Ministry of Land, Infrastructure and Transport

ARAIB/AAR-1903

Aircraft Accident Report

Crash into the sea during takeoff climbing
The National 119 Rescue Headquarters
EC225LP, HL9619
The East Sea near Dokdo, Ulleung-gun, Gyeongsangbuk-do
October 31, 2019

Aviation and Railway Accident Investigation Board

This aircraft accident report is prepared following Article 25 of the Aviation and Railway Accident Investigation Act of the Republic of Korea.

Article 30 of the Act stipulates the following.

> Accident investigations shall be separated from and conducted independently from judicial proceedings, administrative disposition procedures, or administrative contestation procedures related to civil or criminal liability.

Also, Annex 13 to the Convention on International Civil Aviation states in Paragraphs 3.1 and 5.4.1, respectively 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 purposes than to improve aviation safety.

In case of any divergent interpretaion of this report between the Korean and English versions, the Korean text will prevail.

Aircraft Accident Report

Aviation and Railway Accident Investigation Board, crash into the sea during takeoff climbing, the National 119 Rescue Headquarters, EC225LP, HL9619, October 31 2019, aircraft accident report, ARAIB/AAR1903, Sejong City, Republic of Korea

The Aviation and Railway Accident Investigation Board (ARAIB), Republic of Korea, is a government organization established for independent aviation and railway accident investigations. The ARAIB conducts accident investigation under 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 from recurring.

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List of Abbreviations

AFCS	Automatic Flight Control System
ALT	Altitude
ALT.A	Altitude Acquisition
AP	Autopilot
ASOS	Automated Synoptic Observing System
AWS	Automatic Weather Service
BEA	Bureau d'Enquêres et d'Analyses
CFIT	Controlled Flight Into Terrain
CVR	Cockpit Voice Recorder
EC	Eurocopter
EFS	Emergency Flotation Systems
EGPWS	Enhanced Ground Proximity Warning System
FCP	Flight Control Panel
FDS	Flight Display System
FMS	Flight Management System
GA	Go-Around
HDG	Heading
HFACS	Human Factors Analysis and Classification System
HUMS	Health and Usage Monitoring System
IAS	Indicated Airspeed
IMC	Instrument meteorological conditions
kt	Knot
LOC	Loss Of Control
m	Meter
MFD	Multifunction Display
MGB	Main Gearbox
NVG	Night Vision Goggle
POB	Persons on board
RCA	Root Cause Analysis
RPM	Rotation Per Minute
ULB	Underwater Locator Beacon
VS	Vertical Speed

Crash Into the Sea After Takeoff From Dokdo

- ○ Operator: The National 119 Rescue Headquarters
- ○ Manufacturer: Airbus Helicopters, France
- ○ Type: EC225LP, S/N: 2987
- ○ Registration number: HL9619
- ○ Call sign: National Rescue 202, Yeongnam 001
- ○ Location: The East Sea near Dokdo, Ulleung-gun, Gyeongsangbuk-do (37° 14 ′ 06.803 ″ N, 131° 52 ′ 01.830 ″ E)
- ○ Date and time: October 31, 2019, at 23:25 local time[1)]

Synopsis

On October 31, 2019, at 23:25, a helicopter (EC225LP, HL9619) belonging to the National 119 Rescue Headquarters of the National Fire Agency, which affiliates with the National Fire Agency, crashed into the waters 486 m south of Dokdo Helipad (RKDD) after taking off with a patient.

A total of 7 persons on board (POB) were fatally injured, including 2 pilots, 1 mechanic, a rescue worker and paramedic, and 2 passengers (the patient and the caregiver). The helicopter was also destroyed.

The Aviation and Railway Accident Investigation Board (hereinafter referred to as “ARAIB”) determined the cause of this accident as follows: HL9619 crashed due to “spatial disorientation[2)]” in which the pilot failed to recognize its attitude change while entering the dark sea across a slope (cliff) from the well-lit Dokdo helipad.

Further, the factors contributing to the accident were as follows:

1) All times stated in this report are based on Korea Standard Time, which is 9 hours ahead of Coordinated Universal Time (UTC).

2) Spatial disorientation: A crew cannot accurately recognize or judge one's location, direction, and motion status. Spatial disorientation usually occurs due to weather conditions (fog, cloud, and darkness) and flight status (changes in aircraft speed or altitude and turning). Deteriorated vision, sense of balance, and cognitive ability confuse the sensory perception of bodies. A pilot, thus, becomes to perform the opposite of one's ordinary piloting.

1. The crew did not conduct a pre-flight briefing at the National 119 Rescue Headquarters nor a pre-takeoff briefing in detail at the Dokdo helipad on their duty distribution.

2. The pilot believed he was using the go-around (GA) mode while taking off from Dokdo. Also, while increasing the aircraft's speed, the descending attitude was misidentified as ascending.

3. Thus, the pilot continuously pushed the cyclic forward, which resulted in the autopilot (AP) override[3] and an increase in speed and descent rate.

4. The pilot experienced illusions created by various lights during the approach to the Dokdo helipad, and it also affected the takeoff.

The ARAIB, following the findings, issues 7 safety recommendations to the National Fire Agency, 1 to the Korean National Police Agency, and 1 to Airbus Helicopters.

3) The AP became inoperable because the maximum strength of the AP was overridden by the greater force applied to the cyclic by the pilot.

1. FACTUAL INFORMATION

1.1 History of Flight

At 20:50 on October 31, 2019, the Dokdo Security Police received an urgent rescue request through the radio from 88 Daewangho, a fishing vessel, that a patient had amputated a finger while fishing 6 miles south of Dokdo. At 21:05, the chief officer of Dokdo Security Police notified the case and requested the patient transport to the 119 Operations Center of Gyeongbuk (regional) Fire HQ[4)], the Command Center of the Korea Coast Guard, and the Operations Center of the Gyeongbuk Provincial Police.

At 21:13, the chief officer of Dokdo Security Police requested the Operations Center of the National 119 Rescue HQ or the 119 Rescue Operations Center to dispatch a helicopter to transport the patient.

At 21:14, the 119 Rescue Operations Center commanded Yeongnam 001, an aircraft type of EC225LP with the registration mark HL9619 of the Yeongnam 119 Special Rescue Unit, which belongs to the National 119 Rescue Headquarters, to conduct a flight mission. Accordingly, an Air Rescue and Emergency Squad (Air Squad) consisting of 2 pilots, 1 mechanic, 1 rescue worker, and 1 paramedic prepared a departure.

After being informed that a firefighting helicopter of the 119 Rescue Operations Center could take off, the Dokdo Security Police notified both the Command Center of the Coast Guard and the Gyeongbuk Provincial Police Operations Center that their mobilization was no more necessary. The patient and caregiver of the 88 Daewangho at the time moved to the cafeteria of the Dokdo Security Police and waited for a helicopter.

At 21:33, Yeongnam 001 (HL9619) took off the Yeongnam 119 Special Rescue Unit in Dalseong-gun, Daegu, to conduct the mission.

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4) When a call to 119 is made, it atomatically connects to the 119 Operations Center of each region. Thus, the 119 Rescue Operations Center of Gyeongbuk (province) first received the call from Dokdo, which is located in Gyeongbuk. At that time, 2 helicopters from the Gyeongbuk office were not available—Ka-32: a long flight at night over the water was not possible; and AS365 was in an every-four-year inspection. For that reason, a helicopter dispatch request was made to the National 119 Rescue Operations Center of the National 119 Rescue HQ.

At 22:49, HL9619 landed at the naval helipad in Ulleungdo and re-fueled 278 gallons with the engine running. Then it communicated with Ulleung Ground and took off the helipad at 22:57 (see Figure 1).

At 23:17, HL9619 conducted GA on its first approach to the Dokdo helipad (see Figure 2). It landed at 23:22 at the second approach. The patient and the caregiver boarded at the helipad while the engines and rotors were running.

At 23:24, HL9619 hovered, turned the nose 180° to the right toward where it landed, and then took off to the helipad's south. It flew 486 m for 14 seconds and crashed at 23:25 into the East Sea near Dokdo.

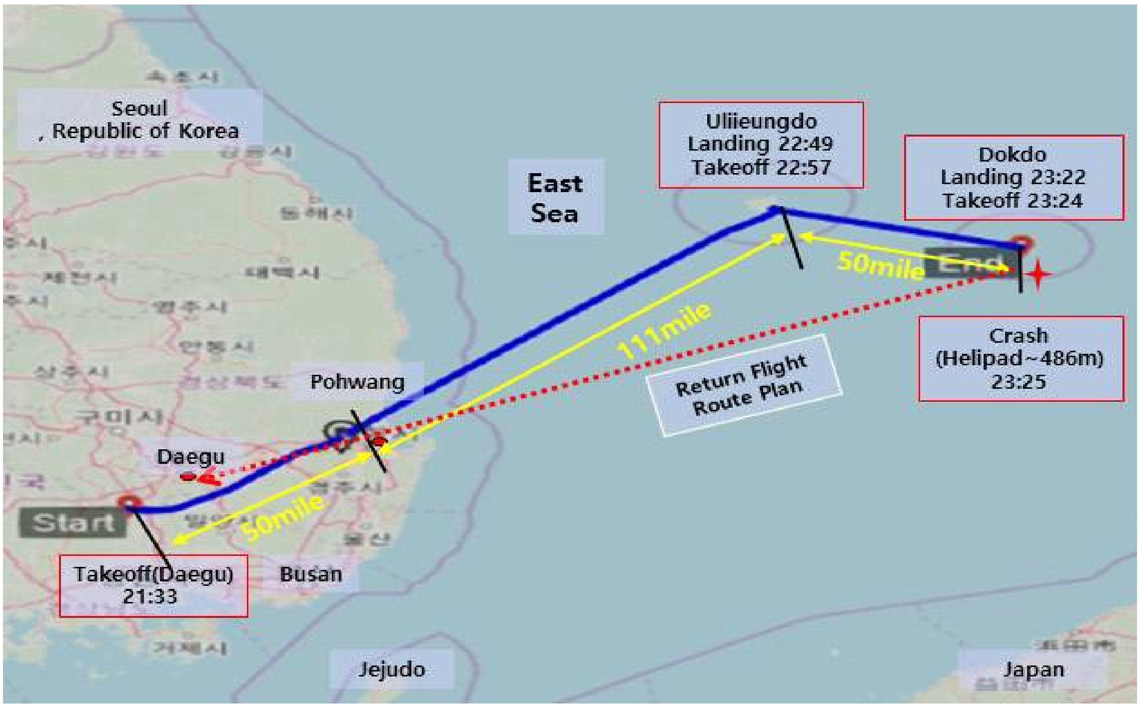


Figure 1. The flight path of HL9619

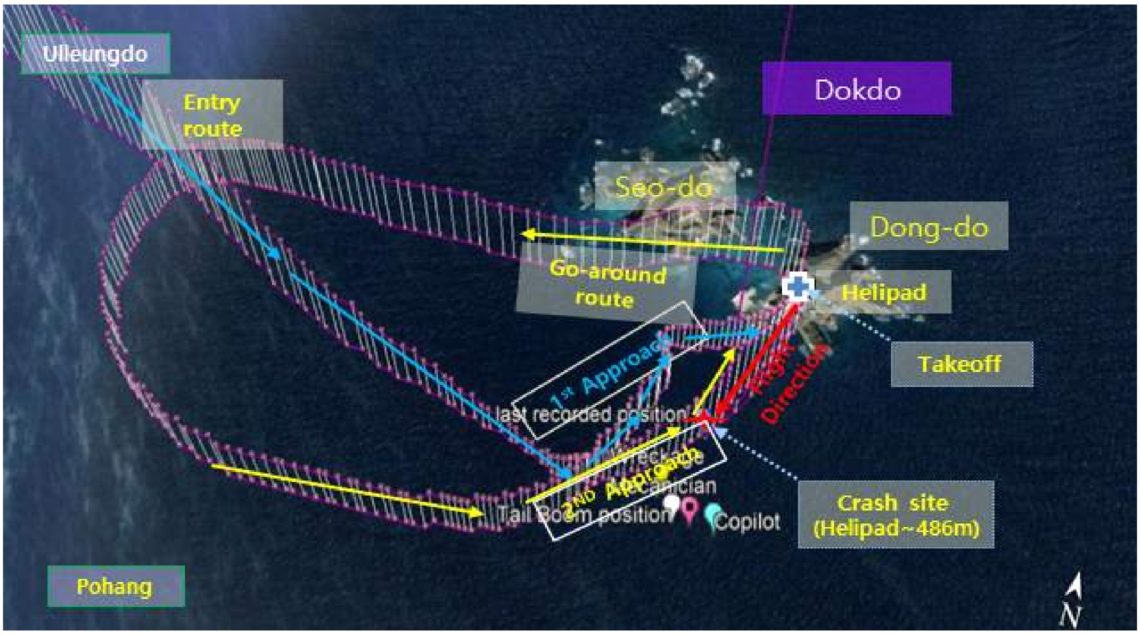


Figure 2. Dokdo helipad approach, a go-around, and takeoff

1.2 Injuries to Persons

There were 7 POB (2 pilots, 1 mechanic, 1 rescue worker, 1 paramedic, 1 patient, and 1 caregiver), and all fatally injured.

39 days of search and rescue (SAR) activity were conducted following the accident, and 4 bodies were recovered (the co-pilot, the mechanic, the paramedic, and the patient). However, the other 3 people－the pilot, the rescue worker, and the caregiver－were eventually not found (see Table 1).

Injuries	Crew	Passengers	Others	Total
Fatal	3	1	0	**4**
Missing	2	1	0	**3**
Serious	0	0	0	**0**
Minor/none	0/0	0/0	0/0	**0**
Total	**5**	**2**	**0**	**7**

Table 1. Injuries to persons

1.3 Damage to Aircraft

The front and rear fuselage were separated due to the impact with the water, and the airframe was destroyed and sunk 72 m under the water.

1.4 Other Damage

No other damage occurred from the crash into the East Sea.

1.5 Personnel Information

See Tables 2 to 4 for the HL9619 crew's information.

Name	Age	Flying time		Certification		Joined (MM/DD/YY)	Rank
		Total	EC225	Pilot	Radio operator		
Kim, ○○ (M)	46	3,827:46	444:43	12-003501 (commercial)	07-34-4-0069 (04/23/07)	05/22/15	Pilot
Lee, ○○ (M)	39	2,666:28	307:59	12-007339 (commercial)	09-34-4-0053 (11/16/09)	10/04/16	Co-pilot

Table 2. Pilot information

Name	Age	Certification (aircraft mechanic)	Joined (MM/DD/YY)	Note
Seo, ○○ (M)	45	05643(10/24/97)	05/22/15	chief mechanic

Table 3. Mechanic information

Name	Age	Position	License	Joined (MM/DD/YY)
Bae, ○ (M)	31	Rescue Worker	2nd-Class Rescue Worker (2016-1-82), the National Fire Agency	05/04/12
Park, ○○ (F)	29	Paramedic	1st-Class Emergency Medical Technician (11270), the Ministry of Health and Welfare	10/13/18

Table 4. Rescue worker and paramedic information

1.5.1 The Pilot

The pilot (age 46, male) had a valid commercial pilot license[5], a 1st-class airman medical certificate[6], a radio operator's license[7], and an aircraft class and type rating[8]. The pilot joined the National 119 Rescue Headquarters on May 22, 2015, belonged to the Yeongnam 119 Special Rescue Unit, and obtained AS365N2 and EC225LP flight qualifications[9].

At the time of the accident, the pilot had 3,827:46 hours[10] flying experience, including 444:43 hours in EC225. In 90 days, 60 days, and 30 days before the accident, the pilot accumulated 13:20 hours, 7:10 hours, and 4:00 hours flying time, respectively.

After joining the HQ, the pilot received transition training to AS365[11] and EC225[12]. He also took flight simulator training[13] and completed aviation safety courses[14].

5) Certification number: 12-003501 (Korea Transportation Safety Authority (TS), May 23, 1998)
6) Airman medical certificate (1st-class), issuance number: 22-25783, valid from October 1, 2019 to October 31, 2020; limitations: none
7) Special-class radio operator (aeronautical): 07-34-4-0069 (Korea Communications Agency, April 23, 2007)
8) Airplane (multi-engine, land), helicopter (multi/single-engine, land), instrument certification (airplane, helicopter), instructor certification (helicopter), ATR42/72, KA32, SK64
9) AS365N2 (qualification acquired on July 7, 2015), EC225LP (qualification acquired on April 2, 2016)
10) EC225 (444:43), B412 (151:03), HH60 (2045:28), B206 (89:20), S64 (174:00), KA32T (823:00), AS350B2 SIM (145:51), AS365N2 (100:12), HH60FTD (08:30), HH32FTD (04:00), LYNX SIM (01:20)
11) Transition training to AS365: ground training (June 1 – 5, 2015), flight training (June 7 – July 7, 2015)
12) Transition training for the EC225 manufacturer: ground and flight training (Airbus Helicopters, France, from February 1 to March 18, 2016)
13) Status in 2019: HH-32 (Air Force Group 6, January 29 and February 19, 2019), HH-60 (Air Force Group 6, August 6 and October 24, 2019), AW-139 (Helikorea, October 11, 2019)
14) Safety training for private/public helicopter operators (the ROKAF Aviation Safety Agency, February 25 – 27, 2019)

1.5.2 The Co-pilot

The co-pilot (age 39, male) had a valid commercial pilot license[15], a 1st-class airman medical certificate[16], a radio operator's license[17], and an aircraft class and type rating[18]. The co-pilot joined the National 119 Rescue Headquarters on October 4, 2016 and operated an EC225LP helicopter[19] at Yeongnam 119 Special Rescue Unit.

The co-pilot had 2,666:28 hours[20] of flying experience, including 307:59 hours in EC225. In 90 days, 60 days, and 30 days before the accident, the co-pilot accumulated 13:40 hours, 10:40 hours, and 2:00 hours flying time, respectively.

The co-pilot continuously received flight simulator training[21]. After being employed, he received a transition[22] to EC225 and the re-qualification[23] training. He also took[24] aviation safety seminars and the Q1 Course of the 19th Aviation Disaster Safety Management.

15) Certification number: 12-007339 (Korea Transportation Safety Authority (TS), September 25, 2009)

16) Airman medical certificate (1st-class), issuance number: 167-0191, valid from September 30, 2019 to September 30, 2020; limitations: none

17) Special-class radio operator (aeronautical): 09-34-4-0053, (Korea Communications Agency, November 16, 2009)

18) Airplane (multi-engine, land), helicopter (multi-engine, land), instrument certification (airplane, helicopter)

19) EC225LP (qualification acquired on Jan. 2, 2017)

20) EC225 (307:59), HH60FTD (96:40), HH60 (1,817:58), EC135 (477:05), B412 (63:26), LYNX SIM (02:50), HH32CPT (06:00)

21) HH-32 (Air Force Group 6, Feb. 19, 2019), HH-60 (Air Force Group 6, July 9, 2019), AW-139 (Helikorea, Oct. 11, 2019), AS350 (the Korea Forest Service, Sep. 10, 2019)

22) Transition training to EC225: ground and flight training (the Air Rescue and Emergency Squad of Yeongnam 119 Special Rescue Unit, from Oct. 10, 2016 to Jan. 2, 2017)

23) EC225 re-qualification training: the Air Rescue and Emergency Squad of Yeongnam 119 Special Rescue Unit, from Dec. 22 to 28, 2017

24) Aviation Safety Seminar (the National Fire Agency, April 25, 2019); the first quarter of the 19th Aviation Disaster Safety Management Course (the ROKAF Aviation Safety Agency, June 3 – 5, 2019)

1.5.3 The Mechanic

The aircraft mechanic (age 45, male) joined the National 119 Rescue Headquarters on May 22, 2015, and worked as a mechanic at the Sudokwon (greater Seoul area) 119 Special Rescue Unit[25)] and Yeongnam 119 Special Rescue Unit. He had a valid aircraft mechanic certificate[26)].

1.5.4 The Rescue Worker and Paramedic

The rescue worker (age 31, male) was employed on May 4, 2012, and has belonged to the Yeongnam 119 Special Rescue Unit (of the National 119 Rescue Headquarters) since November 2, 2015. He had work-related certificates[27)], such as a 2nd-class fireman and Master Scuba Diver. In addition, he completed[28)] a deep diving course and a winter water rescue course.

The paramedic (age 29, female) was employed on October 13, 2018, and worked as a paramedic for the Yeongnam 119 Special Rescue Unit. She had a 1st-Class Emergency Medical Technician license[29)].

1.5.5 The Patient and Caregiver

In HL9619, a finger amputee (age 50, male) and his colleague (age 46, male) as the caregiver were on board.

25) From May 22, 2015 to March 13, 2016
26) Aircraft mechanic: 05643 (Oct. 24, 1997)
27) Fireman (2nd-class): issued by the National Fire Agency; Master Scuba Diver: 09402210564C (issued by the Human Resources Development Service of Korea on June 22, 2009)
28) Deep diving (the Sea Salvage & Rescue Unit (SSU), from Nov. 28 to Dec. 20, 2013); winter water rescue course (the National 119 Rescue Headquarters, Feb. 2 – 13, 2015)
29) 1st-Class Emergency Medical Technician: 11270 (issued by the Ministry of Health and Welfare on Feb. 4, 2012)

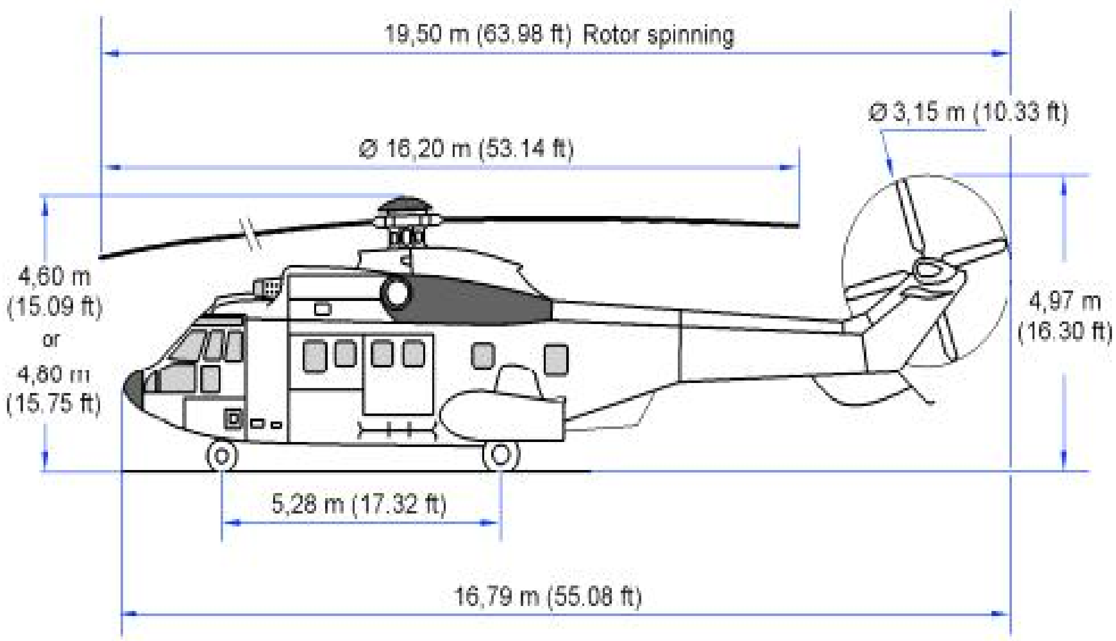
1.6 Aircraft Information

1.6.1 General Details

HL9619 was manufactured by Airbus Helicopters, France on December 18, 2015[30]. The National 119 Rescue Headquarters introduced and operated it in March 2016.

HL9619 held a valid certificate of aircraft registration[31], a certificate of airworthiness (standard)[32], operating limitations specification[33], a certificate of radio station inspection, a radio station license, and a certification of conformity with noise standards.

See Figure 3 for the HL9619's dimensions.



30) Serial number: 2987
31) Registration number: 2016-046, issue date: March 15, 2016
32) Airworthiness certificate number: AB19007, issue date: March 26, 2019
33) Issue number: ABOL19007, issue date: March 26, 2019

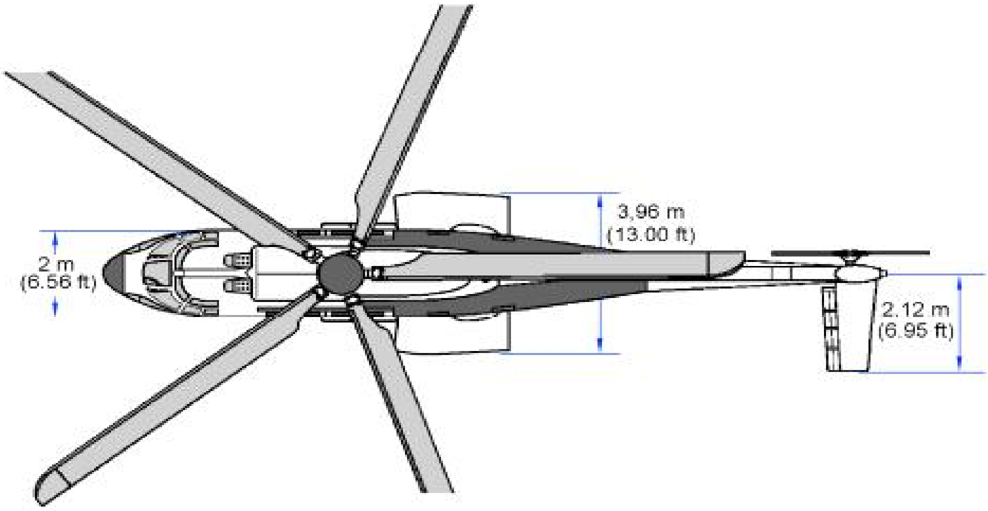


Figure 3. Airframe dimensions

In HL9619, 2 turboshaft engines of the MAKILA 2A1 type made by Safran, France, are installed. The engine operating hours until the day of the accident were 979:33, the same as the airframe operating hours (see Table 5). The aircraft used Jet A-1 fuel.

Aircraft engines		
Manufacturer/State	Safran/France	
Engine type	MAKILA 2A1	
Installed location	Left: T1 (engine #1)	Right: T2 (engine #2)
Serial no.	13441	13440
Date of manufacture	June 08, 2015	June 04, 2015
Date of installation	June 16, 2015	June 16, 2015
Operating hours /cycles	979:33/1,519	979:33/1,519
Hours/cycles	NEW	NEW

Table 5. General information about the engines

The main gearbox (MGB) of HL9619 was manufactured by Airbus Helicopters, France, and was installed in January 2015. The operating hours of the MGB until the day of the accident were 979.33 (see Table 6), the same as the airframe operating hours.

MGB			
State of manufacture	France	Manufacturer	Airbus Helicopters
Installation date	Jan. 22, 2015	P/N	332A32501311
Total operating hours	979:33	S/N	N5388

Table 6. MGB information

1.6.2 Aircraft Maintenance

The National 119 Rescue Headquarters had been performing aircraft inspection and maintenance following the Headquarter's aircraft maintenance manual and the Operational Regulations of Air Rescue and Emergency Squads. Further details for the conduct were abided by in the manufacturer's maintenance manual.

Commanders of each regional 119 Special Rescue Unit take responsibility for inspection and maintenance. An Air Rescue and Emergency Squad (Air Squad) leader from a Special 119 Rescue Unit supervises the maintenance plan, outsourced inspections, maintenance training, and safety management.

A chief mechanic distributes maintenance affairs concerning daily, routine, or special inspections and onboard air log document management and has to report them to the Air Squad leader and operation controllers.

1.6.2.1 Classification of Aircraft Inspections

Inspections follow the standards in a manufacturer's maintenance manual. There are inspections made in-between shift work and a first flight, amidst the flight, after the final flight; daily inspections, and routine inspections.

Also, there are special inspections conducted when a defect is found during operation management and airworthiness inspections and when following the manufacturer’s Service Bulletin (SB). All of these are made to ensure aircraft operate safely.

1.6.2.2 Outsourced Inspection

Article 54 (outsourced inspection) of the Operational Regulations of Air Rescue and Emergency Squads[34] prescribes the following: Inspections that are not capable for the Air Rescue and Emergency Squads to do may assign to an outsourcing company. The Squad leader shall report the established maintenance plan, reflecting the factors required in the Operational Regulations, to the commander of National 119 Rescue Headquarters or the commander of City/Do fire headquarters in advance;

The Squad leader shall designate a mechanic in charge of incoming aircraft subject to outsourced maintenance to follow duties[35] under the Operational Regulations; the mechanic shall report the maintenance results comprehensively and at pleasure following the forms of Operational Regulations.

1.6.2.3. Maintenance Records

The operator and the outsourcing agency held the maintenance and inspections of the HL9619 (see Table 7) and found no specific issues.

Inspection type	Performed date (MM/DD/YY)	Airframe hours	Next inspection (MM/DD/YY)	Performed agency
Every 6 months	05/09/19	864:19	11/03/19	The operator
Every 100 hours	06/09/19	897:44	997:44	The operator
Hoist, every 6 months	07/19/19	919:28	01/15/20	Outsourced
Window seal improvement (ASB56A013)	08/03/19	926:21	-	Outsourced
Every 50 hours	08/20/19	943:50	993:50	The operator
MGB Alert Service Bulletin (ASB04A-016R3)	10/18/19	966:23	-	Outsourced
Every 75 hours	10/18/19	966:34	1041:34	The operator

Table 7. Recent key inspections

34) Enforced on July 26, 2017; Directive of the National Fire Agency No. 2, July 26, 2017, amended by other acts

35) Aircraft warehouse entry inspection, consultation on the aircraft's in-depth maintenance plan, intermediate and outgoing inspections of aircraft maintenance, and implementation of test flights

1.6.3 Weight and Balance

HL9619's W&B was within normal range and defined limits.

1.7 Meteorological Information

Near the summit of Dokdo, the Korea Meteorological Administration has installed equipment for automatic weather measurement. This unmanned operating equipment disseminates weather information to the web, for example, to the Aviation Meteorological Office (AMO) via an integrated situation center.

At 22:57, when HL9619 took off from Ulleungdo, the weather conditions were 10.4 m/s west wind, 13.1 m/s gust, and more than 10 km visibility, with a clear sky and no clouds.

Dokdo's weather conditions at impact were 10 km visibility and 5.8 – 6.7 m/s wind speed on a 290° wind direction, with strong gusts up to 8.8 – 9.6 m/s. Refer to Table 8 for data from the weather stations[36] in Ulleungdo and Dokdo. Also, the moon centering around Dokdo on the accident day rose at 09:41 and set at 19:47, implying the pilots could not use the moonlights for their flight.

	TM	WD (deg.)	WS (m/s)	Gusts (m/s)	Vis (km)	TA (℃)	HM	Note
Ulleungdo	22:57	270	10.4	13.1	10	17.9	34.3	Takeoff
Dokdo	23:22	294	6.7	9.6	10	18.8	71	Landing
	23:24	288	6.4	9.8	10	18.9	71.3	Takeoff
	23:25	**290**	**5.8**	**8.8**	**10**	**19.3**	**71.2**	**Crash**

Table 8. Meteorological data

The Korea Meteorological Administration (KMA) has installed and operated a wind profiler radar[37] since 2003. See Table 9 for the wind con-

36) Ulleungdo: 227-75, Mureung-gil, Ulleung-eup, Ulleung-gun, Gyeongsangbuk-do, Republic of Korea
Dokdo: 30, Dokdo-ri, Ulleung-eup, Ulleung-gun, Gyeongsangbuk-do, Republic of Korea

37) Wind Profiler Radar observes winds receiving radio signals scattered from turbulence

ditions observed at 1000 m altitude above Dokdo, measured by the one installed in Uljin, Gyeongsangbuk-do.

Time	Alt (m)	WD (deg)	WS (m/s)	Zonal wind component (m/s)	Meridional wind component (m/s)	Vertical wind component (m/s)
23:00	1000	337	6.82	2.67	-6.28	-0.31
23:10	1000	334.5	7.56	3.25	-6.83	-0.01
23:20	1000	324.9	9.15	5.26	-7.48	-0.44
23:30	1000	341.1	8.31	2.69	-7.87	0.16
23:40	1000	345.1	7.27	1.87	-7.02	0.4

Table 9. Wind component

Meteorological satellites of the National Meteorological Satellite Center observe radiation emitted or reflected from the surface through equipment with varying sensitivities.

According to the image taken by GEO-KOMPSAT-2A (GK-2A)[38] (see Figure 4), the weather on Ulleungdo and Dokdo at the moment of the flight was satisfactory, without any clouds.

moving along with the wind by transmitting very high frequency (VHF) and ultrahigh frequency (UHF, 300–3000 MHz) radio beams. It generates data every 10 minutes, and the KMA has been operating this equipment since 2003.

38) The meteorological observation satellite, which was launched by the Republic of Korea to the Centre Spatial Guyanais (CSG) in Kourou, French Guiana on December 5, 2018 at 5:37 A.M., has a core mission to monitor typhoons, heavy snowfall, torrential rain, sea ice, fine dust, volcanic ash, and yellow dust in real-time, replacing the role of the Communication, Ocean, and Meteorological Satellite (COMS) launched in 2010.

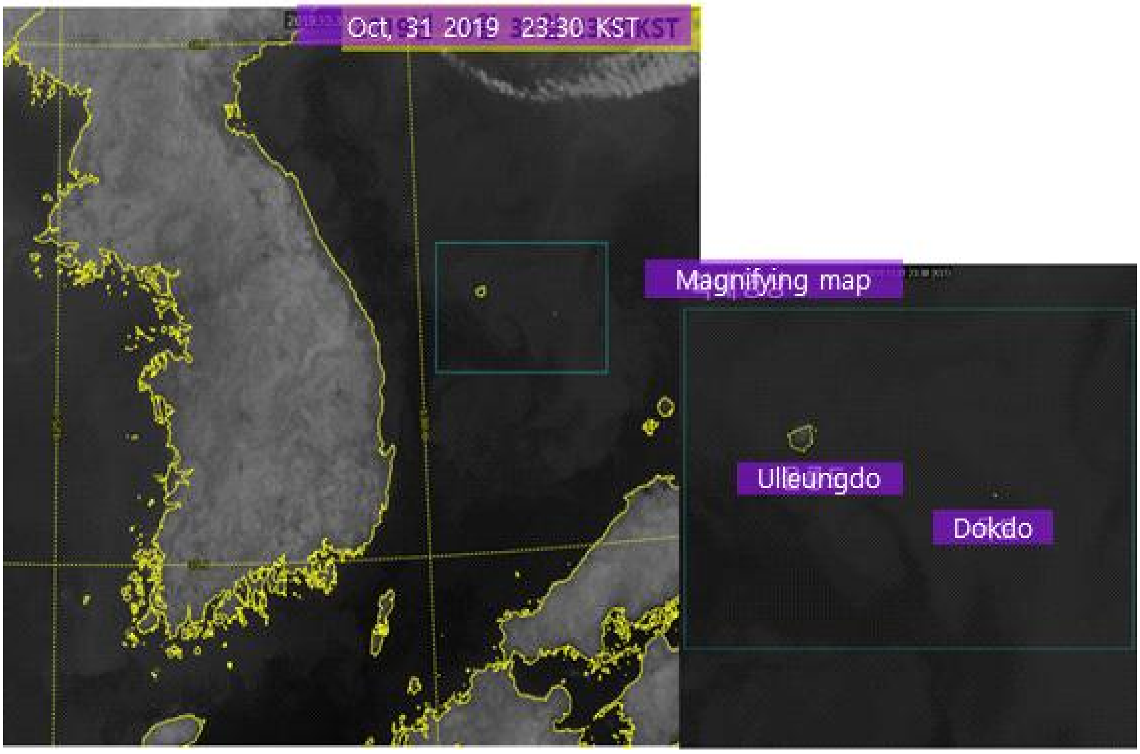


Figure 4. Data given by GK-2A

1.8 Aids to Navigation

HL9619 operated under VFR and did not use any aids to navigation.

1.9 Communications

N/A

1.10 Aerodrome Information

1.10.1 Dokdo

Dokdo consists of two main islands, Dongdo (East Island) and Seodo (West Island). The total area reaches 187,554 m². The address of Dongdo or the Dokdo Security Police is 55 Dokdo Isabu Gil, Ulleung-eup, Ulleung-gun, Gyeongsangbukdo. It is 87.4 km from Ulleungdo and 157.5 km from Japan's Okishima Island (see Figure 5).

Figure 5. A picture of Dokdo and the distances from islands nearby

Located east of the Korean Peninsula, Dokdo has most marine and fishery facilities, including a staffed lighthouse. Dongdo is 98.6 m in height, 2.8 km in circumference, and encircles 73,297 m². It also includes docking facilities, the Dokdo lighthouse, a satellite antenna, the Dokdo Security Police, and other structures. Seodo is located northwest from Dongdo, and residents' living quarters are one of its main facilities.

Dokdo's topographic features, such as the two separated islets of Dongdo and Seodo, create varying upper and lower winds and frequent sudden gusts on nearby surfaces. In particular, winds blown from Seodo affect aircraft taking off and landing at the helipad in Dongdo.

1.10.2 Dokdo Helipad (RKDD)

Installed by the Republic of Korea Navy in December 1981, the Dokdo helipad went through a rebuilding process from September 2011 to August 2012. Since then, it has been under the jurisdiction of the Gyeongbuk Provincial Police. The helipad is officially registered as "RKDD" by International Civil Aviation Organization (ICAO), and its military airport identification code is "N-105 Helipad."

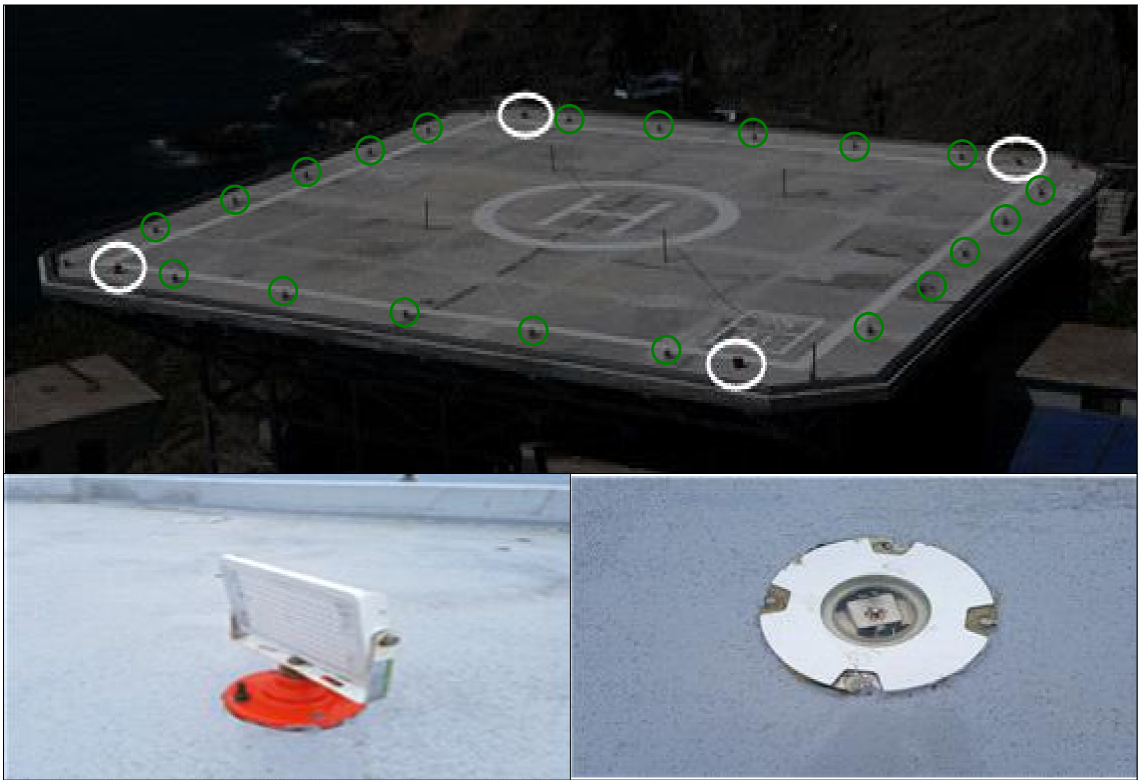
The helipad, made of concrete and measuring 625 m², is a square-shaped facility (25 m in width and length) located in Dongdo. It is the only helipad in Dokdo that has a 99.08 m elevation. See Figure 6 for a panoramic view of the Dokdo helipad.

Figure 6. Dokdo helipad

1.10.3 Dokdo Helipad Lighting

Dokdo helipad is equipped with airport lighting aids. There are 4 floodlights (white; width: 23 cm and length: 18.5 cm) on each edge of the helipad, while 24 TLOF (touchdowns and lift-off area) inset perimeter lights (green; width and length of 20 cm each) are installed along the four sides of the helipad (see Figure 7).

The helipad's lights are operated by the control panel in the Dokdo Security Police's Operations Center. The Security Police officer first operated the TLOF inset perimeter lights (green) and then the floodlights (white).



Floodlights (white)	TLOF inset perimeter lights (green)

Figure 7. Dokdo helipad lighting

1.10.4 Automated Synoptic Observing System and Windsock

At the summit of Dongdo, an Automated Synoptic Observing System (ASOS)[39] has been installed to measure various weather parameters, including temperature, humidity, wind direction, wind speed, atmospheric pressure, sun-light, insolation, precipitation, wave height, and surface temperature.

Windsock as a wind direction indicator (WDI) was at the rooftop of a building 15 m away from the Dokdo helipad. However, only the pole existed at the time of impact, without a windsock and LEDs[40]. See Figure 8 for the

39) ASOS replaced the Automatic Weather System (AWS) in December 2009. The AWS was installed in March 1996.

40) The L-806 (international standard no. 2) requires the installation of a windsock attached to the stainless steel pole, with the sock having 4 LEDs attached to the bigger aperture.

windsock installation status of each pre and post-accident.

Figure 8. ASOS and windsock

1.10.5 Dokdo Lighthouse

The Dokdo Lighthouse, located at the top of Dongdo (a 104 m contour) in the far east of the Korean Peninsula, became a staffed facility in December 1998 after being first established as an unmanned one in August 1954. The Ministry of Oceans and Fisheries manages the facility.

The Dokdo Lighthouse emits a flash[41)] every 10 seconds, serving as a navigational aid for ships passing through the East Sea near Dokdo. The light can reach up to approximately 46 km. Radio signals can be transmitted up to 18 km using a racon (radar beacon). The lighthouse tower stands at a height of 15 m and has an area of 161 m^2. For its operation, 2 diesel generators, each with a capacity of 75 kW, are used in conjunction with a 15 kW photovoltaic system to generate power.

1.11 Flight Recorder

Regarding flight recorders, the HL9619 was equipped with a cockpit voice and flight data recorder (CVFDR), Vision 1000, an enhanced ground proximity warning system (EGPWS), and a health and usage monitoring sys-

41) A light flickering brightly for a brief period

tem (HUMS).

1.11.1 Cockpit Voice and Flight Data Recorder (CVFDR)

The CVFDR[42)] is a recording device that combines the FDR and CVR. It was installed inside the HL9619's rear fuselage and recovered while attached. It was submerged and exposed 77 m under the seawater and recovered 22 days after the accident. (See Figure 9.)

Recovered CVFDR	Memory board

Figure 9. CVFDR and memory board

The ARAIB transferred the CVFDR to the specialized facility of the Bureau d'Enquêtes et d'Analyses (BEA) in France. The data input port was affected by seawater, which caused corrosion in the internal components.

Traces of salt were found on the memory board and inside the connector. To prevent further damage caused by the submersion, the investigators injected argon gas and disconnected the memory chip before extracting data.

Due to significant corrosion on the CVFDR components, it was necessary to remove the corrosion, maintain a vacuum state, and undergo a complicated extraction process to analyze all the flight data and voice recordings.

The FDR recorded 2 hours and 5 minutes in total for the accident

42) Manufacturer: L3COM; Model: FA5001, P/N (part number): 5001-6103-11, S/N (serial number): 001013530

flight. The CVR recorded a total of 17 hours and 28 minutes and stored 4 files across 4 channels.

The Underwater Locator Beacon (ULB), which confirms the location of an aircraft crash, was attached to the CVFDR. The ULB and the CVFDR were recovered and transferred to the BEA to analyze their operational status. See Figure 10 for the HL9619 FDR data from takeoff to the crash.

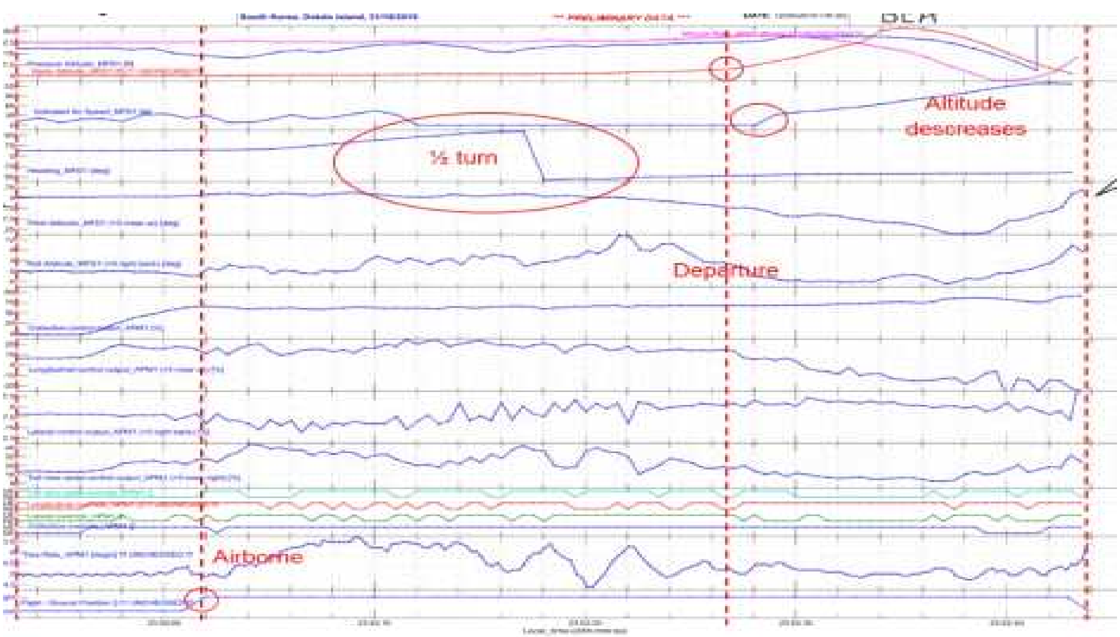


Figure 10. FDR data (from takeoff to crash)

1.11.2 Vision 1000

Vision 1000[43], installed in the cockpit, provides the cockpit and instrument footage. Based on GNSS, Vision 1000 automatically records the aircraft's location, attitude, speed, and video every 0.25 seconds.

Vision 1000 consists of internal and external memory cards. No further data was recorded on the external memory card after May 23, 2019.

Meanwhile, the internal body recorded 15 minutes of footage since the pilot switched the battery on. The recording stopped after October 31, 21:50:37, when it was in the sky of Yeongcheon.

43) Manufacturer: Appareo, P/N: 104030-000008, S/N: VIS-FGDF

Recovering data from internal memory cards and storage devices was not possible despite the joint effort of ARAIB, BEA, and the National Transportation Safety Board (NTSB). Vision 1000 used to receive daily and annual inspections, and the National 119 Rescue Headquarters did them following the procedures.

1.11.3 Enhanced Ground Proximity Warning System (EGPWS)

EGPWS MK XXII model installed in the HL9619 is interchangeable with helicopters that have helicopter terrain awareness and warning system (HTAWS) functions. The ARAIB recovered EGPWS and transferred it to BEA for analysis.

1.11.4 Health and Usage Monitoring System (HUMS)

HL9619 was equipped with a device that monitors the aircraft's condition. The airframe's vibration figure inspection up to the day before the last flight showed no abnormal vibration.

1.12 Wreckage and Impact Information

1.12.1 Wreckage Distribution

According to the FDR, the main fuselage crashed into the water 486 m south of the Dokdo helipad and was found 72 m under the water, 693 m to the south from the helipad's 204° direction. The rear fuselage was found 86 m under the water, 966 m to the south from the helipad's 195° direction.

The cockpit of the forward fueslage was lost after the impact with the water severed it. The rear fuselage was separated from the forward fueslage. The left horizontal stabilizer of the rear fuselage was found bent towards the upper direction, while the tail rotors were generally found in acceptable conditions.

The emergency flotation system (EFS) was seriously damaged; the conditions from the power connection to the EFS were hardly recognizable. In addition, helium gas containers for suspension were separated from the fuselage, so only 2 of 3 containers were found and lifted.

Classification		A location from the helipad			A location from the forward fueslage		
		Distance	Heading	Water level (m)	Distance (m)	Heading	Water level (m)
Main fuselage	Crash location	486	198	-	-	-	-
	Location found	693	204	72	-	-	-
	Pulled location	966	166	86	600	120	-
Rear fuselage		722	195	77	112	124	-
Left-rear door		683	203	-	11	063	72
Cockpit door		648	204	-	46	020	69
Co-pilot door		709	206	-	25	257	72
Engine air inhaler		646	203	-	49	043	69

Table 10. Locations of the wreckage found

The forward fuselage was moved further from 486 m south of the Dokdo helipad, the crash point, due to several causes, including tides. Thus, it was found 72 m under the water, which was 693 m distant from the helipad at 204° south. It was lifted from 86 m under the water, 966 m far from the helipad at 166° south on November 3, 2019, at 13:00 (see Table 10).

The rear fuselage was found 77 m under the water, 722 m distant from the helipad at 195° south, and was pulled up at the same spot where the forward fueslage was lifted on November 21, 2019 at 16:00.

1.12.2 Damage to Aircraft

The forward fueslage (see Figure 11, X2480)—cockpit, front windows, and wheels—were lost or compressed to the rear. Thus, only the center fuselage was lifted. The EFS on the rear section was torn entirely. The rear fuselage was pulled up separately from the forward fueslage.

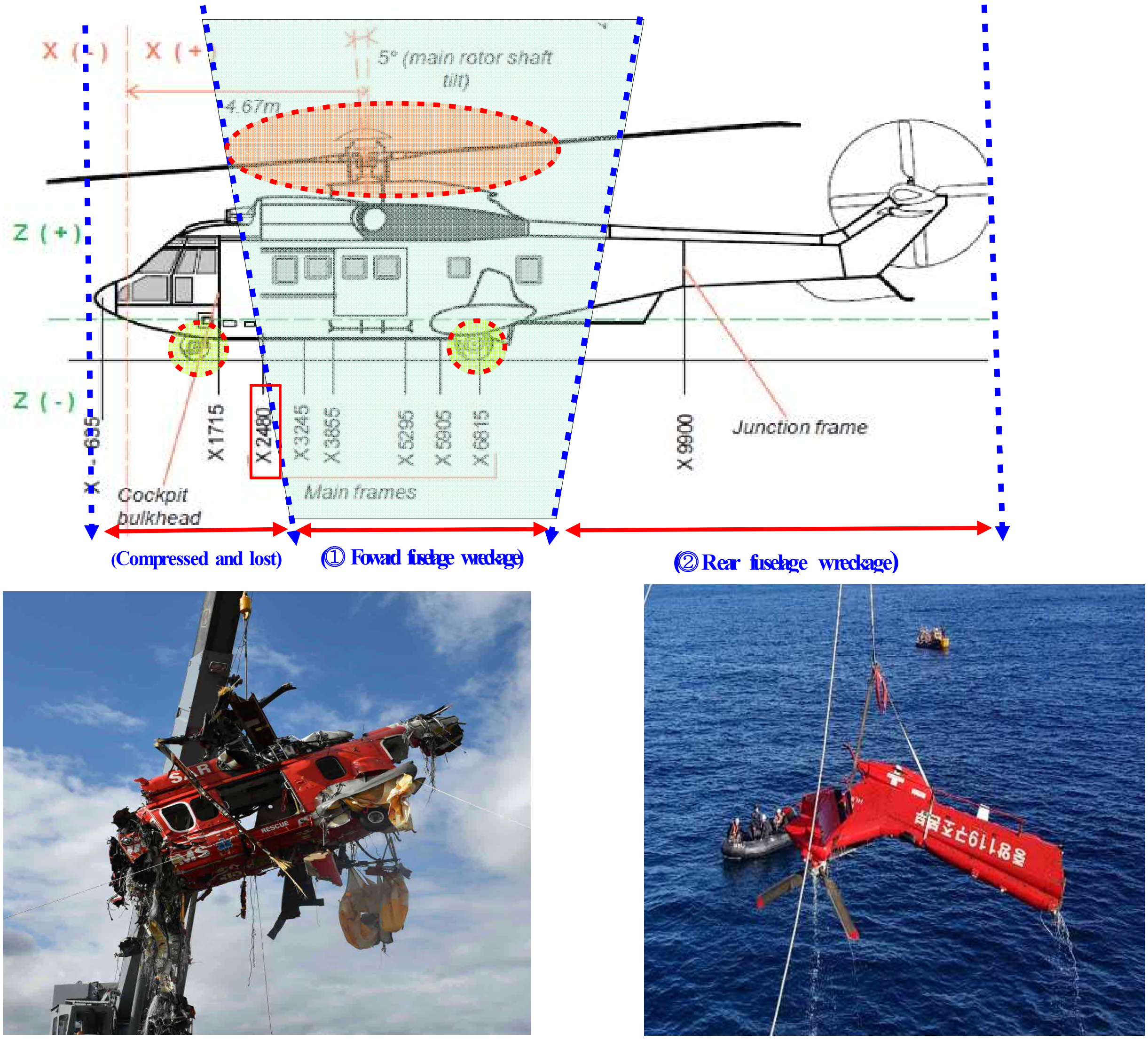
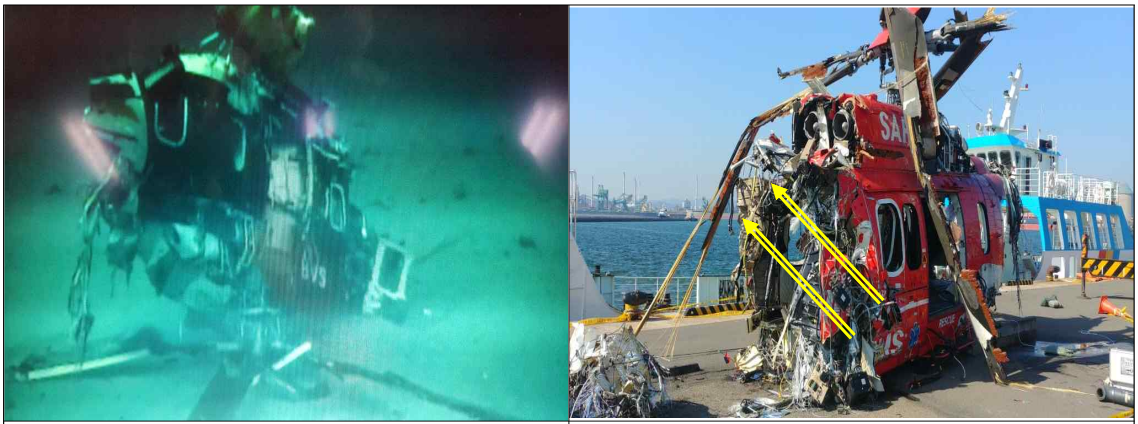


Figure 11. Lifting the HL9619 fuselage

1.12.2.1 Forward Fuselage

The co-pilot seat on the front left fuselage was fully pressed, and the pressed intensity got worse while reaching the pilot seat on the right (see Figure 12).



Under the water	Lifted

Figure 12. Forward fueslage

1.12.2.2 Main Rotor

5 main rotors were broken due to impact with obstacles while rotating strongly with power. As a result, all 5 rotors were seriously damaged and cut at 840 mm from the hub; and traces of constant damages from 850 to 1,000 mm ranges were identified (see Figure 13).

Figure 13. Main rotor damage

In addition, the main rotating area bushing towards the wing root confirmed around 30 to 50 mm gaps. The damage suggests that the impact with the water was made while rotating with power. Also, some components were lost due to the main rotors' intense rotation and the impact with the water.

1.12.2.3 Rear Fuselage and Tail Rotor

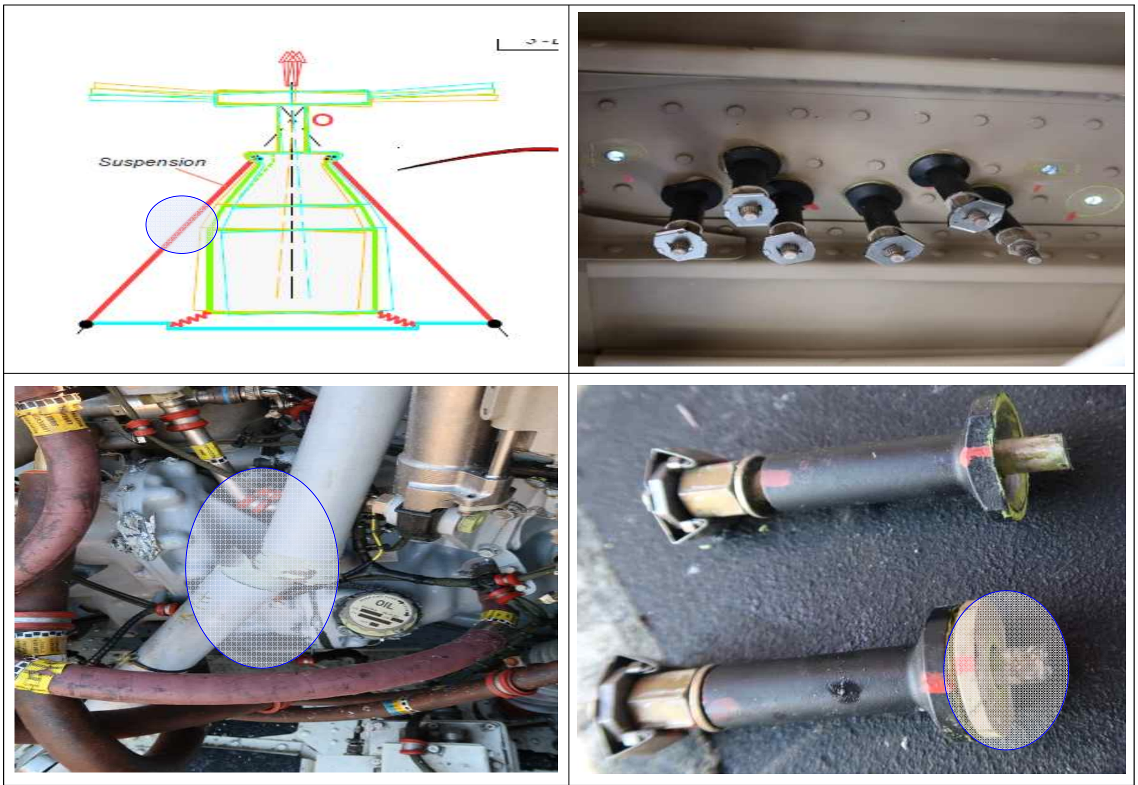
The rear fuselage was separated from the forward fueslage and fell in different directions when it crashed. However, the rear fuselage and tail rotor generally maintained good condition (see Figure 14).

	
Rear fuselage	Tail rotor

Figure 14. Rear fuselage and tail rotor

1.12.2.4 Main Gearbox (MGB)

MGB was linking the engine coupling and the connecting shaft of the tail rotor. One among the 3 suspensions, supporting MGB, recovered bent but broken during transportation (see Figure 15).



Suspension bar	Flexible mounting plate

Figure 15. MGB suspensions

Mounting plates on the front and rear were at their position but were found broken. For abrasion inspection of the internal MGB, full flow/bottom/epic magnetic plug and oil filter were inspected, and yet no chips were found.

1.12.2.5 Coupling Shaft

Coupling shafts transmit power to MGB from each engine, and the coupling tubes, wrapping externally from the shafts, function shaft protection. The right engine (T2) shaft ruptured, and the external tube confirmed buckling. The buckling point matching the point of shaft rupture (see Figure 16) implies the external impact applied on the tube at the crash caused the shaft, rotating at high speed, to rupture.

Figure 16. The severed engine coupling shaft

1.12.2.6 Landing Gear

The landing gear is wheel type and consists of 3 wheels, one in the front and two on both sides of the rear. The nose wheel (front landing gear) was broken and recovered while floating on the sea. The left rear wheel was attached to the frame (Figure 17, left), while the other on the right rear was lost. Around 200 mm above the center of the nose wheel was cut evenly and separated from the airframe (Figure 17, right).

AFT left wheel	Nose wheel

Figure 17. Landing gear of HL9619

1.13 Medical and Pathological Information

The crewmembers' pathological factors, such as drinking and taking medication, were impossible to identify.

1.14 Fire

A fire did not occur in this accident.

1.15 Survival Aspects

A total of 7 POB might not survive due to the crash with high speed and energy into the water and hypothermia after falling into the water.

1.15.1 Rescue Operations

At 23:25, a Dokdo Security Police officer notified its Operations Center of the aircraft crash, while the chief officer reported it to the 119 Operations Center of Gyeongbuk Fire HQ. The deputy chief officer of Dokdo Security Police searched the accident site with colleagues using a self-powered rubber boat but failed to find the fuselage and the POB. The search was halted owing to the high wave.

Upon receiving the notice of the crash at 23:27, the 119 Emergency Operations Center of the National Fire Agency commanded the dispatch of a firefighting helicopter and requested SAR cooperation from naval warships, reconnaissance aircraft, and fishing vessels. At 00:49, 4 naval warships, 4 aircraft, 3 fishing vessels, and 2 helicopters arrived and began the search, reinforcing equipment and personnel.

From October 31, the day the HL9619 crashed, the SAR was conducted until December 8, a total of 39 days. A remotely operated vehicle (ROV) installed in the naval warship expanded the search to underwater, coastal, marine, and air. 726 vessels (including civil), 107 helicopters, 93 aircraft, 3,723 divers, and 350 ground search personnel from the navy, police, and fire agencies were mobilized.

ROV, ultrasound detector, side scan sonar, and underwater security camera were used to search underwater.

As a result, the co-pilot and mechanic were recovered near the fuselage on November 3. The patient was recovered at the fuselage location on November 5, while the paramedic was recovered 2.9 km from the 180° direction of the fuselage on November 12.

Despite the endeavors to allocate personnel from many fields as well as equipment to rescue the POB for 39 days, 4 out of 7 were found dead, and yet the pilot, rescue worker, and caregiver could not be found until the termination of the rescue operation.

1.15.2 Airframe Recovery

During the underwater search, the forward fueslage was found on November 1. It was recovered at 86 m under the water, 966 m south of the helipad on November 3 at 13:00. The rear fuselage was pulled up with the CVFDR on November 21 at 16:00, 22 days after the accident.

1.15.3 Survival Equipment

1.15.3.1 Life Jacket

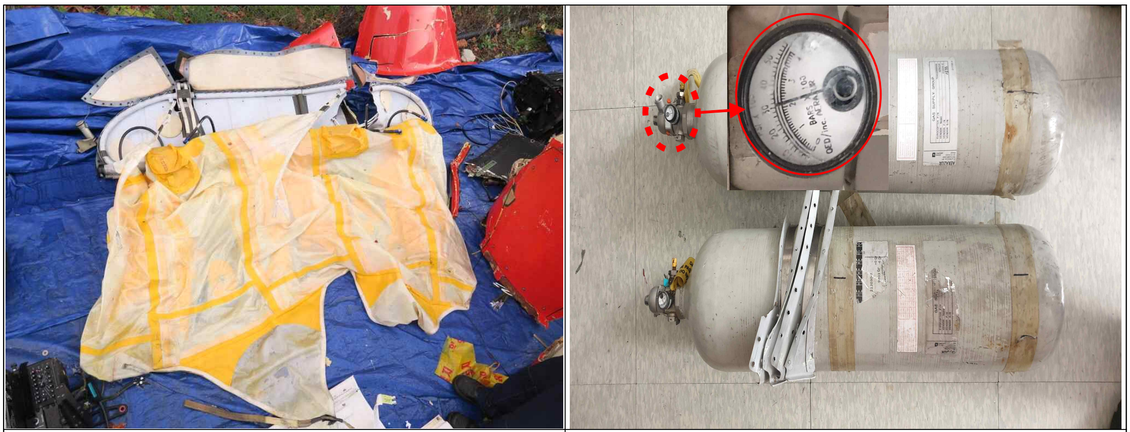
When flying over water, wearing a life jacket is compulsory in accordance with the “Enforcement Ordinance of the Aviation Safety Act[44]” and "the Operational Regulations of Air Rescue and Emergency Squads[45]." The pre-dispatch and landing at Dokdo helipad video recordings confirmed that every crew was wearing aircrew life jackets[46] and emergency breathing devices (HEED)[47]. Further, additional life jackets for another crew and for 3 passengers (a patient, a caregiver, and a doctor) were equipped in flight.

1.15.3.2 Emergency Flotation Systems (EFS)

EFS was equipped on HL9619. The wreckage of the systems, which did not operate at impact, was found separated from the fuselage and destroyed.

Also, 3 helium gas cylinders, supposed to remain attached to the EFS, were separately found apart from the fuselage (see Figure 18). The pressure figures of all those cylinders indicated their normal range.

44) Attached Form 15: First-aid kit equipment and others that shall be equipped in aircraft (in association with Article 110), No. 651 of Ordinance of the Ministry of Land, Infrastructure and Transport, enforced on Sep. 23, 2019
45) Articles 22, and 42 (in-flight safety)
46) Swiltlik US/X-Back Air Crew (Part Number: 710-FASA-191-1-101)
47) HEED, Aqualung US SEA mK/LV2



EFS	Helium gas cylinders

Figure 18. The EFS recovered

1.15.3.2.1 Composition of EFS

Each flotation device is installed separately into 4 in the aircraft. Both sides of each front and rear aircraft are equipped with the device (see Figure 19). A total of 3 helium cylinders are in an EFS, one at the front and the others at each side of the rear.

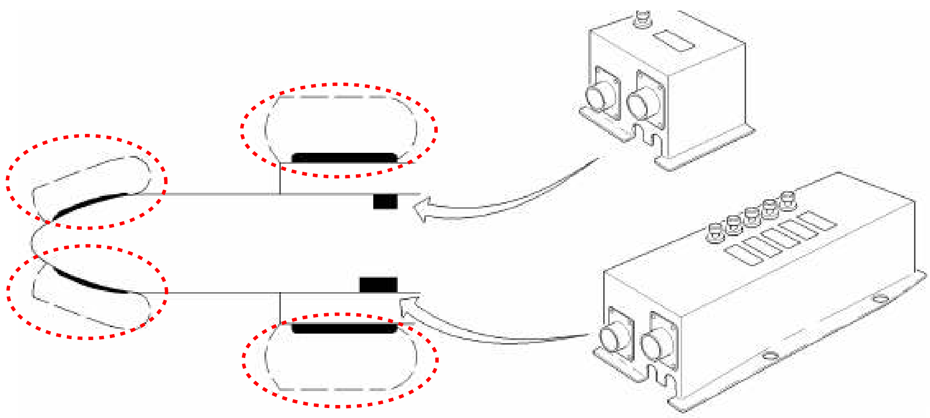


Figure 19. EFS schematic diagram

1.15.3.2.2 EFS Operation

There are two ways to operate EFS. First, it automatically operates when in contact with the water if a pilot has set the instrument panel switch to "ON" (ARM). Second, the system is also operable during flight by pressing the button of the collective. Figure 20 depicts the ways to function the EFS.

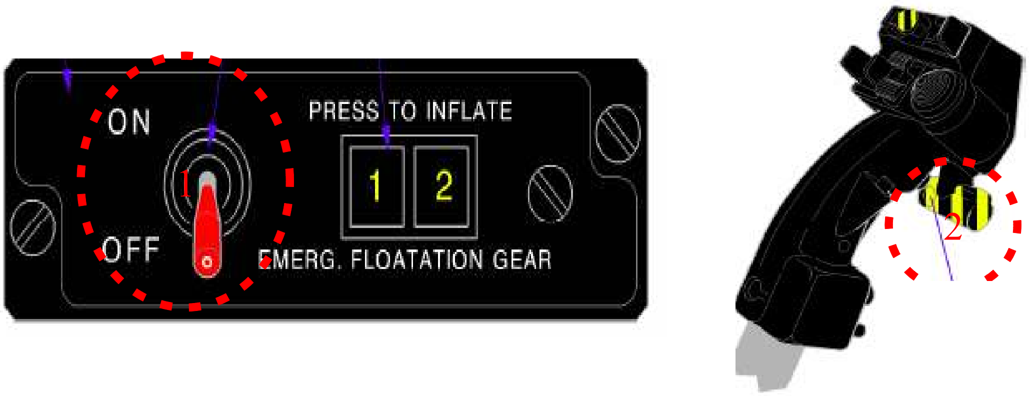


Figure 20. EFS Operation

1.16 Testing and Research

The ARAIB performed detailed examinations of HL9619 jointly with BEA, the European Union Aviation Safety Agency (EASA), Airbus Helicopters, and SafranHE for the airframe, MGB, engines, fuel, and acceleration due to gravity.

1.16.1 Airframe Wreckage Investigation

HL9619's forward fueslage was transported to ARAIB's Gimpo office, the Testing and Analysis Center. The ARAIB, BEA, Safran, and Airbus Helicopters conducted a joint investigation[48] of the wreckage.

BEA, EASA, and ARAIB investigators also visited Airbus Helicopters for the MGB and Safran[49] for the engines to conduct a detailed examination.

48) At the Testing and Analysis Center of the ARAIB, 15 investigators participated, from November 6 to 15, 2019 (10 days).

The examination aims to identify whether any defects or damages existed prior to the impact. The whole wreckage was examined, including the MGB and main rotor hub assembly.

Disassembling the main rotor head (MRH) showed no pre-impact damage on the MRH components (see Figure 21).

	
MGB including MRH	MGB

Figure 21. MGB and MRH

1.16.2 MGB Examination

The lower section of MGB was disassembled and examined. Magnesium powder due to corrosion by sea salt was observed, but no magnetic particles were identified (see Figure 22).

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49) A French multinational company headquartered in Paris, France, provides aircraft engines, rocket engines, and defense-related equipment.

Figure 22. The lower section of MGB

1.16.2.1 L/H and R/H Accessory Module Examination

There were no mechanical damages, and the tightening torque (of nuts) was within a normal range (see Figure 23). All the gears and bearings were in good condition and could transmit the power.

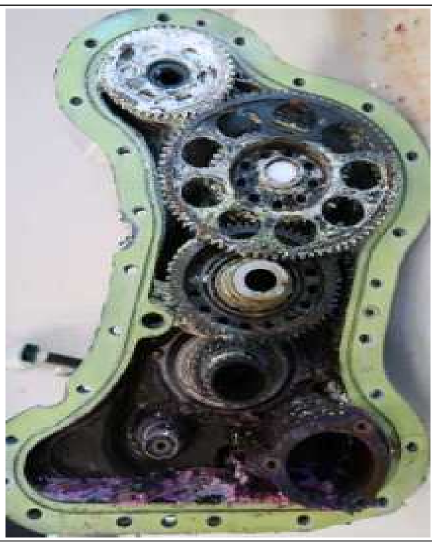
	
Left module	Right module

Figure 23. Internal examination of L/H and R/H accessory modules

1.16.2.2 Rear Table/Module (Equipped With Freewheel Assemblies)

Measuring the tightening torque on one nut of the rear table/module showed figures in normal ranges, and there was no mechanical damage on the rear module separated from the main module. All the gears and bearings were in good condition, despite the corrosion observed. The output flange, connected to the tail rotor drive shaft, was freely rotating and was in ordinary condition.

Both freewheels were disassembled to verify the condition of different elements, including the ramps and the rollers (see Figure 24). They both turned out to be operating and properly transmitting power until the accident.

Figure 24. Freewheels (L/H, R/H)

1.16.2.3 L/H and R/H 23.000 RPM Input Module

The tightening torque of the coupling nuts on both sides of the 23.000 RPM input module was measured within the normal range and did not reveal any mechanical damage. The modules were able to transmit power despite the corrosion inside.

1.16.2.4 Epicyclic Module and Main Module

The detailed examination of the epicyclic module after its removal from the main module did not reveal any mechanical damage. The tightening torque of coupling nuts between the conical housing and the epicyclic module was measured. Two nuts out of three were measured below a minimum torque, which should result from the displacement of the main rotor blades at the time of impact with the water.

The investigation of the oil pump, main bevel wheel, and 23.000 RPM input pinion revealed no mechanical damage; all the gears and bearings consisting of the main module were in good condition (see Figure 25).

Figure 25. Epicyclic module

1.16.3 Engine Examination

Two MAKILA 2A1 engines made by Safran, France, were installed in HL9619. The ARAIB conducted a detailed engine examination at the manufacturing company Safran; it jointly investigated with the BEA and EASA investigators for 4 days from December 16 to 19, 2019.

The purpose of the engine examination was to check the conditions of different components of each engine module to determine whether the damage identified occurred before the accident or at impact.

The structure of a helicopter turbine engine is generally classified into compressor, gearbox, turbine, and combustion section. See Figure 26 for the general description of MAKILA 2A1.

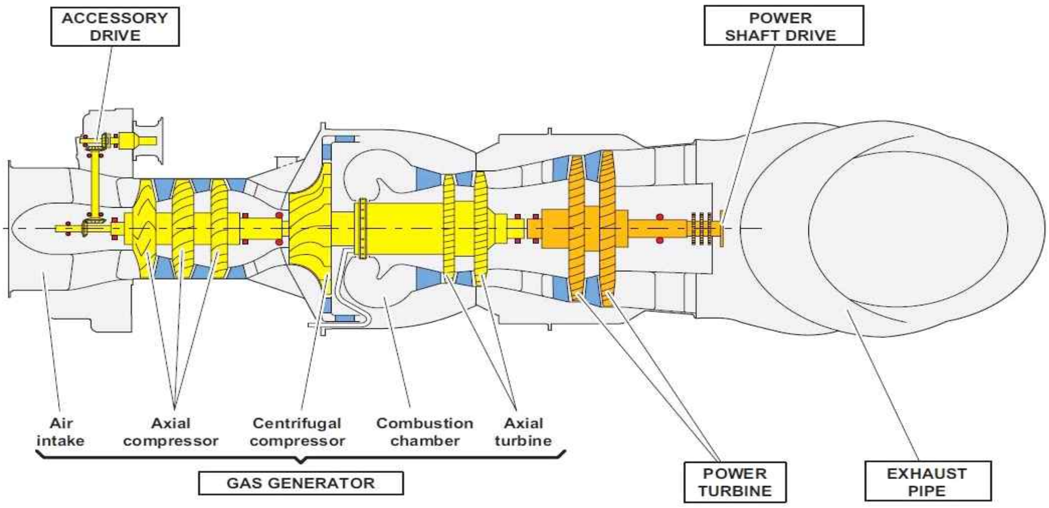


Figure 26. General description of MAKILA 2A1

The external conditions of engine, such as fuel, oil, and each component of air intake section, were first examined. Then each engine module (2 – 4) was disassembled and examined in sequence.

Module 1 stands for air intake, module 2 for the axial compressor section, module 3 for the gas generator section, and module 4 for the power turbine (see Figure 27). The ARAIB disassembled the modules and had a detailed examination of each.

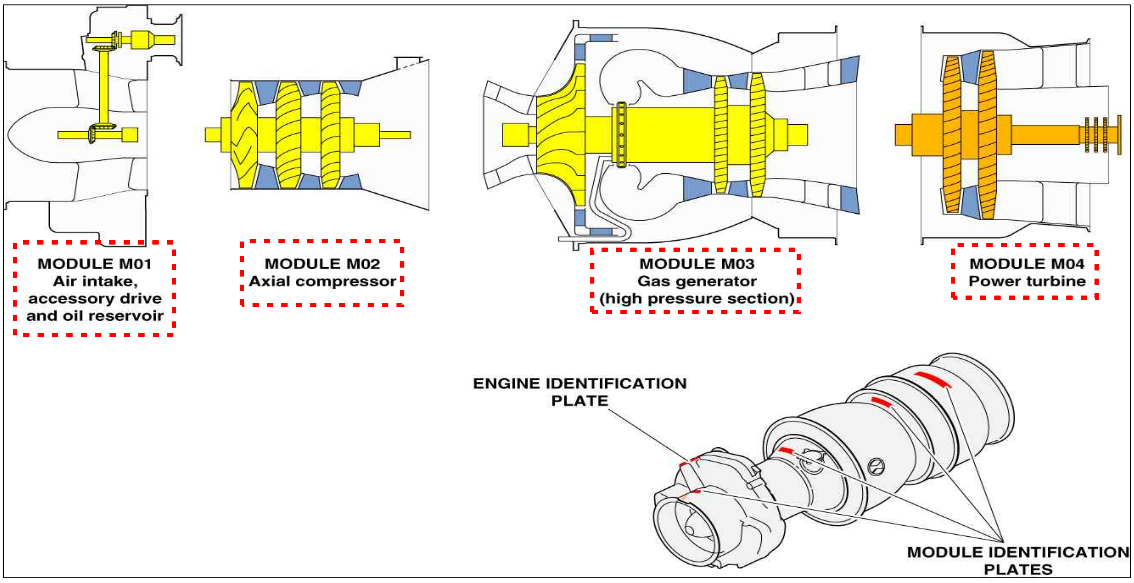


Figure 27. MAKILA 2A1 modules

1.16.3.1 Module 2 Configuration and Examination

In module 2 (axial compressor), damage, scratch, spalling, and impacts were examined by checking component conditions such as axial wheels, diffuser vanes, front and rear roller bearings, and muff coupling. See Figure 28 for the configuration diagram and Table 11 for the examination result.

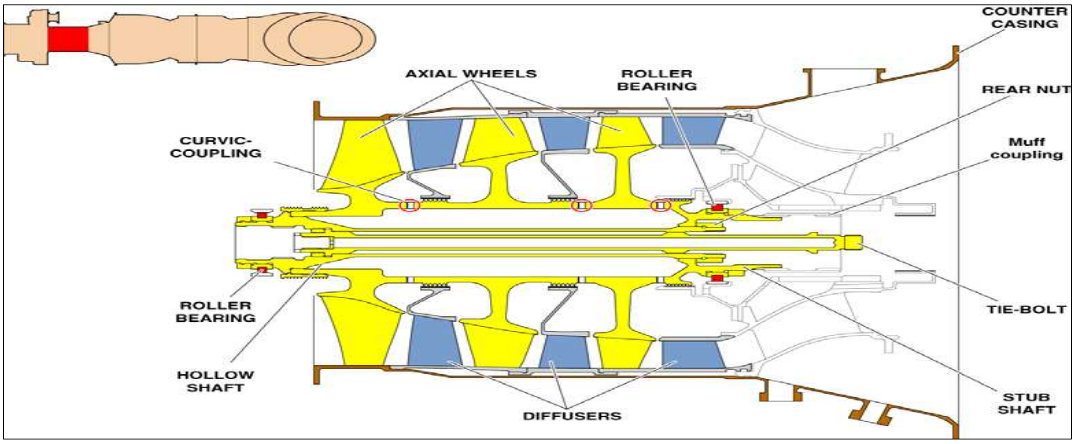


Figure 28. Module 2 configuration diagram

Makila 2A1	# 13 441 (T1)	# 13 440 (T2)
Axial wheel 1st stage	Some blades found bent – No trace of FOD (foreign object debris) Note : The deformation was most probably the consequence of the hydraulic over-load during the injection of water at the moment of the impact with the water	Some blades found bent – No trace of FOD Note : The deformation was most probably the consequence of the hydraulic over-load during the injection of water at the moment of the impact with the water
Axial wheels 2nd and 3rd stage	Visually in good condition No trace of impact (FOD) / no trace of contact on the top of the blades	Visually in good condition No trace of impact (FOD) / no trace of contact on the top of the blades
Diffusers	Visually in good condition – No FOD / no erosion	Visually in good condition – No FOD / no erosion
Front and rear bearings	Traces of corrosion on the balls but free in rotation with no hard point / no rubbing marks on the outer race / no rubbing marks on the inner race faces	Traces of corrosion on the balls but free in rotation with no hard point / no rubbing marks on the outer race / no rubbing marks on the inner race faces
Muff coupling	Visually in good condition - No trace of wear	Visually in good condition - No trace of wear

Table 11. The result of the module 2 examination

1.16.3.2 Module 3 Configuration and Examination

In module 3 (gas generator), centrifugal compressor, combustion chamber (inner and outer parts), fuel injection wheel, HP (high pressure) turbine blades 1st and 2nd stages, HP nozzle guide vanes 1st and 2nd stages, front and rear roller bearings, and others were visually inspected whether damage, scratch, spalling, and impacts observed. See Figure 29 and Table 12 for the configuration diagram and the examination results, respectively.

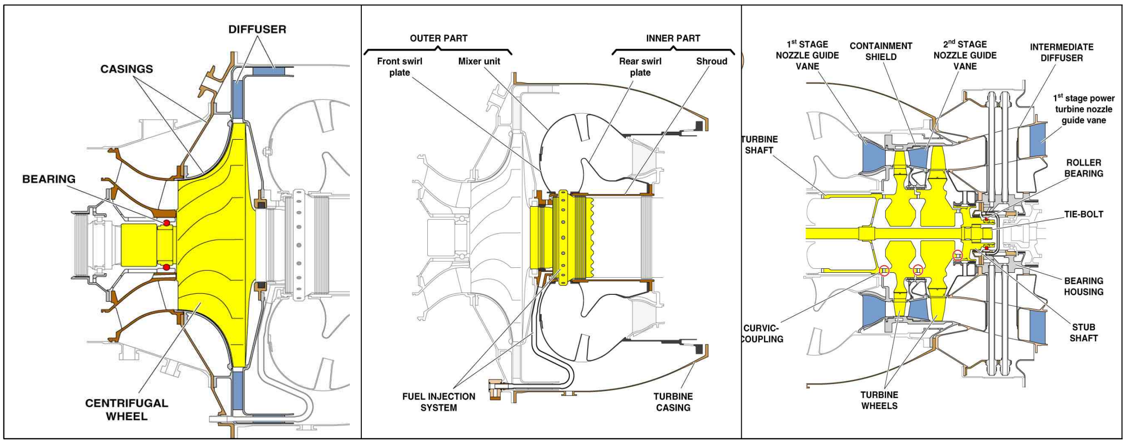


Figure 29. Module 3 configuration diagram

Makila 2A1	# 13 441 (T1)	# 13 440 (T2)
Centrifugal compressor	All the main blades found bent (except one) Note: The deformation was most probably the consequence of the hydraulic over-load during the injection of water at impact	All the main blades found bent (except two) Note: The deformation was most probably the consequence of the hydraulic over-load during the injection of water at impact
Compressor cover	Traces of rubbing with deterioration of the coating, at leading edge and trailing edge sides, but no rub in between. Note: The deterioration of the coating was probably the consequence of the forward movement of the Gas Generator mobile at the moment of the impact.	Traces of rubbing with deterioration of the coating, at leading edge and trailing edge sides, but no rub in between. Presence of corrosion deposit (red) Note: The deterioration of the coating was probably the consequence of the forward movement of the Gas Generator mobile at the moment of the impact.
Centrifugal diffuser	Visually in good condition – No FOD / no erosion – Presence of debris (white and red)	Visually in good condition – No FOD / no erosion – Presence of debris (white and red)
Combustion chamber (inner and outer parts)	Visually in good condition – No trace of over-heating / no crack- Presence of debris (white and red). Note: The debris (paint flakes) were most probably coming from the airframe air intake (cowlings)	Visually in good condition – No trace of over-heating / no crack - Presence of debris (white and red). Note: The debris (paint flakes) were most probably coming from the airframe air intake (cowlings)
Fuel injection wheel	Visually in good condition - No obstruction Curvic coupling visually in good condition	Visually in good condition - No obstruction Curvic coupling visually in good condition
HP turbine 1st and 2nd stage	Visually in good condition – No trace of contact on the top of the blades - No FOD - No trace of over-heating Note: Very light rubbing marks on the rear face of the HP turbine 1st disk which occurred most probably when Gas Generator mobile moved forward	Visually in good condition – No trace of contact on the top of the blades - No FOD - No trace of over-heating

Makila 2A1	# 13 441 (T1)	# 13 440 (T2)
HP nozzle guide vanes 1st and 2nd stage	Visually in good condition	Visually in good condition
Labyrinth	Visually in good condition – No trace of contact	Visually in good condition – No trace of contact
Front and rear bearings	Traces of corrosion on the balls but free in rotation with no hard point / no rubbing marks on the outer race / no rubbing marks on the inner race faces	Traces of corrosion on the balls but free in rotation with no hard point / no rubbing marks on the outer race / no rubbing marks on the inner race faces
Curvic coupling	Visually in good condition	Visually in good condition
Rear bearing support	Presence of coke but oil jets free	Presence of coke but oil jets free
PT nozzle guide vanes 1st stage	Visually in good condition	Visually in good condition

Table 12. The result of the module 3 examination

1.16.3.3 Module 4 Configuration and Examination

In module 4 (power turbine), power turbine (PT) 1st and 2nd stage, PT nozzle guide vanes 2nd stage, labyrinth, front and rear bearings, curvic coupling, and assembly shaft were visually inspected to see if there are any damage, scratch, spalling, and impacts. See Figure 30 and Table 13 for the configuration diagram and the examination results.

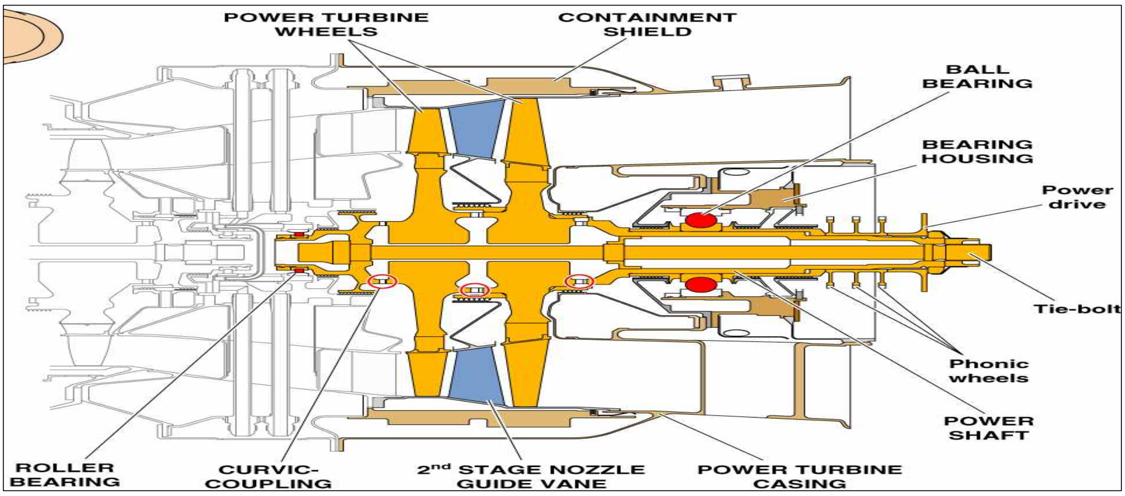


Figure 30. Module 4 configuration diagram

Makila 2A1	# 13 441 (T1)	# 13 440 (T2)
Power Turbine (PT) 1st and 2nd stage	Visually in good condition – Presence of shiny particles on the blades Note: These particles came from the compressor cover coating, which deteriorated during the contact of the centrifugal compressor blades with the compressor cover (forward movement of the Gas Generator mobile)	Visually in good condition – Presence of shiny particles on the blades Note 1: Very light rubbing marks on the rear face of the PT 1st stage disk, which occurred most probably at the moment of the impact Note 2: Presence of contact on the tip leading edge of PT 2nd stage blades
PT nozzle guide vanes 2nd stage	Visually in good condition	Visually in good condition Note: Very light rubbing marks on the front face of the PT Nozzle Guide Vane 2nd stage as a consequence of the contact with the PT 1st stage.
Labyrinth	Visually in good condition – No trace of contact Presence of green deposit in the lips (corrosion)	Visually in good condition – No trace of contact
Front and rear bearings	Traces of corrosion on the balls but free in rotation with no hard point / no rubbing marks on the outer race / no rubbing marks on the inner race faces	Traces of corrosion on the balls but free in rotation with no hard point / no rubbing marks on the outer race / no rubbing marks on the inner race faces
Curvic coupling	Visually in good condition	Visually in good condition
Assembly shaft	Visually in good condition – Trace of corrosion	Visually in good condition – Trace of corrosion

Table 13. The result of the module 4 examination

1.16.3.4 Combustion Chamber

A 1.2-inch hole existed at 225° direction from the combustion chamber case. Several cracks were found in the area of the circumferential direction, which turned out as secondary damage.

1.16.4 Comprehensive Results

No damage was observed in engines from the detailed examinations of each engine module (T1, T2). There was corrosion inside the engines, though, which was caused by exposure to the water for the long term. This concludes that no pre-accident damage or mechanical failure exists.

The airframe and engines of HL9619 were found to operate accurately until the impact, following the detailed examination by the ARAIB and BEA. Partial damages observed inside and outside were confirmed to be secondary damage caused by the impact.

1.16.5 Fuel Analysis

HL9619 landed at Ulleungdo naval helipad at 22:46 and refueled 278 gallons using fuel tank equipment in the storage until takeoff. The fuel in the storage tank was JP-8, supplied by xx Energy on October 24. It passed[50] the pre-supply inspection by the quantity control team of x Oil on October 20.

Also, the ARAIB collected samples directly from the fuel tank at the Ulleungdo naval helipad. It brought them to the Testing and Analysis Center and confirmed no fuel-related problems.

1.16.6 Acceleration Due to Gravity

In the case of a helicopter's vertical collision, the impact energy applied to the airframe goes through the “landing gear→fuselage structure→passenger seats[51]” sequence of structural deformation. This sequence of energy absorption increases the chance of survival. The change in acceleration was analyzed through “conservation of momentum” to check the survivability of POB and the degree of aircraft damage at impact with the water.

The degree of HL9619 damage and the POB injuries were calcu-

50) Fuel test report, issuance number: PQ1910230839
51) Aircraft Crash Survival Design Guide, National Technical Information Service, U.S. Dept. of Commerce, Dec.1989

lated by verifying the acceleration due to gravity. The primary computation was made with the BEA and then additionally made with local specialists to confirm the accuracy.

A minimum of 54.54 G was the calculation result when conducted together with the BEA, while it was estimated to have 59.4 G or more acceleration when done with the local specialists.

1.17 Organization and Management

1.17.1 The National Fire Agency

The National Fire Agency[52)] is a central administrative agency established on July 26, 2017, following amendments to the Government Organization Act. Passing through names such as the Department of Firefighting (under the Ministry of Home Affairs) and the National Emergency Management Agency, the National Fire Agency has developed as an integrated disaster-related organization, enhancing the on-site response system, including disaster prevention, rescue and first-aid services, and on-site management. At the time the accident occurred, the National Fire Agency consisted of 1 office, 2 bureaus, 14 divisions, 2 affiliated organizations, and 18 provincial fire headquarters.

Fire helicopters retained nationwide at the time of the accident were 30[53)]: 4 from the National 119 Rescue Headquarters (an affiliated organization) and 26 from 16 provincial headquarters.

The National 119 Rescue Headquarters owned 2 different types of helicopter: two EC225s and two AS365N2s. Among the provincial HQ, Daejeon and Gyeongsangnam-do operated private rented helicopters. 9 and 7 helicopters serviced for over 20 years and for 15 to 20 years, respectively. 10 helicopters were allocated for emergency medical service (EMS) purposes.

52) Chapter 2 the National Fire Agency, Enforcement Ordinance of Decree on the National Fire Agency and Its Affiliated Agencies (No. 117 of the Ordinance of the Ministry of the Interior and Safety, May 14, 2019)

53) National 119 Rescue HQ (4), Seoul Metropolitan (3), Busan (2), Daegu (2), Incheon (2), Gwangju (1), Daejeon (1, lease), Ulsan (1), Gyeonggi-Do (3), Gangwon (2), Chungbuk (1), Chungnam (1), Jeonbuk (1), Jeollanam-do (2), Gyeongbuk (2), Gyeongsangnam-do (1, lease), Jeju (1)

The Aviation and Communication Division[54] under the 119 Rescue and EMS Bureau of the National Fire Agency deals with[55] air firefighting and communication, operational safety issues, system improvement, aircraft SAR, and work support for firefighting helicopter operations nationwide.

1.17.2 The National 119 Rescue Headquarters

The beginning of the National 119 Rescue Headquarters traces back to 1995, the establishment[56] of the National 119 Rescue Squad in Dobong-gu, Seoul, to command and back-up rescue activities in calamities/disasters, following the promulgation of the Decree on the National 119 Rescue Squad[57]. According to the Decree on the National Fire Agency and Its Affiliated Agencies[58], the National 119 Rescue Headquarters belongs to the National Fire Agency and assists the Fire Commissioner's duties.

The Planning and Cooperation Division, Special Rescue Training Division, Special Equipment and Aviation Team, and Canine Search and Rescue Center consisted of the National 119 Rescue Headquarters. The 119 Rescue Operations Center is in direct control of the HQ's commander.

The duties[59] of the National 119 Rescue Headquarters are as follows.

1. Rescue, on-site command, and support for various catastrophic accidents
2. Research and dissemination of rescue mechanisms by disaster type and the training of SAR personnel (include emergency rescue agency defined in subparagraph 7 of Article 3 of the Framework Act on the Management of Disasters and Safety, emergency rescue and

54) The Aviation and Communication Division has reformed into Fire Aviation Department since October 20, 2021.

55) Paragraph 6 (functions of the Chief Aviation and Communication Division), Article 4 (119 Rescue and EMS Bureau), Chapter 2 the National Fire Agency, Enforcement Ordinance of Decree on the National Fire Agency and Its Affiliated Agencies (No. 117 of the Ordinance of the Ministry of the Interior and Safety, May 14, 2019)

56) Banghak-dong, Dobong-gu, Seoul on December 27, 1995

57) Presidential Decree No. 14791, Oct. 19, 1995

58) Presidential Decree No. 29754, enforced on May 14, 2019

59) Article 17 (duties), Chapter 4. The National 119 Rescue Headquarters, Decree on the National Fire Agency and Its Affiliated Agencies

relief support agency referred to in subparagraph 8 of the same Article and lifesaving training requested by a foreign emergency rescue agency)

3. Rescue and support for disasters and accidents that the commander of the National 119 Rescue Headquarters deems necessary when the Special Metropolitan City Mayor, and each Metropolitan City Mayor, Special Self-Governing City Mayor, Do Governor, or Special Self-Governing Province Governor request
4. Matters concerning the operation of Satellite News Gathering (SNG) vehicles
5. Other rescue and support activities for disaster and accidents that the head of the national emergency rescue control group deems necessary

Sudokwon (greater Seoul) 119 Special Rescue Unit[60] and Yeongnam 119 Special Rescue Unit[61] are in charge of dealing with disasters in their regions where different training facilities and helipads are prepared. They also performed duties required in a disaster zone. Honam and Chungchenong and Gangwon 119 Special Rescue Units[62] were additionally established later to be directly deployed to disaster areas nationwide (see Table 14).

60) Sudokwon 119 Special Rescue Unit (45, Deoksong 3-ro, Namyangju-si, Gyeonggi-do, Republic of Korea, launched on Nov. 19, 2014)

61) Yeongnam 119 Special Rescue Unit (1, Gujiseo-ro, Guji-myeon, Dalseong-gun, Daegu, Republic of Korea, launched on Nov. 19, 2014)

62) Honam 119 Special Rescue Unit (Hwasun-gun, Jeollanam-do, launched on Dec. 11, 2015), Chungcheong and Gangwon 119 Special Rescue Unit (Cheonan-si, Chungcheongnam-do, launched on Dec. 11, 2015)

Branch	Location	Jurisdiction (City, Do)	Total
Sudokwon 119 Special Rescue Unit	Namyangju-si, Gyeonggi-do	Seoul Metropolitan City, Incheon Metropolitan City, Gyeonggi-do	3
Yeongnam 119 Special Rescue Unit	Dalseong-gun, Daegu Metropolitan City	Busan Metropolitan City, Daegu Metropolitan City, Ulsan Metropolitan City, Gyeongsangbuk-do, Gyeongsangnam-do	5
Honam 119 Special Rescue Unit	Hwasun-gun, Jeollanam-do	Gwangju Metropolitan City, Jeollabuk-do, Jeollanam-do, Jeju Special Self-Governing Province	4
Chungcheong and Gangwon 119 Special Rescue Unit	Cheonan-si, Chungcheongnam-do	Daejeon Metropolitan City, Sejong City, Gangwon-do, Chungcheongnam-do, Chungcheongbuk-do	5

Table 14. The National 119 Special Rescue Units

Air Rescue and Emergency Squads of each Special Rescue Unit perform the following duties[63] operating helicopters.

1. Command and control of on-site disaster response within its jurisdiction
2. Lifesaving, search, emergency patient transfer, and fire extinguishing activities within its jurisdiction
3. Transportation of organs and organ transplant patients within its jurisdiction
4. On-site rescue activities backed by cutting-edge search equipment and search-and-rescue dogs

1.17.3 The 119 Emergency Operations Center

The 119 Emergency Operations Center of the National Fire Agency is established and being operated for swift firefighting responses and on-site control under the Article 4 of the Framework Act on Firefighting Services[64].

63) Article 7 (119 Special Rescue Unit) of the Enforcement Ordinance of the Decree on the National Fire Agency and Its Affiliated Agencies (No. 117 of the Ordinance of the Ministry of the Interior and Safety, May 14, 2019)

64) Framework Act on Firefighting Services (Act No. 15300, Dec. 26, 2017, enforced on Dec. 27, 2018)

Subparagraphs 7 to 9 of Article 4, Chapter 2 of the Operational Regulations of the 119 Emergency Operations Center[65] stipulate the following in association with firefighting helicopters: 7. Management and coordinated operations of the dispatched helicopters nationwide, 8. Operation, coordination, and control of radio communication network, 9. Utilization and operation of the flight information system.

The 119 Emergency Operations Center is responsible for the overall management of command and control at disaster sites, air SAR activities, statistics of on-site rescue activities, disaster situation progress, and situation awareness. Similarly, the 119 Rescue Operations Center of the National 119 Rescue HQ, belongs to the National Fire Agency, controls the operations of the Headquarters comprehensively.

1.17.4 Working Process of Operational Regulations

1.17.4.1 Procedures for Operation

The following are paragraphs of the Article 16 (procedures for operation) of the Operational Regulations of Air Rescue and Emergency Squads:

1. Operation controllers of the National 119 Rescue Headquarters and City/Do fire headquarters shall obtain approval from the commander of National 119 Rescue Headquarters or the commander of City/Do fire department headquarters in advance when intending to operate an aircraft;
2. An aircraft shall be operated following the flight manual in attached Form 2 issued by controllers;
3. When a flight operation following paragraph 2 terminates, an Air Rescue and Emergency Squad leader shall report to the controllers whether there exist any abnormal conditions along with the operation result;
4. Notwithstanding paragraph 1, test flights for functional inspection and flights for technical support and piloting ability improvement

65) Operational Regulations of 119 Emergency Operations Center of the National Fire Agency (established rule of the National Fire Agency No. 3, enacted and implemented on Dec. 29, 2017)

may be conducted under an Air Rescue and Emergency Squad leader's responsibility without obtaining approval for the operations;

6. An Air Rescue and Emergency Squad leader shall notify the head of the Operations Center of the National 119 Rescue Headquarters or that of City/Do fire headquarters regularly (during work shifts, at noon, at sunset, and midnight) and frequently about aircraft's operational status and meteorological conditions for takeoff; if any reason incapable of flying arises after a dispatch order, the Squad leader shall immediately notify the head of the Operations Centers, document, and manage the fact.

1.17.4.2 Emergency Operations

According to Article 17 (emergency operations) of the same Operational Regulations, in case of an emergency[66], an emergency operation shall be conducted under the dispatch order by a head of an Operations Center. In this case, the responsible person of an Operations Center shall report the order to the commander of National 119 Rescue Headquarters or a commander of City/Do fire headquarters.

1.17.4.3 Flight Restrictions

Article 21 (flight restrictions and others) of the same Operational Regulations stipulates that flights are restricted when falling into certain meteorological conditions (see Table 15). Nevertheless, the cases of emergency operations shall be immediately reported to operation controllers, who may allow a flight under the operational limitations of the relevant aircraft flight manual (AFM) while reflecting the pilot's opinion.

66) Lifesaving, emergency patient transfer, fire suppression, transportation of organs and organ transplant patients, air SAR activities, command/control of aerial firefighting, transportation of human resources/equipment and others necessary for firefighting, other operations upon emergency occurrence, and in case of a backup request from the Fire Commissioner of the National Fire Agency concerning emergency operation

When there is potential for visibility along the air route or at the destination to decrease below the specified conditions					
Day time	Wind speed	Type-specific manuals	Night time	Wind speed	Type-specific manuals
	Visibility	Ground: 3,200 m or less		Visibility	Ground: 4,800 m or less
		At sea: 4,800 m or less			At sea: 4,800 m or less
	Ceiling	Ground: 300 m or less		Ceiling	Ground: 600 m or less
		At sea: 450 m or less			At sea: 600m or less

Table 15. Flight-restricting weather

1.17.4.4 Operations Under Special Conditions

For nighttime aircraft operations, the following conditions stipulated in subparagraphs from 1 to 4 of Article 22 (operations under special conditions) of the same Operational Regulations shall be satisfied; 1. The meteorological conditions of operation routes shall not affect the flight, 2. Aviation instruments and lighting facilities applied mutatis mutandis in paragraph 2 of Article 134 of the Enforcement Ordinance of the Aviation Safety Act shall be installed in aircraft, and communication equipment in the aircraft shall properly work, 3. Night vision devices (NVD) shall be prepared for SAR missions, 4. Heliports shall be equipped with lighting facilities or able to back up with ground lighting for help identifying objects.

Nevertheless, the cases of emergency operations shall be immediately reported to operation controllers, who may allow a flight under the operational limitations of the relevant aircraft flight manual (AFM) while reflecting the pilot's opinion.

1.17.4.5 Overwater Flight

Subparagraphs 1 to 3 of paragraph 4 of Article 22 (operations under special conditions) of the Operational Regulations of Air Rescue and Emergency Squads stipulate matters to comply with when flying over the water.

1. Installation of flotation systems and instrument flight equipment on a helicopter
2. All POB wear life jackets for aviation
3. Equipped with lifeboats, enough to carry all POB, and with distress flares

1.17.4.6 Restriction of Flight Hours

Article 36 (restriction of flight hours) of the Operational Regulations of Air Rescue and Emergency Squads prescribes that pilot flight hours may not exceed 8 hours a day. In comparison, 6 hours are the limited flight hours during nighttime. However, excessive flight hours are possible in emergency operations following the approval of operation controllers.

Studies have shown that night flight puts a pilot 1.4 times more fatigue than daytime flights. Therefore, the pilot's fatigue management matters more in night flights, especially over the water at night.

1.17.5 Training

Article 62 of the Operational Regulations of Air Rescue and Emergency Squads[67] (the Squad members' training) specifies the following:

1. The commanders of the National 119 Rescue Headquarters and City/Do fire HQ shall train their Squad members in the attached Table 2 to maintain each specialty ranging from flights, maintenance, and rescue/first aid and to improve their work capability;
2. The commanders of the National 119 Rescue Headquarters and City/Do fire HQ shall conduct specialized training for flight skills (including transition training and night/instrument flight), emergency procedure, maintenance technology (including maintenance transition training), air weather situation management, air safety management, the progressed maritime lifesaving operations; if another improvement concerning aviation safety and technology is required, training shall be entrusted to the manufacturer or domestic/foreign training

67) Directive of the National Fire Agency No. 2, enforced on July 26, 2017

agencies;

3. The Air Rescue and Emergency Squads leaders shall report every quarter to the commander of National 119 Rescue Headquarters or the one of City/Do fire HQ about the training performances for pilots, mechanics, rescue worker, and paramedic such as flight training, rescue/first-aid training, and maintenance;
4. A person (qualified) who intends to control a firefighting aircraft shall remain at a proficient flight level by conducting a skill-maintaining flight (including simulator training) for an hour or more at once, every 3 months.

Night flight training hours shall hold 1 hour or more within 90 days from the latest flight. However, the actual mission flight hours may be in place of this (see Table 16).

Subject	Basic flight	Night flight	Instrument flight	Rescue training	Fire suppression
Flight training	2 hours or more every month	1 hour within 90 days	6 hours within 6 months	Sustained throughout a year	More than once
Note	Including flights acquainting with City/Do	Can be replaced by actual hours of mission		In the water/mountain and others	Before the initiation of wildfire response

Table 16. Required amounts of flight training

1.18 Additional Information

1.18.1 Flight Procedures

1.18.1.1 Takeoff From the National 119 Rescue Headquarters

HL9619's pilot and co-pilot conducted pre-takeoff interior checks, engine starting, and pre-takeoff checks, following the checklist while fixing night vision goggles (NVG) to their helmets. At 21:33, they took off from the National 119 Rescue Headquarters at Daegu heliport. During takeoff, the pilot pressed the GA button on the collective to perform an automatic takeoff and then pressed ALT.A and HDG (heading) buttons. Since taking off, the pilot maintained AP function and flew towards Pohang city.

During the flight, the pilot and co-pilot had conversations about the Dokdo helipad. The co-pilot asked about the location to land on Dokdo. The pilot replied that they had to check the spot when they reached the island since there were two helipads in Dokdo: one around the top and the other at the dock.

However, in reality, the helipad at the dock had already been closed long ago; only one helipad behind the Security Police office was operating. Neither the pilot nor the co-pilot had precise information about the Dokdo helipad. The 119 Rescue Operations Center should have checked the helipad information with the Dokdo Operations Center and provided it to the aircraft while on mission.

Initially, after receiving the report of a patient occurrence, the person was supposed to be transported to the Hyeongsan-gang helipad in Pohang. However, during a flight, the HL9619 was informed by the 119 Rescue Operations Center that the destination had changed to Daegu International Airport; and the hospital details were given via mobile phones. The pilot and co-pilot worried about the patient's condition that he could not even have administered painkillers since there were no doctors in Dokdo.

As HL9619 entered the East Sea 27 minutes and 10 seconds after the takeoff from the National 119 Rescue Headquarters in Daegu, the pilot said, “Entered the sea, Float ARM Position,” and the co-pilot repeated, “Switch

ARM.” In preparation for an emergency landing at sea, the pilot operated the EFS before entering the sea.

After taking off from Daegu, the pilot found it impossible to fly back from Dokdo if the aircraft does not refuel in between. Thus, a decision has been made to refuel at Ulleungdo helipad. The HL9619 communicated with Master Control & Reporting Center (MCRC), notified it would stop by Ulleungdo for refueling before they continued to fly to Dokdo. It also requested the 119 Rescue Operations Center a permission to land on Ulleungdo and to refuel.

The co-pilot flew while checking the shooting stars through the NVG. The pilot wore the NVG but flew without the aid of it, having the image intensifier tubes on his head with the mount. When the paramedic asked the co-pilot, "Are you wearing the NVG?" the co-pilot answered, "Yes" and added "This even enables seeing shooting stars better."

The pilot and co-pilot talked about NVG when approaching the Ulleungdo helipad. They said the new NVG for the pilot has a gray screen in which the halo effect[68] is less than the former NVG with a green screen. Assuming both of them could observe shooting stars, they both were considered to wear the NVG when they were approaching the Ulleungdo naval helipad.

1.18.1.2 Approach and Landing at Ulleungdo Helipad

At 22:46, HL9619, flying the sky 17 miles southwest of Ulleungdo, requested permission from the ground staff to land at RKDU[69] (the naval helipad at Ulleungdo). The ground crew informed that the wind was blowing up to a maximum gust of 35 kts from a 270° direction and asked, "Would there be any problem with landing?" The pilot replied that "No problem to land."

While approaching the Ulleungdo helipad, the pilot communicated with the ground that it was 5 minutes before the landing and maintained HDG

68) Halo effect: A phenomenon in which the shape of an object coming into the vision through night vision devices is seen transformed

69) The name registered in ICAO

mode. The pilot and co-pilot turned off their NVG, saying it was too bright to secure the sight for the helipad. The pilot then turned on the landing light, lifted the AP, directly controlled the flight, and landed.

1.18.1.3 Refueling and Takeoff From Ulleungdo

After landing, the mechanic and the rescue worker refueled 278 gallons of fuel with ROK navy personnel through a fuel line connected to storage. While the refueling was in progress, the pilot and co-pilot entered the coordinates of the Dokdo helipad into the flight management system (FMS). After the refueling, the pilot requested the ground control to takeoff and got permission with relevant weather information.

At 22:57, the pilot turned the nose to the left for takeoff. The pilot pressed the GA button on the collective and took off automatically. After that, he headed to Dokdo through AP functions—HDG, IAS, and ALT using the path coordinate saved in the FMS.

1.18.1.4 Overwater Flight and Approach to Dokdo

HL9619 maintained speed and altitude during flight, and the expected flying time to Dokdo was about 23 minutes. At 23:12, the pilot had a pre-landing briefing with the crew, which concluded that they would approach from the south of Dongdo to the north and turn on the landing lights and floodlights. Also, the mechanic in the back seat was determined to identify the helipad location by turning on the searchlight (tracker).

While flying north of Seodo, the co-pilot communicated with the Dokdo Operations Center for the first time that they had 10 minutes left for landing. They also identified the location of Dokdo through the radar installed on the aircraft. The co-pilot said, "Are those beacon lights?" when seeing a rotating light from afar.

The accident investigation confirmed, however, that there were no beacon lights installed on the Dokdo helipad. The rotating light that the co-pilot perceived as beacon lights was, in fact, the lights from the Dokdo lighthouse, which guides ships.

In the conversation between the pilots at a point 12 miles northwest of the helipad, the pilot stated that it would approach the Dokdo helipad from the south to north direction. The co-pilot said, "Through downwind?" The pilot mentioned, "Confirm rotating beacon," and continued approaching.

While approaching the helipad, the pilot said, "Due to the lights outside ... I should turn the NVG off after passing that ship." The pilot radio communicated with the Dokdo Operations Center, "3 minutes before landing." The co-pilot said, "I can see well outside with the NVG," and the pilot replied, "I cannot." The co-pilot turned on the searchlight upon the pilot's request.

While approaching, the co-pilot called out, "Altitude 1,100 ft, descending to 500 ft, 200 ft, Power Check." The pilot said, "Why is the power consuming so much?" When he soon after said, "Aw, the light should not flash upon us," a warning sound, "gong" was heard. This warning sounds when over torque occurs. The mechanic then repeated, "What is wrong, what is wrong, what is wrong?" loudly, in surprise.

Right after that the pilot said, "The altitude is too high. It's turning left. Dizzy." He said, "ALT.A, HDG, IAS, speeding up. Altitude 700," and attempted GA, increasing speed.

After that, the pilot said, "What is wrong with the bank?" at the 40-knot speed. About 20 seconds later, "Uh, searchlight off," he said, complaining of dizziness, and mentioned, "I will go in at a speed of 30 kts. The light is shining straight ahead...." He requested the Dokdo Operations Center turn off the beacon light, but it turned off the entire helipad lights and turned them on again.

1.18.1.5 Illusion During Approach

The pilot decided to GA left due to the high altitude. He climbed to 800 ft and maintained ALT.A, HDG, and IAS. He suddenly said during level flight, "What is wrong with the bank?" "It seems you felt like it is banked," the co-pilot replied, which implies the pilot experienced a sudden illusion.

The co-pilot also felt dizzy for a moment when turning left with a 40-kt speed at the lowered altitude of 500. Thus, he said he would turn off the searchlight. Based on the co-pilot mentioning, "Shouldn't we ask to turn off the beacon light?", both pilots appear to experience momentary illusions caused by the lights from the lighthouse.

However, in fact, the Dokdo helipad was not equipped with beacon lights. The pilot is believed to have deluded the lighthouse lights as beacon lights.

Judging from when the pilot notified the co-pilot that it would approach at a 30 kts speed and said, "The light is shining straight ahead...," a loss of altitude control seemed to occur. It is presumed that the light of a portable searchlight would temporarily and indirectly be caught by the pilots wearing NVG, while a Dokdo police officer shook the searchlight for HL9619 to guide the helipad location.

1.18.1.6 Landing to Dokdo Before the Patient Boarding

At 23:22:30, the HL9619 landed at the Dokdo helipad. The two pilot talked about the previous situation when it was approaching the helipad. The pilot mentioned that they should (but could not) have lowered the altitude about 5 miles before; the altitude, in the end, got higher because the aircraft only dealt with speed; and it failed to measure the visual approach. While he was mentioning those, the patient, the caregiver, and all the other crew finished boarding.

1.18.1.7 Takeoff From Dokdo

The pilot released the parking brake and turned on the flood light and off the landing light. At 23:24:29, 32 seconds before the crash, the pilot hovered to take off toward where it had approached. He prepared for takeoff by turning the nose 180° right.

While turning to the right, the aircraft was pushed slightly to the left, so the co-pilot informed it to the pilot. 14 seconds prior to the crash, the pilot asked "Setting" to the co-pilot and took off. Before long, the pilot said, "ALT.A, HDG," and the warning sound "gong, gong, gong," was heard simultaneously with the co-pilot’s reply, "ALT."

The mechanic said, "Head up ...," at the back seat, while the co-pilot shouted, "Altitude, altitude, altitude." At the same time, a warning sound, "Don't sink, Warning Terrain," came; this was at 23:25:01; the HL9619 crashed into the water only about 14 seconds after it took off the Dokdo helipad.

1.18.2 Work Pattern of Crew

5 people; a pilot, a co-pilot, a mechanic, a rescue worker, and a paramedic were mobilized as a Squad for the patient transport mission. They had a 3-week cycle[70] work pattern. On the day of the accident, October 31, the crew, except the pilot, did night shifts; they arrived at work before 17:30 and started their shift at 18:00.

The pilot was supposed to do a night shift with his Squad but switched to on-duty (work from 09:00 to 09:00 the next morning) because of a daytime worker’s business trip and as such.

1.18.3 Overwater Flight

The Operational Regulations of Air Rescue and Emergency Squads require[71] aircraft the following when flying over the water:

1. Installation of flotation systems and instrument flight equipment on a helicopter,
2. All POB wear life jackets for aviation,

70) Week 1: daytime work (weekday, 09:00 – 18:00), Week 2: a night shift every 2 days (18:00 – 09:00 next morning); a night shift during the weekend refers to on-duty (09:00 – 09:00 next morning)

71) Paragraph 4 of Article 22 (operation under special conditions) of Chapter 5 of the Operational Regulations of Air Rescue and Emergency Squads (Directive of the National Fire Agency No. 2, July 26, 2017)

3. Equipped with lifeboats, enough to carry all POB, and with distress flares,
4. Completion of crew training for marine survival.

The physical and psychological fatigue that arises from night flight affects pilots more than flights in the daytime. It gets even worse on night flights over the water without a subject to refer to. Takeoff and landing at locations with no landing lights or aiding facilities, in particular, increase the risk of pilots experiencing spatial disorientation.

1.18.3.1 Overwater Flight Performance

The pilot performed flights over the water for 168.7 hours, 43 times in total, from the day he was hired to the day before the accident (May 22, 2015 – Oct. 30, 2019). The night overwater flights he operated among the total were 59.8 hours, 20 times.

The co-pilot, since January 2017, had 97.6 hours of flights over the water, 26 times in total; among them, 39.1 hours, 14 times were night flights over the water.

1.18.4 Night Flight

HL9619 was certified as capable of flying at night by wearing NVG. Aircraft instruments and interior lights installed were also operated with conditions that enable night flights with the aid of NVG.

At night, lights are reduced compared to daytime, and the visible ranges become narrowed and restricted. These hinder the functions of one's vision. In addition, ambient light sources such as moonlight, starlight, lighting, and flashlights restrict activities such as terrain readouts, night patient transport, night mountain rescue, and night flight.

To overcome these restrictions, pilots need to be trained for night flights, which cover protecting vision during the night, acknowledging weather restrictions, NVG operations, instrument dependence training to maintain flight attitude, and controlling AP and switches in aircraft. The National Fire Agency did not retain a flight simulator or flight training device concerning night flight or AP training.

Pilots need to remain physically sound to perform night flights. If fatigue is piled up through excessive workouts during the daytime, it may lead to night vision decline, lagging reactions, and a weakened ability to distribute attention. Therefore, physical activities should be carefully managed to avoid the above symptoms and secure favorable conditions for a safe flight.

Fatigue from a night flight is at least 1.4 times higher than fatigue from a daytime flight. However, unexpected flights, such as flights to inexperienced areas or emergency patient transportation cause even more fatigue and stress for the crew. The same goes for the HL9619 case, which had to transport an emergency patient at night, flying over the sea.

1.18.4.1 Meteorological Restrictions

The Operational Regulations of Air Rescue and Emergency Squads restrict[72) a night flight depending on meteorological conditions, such as wind speed to follow the relevant AFM, visibility of 4800 m or less above sea level, and a ceiling of 600 m or lower. However, it does not cover weather restrictions depending on when one is wearing NVG and when not.

1.18.4.2 Operation of NVG

NVG can operate even in small light or starlight at the same magnification as a real object. It enhances illuminance by amplifying light about 25,000 times.

Yeongnam 119 Special Rescue Unit used 15[73) NVGs with two types (M949, F4949). 12 out of the 15 were provided to each pilot for personal

72) Article 21 (restriction on flight and others) of Chapter 5 of the Operational Regulations of Air Rescue and Emergency Squads (Directive of the National Fire Agency No. 2, July 26, 2017)

73) Eight M949s and seven F4949s

use. 1 out of the rest 3 NVGs was shared with 6 mechanics, and the other two were out of order[74] and scheduled to confirm the disuse.

The pilots, during the night flight, were attaching the NVG on their helmets and using it, but the crewmembers sitting on the rear were not equipped with it, for the reason of handling patients and as such. However, even the crew in the back seat should carry a portable NVG to watch or warn of obstacles during flight. See Figure 31 for the helmet equipped with NVG and the view of the image shown through the gear.

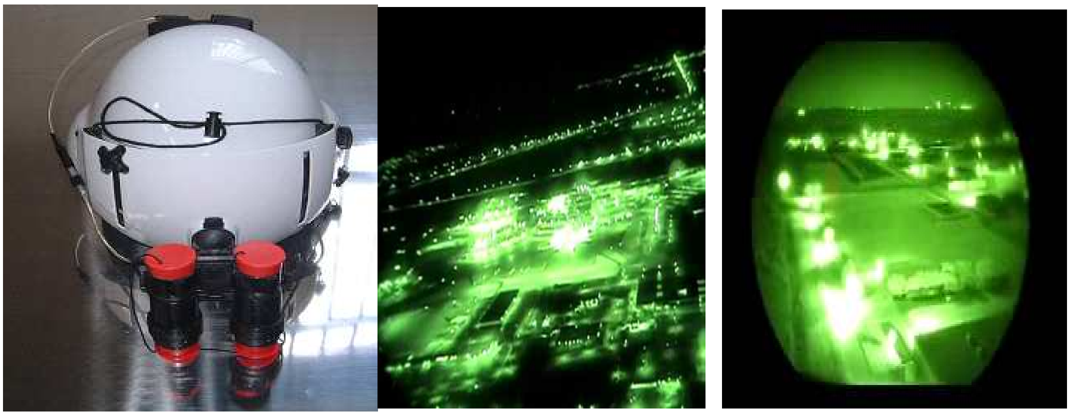


Figure 31. View shown through NVG

1.18.4.3 Night Flight Performance

In 2018, the pilot performed 14 night flights of 28.6 hours (see Table 17). He had 7 night flights over the water from a total of 9 overwater flights. In 2019, he flew at night 9 times for 9.4 hours and flew over the sea twice during the daytime, but had no night overwater flight record.

In 2018, the co-pilot performed 14 night flights and 7 overwater night flights (among 9 overwater flights). In 2019, he flew 11 times at night and 2 overwater flights at night from 4 overwater flights.

Both the pilot and co-pilot performed night flights to islands, such as Jeju, Baengnyeongdo, and Ulleungdo, and the two flew together as a team in most cases.

74) 2 M949s received breakdown decision (Dec. 28, 2018); scheduled to confirm disuse disposition

Classification	Year	Night flight (land and sea)	Overwater flight			
		Times/hours	Total	Daytime	Nighttime	Destination (times)
The pilot	2018	14 / 28.6	9 / 15	2 / 3.5	7 / 11.5	Ulleungdo (3) Jeju (3) Baengnyeongdo (1)
	2019	9 / 9.4	2 / 5.0	2 / 5.0	0	-
The co-pilot	2018	14 / 28.6	9 / 20	2 / 8.5	7 / 11.5	Ulleungdo (3) Jeju (3) Baengnyeongdo (1)
	2019	11 / 16.1	4 / 8.5	2 / 5.0	2 / 3.5	Ulleungdo (1) Jeju (1)

Table 17. Fight performances at night and over the water

1.18.5 Statements of Witnesses and Persons Involved

1.18.5.1 Dokdo Police Officer 1

A Dokdo police officer in the power-generating office building located upward of the helipad witnessed the HL9619 took off and landed. The officer said, "The wind did not seem to be blowing strongly when the helicopter took off and landed. It was odd to see it slowly descended once it got out of the Security Police. While thinking it should increase its altitude, I heard a ‘thud’ into the water, and then everything became silent."

1.18.5.2 Dokdo Police Officer 2

This person guided HL9619 to the helipad. "When it first approached the helipad, it detoured with a big circle for 3 to 5 minutes toward Seodo and re-approached. The wind was variant and strong at the time. Stars were clear without fog or sea fog. I sheltered out of the helipad due to the strong wind while it took off and landed. I saw it took off, and when I just returned to my office, I heard someone shouting which recognized me that an accident occurred," he said.

1.18.5.3 Dokdo Police Officer 3

The police officer was watching the helicopter on the helipad and returned to his office after its takeoff. He stated, “I checked the helicopter taking off without a hitch, but within 10 seconds, I heard a ‘thud’ and had a gut feeling it crashed. The sky and the water were dark with a few stars, and the visibility was good.”

“I searched the water with colleagues using a 30-horsepower boat upon acknowledging the crash, but no helicopter-related suspension was found. The wave was so high as if it flipped our boat over. For that reason, we could not spend more than 30 minutes on the search to secure our colleagues' safety,” he said.

1.18.5.4 Dokdo Police Officer 4

“The airframe emitted red lights and ‘thud’ into the water just like it slipped,” he said.

1.18.5.5 Dokdo Operations Center Officer

The Operations Center officer of the Dokdo Security Police said, “At 22:57, the 119 Rescue Operations Center notified the helicopter took off from Ulleungdo after it refueled. 3 minutes before it landed here, the helicopter radio communicated[75] to turn off white lights (the pilot meant beacon lights). I understood the request to turn all the helipad lights off, so I did it and turned them on again. Due to its location, a staff in the Operations Center can check the exterior situation only through security cameras, and even the range shown through the cameras was limited. Thus, the accident was noticed by the officer, serving his duty outside.”

1.18.5.6 Broadcasting Staff

The broadcasting staff visited Dokdo to examine his company's panoramic camera. He witnessed HL9619 landing and taking off and shot the moment with a cell phone camera.

“The weather was dark and windy, and the waves were high when the fire helicopter came in. The helicopter entered from the south after circling Seodo. I only filmed until it turned the airframe to take off on the ground, and then I avoided winds. While avoiding it, I heard officers shouting, ‘Crash!’”

1.18.6 Security Camera Footage

Dokdo Security Police operates security cameras with recording functions, and the monitoring screens are in the Operations Center. Thus, it re-

75) VHF communications network, call sign “Dokdo Ground”

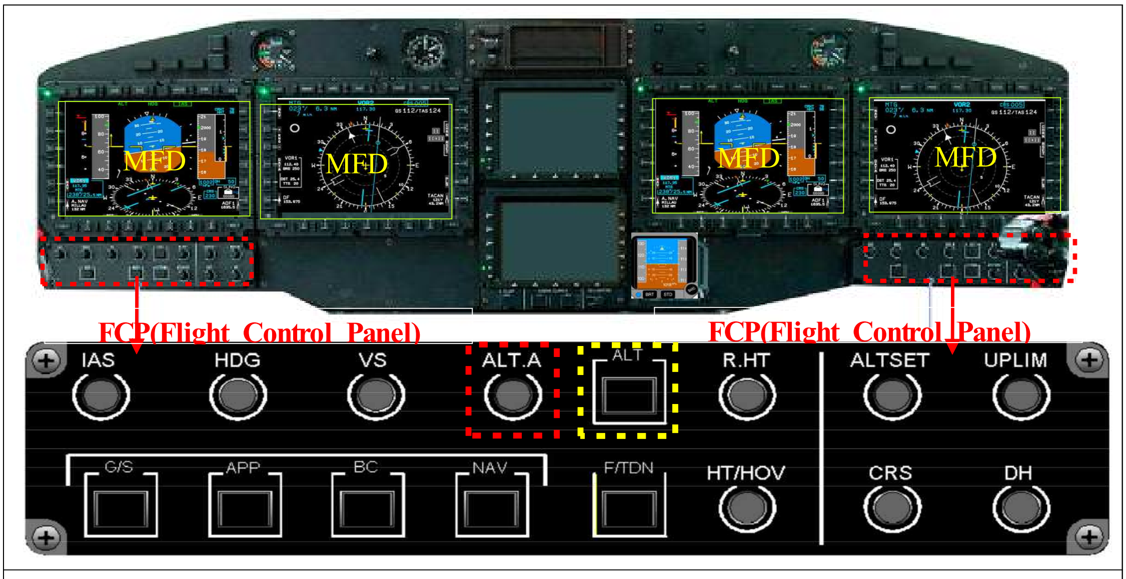
cords aircraft approaching, landing, and takeoff. However, no HL9619 footage was shown after it took off because the place where the cameras filmed, and its took-off direction did not match.

1.18.7 Flight Display System (FDS)

The flight display system presents the data required for flight control and navigation management. The FDS is fully quadruplex. Each multifunction display (MFD) receives data from all the sensors and can be manually reconfigured.

1.18.7.1 Multifunction Display (MFD) and Flight Control Panel (FCP)

The FDS is composed of four MFDs and four processing units (PU). The flight control panels (FCPs) are located right below the MFDs (see Figure 32).



MFD, FCP

Figure 32. MFD and FCP

Pilots use the FCPs to select the flight parameters required for the display system and the AP. The FCP manipulation results are shown on the MFDs. Accordingly, pilots can monitor flight situation via the MFDs.

1.18.7.2 Automatic Flight Control Systems (AFCS)

HL9619 was equipped with the AFCS, which provides automatic flight control in the 4 helicopter control axes. The main functions of AFCS are automatic flight control, dual sensor monitoring, and flight envelope computation.

See Table 18 to refer to the AP functions (the AFCS includes AP).

Name	Function
IAS	Press: Current airspeed hold. Rotate and press: Pre-selection and capture of airspeed.
HDG	Press: Current heading hold. Rotate and press: Pre-selection and capture of heading.
VS	Press: Current vertical speed hold. Rotate and Press: Pre-selection and capture of vertical speed.
ALT.A	Rotate: Pre-selection of an altitude value. Press: Engage VS mode and capture the pre-selected altitude value.
ALT	Current altitude hold
CR.HT	Press: Current radio height hold. Rotate and press: Pre-selection and capture of radio height.

Table 18. AP functions

1.18.7.2.1 Altitude Hold (ALT) Mode

Altitude hold (ALT) mode holds the altitude displayed on the barometer.

- Below 60 kt, altitude is controlled through the collective axis.
- When exceeding 60 kt, the altitude is controlled through the cyclic axis (3-axis operation) or through the collective axis when the IAS (indicated airspeed) is engaged (4-axis operation).
- Adjusting altitude reference value is available through a trim switch on the collective stick.

1.18.7.2.2 Vertical Speed (VS) Mode

The vertical speed mode holds the current vertical speed.

- Vertical speed below 60 kt is controlled through the collective axis. However, if an aircraft speed exceeds 65 kt for at least 5 seconds the mode

switches to the pitch axis.
- When exceeding 60 kt, the speed is controlled through the cyclic axis (3-axis operation) or through the collective axis when the IAS is engaged (4-axis operation).
- Adjusting vertical speed reference value is available through beep trim on the collective stick or through the FCP.
- When approaching the ground, the mode automatically reverts to ALT, to hold an altitude corresponding to a radio height of 150 ft.
- A safety device prevents the vertical speed reference from exceeding the safety value according to airspeed.

1.18.7.2.3 Altitude Acquisition (ALT.A) Mode

ALT.A mode secures and holds a preselected altitude. Turning ALT.A rotary knob on FCP presets a reference altitude (step = 100 ft). Pressing ALT.A rotary knob on FCP maintains VS mode (ascend or descend) that fits with the default vertical speed. VS mode is selected until the gap between the actual and the reference altitude becomes 300 ft or below. After that, ALT mode is automatically engaged.

1.18.7.2.4 Go-around (GA) Mode

GA mode is used for automatic departure from a missed approach or hovering. It secures and holds preselected VS of 1000 feet per minute or current VS (the highest speed of whichever) and Vy or current aircraft speed (the highest speed of whichever). GA mode is engaged by pressing the GA push button located on the collective stick. The associated GA label is displayed on the AFCS strip in the longitudinal and collective axes columns.

1.18.8 Illusions Leading to Spatial Disorientation

During a flight, several illusions occur to the crew, and most of these are related to the sense of balance and visual cause. Some illusions induce spatial disorientation.

Pilots may easily fall into spatial disorientation at night when approaching topography like an island due to restricted visual references and illusions created by lights. In particular, Dokdo has a topography that is apt to delude altitude, speed, or attitude.

A pilot under spatial disorientation may wrongly control an aircraft because of failing to acknowledge current speed, altitude, and attitude. This is often the probable cause of loss of control (LOC) or controlled flight into terrain (CFIT). Varying aircraft's motions provoke different illusions of vision, sense of gravity, and location.

Crewmembers, thus, end up losing the situation awareness; they fail to recognize a situation under risk or pitch opposite from what they are facing.

1.18.9 Effective Investigation Techniques

There are no particularly effective or useful investigation techniques applied for the HL9619 accident investigation.

2. ANALYSIS

2.1 General

In this part, all of the HL9619's flight processes are analyzed; takeoff from the National 119 Rescue Headquarters heliport, landing at Ulleungdo helipad, GA during the approach to Dokdo, takeoff while the patient on board until the crash. Also, to investigate the cause of the crash, all areas including meteorological factors, airframe and engines, flight procedures, AP operation, night flight training, and crew resource management (CRM) were analyzed.

2.2 Meteorological Factors

Among the pilots' conversation amidst the HL9619 flying over the sky of Daegu after taking off from the National 119 Rescue Headquarters heliport, "No clouds and fairly good weather" was mentioned. The co-pilot said, "Many stars out there" when they were entering the sea through Pohang. These implies the visibility during the flight was clear.

The weather information received via a cell phone message during the flight from the 119 Rescue Operations Center was a visibility of 4 miles with south winds blowing up to 30 kts. The sky was clear with stars and without clouds or sea fog. It was confirmed even by workers serving duties in Dokdo and the pilots dispatched to the accident site.

The weather at Dokdo, as measured by the ASOS at the time, indicated 10 km of visibility with wind gusts of 8.8 ~ 9.6 m/s (17.1 ~ 18.6 kts) coming from a 290° direction. The helicopter approached 50 ~ 60° directions of left crosswinds.

The gross weight of the HL9619 when taking off the Dokdo helipad was 9.412 kg. Based on the 300 feet above sea level, the aircraft was in ENVELOPE B presented in its flight manual (see Figure 33). The demonstrated wind envelope in hover flight in envelope B has upwind 50 kt, right crosswind 35 kt, downwind 35 kt, and left crosswind 25 kt.

The KMA issued the maximum gust of 18.6 kt at the time, which did not go over the demonstrated wind envelope. However, it is believed that the HL9619, while passing across the steep slope of Dokdo near the helipad on approach and takeoff, had difficulties using its power and had vibrations in the airframe.

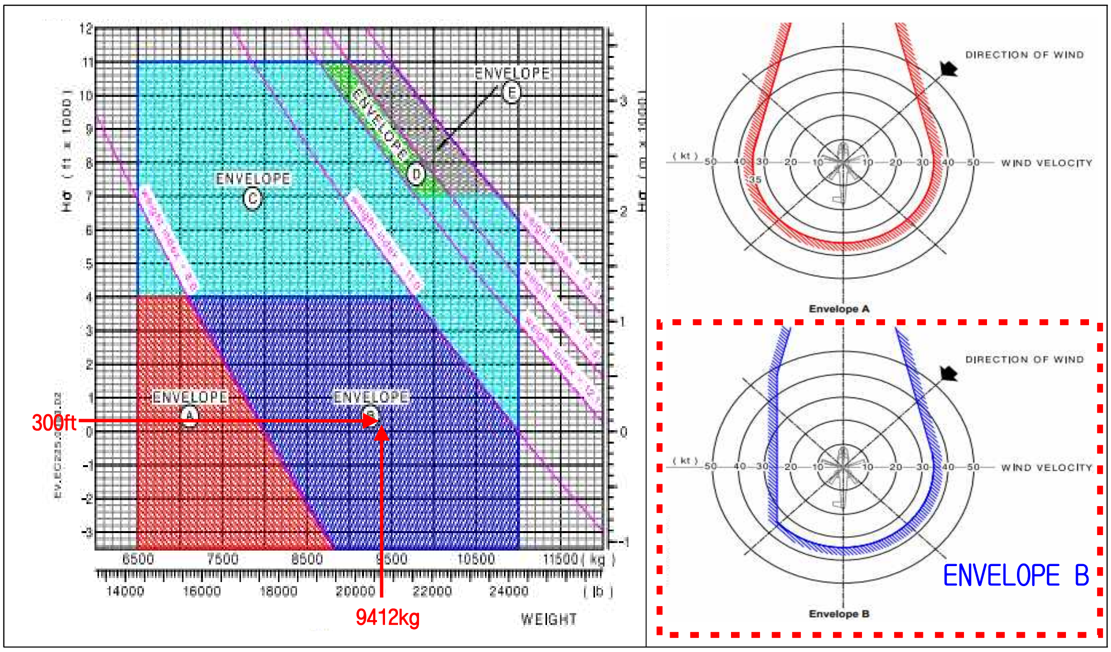


Figure 33. Demonstrated wind envelope in hover flight

The HL9619 took off the helipad in a 230° direction. The wind was blowing from 290° direction, so it became right crosswinds at about 60° from the aircraft aspect (see Figure 34). During the pre-takeoff hover, the co-pilot informed the pilot that the helicopter left drifted, which also appeared to be the cause of the right crosswind.

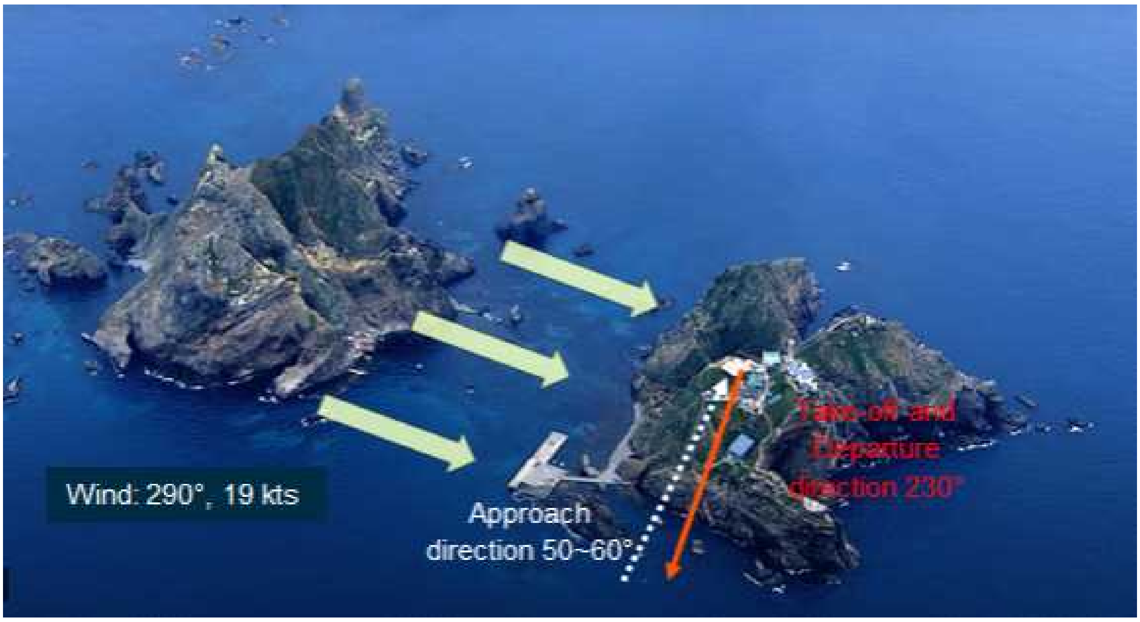


Figure 34. Takeoff/landing directions and the wind conditions

The analysis showed the time of moonrise and moonset in Daegu were at 09:52 and 20:04, respectively. That is, at 21:33, the moment the helicopter took off from the National 119 Rescue Headquarters (in Daegu) was without moonlight. Even if the moon rose, the impact of the moonlight might not be sufficient because it was a crescent moon, only 10% the size of a full moon.

The situation was no different when the HL9619 approached and took off Ulleungdo and Dokdo. See Table 19 for the weather observations data by the Korea Astronomy & Space Science Institute (KASI).

Date	Region	Sunrise	Sunset	Moonrise	Moonset	Moonlight
Oct. 31, 2019	Daegu	06:46	17:32	09:52	20:04	0.106 (10%)
	Ulleungdo	06:39	17:20	09:46	19:50	
	Dokdo	06:35	17:17	09:41	19:47	

Table 19. Flight regions and the sun and moon data

Gusts and strong wind with the lift crosswind the HL9619 faced while approaching the Dokdo helipad would cause anxiety to the pilots. Analysis indicated that the pilot tried to fly through wide space without obstacles for the night flight rather than considering the wind direction.

The pilot turned the nose of the helicopter almost 180° to the right to take off without being backed by any moonlight. He was also rapidly approaching the dark sea from a flashing helipad. These might caused the pilot to experience a transient illusion. Even though the sky was clear without clouds and sea fog, it might be hard to distinguish the sky and sea because of the lack of night lighting during the flight over the water. Therefore, it deems necessary for the HL9619 crew to put on NVGs, which enable the amplification of external lights such as starlight.

2.3 Operation of Dokdo Helipad

The Gyeongbuk Provincial Police is responsible for the operation of the Dokdo helipad and relevant facilities, and the chief officer of Dokdo Security Police is in charge of managing the helipad. Following the data on takeoff/landing at the Dokdo helipad, it confirmed 18 landings since January 1, 2017, including helicopters belonging to the Korean National Police Agency.

Over the past 3 years, HL9619 was the first helicopter to land the Dokdo helipad “at night” among the 18 landings. There was one landing record from a firefighting helicopter to Dokdo in the daytime (August 2019).

When HL9619 took off and landed on Dokdo, it communicated with the Dokdo Operations Center using VHF frequency. 15 minutes before it landed, the pilot requested the approval. The Operations Center officer who communicated with the helicopter was specialized in radar detection and did not have an aviation-related career or received training related to air-traffic control.

Thus, it seems that the two could not well communicate using appropriate air-traffic control terms or the officer operating aviation lights proficiently. Although the pilot wanted to turn off the beacon light, the officer turned off all the lights, increasing the chances of confusion when identifying the helipad.

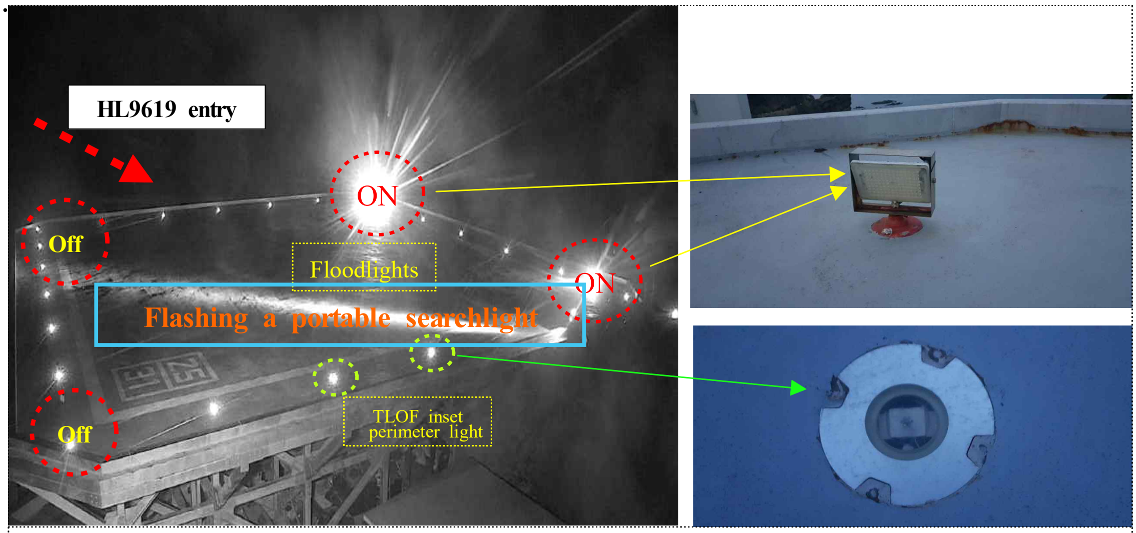
The Korean National Police Agency was not prepared with the procedures of operating the Dokdo helipad. If the Agency provided training to their Operations Center officers about aviation weather, obstacles, and information that would be helpful for communicating with pilots, the pilot and officer at the moment could communicate smoothly and share appropriate information.

Near the helipad was only the pole of a windsock installed; no sock attached that helps check the direction and strength of winds, nor the LEDs. which enable checking wind status through the sock at night. Since the Dokdo helipad has a variant vortex and winds, a WDI, if properly installed, would help the pilots controlling the aircraft.

Lighting facilities and the operational conditions of the Dokdo helipad should be regularly examined, and all lighting should remain in ordinary operation. All 24 TLOF inset perimeter lights (green) were in routine operation on the accident day. However, two floodlights (white) in the east (direction based on the aircraft) out of the four did not operate.

Due to the 2 floodlights did not work, the HL9619 pilots may suffer from identifying the helipad. Also, the imbalanced illumination of the floodlights may lead to their illusion getting worse.

As HL9619 approached the helipad, the officer standing at the front right of the helipad flashed a portable searchlight to guide the aircraft to its location by waving it towards the helipad floor (see Figure 35). However, there is a possibility that the searchlight may have flashed into the cockpit, even indirectly, and temporarily hindered the pilot's vision
.



Helipad lighting system

Figure 35. Helipad lighting conditions when HL9619 approaches

The Dokdo Security Police, which manages the helipad, mainly detect and watch radars to secure Dokdo. Even though duties for helicopter operations are not their original tasks, they have to do their utmost to prevent aircraft accidents and keep the operations safe.

Therefore, the Operations Center officers should thoroughly be trained for air radio communications, enhance the methods of acquiring information including weather data, and manage the helipad facilities. Further, the Dokdo Security Police should make up for their self-utilizing entry and exit procedures to Dokdo so that these can be shared and disseminated to the pilots, supporting safe operations.

2.4 Flight Recorder

2.4.1 Cockpit Voice and Flight Data Recorder (CVFDR)

The CVR and FDR installed in the HL9619 were recovered and thoroughly analyzed.

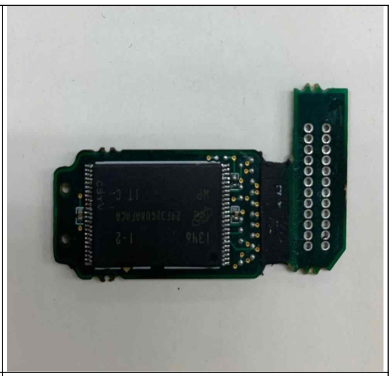
2.4.2 Cockpit Video Recording Data (Vision 1000)

The ARAIB tried to restore the video data of Vision 1000 installed in the cockpit (see Figure 36). It asked for technical support primarily from the BEA and secondary to NTSB, and yet it failed to restore the video data of the residual part.

The recording stopped at 920.6 m altitude, 149.7 kts speed, 9.3° pitch, and 0.2° roll. The reason why the recording did not be saved in the internal memory chips and SD card are not determined.

Vision 1000 main body

SD Card



Internal memory chips

Figure 36. Vision 1000

According to the recorded video, the pilots wore aircrew life jackets and NVGs and started the engines following a checklist (see Figure 37).

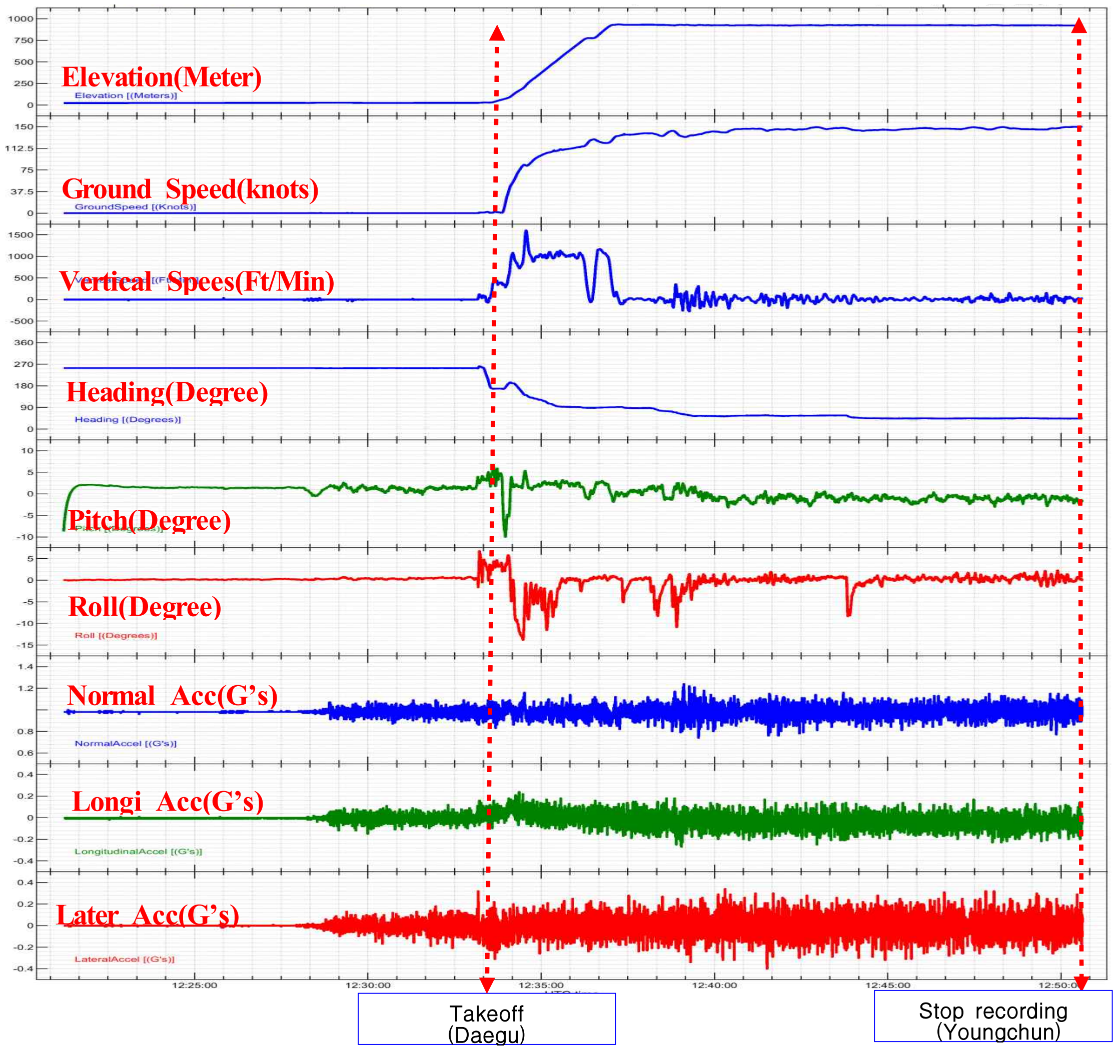


Figure 37. Vision 1000 data

2.5 Investigation Results of Airframe and Engines

The engine and MGB were disassembled and analyzed to determine if they were the cause of the HL9619 accident. The result showed no issues with these sectors, and the CVFDR also showed no abnormal record.

2.6 Survival

When HL9619 crashed, its speed was 125 kts, and its descent rate was -1,360 ft/min. The acceleration due to gravity upon impact with the water was calculated as about 54.54 G or more. The crash destroyed the EFS and compressed the front airframe to the rear, leaving little chances for the POB to survive.

2.6.1 Emergency Flotation System (EFS)

Operating EFS is either setting the EFS switch “ON” for auto operation when the pressure reaches a certain level upon landing on the water or manually pressing the switch on the collective. See Figure 38 for the principle of EFS operation.

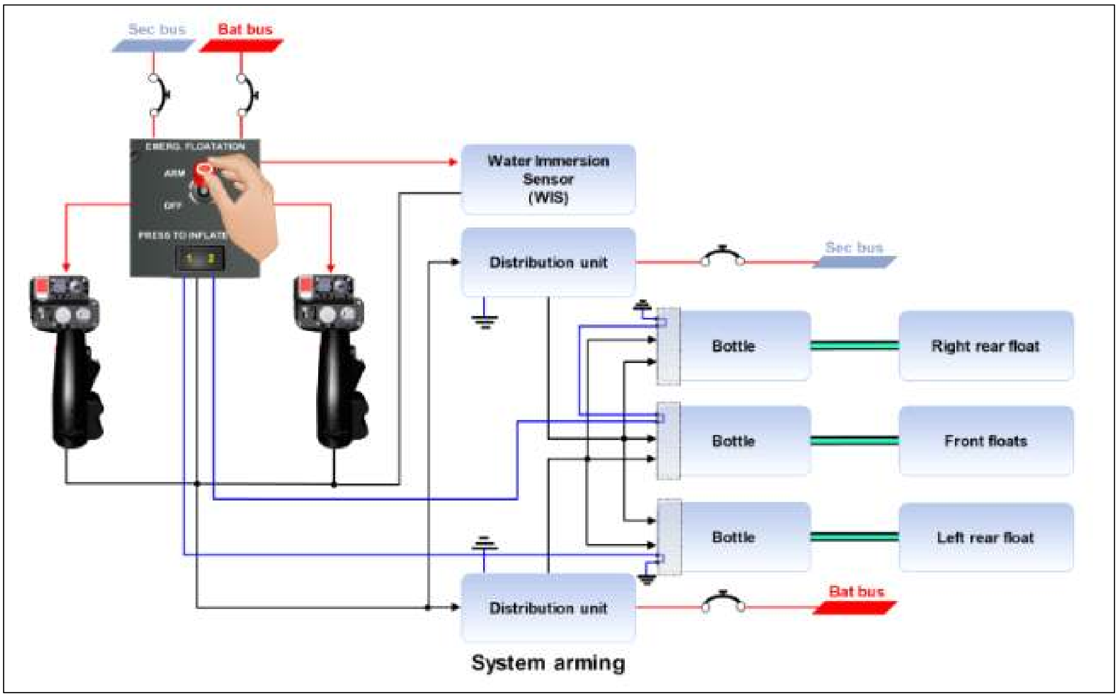


Figure 38. EFS operation principle

The CVR recorded the pilot turning the EFS switch ON while entering above the sea from the sky of Pohang. The reason for the failed EFS operation, however, even if switched on, may be due to the too-intense HL9619's fall energy; the sudden destruction of structures would render the power connections to helium gas cylinders incapable.

Also, the reason why the pilot did not operate the EFS manually would be that he did not recognize the helicopter falling.

2.6.2 Acceleration Due to Gravity

Experts from home and abroad jointly investigated the energy when the aircraft impacted with water to identify the degree of aircraft damage and the possibility of the POB's survival. As a result, the acceleration due to gravity analyzed was at least 54.54 G or more.

A deformation of loads when impacted with the water is not destructive compared to crashes into the ground. It is because the loads separate along the boundary where aircraft and water come into contact. On the other hand, the impact absorption by landing gear from a crash with the water is not effective compared to that of crashes into the ground.

Therefore, the energy formed when impact with the water is prone to deliver directly to POB rather than absorbed by the airframe. It poses a greater risk of serious injury to the POB.

It is determined that the EFS was destroyed at impact and separated from the airframe, so it was impossible to carry out its function. The extreme speed of acceleration due to gravity would damage aircraft and lives but also preclude the operation of EFS.

2.7 The National Fire Agency

2.7.1 Organization

The Aviation and Communications Division[76] of the National Fire Agency is in charge of the duties regarding the Agency's aircraft. The Department consists of the aviation safety team, a fire information team, and a fire communication team, where a total of 12 members are serving their duties. 5 officers of the aviation safety team supervise all aircraft affairs of the Agency.

2.7.2 Performance of Firefighting Helicopters

The Air Rescue and Emergency Squads of the National Fire Agency and each regional fire headquarters conduct various onerous duties, including mountain rescue, patient transport, wildfire suppression, maritime rescue, and night missions (see Table 20).

Category / Year	Operating hours (H)	Rescue/ first-aid personnel (ppl.)	Mission								
			Total	Rescue/ first aid	Fire suppression	Wildfire suppression	Campaign	Training	Patrol	Operational support	Maintenance
Annual average	**5,646**	**2,211**	**5,634**	**2,678 (47.5%)**	**98 (1.7%)**	**266 (4.7%)**	**20 (0.3%)**	**1,738 (30.8%)**	**104 (1.8%)**	**46 (0.8%)**	**684 (12.1%)**
2020	5,676	1,925	**5,671**	2,378	121	226	10	2,057	84	16	779
2019	6,260	2,113	**5,990**	2,647	98	319	18	1,892	209	76	731
2018	5,926	2,223	**5,896**	2,717	157	374	9	1,801	102	30	706
2017	5,659	2,456	**5,675**	2,979	70	269	22	1,608	64	49	614
2016	4,711	2,338	**4,938**	2,669	43	142	41	1,333	61	58	591

Table 20. Helicopter dispatch record

76) The National Fire Agency has reorganized Aviation and Communications Division to Fire Aviation Department since Oct. 20, 2021

The National Fire Agency's five-year record of helicopter dispatch revealed that 2,678 missions (47.5%) were annually conducted on average for rescue and first aid purposes. The average dispatches to respond to wildfires and fires were 364, which accounted for 6.4% of all cases. Those three different missions, directly related to protecting lives and property and require an immediate response, occupy 53.9% (3,042 cases).

2.7.3 The National Fire Agency and On-Board Safety Culture

The Air Rescue and Emergency Squads of the National Fire Agency and each regional fire headquarters conduct various onerous duties, including mountain rescue, patient transport, wildfire suppression, maritime rescue, and night missions. The crewmembers feel grave responsibility for patients in critical moments of life and death. Thus, they occasionally feel guilty when the conditions are unavailable to transport emergency patients due to bad weather and as such.

Even though a pilot is the decision maker of whether operate a mission or not, operation controller is the person who first decide whether an affair is urgent to handle. Additionally, the organization should not place blame or responsibility on the pilot even if a mission is not executed.

In general, members of each sector are mobilized for emergency patient transport by a helicopter; a pilot, co-pilot, mechanic, rescue worker, and paramedic. Each member fulfills different duties and varies in position and rank.

A pilot is the chief officer in flight to control the aircraft, and the division of tasks per sector has to be made. The National Fire Agency should manage its organizational culture and establish training and procedures for CRM to develop appropriate in-flight culture. The safety culture and in-flight culture of the organization should be continuously revisited.

2.7.4 Safety Management System (SMS)

The commander of National 119 Rescue Headquarters is responsible to approve aircraft operations and manage Squad members, while the direct commandership is under the Special Rescue Unit commanders and the Squad leaders.

The aircraft of the National Fire Agency are classified as government organizational aircraft. Thus, those do not fall under the compulsory application of the Safety Management System (SMS) following the Aviation Safety Act. Nevertheless, the SMS is worth being applied by more operators for aviation safety.

The ARAIB issued safety recommendations to apply SMS, following the crash of the Gyeongnam firefighting helicopter in 2019. The basic concept of the SMS is related to the CEO's awareness of safety. Also, decent safety policies have to be established and executed for the safe management.

Supervisors' awareness of safety largely influences aviation safety practices. That is why the National Fire Agency needs to apply the SMS and take responsibility of air safety.

2.8 Crew Training

2.8.1 Night Vision Goggles (NVG)

The National 119 Rescue Headquarters provide NVG to each pilot for night flight missions. The pilot of HL9619 was provided with a gray phosphor NVG in 2018, and the co-pilot received a green phosphor NVG in 2013 (see Figure 39).

Night Vision Goggles (NVG) | View (left: green, right: gray)

Figure 39. NVG and the view

The use of NGVs depends on pilots since the National Fire Agency did not prepare explicit grounds for the operation. When wearing NVG, a crew attaches it to the helmet with the mount fixed on the helmet.

Even though using NVGs is ultimately up to pilots' discretion, wearing them at least on the helmet and making decisions based on the surrounding conditions during night flights seems essential.

2.8.2 The Crew's NVG Operation

On the day of the accident, the crew inspected the aircraft's interior and started the engine while attaching the NVG to their helmets. It was confirmed through Vision 1000 that the pilot and co-pilot wore the NVG on their eyes when taking off.

The recorded conversations of the crewmembers and the CVR also confirmed the pilots' use of NVGs. The CVR analysis showed the two pilots wore the NVG and removed it back and forth during the flight over the sea to Ulleungdo. It indicates that while flying between Ulleungdo and the Dokdo helipad, they were using NVGs to identify the helipad, but while approaching, they did not due to the brightness of the helipad.

They did not seem to wear the NVGs when taking off the Dokdo helipad. If worn, it would more likely overcome the darkness, for example, by magnifying starlight. Although using NVG is a pilot's choice, the Agency should train them for proficient use whenever necessary.

2.8.3 Night Flight Performance

The pilot performed 9 night flights in 2019; they were classified into 3 night flight training, 2 emergency patient transport, 3 wildfire suppression, and 1 water rescue flight. His recent night flight was a training, held for an hour and five minutes, on September 19, 2019. He had no night flights over the water that year.

The co-pilot had 11 night flights in 2019: 3 for night flight training, 4 for transportation of emergency patients or organs, 3 for wildfire suppression, and 1 for water rescue flights. He recently flew over the sea at night to transport a patient from Ulleungdo on September 13. He also did the same night flight training with the pilot and flew an hour and 5 minutes on September 19, 2019. The two pilots had the accident 42 days after their latest night flight.

The Operational Regulations of Air Rescue and Emergency Squads stipulate night flights of 1 hour or more every 90 days to maintain the qualification. However, no conditions are set out to maintain the qualification about flying over the water. Even though the pilots remain qualified to fly at night, the Agency needs to manage the night flight training sustained so that the qualified personnel can exert the skills in practice.

2.8.4 Night Approach and Takeoff Training

Nighttime is riskier to have an accident than daytime, and more likely to be fatal when one occurs. During the approach to an elevated helipad, the illusion of altitude can lead to excessive power or accidents if the landing location is not identified. Several accidents are related to nighttime landings at elevated helipads. Likewise, in areas with little experience, over the sea, or when moving from well-lit to dark areas while taking off can deteriorate physical reactions.

Flying these areas of latent risks requires the pre-procedures of approach and takeoff. Also, saving and leveraging the flight route, altitude, and waypoints in FMS are needed. In addition, these should be repeated when training for night flights.

2.8.5 AP Training

AP training is critical. It relates directly to CRM and takes up a significant stage for a safe flight. Moreover, proficient AP operations during night flights have even more importance.

The pilot and co-pilot of HL9619 did not conduct the pre-call-out and procedure checks for operating the AP. The pilot did not cross-check which button he pressed on the AP, and neither the co-pilot sometimes understood the pilot's intention.

To operate AP, stages from pre-call-out to checking the response and the result after using AP should be gone through. These are the typical courses of CRM and procedural training.

In particular, the AP training should be conducted more frequently in case of nighttime operations, simultaneously with the CRM training. The National Fire Agency should consider optimizing the AP training by introducing a flight simulator or flight training devices.

2.9 Flight Procedure Analysis

The following is the analysis of flight procedures ranging from the National 119 Rescue Headquarters in Daegu (takeoff), the Ulleungdo helipad (approach, landing, and takeoff) to the Dokdo helipad (approach, GA, landing, takeoff with the patient, and the crash).

2.9.1 Taking off the National 119 Rescue Headquarters

The crewmembers should have studied the topography of the destination, checked the location of the helipad, lighting status, weather conditions, approach, and outbound routes, and had a briefing of their mission. Since they were mobilized promptly for the emergency patient transport, they decided to receive information from the 119 Rescue Operations Center while they were in flight.

The HL9619 crew did not receive adequate information on the topography or the helipad as much as they needed. They should have received information on the destination and the patient's status before taking off.

The two pilots had conversations such as, "Isn't it necessary to receive the landing training for Dokdo during the daytime?", and "Many police helicopters fly to the Dokdo helipad and are familiar with the area, so I hope they carry out night missions as well." Judging from the conversations, the pilot and the co-pilot seem pressured to fly toward the inexperienced area.

The pilot said he had experienced 2 daytime flights to Dokdo when serving as a military pilot, while the co-pilot said he never had. They also did not know how the Dokdo helipad was being managed. This implies that the two were dispatched urgently without knowing the general topography and the helipad information.

2.9.2 First Approach to Dokdo and GA

The pilot communicated with the Dokdo Operations Center[77] and notified them, “Landing, 3 minutes left.” While approaching, engine limits were temporarily exceeded, as shown in the extracted FDR (see Figure 40).

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77) While communicating, the pilot mentioned “Dokdo ground,” which implies the Dokdo Operations Center.

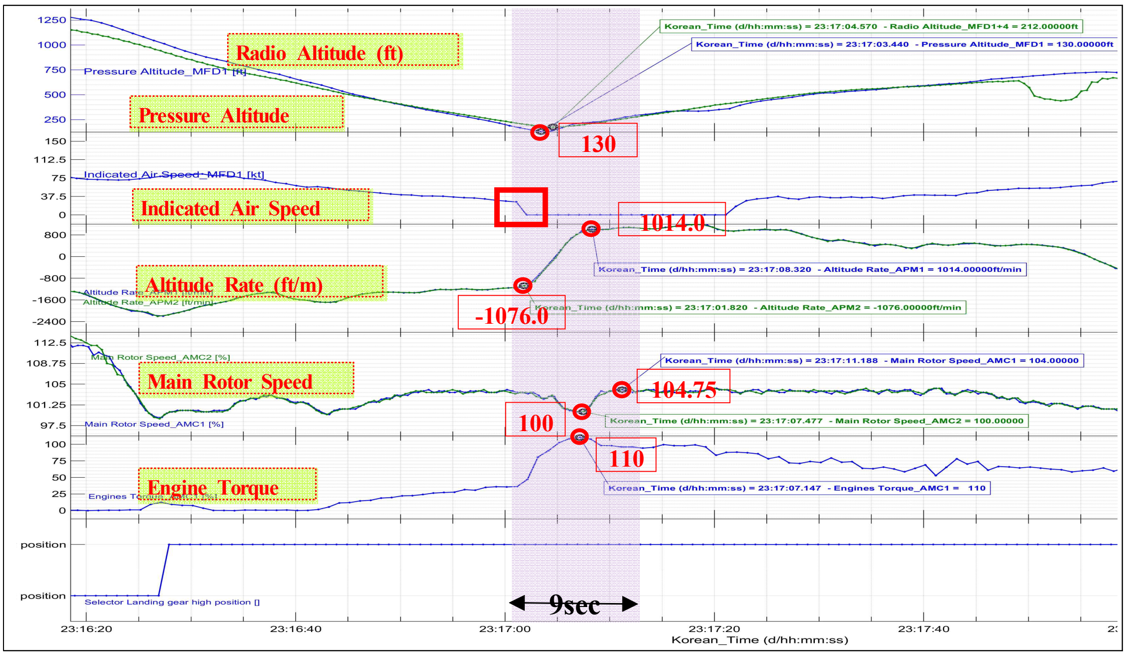


Figure 40. Temporary excess of engine limits while approaching

The co-pilot confirmed the helipad by the TLOF inset perimeter lights and downed the landing gear. He checked the altimeter, called out "Altitude recheck 1,100 ft," and entered. At that moment, the altitude dropped suddenly to 500 ft, and when the pilot recognized it, the altitude fell to 200 ft.

At this time, the pilot said, "Aw, the light should not flash upon us." Seemingly, the portable searchlight flashed and was waved by a standby worker who intended to guide the helipad's location. However, it seems the light indirectly illuminated the cockpit and temporarily affected the pilots wearing NVG.

When a pilot uses NVG, external flashing lights coming through the image intensifier tubes, even indirectly, can affect the pilot more than expected.

The HL9619 failed to identify the helipad during the approach. The Dokdo Operations Center officer turned all the helipad lights off for 11 seconds upon the pilot's request to turn off the beacon light.

Then a "gong" sound was heard. It is the warning of a sudden reach to its power limit by the pilot's rapid manipulation of the collective, who intended to increase the altitude to offset the aircraft plummeting. What the pilot said, "Why is the power consuming so much?" indicates the difficulty of maintaining the attitude and power owing to the altitude changes and topography-related gusts.

The pilot could not evenly maintain the approach angle when approaching the Dokdo helipad, so the descent rate dropped until -1,076 ft/m. The pilot escalated using the collective, so the ascent rate went up to +1014 ft/m in 7 seconds. Against this backdrop, the main rotor RPM increased to 104.75%, and at the same time, the torque warning sound was heard as it reached 110%.

The power limit was exceeded when the pilot rapidly altered the flying altitude down and up after noticing he approached the helipad from too high. The crewmembers should have accurate information, such as the helipad’s sea level, to verify their altitude before approaching.

The HL9619 crewmembers, during the approach, had difficulty maintaining the aircraft's altitude, speed, and attitude due to different flashing lights. Also, the pilot said several times, "I feel dizzy," and mentioned, "The airframe banked to the left," despite the attitude indicator showing level flight. That is, he seemed to have already experienced an illusion during the approach.

On the basis of the limit exceeding while conducting GA lies an altitude illusion related to approach angles. The altitude setting for the nighttime landing was unclear, causing the aircraft to rapidly descend or ascend.

Adding to those situation, the crew felt dizzy because of various flashing lights, such as the Dokdo lighthouse and the Daewangho fishing vessel, which in turn worsen the altitude illusion, exceeding limits and conducting GA. Dizziness and the altitude illusion are considered important factors that led to the pilots' spatial disorientation from takeoff at Dokdo until the crash.

2.9.3 Patient Boarding After Landing at Dokdo

While the crewmembers in the back seats had the patient on board, the pilot and co-pilot talked about problems when approaching, such as exceeding power, rapid altitude changes, and the influence of lights.

During the briefing on these issues, in-flight communication reported that the patient and caregiver had boarded. The pilot took off, turning the aircraft 180° to the right through hover. It was filmed that strong right winds pushed the airframe, taking off, to the left.

Despite the sudden inform of the patient boarded, the pilot and co-pilot should have read back the pre-takeoff preparations. In particular, they should do pre-briefings about the takeoff direction and AP operations such as HDG, ALT, ALT.A, IAS, and others, but they did not.

2.9.4 Takeoff From Dokdo Till the Crash

2.9.4.1 Normal Takeoff

The pilot attempted normal takeoff procedures. When taking off from an elevated helipad, a pilot must increase the speed at a higher angle than normal takeoff in preparation for the heliport environment, engine failure, and other flight hazards. At that time, however, the pilot pushed the cyclic forward as done in a normal takeoff, so the speed increased more rapidly than the altitude level, resulting in the altitude drop.

2.9.4.2 Change in Lighting

The crew was exposed to various flashing lights even after the landing. While it hovered to turn the nose 180° right, its front became the dark sea from the bright lights.

From the moment it passed the slope near the helipad, there were no lights. In this sudden illumination change, rod cells[78] did not have enough time for dark adaptation[79].

78) Rod cells function in the dark and distinguish light and shade rather than perceive colors.
79) A phenomenon in which things are initially invisible and gradually become visible over time when entering a dark area from a bright place. Adaptation to darkness takes up to 45 minutes.

2.9.4.3 Pilot's Flight Control

The pilot experienced the illusion of operating AP. He pressed the GA button, which seemed he had thought the aircraft would soon ascent. Although he noticed the situation later and instructed the co-pilot ALT.A., the CVFDR confirmed that technically the ALT button was pressed, 5 seconds before the crash. ALT operated for 4 seconds, but the chances were little to stop the aircraft from falling at high speed and descent rate.

There is also a possibility that the pilot was under the somatogravic illusion. Insufficient visual reference, such as at night or encountering an unintended flight in IMC (instrument meteorological conditions), may affect the vestibular organ to cause the illusion.

When a pilot accelerates for takeoff, a combined force of inertia and gravity makes the otolith refract the sensory hair. It lets a pilot perceive he is in an ascending posture with the head tilted back, so he gets to manipulate the aircraft to pitch forward to counterbalance the nose heading up. It may be the reason the pilot continuously pushed the nose forward.

Moreover, visual illusions may affect the pilot. While approaching Dokdo, he already deluded himself by saying the aircraft was banking while turning. Though he saw the altimeter and airspeed indicator, he would not have perceived them changing.

Without any visual reference during the rapid speed increase, the sensory organs were deluded into perceiving the altitude ascended. Thus, pushing the cyclic continuously forward, the nose excessively went down.

2.9.4.4 Exceeding Operating Limitations and EGPWS Warning

The descent continued at high speed after taking off from the Dokdo helipad. Just before the crash, the pilot rapidly raised the collective, exceeding operating limitations. EGPWS rang when the aircraft came near the water surface (see Figure 41).

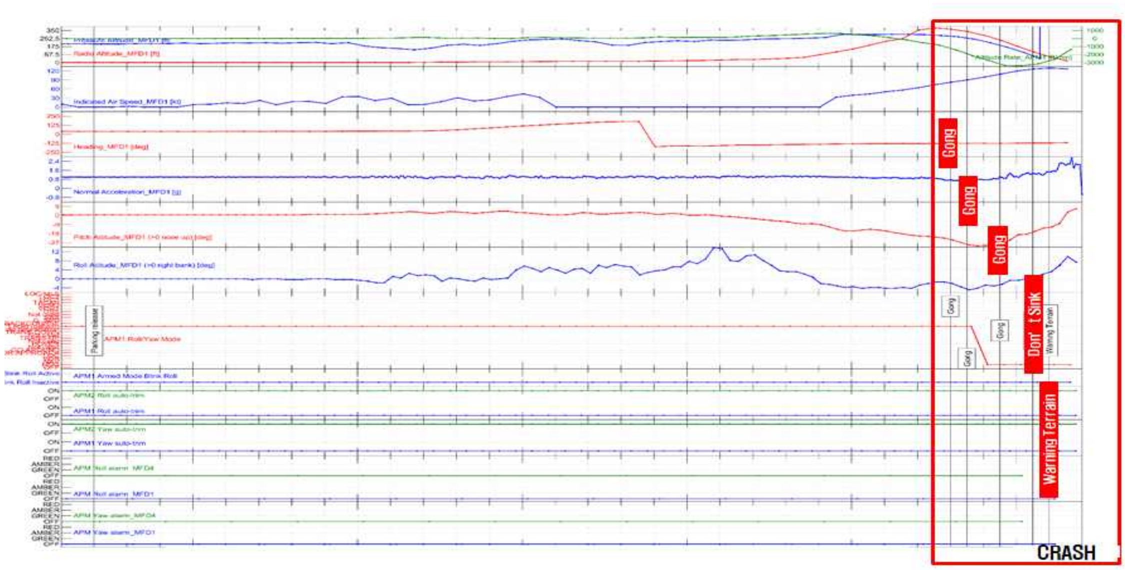


Figure 41. Exceeding operating limitations and EGPWS warning

2.10 Crew Flight

2.10.1 Crew Fatigue

The crewmembers, except the pilot, did night shifts (18:00 - 9:00 next morning) on the accident day. Thus, the co-pilot, mechanic, rescue worker, and paramedic arrived at the workplace at around 17:00—night shift workers generally attend work at about 17:00 because they have to check several things before the shift.

The pilot was supposed to do a night shift with his Squad but switched to on-duty work (09:00 - 09:00 the next morning) because of daytime workers' business trips and as such. Therefore, the pilot arrived at the workplace at around 8:30 A.M. on the accident day. After he began the on-duty shift, he flew in 13 hours and had the accident in 15 hours; it was about 2 hours since he had flown.

There were no straightforward relations between the crew's work pattern and the accident. Nevertheless, self-management of one's health, whether the crew is at or after work, is critical in order not to be affected by tiredness in case of conducting emergency flights.

According to the CVR, the pilot pleaded fatigue to the co-pilot in the flight to Ulleungdo, 1 hour after they took off from the HQ in Daegu. He appealed the fatigue 3 times total to the co-pilot.

The pilot is considered to fly in fatigue, judging from what he said the aircraft was turning, even in AP mode, followed by the answer of the co-pilot that it was in level flight.

The National 119 Rescue Headquarters should provide the crew space for rest and ensure enough time to rest for a safe night flight. Also, in the case of night shifts, adjusting working hours can be a way for pilots to be prepared for emergency flights.

Under the organizational structure, it is inevitable for the National Fire Agency to assign 24-hour personnel to standby for an emergency flight. Apart from this, individuals and organizations have responsibilities to manage fatigue. Flying with fatigue has a risk of entering into spatial disorientation caused by illusion.

Therefore, the Agency should provide adequate space and enough time to rest. It will help reduce the hazard of conducting night flights or sea flights from fatigue.

2.10.2 In-flight CRM

Firefighting helicopters generally have a total of 5 crewmembers including 2 pilots, a mechanic, a rescue worker and a paramedic, for operating patient transport or rescue missions. Boarding a patient and caregiver will become 7 people in a helicopter, so the CRM, the communication in flight, is imperative.

2.10.2.1 Cockpit CRM

The crewmembers should have in-depth discussions on each one's duty and role for smooth communication in flight. During the flight, there need the clear-cut allotted tasks between the pilot holding the flight control and the pilot monitoring. Pilots who want to operate the AP must first precisely state their intention of operating it.

The HL9619 pilot did not adequately convey the intention of operating the AP, prior to the use, to the crew. Thus, the co-pilot failed to embrace the pilot's objective of operating.

The pilot pleaded fatigue several times during the flight and had an illusion due to various lights when approaching Dokdo. In this case, the pilot should have left the flight control to the co-pilot and fly while cross-checking the instruments.

2.10.2.2 Flight Crew CRM

CRM among crewmembers is also indispensable. When the pilot failed to maintain altitude during the first approach to Dokdo, the mechanic loudly said, "What is wrong, what is wrong, what is wrong?" This action may make the pilot even more strained. The mechanic also shouted, "To the left, left," when the helicopter hovered for takeoff, which added tension to the pilot.

Every crewmember is tensed and stressed during night flights. Meanwhile, a pilot has the overwhelming role of securing the safety of an aircraft, which can be a great source of stress. Thus, crewmembers should train in communication skills, including appropriate advice and tone to deal with it.

The stress and anxiety of pilots limit the balanced distribution of attention required for operations. Attention dispersion gets even worse by visual and auditory stimuli. Loud sounds cause a startle reflex and may limit continuous flight control ability for up to 60 seconds.

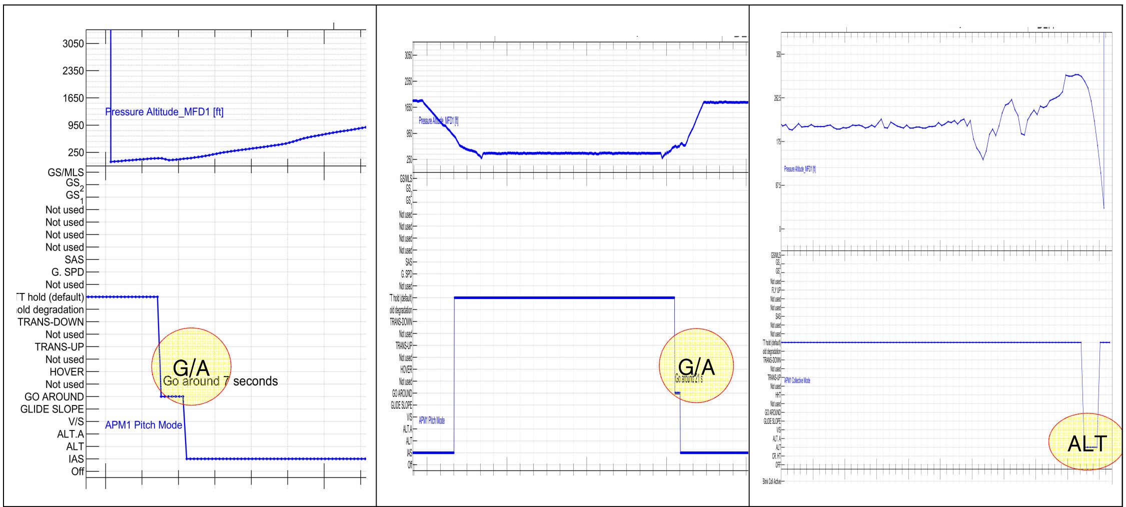
The crew in the back seat should advise the pilot in a way to help the person calm down and relax. Sharing information, such as instrument status and obstacle alerts, can be required to relieve the tension of pilots, who may suffer from accurately identifying the surroundings.

Firefighting helicopter crews must receive periodic education and training on CRM. The intimacy among the crewmembers does not imply CRM is established. It is necessary to train all the crew how to utilize CRM since the way of communicating, such as coercive word use and speaking manners to make the listener startled, affects the pilot.

2.10.3 The Pilot's Flight Habits

Fellow pilots stated that the HL9619 pilot tended to use GA during takeoff. The pilot used GA for about 7 seconds when taking off from the Daegu Headquarters and for 21 seconds while taking off after refueling at Ulleungdo.

However, the GA did not operate when taking off from Dokdo (see Figure 42). Seemingly, it was not deliberate; the pilot seemed to think he was applying the GA.



Takeoff from Daegu (GA, 7 seconds)	Takeoff from Ulleungdo (GA, 21 seconds)	Takeoff from Dokdo (ALT, 4 seconds)

Figure 42. GA mode used when taking off

2.11 Autopilot

2.11.1 Terminology in Flight Manual

The "SECTION 1.4 TERMINOLOGY," issued by Airbus Helicopters, a manufacturer of the HL9619, describes "NOTE," "CAUTION," and

"WARNING" as follows (see Table 21). The crew has to deal with each situation appropriately.

WARNING	**AN OPERATING PROCEDURE, PRACTICE, ETC., WHICH IF NOT CORRECTLY FOLLOWED, COULD RESULT IN PERSONAL INJURY OR LOSS OF LIFE.**
CAUTION	**AN OPERATING PROCEDURE, PRACTICE, ETC., WHICH IF NOT CORRECTLY FOLLOWED, COULD RESULT IN DAMAGE TO, OR DESTRUCTION OF EQUIPMENT.**
NOTE	**AN OPERATING PROCEDURE, CONDITION, ETC., WHICH IS ESSENTIAL TO HIGHLIGHT.**

Table 21. Terms and definition

2.11.2 ALT Mode

The flight manual of Airbus Helicopters explains the function of ALT and how to switch modes as follows: Altitude when pressing the ALT button is set as the current pressure altitude. Below 60 kt and above 60 kt altitude are controlled by the collective and cyclic axis, respectively. Meanwhile, when IAS is engaged, it is controlled by the collective axis.

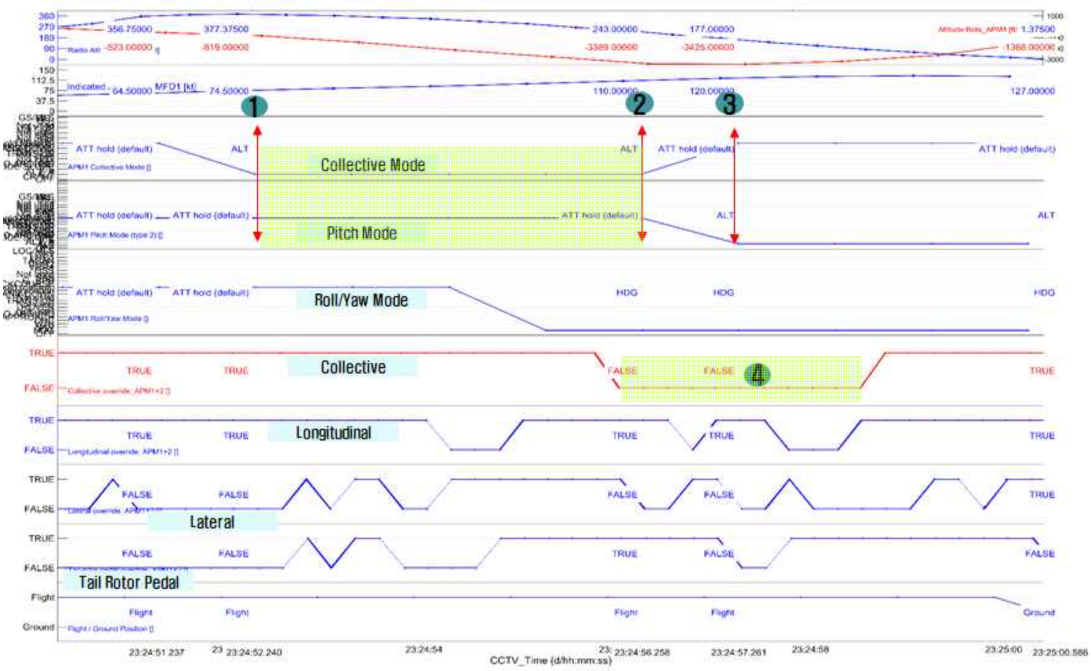


Figure 43. Pitch changes

The FDR (see Figure 43) showed the HL9619 used a collective axis from sections 1 to 2 as in the manufacturer's flight manual. The control through the collective axis (1 to 2) remained for 4 seconds. The pitch axis was used in section 4, and section 3 is the time taken to change into the pitch axis. When transitioning from collective to pitch, the aircraft speed rapidly increases, as does the descent rate.

See Table 22 for the functions of "ALT" and things to "NOTE.“

Altitude hold (ALT) **The ALT mode maintains the current barometric altitude upon engagement.** **- Below 60kt the altitude is controlled through collective axis,** **- Above 60kt, the altitude is controlled through cyclic axis (3 axes operation), or through collective axis when IAS is engaged (4 axes operation),**

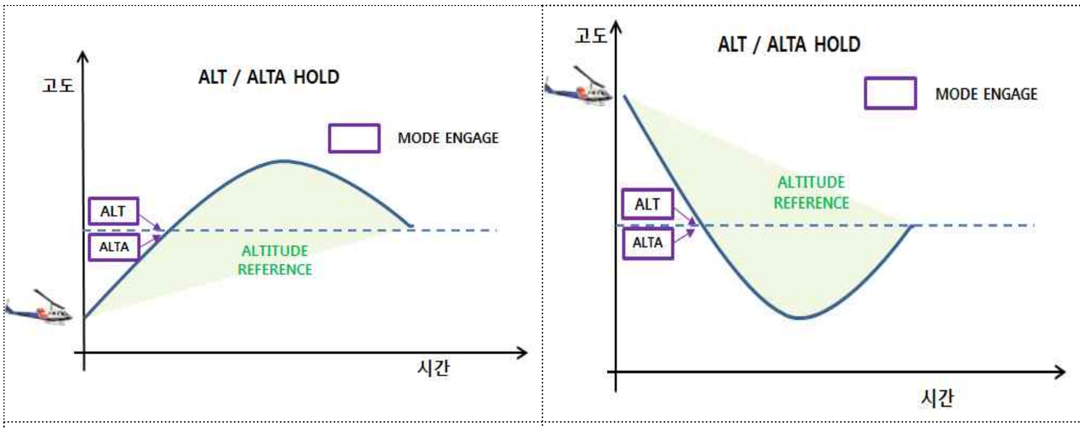
NOTE
1. ALT engagement with a high vertical speed will result in an overshoot, and possibly in an excessive deviation annunciation. **2. During a speed reduction down to 0 with ALT engaged, the AP will adjust the ALT index in order to maintain a constant altitude (static port compensation).**

Table 22. ALT and NOTE

2.11.3 ALT.A Mode

Pilots use ALT to remain flying at their current altitude, meanwhile pressing ALT.A to acquire and hold a pre-selected altitude (see Table 23). The left image of Figure 44 shows the aircraft's response to the ALT, or ALT.A, while ascending. On the one hand, maintaining an intended altitude cannot be accomplished right away. Though different regarding ascent pace and rate, the aircraft reaches a higher altitude before lowering to the set altitude.

The image on the right of Figure 44 indicates when an aircraft is descending. Either the ALT or ALT.A button is activated, it will first descend below the set altitude at a varying pace and rate.



1. ALT/ALT.A while ascent	2. ALT/ALT.A while descent

Figure 44. Applying ALT/ALT.A while ascent/descent

Altitude hold (ALT.A) **The ALT.A mode acquires and holds pre-selected altitude.** **Turning ALT.A rotary knob on FCP presets a reference altitude.**

Table 23. ALT.A functions

During daytime flights, visual references are available. Thus, pilots can acknowledge the flight attitude or altitude even when applying the ALT or ALT.A. However, taking off at night, confined areas with poor weather or at an elevated helipad like the one in Dokdo with excessive speed and decent rate are challenging to recognize the situation accurately.

2.12 Human Factors Analysis and Classification System (HFACS)

RCA (root cause analysis) was made through HFACS to find the HL9619 accident cause. The HFACS explains a failure based on latent and active failures. The following analysis focuses on the backdrop of the pilot falling into illusion.

2.12.1 Various Lighting Systems

Many lights affected the vision of the HL9619 crewmembers when approaching and taking off from Dokdo. The surroundings of the dock were prone to obscure the pilot's vision and create an illusion with the lights from the Daewangho fishing vessel, buildings, helipad, and the beacon-type lighthouse (see Figure 45).

Figure 45. Lights from Dokdo during the approach

2.12.2 Unsafe Act, Active Failure

The pilots have made decision errors; they did not have pre-takeoff briefings about a takeoff direction, task share of the AP operation and takeoff procedures. The wind was blowing in a 290° direction, and it had to face right crosswinds to takeoff, blowing from a 227° direction. The pilot did a normal takeoff process instead of a steep or maxi takeoff.

Unusually, the pilot took off without operating GA. He predicted the aircraft would ascend soon and believed it was ascending as expected. After he figured out the GA button was not pressed, he asked the co-pilot to press ALT.A. However, it appears that the co-pilot technically pressed the ALT. The pilot continuously pushed the cyclic forward, resulting in the ALT override.

While the HL9619 was passing through the slope area after the halipad, the pilots should have monitored the instruments' figures and the aircraft's status. They seemed to see the instruments, however, not watching the figures.

The pilot continuously pushed the cyclic, seemingly mistaking the aircraft as ascending, where he encountered a sudden change to the dark sea from the well-lit helipad. The pilot pushed the cyclic, holding and releasing it back and forth, and yet the pushing force was stronger.

At the altitude of 177 ft in the air, the airframe was fully tilted forward with a descent rate of -3425 ft/min and the nose down to -18.63°. Without any visual references, the perceptual error would arise, resulting in perceiving the aircraft as ascending and thus, pushing the cyclic.

See Figure 46 for the HL9619's changes in altitude, speed, descent rate, and the airframe attitude from its Dokdo takeoff to the crash. Also, see Figure 47 for the power limitation occurrence and EGPWS warning.

Figure 46. HL9619 attitude changes

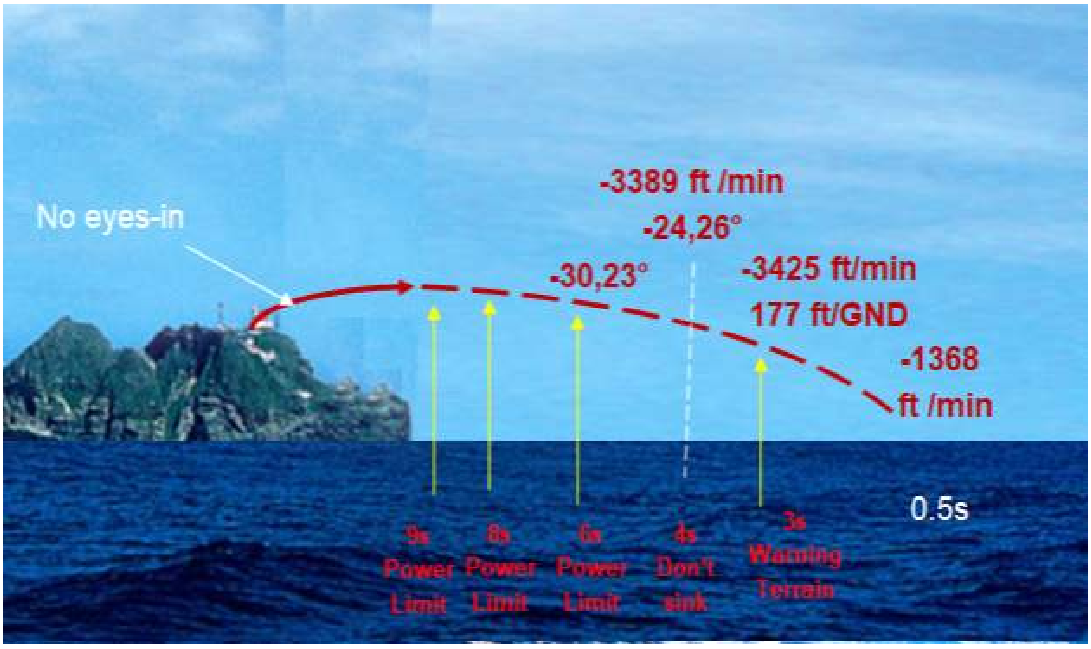


Figure 47. Power limit and EGPWS warnings

2.12.3 Latent Failure

Latent factors indicate failures in sufficient AP operation training, NVG operations, preparation for inexperienced areas, situation awareness, in-flight communication, and fatigue management. The management failure as such contributed to spatial disorientation. Unsecured standard procedures of nighttime takeoff and landing at confined areas have resulted in flying without previewing appropriate procedures.

The pilot and co-pilot felt pressure due to the confusion from the lighting in their first attempt to approach Dokdo. The exceeding operating limitations, which arose from mishandled speed and altitude, weighed the burden. In particular, during the GA after the first approach, the pilot had already entered illusions, distrusting the instruments.

To curb the challenges, entering approach and outbound routes on FMS and writing down speeds and altitude per location in advance are recommendable.

2.13 Illusion During Approach and Spatial Disorientation During Takeoff

Different visual illusions are prone to occur when approaching a confined area through the long hours of a nighttime flight over the water. In this circumstance, pilots have to adjust the approaching altitude, judging the aircraft's speed and distance based on the helipad.

Topographies without visual references, such as on night flights, make it challenging to maintain approaching altitude through vision. It is risky to undergo spatial disorientation arising from illusion.

On the first approach to Dokdo, the pilot already experienced illusions of altitude and slope and felt dizziness. Even then, the aircraft was in peril and might lead to an accident.

At the Dokdo helipad, the pilot informed the co-pilot of the illusion he had during the approach, and the co-pilot replied that he noticed it. The aircraft then took off, after turning the nose, and entered to the dark sea, passing the illuminated helipad behind.

For taking off, the pilot increased speed with the nose pitched down. The pilot misconceived the aircraft was ascending, despite the continuously increasing aircraft speed with the nose downward. This is considered the reason the pilot consistently pushed the cyclic.

Due to these causes, the pilot entered a state of spatial disorientation and failed to recognize the situation. The pre-briefing about the two pilots' duty distribution should have been made because taking off toward sea with nothing to refer to entails a risk of encountering spatial disorientation.

The pilot should have handed over the flight control to the co-pilot because he was already under an illusion when approaching, but he did not. It seems the co-pilot or the mechanic should have suggested handing over the flight control if the pilot did not.

3. CONCLUSION

3.1 Findings

1. HL9619 took off from Daegu Headquarters, refueled on Ulleungdo, boarded the patient and caregiver at Dokdo Helipad, and then crashed while taking off.

2. The aircraft was destroyed, and all 7 POB－the 5 crewmembers, the patient, and the caregiver－were deceased.

3. The crew possessed and maintained the qualifications required for operation and completed training in accordance with the relevant regulations.

4. HL9619 held a valid certificate of aircraft registration, a certificate of airworthiness (standard), an operating limitations specification, a radio station license, and a certification of conformity with noise standards.

5. HL9619 had valid insurance for its operation.

6. The weather at Dokdo, observed by ASOS, was 10 km visibility with gusts of 8.8∼9.6 m/s from a 290° direction, but it did not directly affect the accident.

7. The Dokdo helipad was officially registered as RKDD in ICAO and being managed by the Korean National Police Agency, but it did not adequately prepare entry/exit procedures, personnel training, and as such procedures to operate.

8. The CVFDR was recovered 22 days after the crash, and the data analysis showed no defects in the airframe or engines' operations.

9. In-depth examination of the engines and MGB after disassembly revealed no defects.

10. EFS was equipped in HL9619 but destroyed at impact with the water and did not operate.

11. The crew did not conduct a pre-flight briefing at the National 119 Rescue Headquarters nor a pre-takeoff briefing in detail at the Dokdo helipad on their duty distribution.

12. HL9619 refueled at the naval helipad in Ulleungdo and took off to Dokdo.

13. The pilot complained of fatigue 3 times to the co-pilot.

14. The pilot and co-pilot have never flown to Dokdo at night, nor did the National Fire Agency prepare takeoff/landing procedures for night flights.

15. AP training for the pilot and co-pilot and CRM training for the other crew should have been provided.

16. Flight simulator training is necessary to properly respond to takeoff and landing at night, severe weather, aircraft malfunctions, and flight illusions.

17. At the Dokdo helipad, some lighting systems were out of order, and a windsock (lights) was not properly installed.

18. The pilot experienced illusions created by various lights during the approach to the Dokdo helipad, and it also affected the takeoff.

19. HL9619 exceeded its power operating limits due to visual and altitude illusions in the first approach to Dokdo, so it conducted GA and re-approached.

20. While the pilot and co-pilot were talking about the difficulties they had while approaching Dokdo, the patient and other crewmembers boarded, and the helicopter took off right after without a takeoff briefing.

21. The pilot commanded the co-pilot to press ALT.A, but it was ALT that was pressed, according to FDR.

22. The impact with water separated the forward and rear fuselage; the destroyed forward fuselage was found 72 m under the water.

23. At least 54.54 G of acceleration due to gravity was confirmed.

24. In 14 seconds from the Dokdo helipad takeoff, 486 m away, the helicopter crashed into the water.

3.2 Cause

The ARAIB determined the cause of this accident as follows: HL9619 crashed due to "spatial disorientation," in which the pilot failed to recognize its attitude change while entering the dark sea across a slope (cliff) from the well-lit Dokdo helipad.

Contributing factors to the accident were as follows:

1. The crew did not conduct a pre-flight briefing at the National 119 Rescue Headquarters nor a pre-takeoff briefing in detail at the Dokdo helipad on their duty distribution.

2. The pilot believed he was using GA mode while taking off from Dokdo. Also, while increasing the aircraft's speed, the descending attitude was misidentified as ascending.

3. Thus, the pilot continuously pushed the cyclic forward, which resulted in the AP override and an increase in speed and descent rate.

4. The pilot experienced illusions created by various lights during the approach to the Dokdo helipad, and it also affected the takeoff.

4. SAFETY RECOMMENDATIONS

The ARAIB issues the safety recommendations below, following the findings from the investigation of the helicopter accident that belongs to the National 119 Rescue Headquarters and which occurred on the sea near Dokdo in Ulleung-gun, Gyeongsangbuk-do, on October 31, 2019.

4.1 To the National Fire Agency

1. Prepare and implement fatigue management programs in preparation for emergency dispatch. (AAR-1903-1)
   ※ In particular, pilots' emergency flights at night should secure safety through fatigue management and measures to rest.

2. Secure and enhance training with a flight simulator in preparation for take-off and landing at night, severe weather, aircraft malfunctions, and flight illusions. (AAR-1903-2)

3. Establish heliport approach and outbound procedures and training programs to fly in inexperienced areas, under severe weather, or at night, and provide recurrent night flight training. (AAR-1903-3)

4. Enhance aviation safety awareness by regularly training the responsible persons in safety management (the Special Rescue Unit commanders, Squad leaders, and such) about safety issues and operating the Squads. (AAR-1903-4)

5. Establish NVG operating procedures and conduct recurrent training on wearing NVG, takeoff and landing in confined areas, and elevated helipads. (AAR-1903-5)

6. Be capable of a specialized aviation system, including flight management, maintenance, and training within the National Fire Agency. (AAR-1903-6)

7. Provide AP and flight training periodically to pilots, and provide CRM training to crew. (AAR-1903-7)

4.2 To the Korean National Police Agency

1. Establish and implement Dokdo helipad operation procedures (entry/exit procedures, helipad management, Operations Center officer training, and such). (AAR-1903-8)

4.3 To Airbus Helicopters

1. Issue a safety information notice regarding AFCS operations to secure safe piloting of helicopters designed by the manufacturing company and disseminate it to the operators. (AAR-1903-9)

※ The ARAIB identified the importance of operating AFCS, and Airbus Helicopters issued Safety Information Notice No. 3558-S-22 (Subject: Auto flight, use of 4-axis digital AFCS) on December 3, 2020.