crosses the threshold at 50 ft RA, the ARAIB concludes that HL8224 was not that below glideslope.

When crossing the runway threshold, HL8224 maintained the runway centerline, flying at 28 ft RA at an airspeed of 155 kts, 9 kts above V_{app} of 146 kts. Passing through 20 ft RA, the captain felt the aircraft was sinking, so he over flared, caused the aircraft to float, and finally touched down about 2,000 ft past the runway threshold.

Just before touchdown, crosswind from the left caused the aircraft to veer right and touch down on the right hand edge of the runway about 2,000 ft past the runway threshold. Judging by the fact that the FO advised the captain twice to steer the aircraft left after touchdown, the ARAIB concludes that they probably did not recognize that the aircraft would touch down at the right hand edge of the runway.

The ARAIB concludes that the reason why HL8224 touched down at the right hand edge of the runway while veering right under the influence of crosswind from the left at a low altitude was that the captain failed to apply not only upwind aileron sufficiently to prevent the aircraft from veering right but also downwind rudder adequately to align the aircraft longitudinal axis with the runway centerline.

The captain probably felt pressure to succeed in landing because weather conditions in GUM were above the landing minimum requirements and because the previous flight 733 made a safe landing, otherwise a diversion to KIX would have been necessary.

The aircraft started to veer right about 2,200 ft past the runway threshold and departed the paved surface of the runway. Both main landing gears were completely off the runway about 3,000 ft past the runway threshold before the aircraft reentered the runway abut 4,400 ft past the runway threshold. Judging by this fact, the ARAIB believes that, immediately after touchdown, the captain failed to steer the aircraft back towards the centerline.

The ARAIB concludes that the captain was unable to recognize the aircraft's touchdown point was not appropriate. In this regard, Korean Air should emphasize to its flight crew that go-around shall be executed when a safe landing is impossible.

2.7 Auto Landing at GUM

Korean Air's K-File in 2009 stated that several over flare events have been reported during auto landing on runway 06L/R, and thus, it is not recommended to conduct an auto landing on runway 06L/R to avoid the over flare. Later, in the revised 2013 June edition, a previous passage "it is not recommended to conduct an auto landing" was revised to "it is prohibited to conduct an auto landing."

The captain, in accordance with the ban on auto landing in the revised K-File, made a manual landing in night conditions and heavy rain under the influence of the typhoon.

After this serious incident, Korean Air conducted four test flights on B737, B777, and B744 each, performing an auto landing at GUM, and analyzed those flight data, based on which the company deleted, from the K-File in 16 September 2015, the passage: it is prohibited to conduct an auto landing on runway 06L/R to avoid the over flare.

2.8 Flight Crew Training

The ARAIB reviewed the records of the flight crew training, including recurrent, captain upgrade, and simulator training.

The evaluation results of the captain's upgrade training on 10 April 2014 said that, on the final approach, the captain moved the thrust lever a bit excessively to

maintain V_{app}.

The evaluation results of the captain's line check on 28 April 2015 stated that he did not make a soft landing because he decreased power early when the aircraft was heavy in a crosswind situation.

The ARAIB believes that those items have been commonly pointed out during previous training evaluation, but judging by this serious incident, concludes that Korean Air needed to enhance simulator training by increasing focus on various situations involving weather conditions, braking action, etc.

Korean Air specified considerations according to runway braking action, wind limitations, and crosswind landing techniques in the FOM, FCRM, and FCTM, and familiarized its flight crew with them during recurrent training.

A review of the B737 simulator training curriculum revealed that the company has regularly provided the flight crew with training on crosswind landing in adverse weather conditions, but needed to train them in the B737 simulator in order for them to land the aircraft safely in more various difficult conditions like low ceiling, low visibility, slippery runway, and crosswind.

The ARAIB concludes that Korean Air needed to enhance simulator training by training the flight crew in various difficult conditions like poor braking action, slippery runway, etc.

3. Conclusions

3.1 Findings

1. HL8224 touched down on the right hand edge of runway 6R about 2,000 ft past the runway threshold, then started to veer right about 2,200 ft past the runway threshold and departed the paved surface of the runway. Both main landing gears were completely off the runway about 3,000 ft past the runway threshold before the aircraft reentered the runway about 4,400 ft past the runway threshold and came to a stop.

2. As HL8224 veered off the runway and ran through grass, the aircraft engine and part of the fuselage sustained damage, and two runway edge lights, two taxiway lights, and a taxiway D sign were also damaged.

3. The flight crew held a valid airman certificate and airman medical certificate, and did not take any illegal medication that could have affected the flight.

4. The flight was operated within the allowable range of weight and balance.

5. The captain had accumulated 7,933 total flight hours, including 1,884 hours in B737. He was appointed as B737 captain on 18 April 2014 and had logged 749 hours in B737 as PIC.

6. The captain and the FO conducted three flights and one flight to GUM in 2015, respectively. Korean Air's B737 team put limitation on flight hours and gave a GUM flight only to the PIC with more than 500 flight hours.

7. When flight planning, Korean Air's dispatcher not only assigned KIX, farther than SPN, as an alternate airport but also loaded additional fuel to prepare for

unexpected adverse weather because SPN was expected to be indirectly affected by the typhoon.

8. Weather conditions when HL8224 landed at GUM were as follows: runway visible at 500 ft; visibility 1 mile; braking action FAIR; heavy rain, no turbulence, and crosswind at 8 to 9 kts.

9. When reporting braking action according to the FAA of the United States, any of the following terms may be used: GOOD; FAIR (or MEDIUM); POOR; and NIL. The flight crew apply crosswind limitations for landing specified in the B737 POM, and according to POM, if the braking action is reported as FAIR and POOR, the crosswind limitation is 20 kts and 10 kts, respectively. Therefore, the crosswind at the time of the event was within its limitation for landing.

10. The captain, in compliance with the ban on auto landing on GUM runway 06L/R, as specified in Korean Air's K-File, made a manual landing in night conditions and heavy rain under the influence of the typhoon.

11. During the first landing, the captain executed a go-around because he was unable to visually verify runway 6R. During the second landing, he landed the aircraft manually in adverse weather conditions, but after touchdown, both main landing gears were completely off the runway, reentered the runway, and came to a stop.

12. The aircraft was designed to land automatically, and GUM also had landing and approach procedures enabling auto landing of the aircraft.

13. Korean Air needed to train its flight crew in the B737 simulator in order for them to land the aircraft safely in more various difficult conditions like low ceiling, low visibility, slippery runway, and crosswind.

3.2 Probable Cause

The ARAIB determines that the probable cause of the serious incident was ① the captain's inappropriate judgement while landing on runway 6R at Guam International Airport at night with heavy rain under the influence of a typhoon, which led to a runway excursion; and ② the captain's decision to continue to land instead of executing a go-around although visual references were not established.

4. Safety Recommendations

As a result of this investigation, the ARAIB makes the following safety recommendations:

4.1 To Korean Air

1. Reemphasize to your flight crew that go-around shall be executed if a safe landing is impossible because visual references are not established during landing in adverse weather conditions. (AIR-1505-1)

2. Take measures to provide your flight crew with a more enhanced simulator training to ensure that they can land the aircraft safely in difficult conditions like low ceiling, low visibility, slippery runway, and crosswind. (AIR-1505-2)