HELLENIC REPUBLIC
MINISTRY OF INFRASTRUCTURE AND TRANSPORT

AIR ACCIDENT INVESTIGATION
AND AVIATION SAFETY BOARD
(AAIASB)

ACCIDENT INVESTIGATION REPORT
HELICOPTER SX-HTO
AT THE SEA AREA BETWEEN POROS ISLAND - GALATA
ON AUGUST 20, 2019

04 / 2022

Accident Investigation Report
04 / 2022

Accident of Helicopter Agusta A109C with registration SX-HTO
at the sea area between Poros Island – Galata
on August 20, 2019

This accident investigation was carried out by the Air Accident Investigation and Aviation Safety Board according to:

- **Annex 13 of the Chicago Convention**
- **EU regulation (EU) 996/2010**
- **Law 2912/2001**

"According to Annex 13 of the Chicago Convention of the International Civil Aviation, EU Regulation 996/2010 and Law 2912/2001 Accidents and Incidents Investigation is not intended to attribute blame or liability. The sole purpose of this investigation and the findings is to prevent accidents and incidents.
Therefore, the use of this report for any purpose other than to prevent future accidents and incidents could lead to misinterpretations."

Members of the Air Accident Investigation and Aviation Safety Board

Chairman
Ioannis Kondylis
Airline Captain, Investigator

Members

Vice Chairman Akrivos Tsolakis
Airline Captain, Investigator

Grigorios Flessas
Airline Captain

Christos Valaris
Ret. A. F. Brigadier General

Charalampos Tzonos-Komilis
Airline Captain, Investigator

Secretary: Kyriakos Katsoulakis

Table of Contents

Abbreviations

AIA	Athens International Airport	ft	Feet
AGL	Above Ground Level	GEN	Generator
AOC	Air Operator Certificate	hrs	hours
App.	Appendix	ICAO	International Civil Aviation Organization
ATO	Approved Training Organization	ILS	Instrument Landing System
ATPL(H)	Airline Transport Pilot Licence (Helicopter)	INV	Inverter
BAT	Battery	Kg	Kilograms
HCAA	Civil Aviation Authority	kt	Nautical Miles per Hour
Cdr	Commander	LT	Local Time
CG	Center of Gravity	NM	Nautical Mile
COM	Communication	m	meter
CPL(H)	Commercial Pilot Licence (Helicopter)	MSN	Manufacturer Serial Number
CTM	Crew Training Manager	OAT	Outside Air Temperature
CVR	Cockpit Voice Recorder	OM	Operations Manual
E	EAST	OPC	Operator Proficiency Check
FCOM	Flight Crew Operations Manual	Par.	Paragraph
FDR	Flight Data Recorder	PDI	Pre Departure Inspection
FDR	Flight Data Recorder	s	Second
FIC	Flight Information center	TMA	Terminal Control Area
Fig.	Figure	UTC	Universal Time Coordinated
fpm	Feet Per Minute	VFR	Visual Flight Rules
FOM	Flight Operations Manager	VHF	Very High Frequency

OPERATOR	**:**	IFLY
OWNER	**:**	PORTO CARRAS SA
MANUFACTURER	**:**	LEONARDO
A/C TYPE	**:**	A109 C
COUNTRY of MANUFACTURE	**:**	ITALY
NATIONALITY	**:**	GREEK
A/C REGISTRATION	**:**	SX-HTO
LOCATION of ACCIDENT	**:**	Sea area between Poros Island - Galata
DATE and TIME	**:**	August 20, 2019 at 15:35 LT
Note	**:**	All Times are LT. Summertime LT = UTC + 3

SYNOPSIS

On 20/8/2019 at 15:35 h, an Agusta A109C Helicopter with registration SX-HTO of IFLY SA Company took off for a commercial air transport flight from the Landing Field in the area of Galata with destination Athens International Airport. The Pilot and two passengers were on board. 34 seconds after take-off, the Helicopter collided in sequence three Power Cables that crossed the channel, (positioned 314 meters from the take-off point), and then crashed into the sea. The Helicopter was destroyed by the collision with the Cables and by the impact with the sea surface. The three occupants of the Helicopter were fatally injured.

AAIASB was informed about the accident on 20/8/2019. An Investigation Team was appointed on 21/8/2019 while on 22/8/2019, AAIASB notified the States of Design and Manufacture, the State of Victims, the European Union, the European Aviation Safety Agency, the International Civil Aviation Organization, the Hellenic Civil Aviation Authority, and the Security Incident Reporting Committee.

1 FACTUAL INFORMATIONS

1.1 History of Flight

The Helicopter with registration SX-HTO departed from AIA on 19/08/2019 with destination Kranidi LF. That flight was the third flight of the day for the Pilot and Helicopter. In none of these flights did the Pilot record any malfunction on the Helicopter Technical Logbook, nor was the performance of the PDI certified, including the Inspection of the first flight of the day. The amount of fuel remaining after the third flight was 250 kg.

The next day, on 20/8/2019, the Helicopter was scheduled to operate IFLY 06, a commercial air transport flight from the Kranidi LF to AIA. According to the submitted Flight Plan, the flight would be a VFR at 2000 ft with a scheduled departure from Kranidi at 14:35 h and an estimated flight duration of 00:55 h. The Helicopter would go through the points GALATAS-EAST AIGINA-HELLENIKON-HOLARGOS-STAVROS-AGIOSTHOMAS (App. 5.1 Fig. 2) while it would make an intermediate landing at the Galata LF with a scheduled stop of 20 min in order to pick up two passengers that would be transported to AIA. The passengers had disembarked, on the day of the accident, from a sea Yacht in Poros Island.

For the flight to Galata LF, the Flight Plan provided a duration of 10 min for a distance of 19.3 NM with a ground speed of 117 kt and a fuel quantity on departure from Kranidi 257 kg and a remaining fuel of 229.1 kg at Galata LF.

On 20/8/2019, the Captain requested, by telephone from the Operator Flight Watch, photographic material to confirm the location of the Galata LF. At 11:36 h he received electronically two images (App. 5.1, Fig. 4) which indicated the exact location of the Galata LF, while at 11:37 h the Captain confirmed by e-mail to the Flight Watch that the indicated LF was the one he knew.

As part of the investigation an interview was conducted with the Operator Flight Watcher on duty in which he stated that he was aware of the existence of the Power Cables. He also stated that, in the communication with the Pilot, he did not mention about it, because not only it was not requested by the Captain, but also, he was given the impression that the Pilot knew well the specific area.

At a distance of about 314 m EAST of the LF in Galata, were three medium voltage aerial Power Cables which crosses the sea channel between Galata and Poros Island, with direction North East-South West. The location of the Power Cables is not indicated in the maps sent to the Pilot.

At 14:28 h, the Helicopter took off from Kranidi LF, coordinates 37^0 22 '15' 'N, and 023^0 05' 24 '' E, the fuel quantity, according to the Technical Logbook was 250 kg and executed a Flight duration (according to the Spidertrack system located inside the cockpit) of 28 min, as shown in Fig. 3 of App. 5.1, with destination Galata LF with coordinates 37^0 29' 40.7''N and 023^0 27' 22.6'' E.

At 14:50:30 h the Spidertrack system recorded the position of the Helicopter as 37^0 29 '12.3''N, 23^0 27' 41.0 '' E, at an altitude of 375 ft and a heading of 85^0, (App.5.1, Fig. 6).

From this point the Helicopter approached the Galata LF in a westerly direction. According to testimonies, the Helicopter appeared from the area of Ermioni / Kranidi and approaching the LF it flew at a low altitude above the sea channel passing under the three Power Cables as shown in Photo 1.

At 14:52:30 h the Spidertrack system recorded a position of 37^0 29 '40.7' 'N and 23^0 27' 22.7 '' E (above the LF), at an altitude of 40 ft and a heading of 265^0, (App .5.1, Fig.8).

The Helicopter landed at Galata LF and was parked in a northerly direction. After the landing, the Pilot did not record any malfunction in the Technical Logbook, while also the fuel remaining was not recorded.

At 15:32 h, the Captain had a telephone conversation with the VFR TMA of Athens, stating that he would depart Galata within a period of five (5) minutes with destination AIA.

At 15:35 h and after the two passengers had boarded, the Helicopter took off with destination AIA. Examination of the video material shows that immediately after lift-off, the Helicopter performed, a low altitude hovering, right rotation turn of about 90^0 around its vertical axis and headed in an East-Southeast direction (Fig.1).

Photo 1: **The flight of the Helicopter under the Power Cables during its approach to Galata LF.**

After take-off, the Helicopter moved horizontally for 8 s at low altitude, followed by a climb for 9 s and the next 3 s moved horizontally with its rotor being at an altitude of 134.5 ft (41 m), at the same height with the Power Cables (Fig.1).

At the end of the 3 s horizontal movement, the blades of the main rotor came in contact with the first and second of the three Power Cables. After the contact with the two Power Cables and before the contact with the third one, the Helicopter rolled and yawed to the left. After the contact with the third Power line the main rotor and the gear box were detached and fell into the sea followed by the detachment of the tail rotor section.

At 15:35 h, in conditions of full sunshine, the Helicopter and the detached tail section, fell into the sea at the coordinates 37^0 29’ 35.16’’ N, 23^0 27’ 38.94’’ E and 37^0 29’ 34.44’’ N, 23° 27’ 37.86’’E respectively.

At the take-off time of the Helicopter, the Yacht from which one of the passengers came from, was at 37^0 35’ 33.948’’ N, 023^0 39’ 8.5068’’ E (App. 5.14).

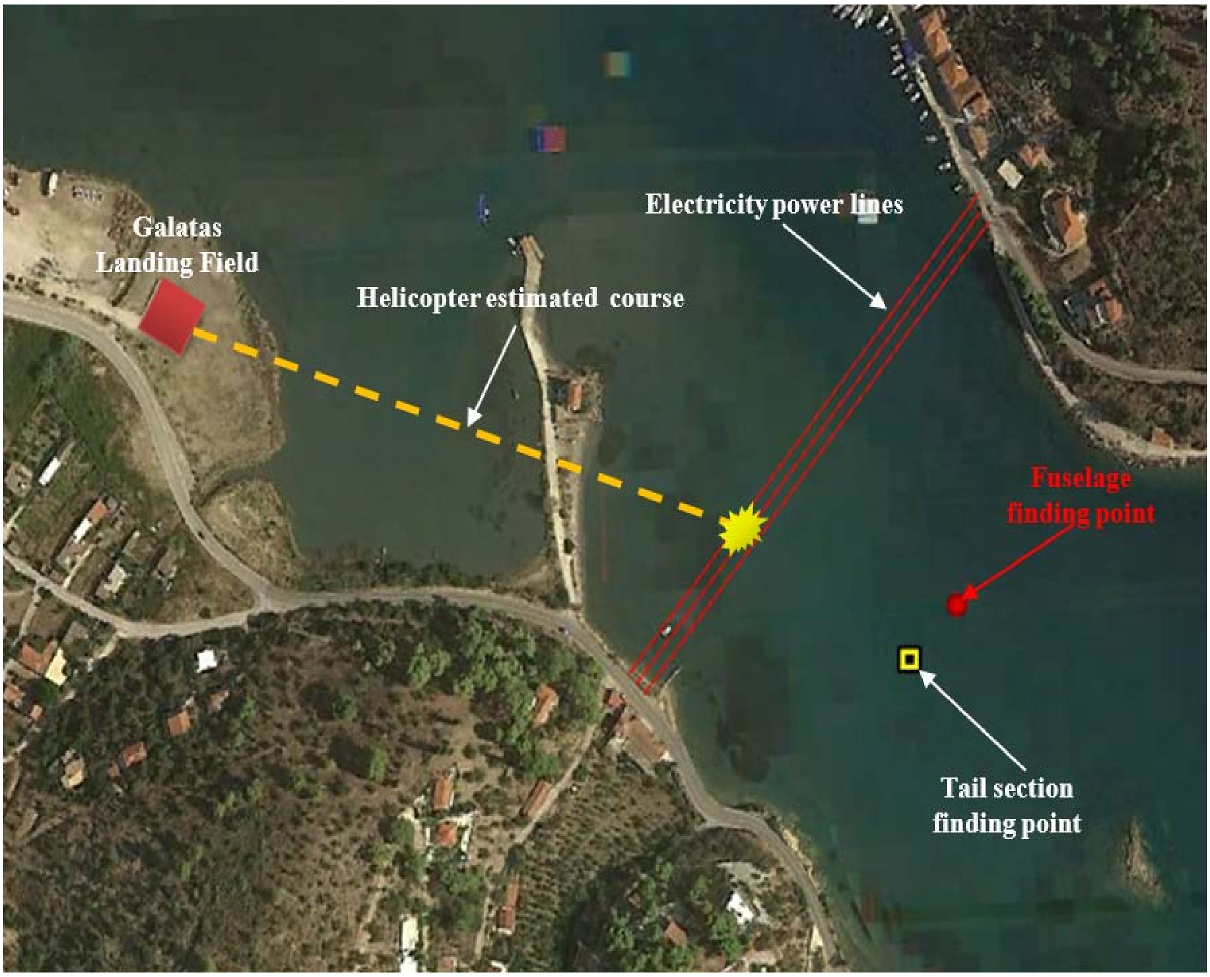


Image 1: **Galata LF, Estimated Helicopter course after take-off.**

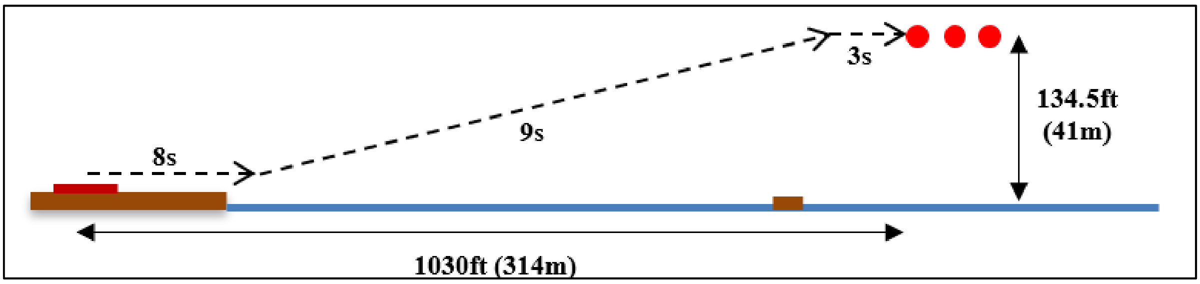


Fig 1: Side view of the Helicopter course.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal injures	1	2	0
Serious	0	0	0
Minor/None	0/0	0	0
Total	1	2	0

1.3 Damages to the Helicopter

The Helicopter after the impact with the Power Cables and its crash into the sea was completely destroyed.

1.4 Other damages

The impact of the Helicopter on the three Power Cables, resulted in the rupture of all three Cables and they fell into the sea channel, resulting in the temporally Power outage to the island of Poros, while macroscopically no marine pollution was found.

1.5 Personnel information

1.5.1 Captain

The Captain was 57 years old, retired Airforce Officer Pilot on 21/05/2017.
On 24/06/2019 he was appointed by IFLY as Captain to the type A109 Helicopter. He also had in force the authorizations for the performance of: daily inspection (PDI) and Helicopter's engine compressor washing.
From interviews conducted, in the course of this investigation, it was mentioned that the Captain was aware of the existence of the Power Cables as during his Airforce carrier he operated flights to Poros Heliport. It was also mentioned that during his flights with the Airforce he always had a Co-Pilot on board.

License/Number	CPL(H) issued on 13/06/2019.
Type Rated on	• A 109 with no restrictions, date of revalidation on 30/06/2020. • R22 with no restrictions, date of revalidation on 31/03/2020.
Medical Certificate	• Class 1 issue date 31/07/2019. • Expiration date 31/01/2020. • Restrictions: Close and long vision corrective lenses.
OPC	Valid until 15/12/2019.
LPC	Valid until 23/06/2020.

After Helicopter recovery from the sea, a green bag was found having inside Captain's personal belongings among which a pair of corrective lenses.

1.5.2 Captain's Flight Experience

Until 21/5/2017:	**Total Flight Hours**
➢ Airplanes	3466:06 h
➢ Helicopters	3844:48 h
➢ Helicopter (Two Pilots)	3844:48 h
From 24/6/2019 as Captain:	
➢ A109 A I I Helicopter	16:40 h
➢ A109 C	45:00 h
Last total Flight Hours on the last:	
➢ 24 h	01:50 h
➢ 7 days	09:35 h
➢ 90 days	76:00 h

On 19/08/2019 the Captain had accumulated a total duty time of 04:45 h

1.5.3 Captain's rest period

On 19/08/2019 14:15, the Captain arrived at Kranidi performing the flight form AIA to Kranidi. He had 22 hours rest time at a Porto Heli accommodation.

1.6 Helicopter Information

1.6.1 General information

Manufacturer	LEONARDO
Type	A109 C
M.S.N.	7671
Date of Manufacture	27/02/1995
Registration	SX-HTO
Total flight hours	3328:15 h
Total landings	5421
Total flight hours from last inspection	12:30 h
Airworthiness Review Certificate	Issued: 07/5/2019. Valid until: 07/5/2020.
Insurance	From 22/3/2019 to 21/3/2020.
Radio license	Issued: 10/7/2018 Valid until: 09/7/2021.

Engines

Manufacturer	Rolls - Royce
Type	250-C-20R1
Number of engines	2
M.S.N.	Left: CAE-295553, Right: CAE-295545
Total Flight Hours/Cycles from manufacture	Left Eng.: 3236:25 / 5092 Right Eng.: 3325:39 / 5284

Main Rotor

Type	109-0101-01-115
M.S.N.	401

Tail Rotor

Type	109-8131-02-125
M.S.N.	109

1.6.2 Maintenance

The maintenance of the Helicopter was carried out in accordance with a maintenance program approved by the Hellenic Civil Aviation Authority.

According to the Flight Manual and the Helicopter's Maintenance Program, an inspection is foreseen according to the instructions of the Checklist before the first flight of the day but also before each flight. The Maintenance Program also provides for an inspection after the last flight of the day.

On 20/08/2019, the day of the accident, the PDI was not certified in the Tech Logbook as well as the before first flight of the day inspection but also on 19/08/2019 the post flight inspection on the last flight of the day. From the review of the last Technical Logbook there were: 17 cases of no certification of the first daily flight inspection, 23 cases of no certification of PDI and 15 cases of no certification of PFI on the last flight of the day.

From the Helicopter and engines records, the following inspections were performed according to the approved Maintenance Program:

HELICOPTER INSPECTION	DATE	Flight Hours from new
25 h / 30 Days	14/8/2019	3315:45 h
150 h / yearly	05/9/2018	3188:45 h
600 h	16/4/2018	3041:00 h
2400 h	17/7/2015	2452:15 h

ENGINE INPECTION	LEFT ENGINE		RIGHT ENGINE	
	Hours since new	Date	Hours since new	Date
150h / 12 months[1]	3154:50 h	19/4/2019	3244:05 h	19/4/2019
300h / 12 months	3154:50 h	19/4/2019	3244:05 h	19/4/2019
600 h	2724:10 h	26/3/2017	3249:05 h	27/6/2019
1500 h	2776:00 h	13/5/2017	2745:00 h	25/8/2016
1750 h	2998:00 h	23/6/2018	3007:30 h	22/8/2017

At Helicopter 25h/30 Days Inspection**,** Fuselage - LH Side, it is predicted among others:

- *Accessible wiring and accessories for loose connections and condition.*
- *Starter-generator for condition and security. Electrical connections for arcing and/or short circuit evidence.*

At Helicopter 150h/yearly Inspection, Power Plant, it is predicted among others:

- *Fuel and oil flexible tubes for condition and chafing.*

On the last inspection of the Helicopter, one week before the accident, the Power Check of the engines took place according to diagram APP. 5.8. From this, according to the prevailing conditions[2] of ambient temperature and pressure altitude during the test, the following values were obtained:

ENGINE	Minimum required torque (%) according to the Flight Manual	Engine Torque (%) during test
LEFT	83	96
RIGHT	77	86

[1] According to the engine Maintenance Manual, the 150h inspection is included in the 300h inspection.

[2] During the test, the conditions were: OAT 36^0 C, at Sea Level, indicated Turbine Outlet Temp 752^0 C.

1.6.3 Main Rotor Hydraulic Actuators

The Main Rotor is activated by three Hydraulic Actuators which are distinguished based on their color, red, blue, and yellow. On the day of the accident, their operating hours were:

Actuator	Total Hours	Time Between Overhaul TBO
RED	1545:35 h	3600 h
BLUE	3328:15 h	
YELLOW	3328:15 h	

1.6.4 Helicopter Hydraulic Pumps

The Helicopter was equipped with two Hydraulic Pumps supplying the systems. The total operating hours of both pumps were:

PUMP	Total operating hours
No. 1	1144:10 h
No. 2	3273:15 h

According to Helicopter Maintenance Manual, for the Part Number of the specific pumps no operating time is defined for TBO. The hydraulic fluid used by the Hydraulic Pumps has the specification MIL-H-5606.

1.6.5 Helicopter Fuel

The Helicopter is certified by the Manufacturer, for temperatures higher than -18^0 C, to use fuel with specifications JP5, Jet A and Jet A-1. On 19/8/2019 before the third and last leg from AIA to Kranidi, the Helicopter was refuelled at AIA with 337 lt of Jet A-1 type fuel which, according to the Technical Logbook corresponded to 260 kg.

After the refueling, a total of 360 kg of fuel was onboard, while after the flight from AIA to Kranidi, according to the Technical Logbook, a residual amount of fuel of 250 kg remained on board, which was the amount of fuel onboard on 20/8/2019 upon departure from Kranidi to Galata.

There was no entry in the Tech Logbook for the remaining amount of fuel after landing at Galata.

1.6.6 Helicopter Weight

The Maximum Take-off Weight of the Helicopter is 2720 kg and the Zero Fuel Weight 2297 kg. The certified CG limits is between 3168 mm and 3500 mm from the Datum Point, while the calculated CG on departure from Kranidi was 3428.9 mm and on landing at AIA was 3420.5 mm.

1.6.7 Altitude Diagram- Helicopter Speed on Landing and Take-Off

The Helicopter FM presents the altitude-speed diagram where the proposed height-speed relations during the Take-off and Landing are presented, as well as the altitude-speed relations that should not be attempted (App. 5.11).

1.6.8 Wind Limits

1. In FM, Section 1 (Limitations), no wind limits are specified which are restrictive for the Helicopter flight as per Helicopter's Certification Requirements.
2. In FM, Section 4 (Performance), it is stated:

   "Satisfactory stability and control in rearward and sideward flight has been demonstrated, at all loading conditions, for speeds up to and including:

   - *30 Knots in rearward flight.*
   - *20 Knots in sideward flight.*

   However, this is not to be considered as a limiting value since the maximum operating wind velocities have not been established."
3. In the Operating Manual Part B, there are not specified wind limits that are restrictive for helicopter flight.

1.7 Meteorological information

The meteorological data in the possession of the Captain for the LF at Kranidi, came from the recordings of a meteorological station, at a distance of 48 NM from the Kranidi LF. The following emerged from the report issued on 20/08/2019, at 13:43 h:

Wind	Visibility	Ceiling	Clouds	Temperature	QNH
360°/13 kt	> 7 NM	12000 ft AGL	FEW 2500 ft	32° C, DP:11° C	1015 hpa

There are no meteorological stations in the Galatas area. According to the Certificate of the National Meteorological Service, it was estimated that in the wider area of Galata - Poros on

20/08/2018 from 11:37 h UTC to 13:37 UTC winds were from the North - Northwest moderate with temporarily strong gusts.
The Meteorological data collected from the nearest Meteorological stations in Galatas revealed the following for the Galatas - Poros area upon arrival and departure of the Helicopter:
On Arrival:

Wind	Temperature	QNH
316°/12 kt to15 kt	31° C, DP:13° C	1016 hPa

On Departure:

Wind	Temperature	QNH
316°/12 kt to15 kt	31°C, DP:14° C	1016 hPa

1.8 Navigation aids

Not applicable.

1.9 Communication

The Helicopter was equipped with two VHF / COM / NAV transceivers type BENDIX KING KX165 and BENDIX KING KX165A. After take-off from Galata LF, there are no recorded conversations with the FIC.

1.10 Landing Field information

The LF that was used for the landing and take-off in Galatas Fig. 1, was a flat square space, dimensions 27x27 m with coordinates 37° 29 '40.7' 'N, 023° 27' 22.6 " E, surface area 729 m2 at an altitude of 3 ft. This LF was not a Helipad Licensed by the HCAA.

1.11 Flight Recorders

The Helicopter was not equipped with a CVR and FDR as they were not required by the Regulations.
Inside the Helicopter were found and recovered a Laptop Computer and a Portable Tablet type device, which were handed over to the Directorate of Criminological Investigations of the Police for examination.

During the laboratory examination of the above devices, it was found that they were non-functional, and the data could not be recovered.

1.12 Wreckage and impact information

1.12.1 Crash Site Description

The Crash site is in the sea Chanel between Galata and Poros island. At the Crash site the sea depth is 4,5 m and the sea Chanel is 246 m wide.

Above the sea Channel, there are three medium voltage (20 kV) Power Cables crossing horizontally over it, suspended to the air between poles placed at a height of 73 m in Galata and at a height of 64 m in Poros. The LF from where the Helicopter took-off, is approximately 314 m from the point of impact on the three Power Cables.

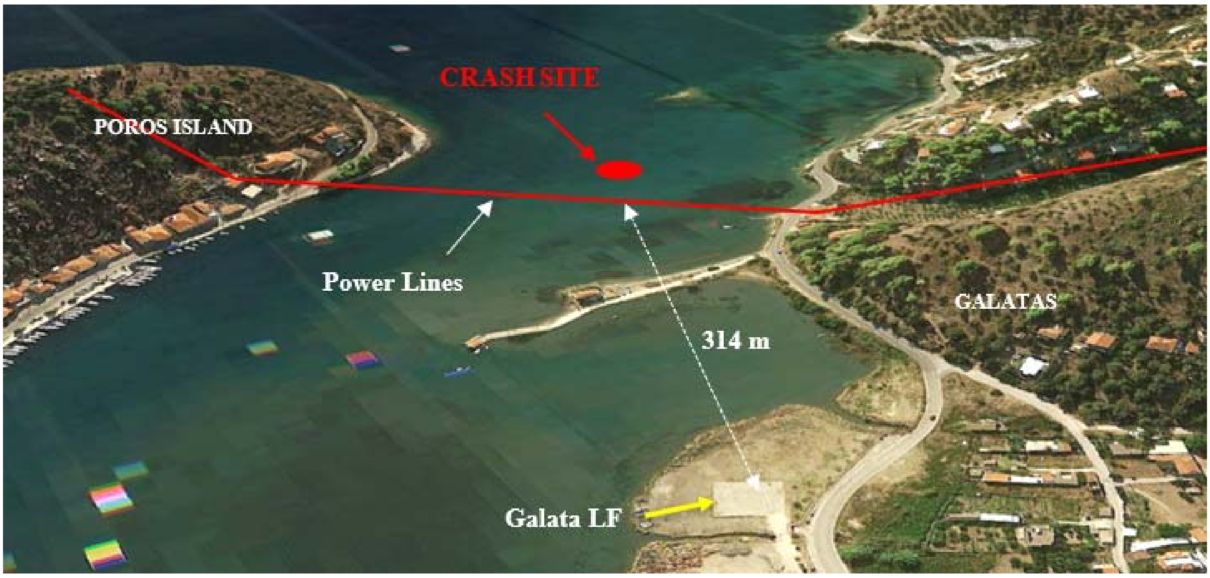


Fig 2: The Crash site in the sea Channel between Poros Island and Galatas.

1.12.2 Power Cables Elements

According to the written response of The Hellenic Electricity Distribution Network Operator to a relevant question of AAIASB, the three Power Cables were of medium voltage and the distance between them was about 5.50 m. The height of the Power Cables from the sea surface at the point where it is estimated that the Helicopter collided, was 134.5 ft (41.0 m), at an ambient temperature of 35^{o} C under shade and with an estimated load I = 125 A.

1.12.3 Helicopter Impact

The Helicopter after its 3 s horizontal flight and before the impact with the Power Cables, showed a decrease in pitch. Almost simultaneously with the reduction in pitch angle, although the Helicopter had stable attitude, the blades of the main rotor collided the first and second Power Cable and smoke appeared.

After the collision with the two Power Cables the attitude of the Helicopter changed to a left angle and yaw and collided with the third Power Cable.

After the collision with the third Power Cable, instantaneous ignition appeared in the area of the main Gear Box and the Main Rotor was detached from the Helicopter while the Tail part was detached and was found at a distance of 35 m from the fuselage. The Helicopter crashed into the sea Channel with a negative pitch while the Main Rotor and Gear Box ended up a short distance from main Helicopter fuselage (Photos 2, 3, 4).

Photo 2: The Helicopter, main Gear Box and Rotor during their fall into the sea channel.

Photo 3: The Helicopter after its impact with the sea before it is submerged.

The three poles of the Power Cables on the side of Poros can be seen.

Photo 4: Detail A. The ends of the blades of the Main Rotor as well as the rear of the fuselage.

1.12.4 Helicopter Wreckage Examination

The Helicopter wreckage was moved from the scene of the accident by order of the Port Authority to the location Plaka where it was recovered. After its recovery it was examined in the area of the accident by the AAIASB Investigation Team. After its transfer to the storage area, it was re-examined by AAIASB as well as by a Manufacturer Team under the supervision of AAIASB. During the examination period by the Manufacturer Team, the Tail Part had not yet been found.

On 29/08/2019 the Tail Section was found at a distance of 35 m from the rest of the Helicopter and was moved to the location Plaka where it was lifted and transferred to the Helicopter storage area for examination.

Individual units such as the Engines, the main Rotor Hydraulic Actuators as well as the two Hydraulic Pumps in addition to their macroscopic examination, were examined in certified centres of their Manufacturers under the supervision of AAIASB.

From the macroscopic examination by AAIASB the followings were ascertained:

1.12.4.1 Cockpit

A detailed description of the position of the switches is included in App. 5.21. In addition to those mentioned in App. 5.21, it was found that:

- The right Engine Fuel Shut off Valve Switch was found inside the Switch Socket. From the position indicator of the valve, which was in the open position, to the Socket of the Switch and to the left of the Socket, abrasions and cracks were created on the control surface (Photo 5 and App. 5.6, Photos: 34, 35).
- On the right side of the above control panel, a deformation had been created upwards, while its structural frame had been distorted to the left (App. 5.6, Photo. 36).
- The rear of the mounting thread of the right Engine Fuel Shut off Valve on the control panel, was damaged (App. 5.6, Photos 37 and 38).
- The Collective Control Lever had a perforation measuring 3.0 x 3.5 cm at its bottom (App. 5.6, Photo 40).

Photo 5: The Right Engine Fuel Valve Switch.

1.12.4.2 Fuselage – Tail Section

1.12.4.2.1 Fuselage

A detailed description of the findings is included in App.5.22. In addition to those mentioned in App. 5.22, it was found that:

- The forward Fuselage Section was deformed upwards, consistent with the impact angle at sea (Photo 6).
- Traces of contact with the Power Cables were observed on the metal cover of the Right Engine, while at the point where the metal cover surrounds the exhaust of the Right Engine, traces of an electric arcing were observed from the contact of the metal cover with the Power Cables (App. 5.3, Photos 26, 27, 28).
- Fracture of the Tail Rotor Shaft at the point of detachment of the Tail Section, with obvious twisting of the Shaft (App. 5.20, Photo 44). The fracture point showed characteristics of static fracture (App. 5.20, Photo 45).
- The fracture point of the front part of the Tail Rotor Shaft near the point of its connection with the main Gearbox, showed characteristics of static fracture during its rotation while surface abrasions were observed (App.5.20, Photos 46, 47).
- The Left Engine Fuel Shut off Valve was in the open position while at the Right Engine it was in the closed position.

Photo 6: Upward deformation of the forward fuselage section

Photo 7: Gear box section

1.12.4.2.2 Tail Section and Tail Gear Box

The Tail Section was detached from just behind the Rear Antenna of the Radio-Altitude, at the Fuselage Station 7821. The deformations that occurred at the point of fracture are consistent with static fracture during the detachment of the Tail Section.

The connections on the Tail Rotor Gearbox for changing the pitch of the rotor, no discontinuities were found, while the two Push - Pull Rods, for the change of pitch of the Rotor and the movement of the two Balancing Surfaces of the Tail, were connected and secured while their deformation was consistent with static fracture.

The Tail Rotor Shaft Cover and the Shaft itself were missing while the Axle Front Bearing rotated freely. The second Bearing together with its Support, 5 cm wide, were broken at the base of the Bearing and the fractured surface had characteristic of static fracture.

The deformations in the area where the Rotor Shaft was located (Photos 8, 9), in the Vertical Fin (Photo 8 and App. 5.4 Photo 29) but also in the Right Horizontal Stabilizing Fin are consistent with the impact of the Main Rotor Blades.

Photo 8: The Helicopter Tail Section.

Photo 9: Deformations in the area of the Shaft of rotation of the Tail Rotor. The photo has a forward direction.

1.12.4.3 Main Rotor and Gear Box

1.12.4.3.1 Examination of Main Rotor

A detailed description of the findings is included in App. 5.23. In addition to those mentioned in App. 5.23, it was found that:

- On the white blade there is a 5 cm long deformation blow on the leading edge at a distance of 48 cm from the Blade Tip. At the Blade Tip there are imprints of the same color as that of the Helicopter, while there are also deformations in length 24.5 cm along the tip of the blade.
- In all four blades of the Main Rotor, abrasion and detachment of material from their upper and lower surface was observed.
- In the Main Rotor Link Assy, the blue and yellow blade Connecting Rods were deformed and statically fractured, while the white and red vane Connecting Rods were not fractured. In all four Connecting Rods, their Rod Ends were connected and secured.
- The Rotating Scissor was not fractured and was secured. The three Connecting Screws to the Main Rotor Hub were broken and a laboratory examination was performed on them, the results of which are reported in Par. 1.12.7.

1.12.4.3.2 Examination of Main Gear Box

The Main Gear Box was intact without external fractures. Its mounting points on the fuselage were fractured with static fracture characteristics due to its detachment from the Helicopter after the impact on the third Power Cable. The Differential Pressure Indicator of the External Gear Box Lubrication Filter was not activated, and the Outer Oil and Hydraulic Fluid Pipes were found broken and deformed.

1.12.4.4 Fuel Filters

The two Fuel Filters were examined macroscopically and there were no signs of pre-crash clogging. Also, their Part Numbers were in accordance with the ones specified in the relevant Manufacturer's Manual.

1.12.4.5 Hydraulic Filters

During the examination, the two Hydraulic Filters Modules were removed. After their removal, it was found that in the No. 1 Module, the Differential Pressure Indicator of the Return Filter had been extended (Photo 10). After the Filter removal and macroscopic examination of the Filter and its Bowl, there were no findings which justify the extent of the Indicator and the pre-crash blockage of the Filter (Photo 11).

Note: When the differential pressure of the Filter increases beyond the limit of retention of the Indicator, then it extends and shows a blockage of the Filter by 75%.

At the same time, the other Hydraulic Filters as well as their Bowls were examined macroscopically and there were no indications for their pre-crash clogging, while the Part Number of the Hydraulic Filters was found to be in accordance with the relevant Manufacturer's Manual.

Φωτ. 10: The No1 hydraulic filter assembly with the indicative extended (yellow arrow) of the return filter.

Φωτ. 11: The return filter during its examination.

1.12.5 Engines

Both engines were still on the Helicopter. The following was identified from AAIASB initial macroscopic examination:

1.12.5.1 Left Engine

- The Compressor Front Support had been deformed in its Upper Right Quadrant (Photo 12).
- The leading edge of all Compressor First stage Blades had been damaged which was consistent with the suction of foreign objects during engine operation (Photo 12).
- The Drive Shaft from Engine Gearbox to the Main Rotor Gearbox was connected to the engine and it was fractured at the junction with the Main Rotor Gearbox. After its disconnection from the engine, it had visible abrasions all over its periphery.
- The Engine Oil Return Filter Pop Out Indicator was not activated. After the removal of the Return Filter and the macroscopic examination of the Filter and the Bowl, there were no signs of pre-crash clogging.
- The engine Gear Box was corroded due to its submersion in sea.
- The wiring and the hoses of the engine did not show any signs of fire.
- The oil breather flexible tube was found worn due to a chaffing with a heat shield.
- A starter-generator Cable insulation was found damaged and repaired with insulating tape.

Photo 12: Left Engine Compressor Inlet and its Front Support.

1.12.5.2 Right Engine

- The engine was displaced along the longitudinal axle. This displacement is consistent with the Helicopter attitude during its impact with the sea (Photo 13).
- The Engine Mounts were deformed (Photo 15) which was consistent with the axial forward movement of the engine.
- The Front Support part of the Compressor was deformed in its left side part (Photo 14).
- All the First stage Compressor Blades Leading Edges had been damaged which was consistent with the suction of foreign objects during its operation.
- Puncture in the upper part of the Compressor Diffuser from outside to inside, as well as dent in the left Air Duct from the Compressor to the Combustion Chamber.
- The Position Indicator of the Fuel Metering Valve on the Fuel Regulator was at the maximum open position.
- The Engine Oil Return Filter Pop Out Indicator was not activated. After the removal of the Return Filter and the macroscopic examination of the Filter and its Bowl, there were no signs of pre-crash clogging.
- The engine Gear Box was corroded and punctured due to its submersion in sea.
- The wiring and the hoses of the engine did not show any signs of fire.

- The Drive Shaft from the Engine Gearbox to the Main Rotor Gearbox was connected to the engine while it was fractured at its junction with the Main Rotor Gearbox. After disconnecting it from the engine, it had visible abrasions all over its periphery.

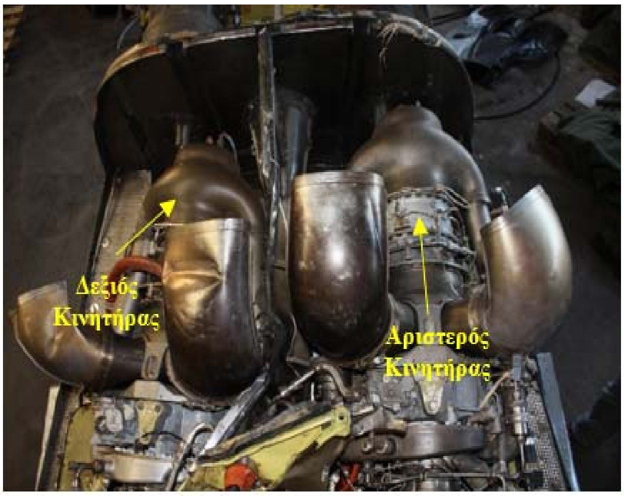


Photo 13: The axial displacement of the right motor to the left .

Photo 14: The intake of the right engine compressor with the deformation of its front support part.

Photo 15: Deformed engine mounts (yellow arrows).

1.12.6 Examination of Helicopter and its components from the Manufacturers

1.12.6.1 Examination from Helicopter Manufacturer

After the examination of the Helicopter by the Manufacturer, the following was reported:

- All the data obtained during the examination of the Helicopter, seems to confirm that the damage is probably attributed to multiple collisions with Cables, of the Main Rotor Blades, the Upper Rear and Front Fuselage and Tail Section (Tail Boom).
- The short-lived ignition that occurs in video material could be generated by the dispersion of hydraulic fluids / lubricants under high pressure in the area of the Main Gearbox after its detachment.
- No pre-existing damage or failure was found on all inspected components.

1.12.6.2 Engines and Components Examination

The two engines were removed from the Helicopter by Approved Maintenance Organization Engineers, in the presence of the AAIASB Investigation Team member and were transferred to a certified repair center of the engine Manufacturer. There was a tear down to examine the engines and their accessories, in the presence of an Engine Manufacturer Representative and a Member of AAIASB Investigation Team.

Examination of the engines and their accessories did not reveal any findings that could affect the engines normal operation. From the examination of the two engines it was found that the two engines were operating during the crash of the Helicopter due to the following:

- The leading edge of First stage Axial Compressor Blades was damaged.
- It was observed rubbing of all stages Axial Compressor Blades Tip with the Axial Compressor Case.

- At the Centrifugal Compressor Impeller Forward and Aft section, it was observed wear throughout its circumference, as a result of friction with its Forward Cover and its Rear Support.
- Traces from the Turbine Rotor Fourth stage on the Stator of the stage but also on the Sealing Part of the Stator.

1.12.6.3 Hydraulic Pumps

During the investigation, the two Hydraulic Pumps were removed from the Main Rotor Gearbox and sent to their Manufacturer for examination in the presence of a Member of the AAIASB Investigation Team, as well as a Representative of the Helicopter Manufacturer.

During the examination of the two Hydraulic Pumps, it was observed that their Shafts did not rotate while they had not been fractured or torsionally deformed. Due to Pumps' Shaft rotation inability, a functional test was not possible to be performed and both Pumps were teared down and examined.

Residues such as sand, shells and algae were found inside the Pumps, while advanced galvanic corrosion was observed due to the exposure of the Pumps to seawater.

The results of the examination of the two Hydraulic Pumps did not reveal any findings that indicate a malfunction of the Pumps prior the Helicopter crash.

1.12.6.4 Hydraulic Actuators

The three Main Rotor Hydraulic Actuators were removed and sent for examination to their Manufacturer, in the presence of a Member AAIASB Investigation Team, as well as a Representative of the Helicopter Manufacturer. Due to the Hydraulic Actuators condition, it was possible to perform a test bench operational test.

The macroscopic examination and the operational test of the Actuators did not reveal any signs of malfunctions prior to the accident.

Macroscopically it was found that the red and blue Actuators Summing Levers had been fractured.

The above fractured Summing Levers undergone an additional laboratory fracture examination, where it was found that the fractures were static due to Helicopter crash.

1.12.6.5 Laboratory test on the Rotating Scissor Joint Bolts with the Main Rotor Hub

The Rotating Scissor was mounted on the Main Rotor Hub with three Bolts. During the macroscopic examination of the Main Rotor, the three Bolts were found broken as shown in the Photo 16.

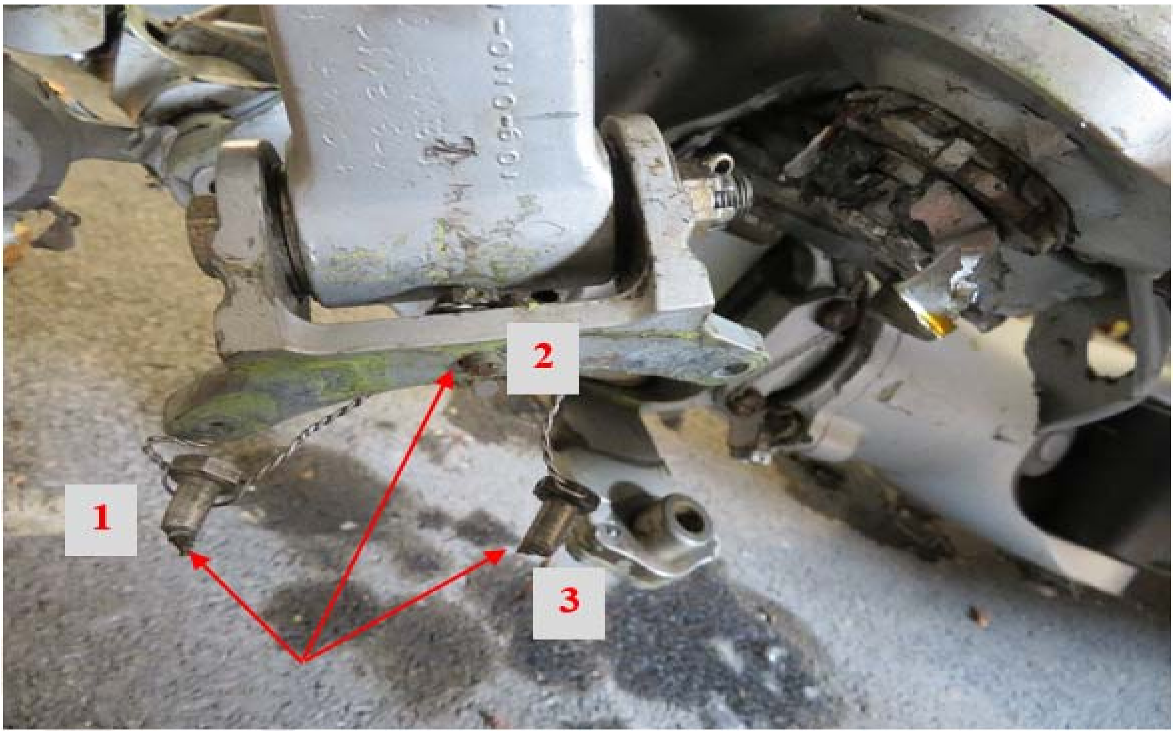


Photo 16: The three connecting Bolts of the Rotating Scissor with the Hub of the Main Rotor.

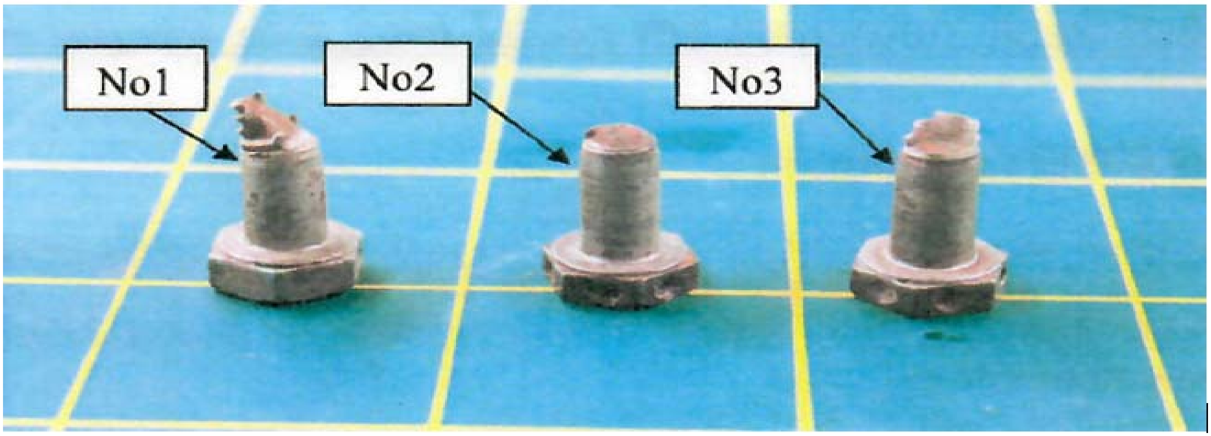


Photo 17: The examining Bolts 1, 2, 3.

The three Bolts were examined to a laboratory test where it was found that from the macroscopic examination of Bolts 1 and 3, as well as by the microscopic examination in Scanning Electron Microscope (SEM) submitted Bolt 2, the breakage of all three Bolts was abrupt due to abnormal tensile load.

1.13 Medical and pathological information

The Captain and the two passengers underwent a toxicological examination to detect alcohol, drugs, and substances. According to the results of the examination, the presence of alcohol, drugs and substances was not detected to the Captain and the two passengers.

Also, from the undergone forensic examination on the Captain, no findings emerged that affected his ability to handle the Helicopter. Also, for the two passengers, no findings emerged which indicate the existence of a pathological finding before the accident.

1.14 Fire

From the video material that is in the possession of AAIASB, it seems that after the collision of the Helicopter with the third Cable, an instantaneous ignition appeared in the Aft Section of the Main Gearbox, which started near the exhaust of the two engines.

1.15 Survival aspects

Flight Information Centres (FIC), after being informed of the accident in the sea area between Poros & Galata, informed the Search & Rescue Coordination Center and the search and rescue operations began.

At 15:44 h, the FIC informed the Athens Terminal Area (TMA VFR) about the accident in Galata.

At 16:10 h, the Submarine Missions Unit of the Coast Guard received a phone call from the Search & Rescue informing them of the accident.

At 17:15 h, a boat of the Coast Guard arrived at the accident site, with five members of the Submarine Missions Unit.

At 17:40 h, the three fatally injured people on board the Helicopter were recovered, by the Submarine Missions Unit members.

According to a written report of a member of the Coast Guard team that recovered the three people from the Helicopter, all of them were fastened with seat belts. The two passengers of helicopter were at the Aft Section of the Fuselage.

The local Port Authority of Poros immediately activated the emergency plan for search and rescue incidents. Immediately after the accident, boats of the Port Authority of Poros, private boats, private divers, boats of neighbouring Port Authorities as well as Helicopters of the Air Force arrived at the accident site.

1.16 Tests and Research

1.16.1 Examination of Fuel and Engine Oil

Due to the Helicopter sinking in the sea, during the examination, at the accident site, no amount of fuel and oil was found to be collected for examination. During the refuelling at AIA on 19/08/2019, the check for the presence of water in the fuel was certified in the Fuel Consignment Note, from which no water was present.

1.16.2 Simulation of Accident Flight

As part of the investigation, a Helicopter flight was carried out in the area of the accident with the participation of three members of AAIASB and the two Pilots. All five members of the simulation flight were aware of the exact location of the Power Cables.

Of the two Pilots on board the simulation flight, the Captain had performed a flight at the Galata LF on 11/08/2019 while the second was one of the trainers of the accident Captain.

The simulation flight followed the flight path of the accident recorded in a Navigation System as well as, based on the available photographic data, the estimated approach path for landing in the LF, Figs. 5, 6, 7, of APP. 5.1. For flight safety reasons, the execution of the Helicopter simulation flight to the Galata LF, was performed at an altitude of 500 ft above the sea channel.

After passing over the LF with a right turn, the Helicopter moved North of Poros and then with a Southern course and from above the island, the approach was repeated at the LF where a simulation landing was made with low hovering at a height of about 2 m above the LF (App. 5.2, Photo 21).

From the flight described above it was realized that the Power Cables were not visible on any of the routes above the channel, nor from the ground in the LF despite the fact that the sky was covered with clouds that offered good contrast to the black wires.

The Cables were perceived only in the phase of the final approach and at a very short distance from them (about 100 m) and only because all on board were aware of their exact position and looked for the poles in order to conclude their course. It is also pointed out that hills rise around the LF, except for the narrow sea strip east - west, with the result that the electrical Cables are projected in the Grey and Green of the terrain.

1.16.3 Helicopter Performance Evaluation by the Manufacturer

In the context of the investigation, the Helicopter Manufacturer carried out a performance evaluation, based on data provided by AAIASB at the request of the Manufacturer.

From the video material analysis based on the fact that the Helicopter reached a height of 41 m in 9 s, it was evaluated that its average rate of climb was 885 fpm.

In this context, three cases of climb were examined:

1) With an average rate of climb of 885 fpm.
2) With a rate of climb derived with the engines at Max Continuous Power.
3) With a rate of climb with Take-off Power.

The first case (#1) is compatible with the conditions during the event, as estimated by the available video. The results of the analysis of #2 and #3 possible scenarios are reported in Table 2 of App. 5.18.

In the Manufacturer report, based on the values of the rate of climb of the three above cases, it was evaluated the height that the Helicopter would have climbed if its climb had not stopped in the last 3 s. The results of the evaluation are reported in Table 3 of App. 5.18. At the same time, the Manufacturer examined, according to the last Power test of the engines, their available Power.

According to the Manufacturer analysis conclusions:

- The available engine Power was higher than the minimum allowed specified by the Helicopter Flight Manual.
- The Helicopter take-off weight confirms that it was in accordance with the instructions of the Flight Manual.
- The Helicopter could climb at least 13.5 m in the last 3 s, (with an average rate of climb of 885 fpm).
- The Helicopter was able to overfly the Power Cables.
- Experimental Manufacturer data collected during the A109C certification, shows that the acceleration from hovering in ground effect up to about 70 kts (for take-off weight greater than 2.500 kg) can be achieved with Max Continuous Power in 15 to 24 s. These data confirm that the estimated speed of 60 kt, by the AAIASB Investigation Team, has a reasonable value.

1.17 Organizational and Management Information

1.17.1 Operator Certificate

The Operator had a Certificate (AOC) which had an initial issue date of 28/10/2014 and was revised on 18/6/2019. According to this, the Air Carrier was authorized to operate passenger and cargo flights, it had the restriction of the to operate in Visual Flight Rules in day light conditions while the accident Helicopter was included in the Certificate.

1.17.2 Captain's Minimum Qualifications Requirements

1. In accordance with Operator's Manual, Part A the minimum qualifications requirements for I Fly Pilots to act as commercial air transport Commander for a single pilot operation are:

a. Attainment of company's specified minimum experience level for all pilots joining as direct entry Commanders, are not less of 1000 hrs as pilot in-command on Helicopters, and

b. For an ATPL(H) or CPL(H) Pilot Licence, an experience of more than 2000 flight hrs total on helicopter, of which:

- 1000 hrs flight time as PIC on helicopters.
- 500 hrs flight time as PIC on helicopters with turbine engine.

c. No absence from the flight line the last five years. In case of absence for more than five years from the flight line the CTM is authorized to determine the total flight hrs under supervision, not exceeded the 300 hrs.

d. Successful completion of an appropriate conversion course.

e. When a flight crewmember is required to operate a Helicopter, following completion of a Type Rating or the conversion course and the associated line flying under supervision, is not to be designated to commence a revenue or hired flight before he achieves the requirements on flight hrs of the type as it referred below according to the total Helicopter PIC flight experience:

- Has achieved 10 flight hrs totally on the type within a period of 60 days and performed at least 10 sectors, only for Commander with more than 2000 flight hrs as PIC on Helicopters.

2. According to the Operations Manual, Part D when a flight crewmember is required to operate a Helicopter, following completion of a type rating or the conversion course and the associated line flying under supervision, is not to be designated to commence a revenue or hired flight before he achieves the requirements on flight hrs on type as is referred below according to the total Helicopter PIC flight experience.

- Has achieved 10 flight hrs totally on the type within a period of 60 days and performed at least 10 sectors only for Commanders with more than 2000 flight hrs as PIC on the Helicopters.

3. According to the Operations Manual Part A the Operator shall only assign a crew member to act as pilot-in command/commander when he/she has:

a. Completed the I Fly Conversion course.
b. Acquired adequate knowledge of the route or area to be flown and of the aerodromes, including alternate aerodromes, facilities, and procedures to be used.
c. Completed a line training.
d. Completed the command course.

1.17.3 Duty Time Limitations

According to Operator's Manual Part A, the total crew flight hrs must not exceed:

- 8 hrs in any 24 consecutive hrs
- 30 hrs in any 7 consecutive calendar days
- 100 hrs in any 30 consecutive calendar days
- 280 hrs in any 90 consecutive calendar days
- 900 hrs in any 12 consecutive calendar months

In addition, a crew member has been provided with a rest period at least as long as the preceding duty period, or 12 hrs (10 for out of base), whichever is greater.

1.17.4 Pre-Flight Preparation and Flight Watcher personnel Duties

From the interviews taken in the context of the investigation, it was reported that during the preparation of the flights, in addition to the details of the flight dossier, the FOM did verbally inform the respective Captain regarding the possible particularities and points to be observed at the flight destination.

In the same context, the FOM stated that he was convinced that the Captain was aware of the existence of Power Cables. Also, on the day of the accident he spoke to the Captain twice without mentioning the Power Cables because he took it for granted that the Captain knew about their existence due to his previous many years of flying experience to the Poros Heliport.

Regarding the duties of the Flight Watcher, as they are mentioned in the Operation Manual in Part A, it is among other things, to give the Pilot all the necessary information during the flight such as NOTAMS, meteorological information and any other relevant additional information.

The Pilot could also consult the flight watcher at any time for additional information or assistance.

1.17.5 Risk Assessment

According to the Safety Management System Manual, approved by the HCAA:

- The management system includes the identification of aviation safety hazards entailed by the Operator activities, their evaluation and the management of associated risks, including taking actions to mitigate the risk and verify their effectiveness.
- The safety hazards should be classified to facilitate their association with potential or actual occurrences. The identified hazards should be stored in a database with their classification.
- The Safety Management System which is an integrated part of the Management System includes hazard identification and risk management schemes which address reactive, proactive, and predictive schemes.
  - ➢ The reactive approach consists of the analysing accidents and incidents which have already occurred.
  - ➢ The proactive approach consists of analysing the organizations activities without having an occurrence.
- Significant deviations from everyday operation such as, among others, in new routes or destinations, require a risk assessment and analysis before operation can take place.
- All hazards reported to the Safety Department via the hazard report form are assessed and mitigated by the department or forwarded to the appropriate department for the risk management process to start.
- All risk management process must be demonstrated, and all documents must be communicated to the Safety Department.

From data in the possession of AAIASB, the Operator maintained in a database the recording of events during the flights (Flight Occurrences Database) with an assessment of their risk and the corrective actions that were taken. The Air Carrier also maintains a database of the recorded risks arising from its activity.

This database has the recording of a Hazard on 12/02/2015 which was revised on 24/12/2015, which is also included in the list of events during the flights (Flight Occurrences Database).

1.17.6 Travel Contract - Charter Agreement

In order to execute a revenue route, a travel contract was drawn up between the Operator and the client. This contract, among other information, mentioned the date of the trip, the places of departure and destination and the number of passengers.

1.17.7 Flight Operation in Landing Fields

In the Operator's Manual, Part C it is stated, among others:

- For the Helicopters of the Company, passengers boarding and disembarkation, can be conducted at any private heliport or landing site.
- For take-off, position the Helicopter, taking advantage of the wind, obstacles, and the availability of the area in case of force landing on take-off.
- As the obstacles are cleared, adjust the altitude of the Helicopter to achieve a normal climb airspeed and rate of climb.
- For sites that are not pre-surveyed, the Operator has in place a procedure that enables the Pilot to make, from the air, a judgment on the suitability of a site. In this context the following items, among others, are considered:
  - The location and height of relevant obstacles to approach and take-off profiles, and in the manoeuvring area.
  - Approach and take-off paths.
  - If Helicopter is authorised with reference to performance requirements.
- During the landing procedure an area site evaluation is performed through a high and low reconnaissance. The course followed depends on the area topography, the wind, the obstacles, and the availability of the area in case of force landing. A high reconnaissance is flow at approximately 300 ft above the site, offset to the site, and into the wind (if direction is known). Minimum speed is 50 kts. At the low reconnaissance the Pilot may descend to a minimum of approximately 50 feet above the highest obstacle along the flight path at a minimum speed of 50 kts.
- Without a high and low reconnaissance, at the Pilot discretion, the low reconnaissance may be performed on final approach if out of ground effect is available. There are occasions when the high and low reconnaissance need not be performed, such as when, among others, when performing known sites approaches.

1.17.8 Civil Aviation Authority SMS Audits

During Investigation, the SMS Audits to the Operator performed by Civil Aviation Authority in years 2016, 2017, 2018 were reviewed. From the reviewed audits checklist, it was identified that the Operator was in compliance with the checklist item: "*Is the hazard identification and Safety Risk Management integrated into the day to day activities of the Organization*".

1.18 Additional Information

1.18.1 European Regulation EU 965/2012

European Regulation EU 965/2012 in section CAT.OP.MPA.105 concerning the use of airports and areas of operation provides:

α) An operator shall use only airports and places of operation which are suitable for the aircraft(s) type(s) and the relevant flight operation(s).

b) The use of the operating areas is valid only for:

1. *motorized airplanes other than composite and*
2. *helicopters.*

In section ORO.FC.205 concerning Command course, it is stated among others that:

For aeroplane and helicopter operations, the command course shall include at least the following elements:

(4) line training as commander under supervision, for a minimum of:

(i) 10 flight sectors, in the case of aeroplanes; and

(ii) 10 hours, including at least 10 flight sectors, in the case of helicopters;

Also, in section ORO.FC.220 concerning Operator's conversion training and checking it is stated among others that:

(c) The amount of training required by the flight crew member for the operator's conversion course shall be determined in accordance with the standards of qualification and experience specified in the operations manual, taking into account his/her previous training and experience.

1.18.2 Protection of the aviation facilities from the risk of Constructions - Obstacle's development around them, as well as the Aviation from the high constructions throughout the country.

According to the Government Gazette no. 191B, 05/02/2009 are provided:

1. *The introduction of the issuance by the Civil Aviation Authority (HCAA) of "Opinions", which are administrative acts for the purpose of the calculation after aeronautical study - of the maximum permissible altitudes of the constructions as well as any special requirements or constraints of Construction nature (marking, lighting and etc.), in accordance with the specific regulations of the HCAA and the requirements of the Chicago Convention on International Civil Aviation of the ICAO.*
2. *The establishment of the following areas for which the above "opinions" of the HCAA are mandatory before the approval of any Construction (Electricity poles -*

Telecommunication poles, wind turbine antennas, crane bridges, cranes, etc.) by the competent authority.

a. *For all Civil Airports of the country that serve public transport, the controlled area is generally defined within a radius of five (5) kilometers from each airport, unless this or another decision defines something specific for a specific airport.*
b. *For Heliport that serve public transport or are of public interest, the controlled area is defined within a radius of 1.500 meters from each Heliport, unless this or another decision defines something specific for a specific Heliport.*
c. *For radio aids serving air navigation, the controlled area is defined as:*
   i. within a radius of 600 m around the VOR
   ii. within a radius of 100 m around the NDB
   iii. within a radius of 5.000 m around the ILS
   iv. within a radius of 2.000 m around RADAR
   v. within a radius of 500 m around the Telecommunication station.

3. *For all other areas of the Greek territory, which are outside the boundaries of the areas of paragraph 2 hereof, the opinion of the HCAA is required for "ultra-high" constructions as follows:*
   a. *High-rise structures, individual or extensive, located within residential areas and exceeding 45 meters from the natural ground.*
   b. *High-rise structures located outside residential areas and exceeding 30 meters from the natural ground in the case of individual structures, and 45 meters from the natural ground in the case of extensive structures.*
   We noted that the Public Electricity Company high voltage networks are considered extensive constructions.

1.18.3 Helicopter Translational Lift[3]

Improved rotor performance as a result of forward flight is called transient lift. During the transition from the hovering phase to the forward flight as the Relative Airflow produced by the movement of the Helicopter in combination with the wind and the rotor increases, the vortexes decrease, and the air flow becomes more horizontal. At the same time the tail rotor becomes more aerodynamically efficient.

[3] FAA Helicopter Flying Handbook

At a speed of 16 to 24 kts, the main rotor completely overcomes the aerodynamic recirculation, and the air flow is relatively smoother and more horizontal. The induced flow and drag are reduced while the angle of attack is increased resulting in the rotor being more efficient and requiring less engine Power (App. 5.13, Fig. 9).

1.18.4 Cabin heating system through engine air extraction

The passenger compartment heating system consists mainly of an engine bleed air circuit, mixer, temperature sensor, and overheating switch and distribution circuit (App. 5.16, Fig. 10). The compressed bleed air from the engines is distributed to the mixing valve. The mixing valve provides hot air mixing, air from the engines with free air flow. The valve is controlled by an electric solenoid, which is operated by a switch that is installed on the upper right side of the cockpit and has the positions:

- ON, the valve is activated (valve open).
- OFF, the valve is off (valve closed).

1.18.5 Rotating Scissor

The Rotating Scissor consists of two hinged joints that are connected at one end to the main rotor hub component and at the other end to the swashplate outer ring (App. 5.17, Figs. 11 and 12).

The Rotating Scissor guides the Plate Outer Ring and allows the Outer Ring to tilt and move vertically in response to commands from the Cyclic and Collective controls.

1.18.6 Characteristics of flammability[4],[5] of aircraft hydraulic fluids of MIL-H-5606 specification

- Flash point: 104^0 C.
- Ignition temperature: 204^0 C
- Flash point of sprayed hydraulic liquid in hot conductor: 388^0 C.

1.19 Useful or Effective Investigation Techniques

Not Applicable.

[4] Federal Agency Aircraft Accident Investigation, May 1996

[5] Assessment of the flammability of aircraft hydraulic fluids, Monsanto research corporation, July 1979

2 ANALYSIS

2.1 Helicopter Flight from Kranidi LF to Galata LF.

As certified by the Helicopter Technical Logbook, the flight from Kranidi LF to Galata LF took place without any Helicopter technical malfunctions while the Helicopter Certificates were valid. Also, the centre of gravity was within the allowed limits. The Captain had adequate Crew Rest with all of his Certificates and Licences valid, while his total flight hours were within the specified limits according to the Operator's Operational Manual.

Upon the arrival in the vicinity of Galata at 14:48:30 h (point A) (App. 5.1, Fig. 5), the Captain due to the prevailed west-north-westerly wind in the sea channel, decided to go to point B (App. 5.1, Fig.6) to execute the approach opposite to the direction of the wind in the sea channel.

During the transition from point A to B, based on the available data, it is not known whether he flew close to or above the LF as the carried Spidertrack position recording system, showed the position of the Helicopter each two minutes and not its flight path.

From point B at a height of 375 ft the exact course followed to the LF is not exactly known. According to the available data, it is estimated that the Captain followed the course of Fig. 7, App. 5.1.

Based on the flight data at point B (375 ft, Ground Speed 40 kt), the fact that during the approach and landing procedure by reducing the altitude the indicated air speed decreases, as shown by the Height - Speed diagram of App. 5.7, but also due to the opposite northwest wind the Ground Speed decreased, the period of two minutes of flight until the next recording of the position of the Helicopter above the LF (40 ft, Ground Speed 2 kt), it is not considered sufficient for the Captain to perform the process of high and low reconnaissance of the area as required by the Part C procedure of the Operator.

As recorded in the simulation flight (App. 5.2, Photo 20), from point B where the Captain started the landing procedure, except for the existence of Power Cables that were not visible, the approach from east – southeast to the LF seemed free of obstacles.

The above contributed to the Captain's decision to carry out the landing procedure directly in the LF by flying at a low altitude over the sea channel as it results from the passage under the Power Cables at a distance of approximately 314 m from the LF approaching with a small descent angle. From the examination of the relevant photographic material, it is estimated that the height of the Helicopter during the passage under the Power Cables was about 100 ft above sea level.

The investigation revealed that the Captain was aware of the Power Cables existence at the sea channel, but it does not appear whether he knew their exact position in relation to the LF.

If the Captain knew that the Power Cables were located east of the LF, then when approaching the LF he would not fly at a low altitude below the Power Cables but would maintain a safe altitude above them. In this case, the distance of 314 m between the Power Cables and the LF was sufficient for the Helicopter, from a safe altitude, to make a landing in the LF[6].

Apart from the fact that the electrical Cables were not visible as they were not marked, as evidenced by the simulation flight, the presence of the Power Cables during the Helicopter flight over the sea channel was probably not perceived by the Captain for the following reasons:

- During the left turn made by Helicopter from position B to the LF, the Captain, due to his right position in the cockpit, had a part of his external field of view covered by the left part of the Helicopter cockpit.
- During the Helicopter low flight over the sea channel, the Power Cables were above the Captain's sight, while at the same time the Captain had focused his attention on locating the LF, as he had requested the confirmation of LF exact location before flight.
- At the time of the approach to the LF (from 14:50 h to 14:52 h), the position of the sun may not have made it easier for the Captain to distinguish the Power Cables.

The actual flight duration was 18 min longer than planned and the average ground speed was determined to be approximately 42 kt. After landing in Galatas, the Captain did not record the remaining amount of fuel in the Technical Logbook. From the available data it was evaluated[7] that this was 171.6 kg, and the take-off weight from Galata LF was evaluated[8] to be 2469 kg.

If the actual duration of the flight was 10 min as planned, then the remaining amount of fuel in Galata was evaluated to be 222 kg and the take-off weight would be 2519 kg.
From the above it seems that the increased flight duration had as a result the increase of the amount of fuel consumed during the flight and the reduction of the remaining quantity and the take-off weight from Galata LF.

---

[6] It was calculated that with a height of 276 ft above the sea channel at a distance of 314 m from the LF he would perform an approach with a descent angle of 15^0

[7] Based on the 28 min flight from Kranidi to Galatas, and an average fuel consumption of 2.8 kg / min (28 kg in 10 min flight) but also the 250 kg of the Helicopter fuel on departure from Kranidi.

[8] Based on the remaining fuel and the zero-fuel weight.

It is possible that the pilot chose to increase the flight duration so that having less remaining fuel in Galata, the take-off weight on departure from the Galata LF would have been reduced.

After the realization of the simulation flight (App. 1.16.2) and based on the findings that resulted from it and in combination with the provisions of the legislative framework of App. 1.18.2, AAIASB sent to the HCAA a document according to which the following were proposed:

- The immediate marking of the Powerlines with appropriate optical aids pending their conversion into submarine Power Cables, noting that the request is pending a previous recommendation with the document 1480 / 11.5.2018.

At the same time, there are areas, in Greece, where there is increased aviation activity and LFs are used. There are hazards in these areas which increase the risk for flights. In this context, AAIASB proposed to the HCAA:

- The HCAA, utilizing data from the Flight Plans submitted daily, to identify areas of increased aviation activity and to carry out a risk assessment in these areas. Based on the above evaluation, to take any necessary actions to improve flight safety.

2.2 The Helicopter at the Galata LF

After landing, the Helicopter remained, in a northerly direction, at the Galata LF for 39 min until its take-off for AIA. During this period, the Captain should have carried out a PDI for the Galatas to AIA leg, but without documenting its execution, due to its non-certification in the Technical Logbook. However, it cannot be ruled out that the PDI was executed and not being recorded before departure.

According to the Helicopter Flight Manual instructions, during the execution of the PDI, among other things, a visual inspection must be made from the left side of the Helicopter (App. 5.15, sections 4,5,6 of the PDI).

Although the Captain had his field of vision towards the Power Cables for the execution of the PDI in the above sections, it is not considered probable that he could locate them because his main sight and attention would be focused on the Helicopter inspected part, while since the Power Cables were indistinguishable, it is not considered probable that they could be detected by its peripheral vision. At the same time, the distance of the Captain from the Helicopter during the execution of the PDI is such that it is possible that the Helicopter covered the Power Cables.

For the other sections of the PDI (App. 5.15, sections 1,2,3), the Captain would have his field of vision as opposed to the Power Cables.

During the investigation process, it was revealed that, knowing the exact location of the Power Cables, they were distinguished from the Galata LF. This observation took place the day after the accident with meteorological conditions and sun position, same as of the day of the accident.

It is possible that the Captain did not locate the Power Cables during his stay at the Galata LF because:

- The Power Cables were particularly indistinguishable if their exact location was not known.
- The Captain, having previously landed on the east side and not locating the Power Cables, considered that they were west of the LF, as a result of which he did not search to locate them before taking-off for AIA.

2.3 The Accident Flight

At 15:35 h and while the two passengers had boarded, it took off with destination AIA. As certified by the Technical Logbook, the Helicopter took-off from Galata LF without having any technical issues.

From the comparison of hovering maximum take-off weight values as mentioned in App. 5.18 and 5.19, and the actual evaluated take-off weight from Galata LF of 2469 kg, it is concluded that the actual take-off weight was lower than the maximum. Also, the center of gravity was within the prescribed limits.

From the available video footage analysis, it is shown that immediately after its take-off, the Helicopter performed a low hovering right turn about 90^0 around its vertical axle (Yaw) and moved to east-southeast track, estimated at 113^0. In addition to the meteorological data in the vicinity of Poros – Galata area, where the estimated wind was from a north-northwest direction, the examination of the video material showed that locally in the sea channel during the take-off, there was a light westerly wind. From the Helicopter followed track after its hovering, it appears that it took-off from the Galata LF with a light tailwind.

As reported in paragraph 1.6.8 (2), Section 4 “Performance” of the FM are specified the speeds that under all loading conditions, satisfactory stability and control in rearward and sideward flight has been demonstrated. Although these speed values are not considered limiting, it is reasonable to expect a lesser degree of stability and controllability at speeds higher than what

was safely tested. The light tailwind that existed during takeoff, did not cause conditions that could render the Helicopter unstable or uncontrolled.
The decision of the Captain to take-off in an east-southeast direction, is probably because he had earlier made the direct approach and landing coming from the east side of the LF, thus considering this side free of obstacles as not having located the Power Cables. The last experience acted as a deterrent for the Captain to take-off in a west-northwest direction, into the headwind.

At the same time, it was considered the possibility for east-southeast course take off so that the two passengers could make a passage above the yacht that they disembarked in the morning of the same day. From the data collected it emerged that the yacht at the time of take-off was at a distance of 11.10 NM, northeast of the LF. Due to the position of the yacht, this might be a possibility.

After hovering and the right yaw, the Captain performed a 8 s low altitude flight so that the Helicopter would gain the translational lift speed. The effect of the tailwind resulted in this speed being obtained at a greater horizontal distance than in the case of a headwind. This resulted in a Helicopter climb that started closer to the Power Cables and was executed with a smaller angle compared to the angle that it would have if it took-off with a headwind.

In headwind condition, with the same engine Power settings, in 9 seconds the helicopter would have gained a sufficient height to overflying the Power Cables. However, the day of the accident the wind was blowing on the opposite direction and the Helicopter took-off in an East – Southeast direction, towards the Power Cables and under the tailwind conditions. These two circumstances were causal factors to the accident.

One week before the accident, the engine torque produced was higher than the minimum required. The examination of the engines, at the repair center after the accident, did not reveal any signs of malfunction.

The macroscopic examination of both engines showed no signs of fire on either engine, which would trigger the Cockpit fire alarms and possibly distract the Pilot during the take-off and climb phase. Also, the examination showed that no fire was extinguished on any engine as the red discs of the fire extinguishing cylinders of the fire extinguishing system were intact.

At the same time, as found by the relevant examination, the control units of the main rotor blades related to the control of the Helicopter (hydraulic actuators) but also the hydraulic Power supply to them (hydraulic pumps), did not show signs of malfunction before the impact to the Power Cables.

From the Video material analysis, it was found that the Helicopter stopped climbing 3 s before impact with the Power Cables, while about 1 s before the impact it acquired a pitch down attitude.

AAIASB Investigation Team as well as the Helicopter Manufacturer, evaluated the height that the Helicopter would have climbed if the last 3 s, its climb had not been discontinued.

The Helicopter 3 s before impact, had reached an altitude of 134.5 ft (41m). Based on this data of the 9 s climb the average rate of climb was estimated to be 885 fpm. As shown in Table 3 of App. 5.18 but also in Table 5 of App. 5.19, in the last 3 s the Helicopter would have climbed at least 44 ft (13.5 m) while the cleared height above the Power Cables would have been at least 34 ft (10.4 m). From the above it is concluded that if the Helicopter with the estimated climb rate had not levelled off the last 3 s, it would have overflown the Power Cables.
The AAIASB Investigation Team, assumes that the manoeuvre resulting in the impact was initiated by the Captain after the sudden identification of the Cables over the blue background of the horizon. The 3 s time until the pitch down reaction is compatible with the internationally accepted reaction time after the detection of an air impact hazard. The Helicopter-specific "High Wire" illusion may have also contributed to the Captain's decision to pitch down. During this illusion when approaching aerial Cables, a helicopter pilot feels that the Cables are higher than his flight path when in fact they are at the same or lower altitude. The illusion is even more intense when the flight takes place over a sea channel due to the apparent movement of the Cables due to the Ponzo[9] perspective illusion.

The discontinuance of the Helicopter's climb in the last 3 s, was determined as a causal factor to the accident.

From the performance evaluation results as mentioned in App. 5.18, it is concluded that the Helicopter was capable of climbing the last 3 s at a rate of climb higher than the evaluated of 885 fpm and overfly the Power Cables.

[9] (Patterson, F. R., Arnold, R. D., & Williams, H. P. (2013). Visual Perspective Illusions as Aviation Mishap Causal Factors. 17th International Symposium on Aviation Psychology, 512-517. https://corescholar.libraries.wright.edu/isap2013/29).

Since the available Power of the engines was higher than the minimum required, as it emerged from the last Power test (Par. 1.6.2), the values of the rate of climb as mentioned in App. 5.18 may be increased resulting in a higher height over Power Cables.

2.4 Flight Preparation

The flight performed on the day of the accident was the second performed by the Operator to the Galata LF. According to the approved Management Procedures described in the Organisation Management Manual (Ch. 4, par. 4.2.7: Risk Identification and Mitigation Procedures), the Operator should have carried out a risk assessment and analysis before Operation can take place.

The review of the Safety Management System data that came into the possession of AAIASB, did not show any indications that the Operator had carried out a risk management before the start of the flight activity in the Galata LF and in other new destination.

Oral briefing conducted by the FOM, apart from the fact that it was not a risk management process under the Safety Management System, did not ensure standardization in the information provision to the Pilots.

In this context, the FOM and the Flight Watcher, considering that the Power Cables were known to the Captain, due to his past vast experience in the Air Force, did not make any reference to the existence of the Power Cables during their communication with the Captain before the flight.

It is considered that if, in the context of the standardized implementation of the Safety Management System, a risk management had been carried out before the flights initiation in the area of the Galata LF, Power Cables hazard would have been recognized in time and risk mitigation measures would have been taken and would have been shared to the Operator's Captains as well, so that they have a clear knowledge of the exact location of the Power Cables.

The lack of standard execution of the risk management system was a contributing factor to the cause of the accident.

2.5 Safety Management System

As part of the Safety Management System, the Operator maintained a database where the identified risks arising from the Operator's flight activity were recorded. According to the approved Operation Manual, the Operator operated from and to un-surveyed LFs, where the possible presence of nearby Power Cables posed, among other hazards an accident hazard.

A review of the database held by AAIASB showed that the Operator had managed Safety System only for the events that had already occurred during the flights, thus focusing on the system Reactive Approach.

Additionally, recording and review of flight activity risk management, was not identified under the System Proactive Approach. In this context, the Operator did not follow the Safety Management System Proactive Approach, through the timely identification of hazards within the risk assessment process.

The lack of flight activity Proactive Approach within the Safety Management System by the Operator, was a contributing factor to the accident.

The lack of flight activity proactive approach within the Safety Management System, was also result of the HCAA audits failure to detect in a timely manner the non-compliance with the approved OMM procedures, in terms of the risk management before the operation to a new route takes place.

The failure of the HCAA audits to detect the lack of flight activity proactive approach within the Safety Management System, was considered as a contributing factor to the accident.

2.6 Helicopter Captain

From the examination of the Captain’s duty schedule and rest period, were within the Operating Manual requirements.

As it was determined by the Captain's Logbook, the total Helicopter’s flight hours of 3844:48 h were in the presence of a Co-Pilot. In this context, the transition of the Captain to a single-Pilot flight environment, resulted in the increased workload, with a possible negative effect on the situational awareness and at the same time risk increasement. The Captain’s increased workload, probably affected his ability to detect the Power Cables after take-off.

From the review of the Captain's training records and in accordance with the approved Operator’s Part A and D Operating Manuals, it was found that the Captain complied with the criteria of paragraph 1.17.2 (3) for performing the Captain's duties since he had received, from the Air Carrier, the relevant training with all relevant Certificates.

Regarding criteria 1e and 2 of App.1.17.2, these are unclear because they do not specify the status under which the pilot should fly (with instructor or not), while at the same time they contradict criterion 3 of the same paragraph where the Pilot, in compliance with the prescribed conditions, can perform the duties of Commander at the Air Carrier.

The review of the charter agreements in combination with the Helicopter Technical Logbook, emerged that the pilot immediately after his assignment as Commander started the Operator's revenue flights, which is contrary to the criteria 1e and 2 of App.1.17.2 but in accordance with criterion 3 of App.1.17.2.

From the above it appears that the approved, by the HCAA, Operation Manual (Part A and Part D), regarding the criteria for the assignment to the duties of Captain, were different.

2.7 Helicopter wreckage examination

2.7.1 Helicopter's Cockpit

From the wreckage examination it was found that in the cockpit the position of the switches of the fuel system, hydraulics, engine de-icing and heating of pitot static probes was consistent with the flight phase in the prevailing climate conditions. Regarding the position of the indicators of the two fuel valves, this was in accordance with the predicted position when the Helicopter is not supplied with electrical Power.

In the cabin heating system, although the two shut-off valve switches for the air flow from the engines (Engine Shutoff Valve 1, 2) to the cabin heating system, were in the 'OPEN' position, this system was not operating because the mixing valve switch was in the 'CLOSED' position so as not to cause an engine Power reduction during take-off.

The Electrical Power System switches have been found in the expected positions after the impact without Pilot input. Specifically, the switches GEN 1 BUS, GEN 2 BUS but also GEN 1, GEN 2, INV 1, INV 2, INV 3 were consistent with the Power lose during the impact, as the switches GEN 1 BUS, GEN 2 BUS automatically return to the 'CLOSED' position with a Power lose while the other mentioned switches must be positioned to the 'CLOSED' position manually.

Regarding the deformations that had undergone the control surface and the control switches of the fuel and hydraulic systems, these are consistent with the application of an irregular load downwards and to the left during the impact of the Helicopter. At the same time, the observed cracks, and abrasions of the control surface as well as the deformation of the rear side of the mounting threads of the right fuel valve control switch are consistent with the application of vertical irregular load on the switch, when it was in the "ON" position (fuel valve open). The appearance of the hole at the bottom of the Collective control lever is consistent with the impact of the lever on the right fuel control valve switch. The result of the above load was the detachment of the switch from its mounting position, its initial forward movement, and its final retraction in the control surface's switch socket.

As it emerged from the relevant examination, the two engines were operating until impact, a fact that indicates that the two fuel valves were in the 'OPEN' position. The 'CLOSED' position (OFF) of the right fuel valve recorded during the examination is probably due to the exercise vertical irregular load on its control switch and its subsequent movement resulting in the closure of the electrical contacts that gave the shut-off command on the fuel valve.

2.7.2 Fuselage – Tail Section – Main Gear Box – Main rotor

From the analysis of the video material, it is ascertained that the Helicopter collided with the sea at a pitch angle which was estimated to be -24^0. The deformations of the front part of the fuselage were consistent with the Helicopter attitude during its impact on the sea.
Due to the above angle of impact on the sea, the windshield broke and resulted in a sudden inflow of water into the cockpit, which was the probable cause that the two engines Power levers moved backwards to the positions mentioned in App. 5.21.

From the examination of the main rotor white blade and tail section it was shown that the 5 cm induced deformation on the blade leading edge was dimensionally and morphologically consistent with the 5 cm fracture of the tail rotor shaft second bearing support carrier. Also, the caused deformations and fractures of the blade and the tail section are consistent with the white blade impact on the tail section, after the main gearbox detachment from the Helicopter, which resulted in the separation of the tail section towards the right.
The three other main rotor blades fractures at approximately the same distance from their root (1.00 m to 1.10 m), are consistent with the Helicopter attitude (left roll and yaw) during its impact on the third Power Cable which resulted to the main gearbox detachment.

Due to the rupture of the oil and hydraulic piping, as a result of the impact on the third Power line and the detachment of the main gearbox, the pressurized liquids were released into the surrounding area and came in contact with the hot parts of the engines exhaust gases but also with the spark caused by the electric arc possibly between the third Power line and the metal cover of the right engine. The result of the above was the ignition of the expanding liquids, a fact which is compatible with the flammability properties of the hydraulic fluid MIL-H-5606 mentioned in paragraph 1.18.6. As can be seen in the video footage, the above is compatible with the fact that the ignition started in the area near the engines exhaust.

The free rotation of the bearings of the rotor shaft rotation as well as the surface abrasions and the shape of its fractures are characteristic of its rotation during the fracture, due to the detachment of the main gearbox and the tail section.

The tail rotor shaft rotation is in accordance with the rotation of the tail rotor during the flight as it emerged from the analysis of the video material where the flight was controlled without the presence of yaw.

From the wider examination of the fuselage and the tail part it was found that the caused fractures were a result of the impact with the Power Cables and later with the sea, while there was no evidence of failure before the accident.

The above are compatible with the smooth and controlled Helicopter flight from its take-off to its impact on the first Power Cable as recorded in the examined video footage during the investigation.

2.8 Helicopter Maintenance

Examination of the maintenance records of the Helicopter and its two engines revealed that there were no recorded maintenance tasks that were outside the time limits set by the Manufacturer. Also, the Helicopter and engine components that required overhaul or were characterized by a Life Limit Parts (LLP), were within the time limits set by their Manufacturer. Also, the worn breather flexible tube and the damaged starter - generator Cable insulation, even though failed to be detected during the scheduled 25h /30 days and 150h / yearly Maintenance, had not contributed to the accident. In addition, the Cable's insulation repair with insulating tape has not been able to be determined when it had been carried out.

Concerning the PDI and the inspections before the first flight of the day but also after the last flight certification in the Technical Logbook, it was found that the standard procedures for completing the required fields were not implemented by the involved personnel. The above did not contribute to the cause of the accident.

From the Helicopter examination and the review of Maintenance records, there is no evidence that the Helicopter maintenance contributed to the accident.

3 CONCLUSIONS

3.1 Findings

3.1.1 Helicopter

- The Helicopter's Certificates were in force.
- The flight from Kranidi LF to Galata LF took place without the Helicopter having any technical deficiency.
- The Helicopter took off from the Galata LF without having any technical deficiencies.
- There were no maintenance tasks that were outside the Manufacturer's time limits.
- There is no evidence that the Helicopter maintenance contributed to the accident.
- The Helicopter and engines components that required overhaul or were characterized by LLP, were within the time limits set by their Manufacturer.
- The Helicopter center of gravity was within the prescribed limits.
- The engines were in operation during the collision with the Power Cables.
- There was no evidence of malfunction or reduced engine performance during the flight.
- There was no evidence of malfunction of the main rotor hydraulic actuators and the hydraulic pumps before the impact with the Power Cables.
- There was no evidence of engine fire and there was no engine fire extinguished during the flight.
- The position of the switches of the fuel system, hydraulics, engine de-icing and heating of pitot static probes was consistent with the flight phase in the prevailing climate conditions.
- The cabin heating system was in 'OFF' position.
- The positions of the electrical Power switches were consistent with the Helicopter's Power loss during its impact.
- The right engine fuel shut off valve was found closed.
- The deformations that the control surface had undergone and the control switches of the fuel and hydraulic systems, were consistent with the application of an abnormal load, directed downwards and to the left during the impact.
- The 'OFF' (closed) position of the right fuel shut off valve is probably due to the application of vertical irregular load on its control switch and its subsequent movement during the impact.
- The Helicopter collided with the sea channel with an estimated pitch angle of -24^0.

- The deformations of the front part of the fuselage were consistent with the Helicopter attitude during its impact on the sea surface.
- The deformations and fractures of the white blade and the tail section were consistent with the impact of the white blade on the tail section, after the main gearbox detachment, resulting in the separation of the Helicopter section towards the right.
- The deformations of the three other main rotor blades are consistent with the Helicopter attitude during its impact on the third Power Cable that led to the detachment of the main gearbox.
- The tail rotor rotated throughout the flight.
- The two push-pull rods, for the change of the tail rotor pitch but also the movement of the two tail balancing surfaces were connected and secured to the tail rotor while their deformation was compatible with static fracture.
- The caused instantaneous ignition, was a result of the expansion in the surrounding area of the pressurized hydraulic liquids that came in contact with hot parts such as engine exhaust but also with the spark caused by the electric arc possibly between the third Power Cable and the right engine metal cover.
- The caused fractures of the Helicopter were a result of its impact with the Power Cables and subsequently with the sea.
- There were no signs of any Helicopter failure before its impact with the Power Cables and subsequently with the sea surface.

3.1.2 Captain

- The Captain had the required rest period before the flight and his Certificates were valid.
- The Captain's Flight Duty Period of the day was within the prescribed limits.
- The Captain had received the prescribed training in accordance with the approved OM-D.

3.1.3 Helicopter Flight

- The actual duration of the flight from the Kranidi LF to Galata LF was 18 min more than planned.
- The Captain did not locate the Power Cables during his stay at the Galata LF.
- The weight of the Helicopter at its departure from Galata LF was less than the maximum allowed for hovering.
- The Helicopter took off from Galata LF with a light tailwind.

- The light tailwind that existed during takeoff, did not cause conditions that could render the Helicopter unstable or uncontrolled.
- If the 9 s climb of the Helicopter was done with a headwind, it would have acquired in this time period more height than that of the Power Cables.
- If the climb of the Helicopter had not been discontinued in the last 3 s, it would have flown over the Power Cables and would have not collided with them.
- The Helicopter had the capability to make a climb with higher rate than the one evaluated during its climb.

3.1.4 Operator

- The Operator's Operating Manuals (Part A and Part D), approved by HCAA, regarding the criteria for the assignment of Captain's duty, are different.
- The Operator had not performed a risk management before the start flight activity in the Galata LF but also in another new destination.
- The Operator was not following flight activity Safety Management System Proactive Approach.

3.1.5 Hellenic Civil Aviation Authority

- The HCAA audits, did not detect the Operator's non-compliance with the approved procedures of the Organization Management Manual, regarding the risk management before the start of any flight activity on a new route.

3.2 Causal Factors

From the Accident Investigation it was identified that the helicopter impact on the Power Cables and its resulting crash on the sea, was due to the following probable causal factors:

- The discontinuance of Helicopter climb in the last 3 s before impact with the Power Cables.
- The Helicopter take-off in an East - Southeast direction under the tailwind conditions.

3.3 Contributing Factors

The following contributing factors are recognized:

- The non-detection of Power Cables during the approach to the LF.
- The lack of standardised execution of the risk management System before the start of the flights to Galata LF.
- The failure of the HCAA audits the detect the lack of flight activity proactive approach within the Operator's OMM Safety Management System.

4 SAFETY RECOMMENDATIONS

4.1 To the Operator

- The investigation process revealed that the Operator, in the context of Safety Management System, focused on the flight activity reactive approach but did not follow the flight activity proactive approach through the timely hazard identification and risk assessment process.

2022-02: It is recommended to the Operator, to re-evaluate the Safety Management System implementation process in order to timely identify the hazards arising from its activity that potentially can cause accidents or serious incidents**.**

- From the last Helicopter's Technical Logbook review, there were recorded repeated cases of non-certification of the execution of: the first flight of the day, the pre-flight inspection (PDI) but also the inspection after the last flight (PFI).

2022-03: It is recommended to the Operator to review the training process of the involved personnel in the task accomplishment certification in the Technical Logbook.

4.2 To the Operator and Hellenic Civil Aviation Authority (HCAA)

- From the Investigation and the relevant review of the Operation Manuals (Part A and Part D), it was identified that the approved procedures regarding the criteria for the assignment of Captain duties were different.

2022-04: It is Recommended to the Operator to review and revise the described procedures in the Operation Manuals as well as the procedures followed for the establishment of the Operation Manuals.

2022-05: The HCAA to review and revise its internal procedures in order to eliminate any contradictions in the submitted Manuals for approval.

4.3 To the Operator's Part 145 Maintenance Organization

- From the wreckage examination, failure was identified of Part 145 Maintenance Personnel to comply, in the context of scheduled Maintenance, with the Maintenance task card requirements regarding the identification of No. 1 Engine faulty parts (worn breather flexible tube and damaged starter-generator Cable).

2022-06: It is recommended to the Maintenance Organization to make sure that all procedures included in the Maintenance Organization Exposition (MOE), are followed.

4.4 To the HCAA

- From the review of the Captain's Logbook during the investigation, it was identified that the Captain's total Helicopter flight hours were performed in a Multi Crew Environment. In this context, the transition of the Captain to a single-Pilot flight environment, resulted in the increased workload, with a possible negative effect on the situational awareness and at the same time risk increasement.

2022-07: It is recommended to the HCAA to reconsider training requirements for pilots coming from multi crew environment to single crew environment and vice versa.

- From the investigation it was identified failure of HCAA during audits to detect non-compliance with the approved Operator's OMM procedures, in terms of the risk assessment and analysis accomplishment before the operation on a new route.

2022-08: The HCAA to ensure adherence to its published auditing procedures.

Nea Philadelphia, 09 June 2022

CHAIRMAN	**MEMBERS**
Ioannis Kondylis	**Akrivos Tsolakis**
	Grigorios Flessas
Exact Copy **THE SECRETARY**	**Christos Valaris**
Kyriakos Katsoulakis	**Charalampos Tzonos-Komilis**

5 APPENDICES

5.1 Flight Plan Track of the Helicopter

Fig. 2: The Helicopter track according to the Flight Plan.

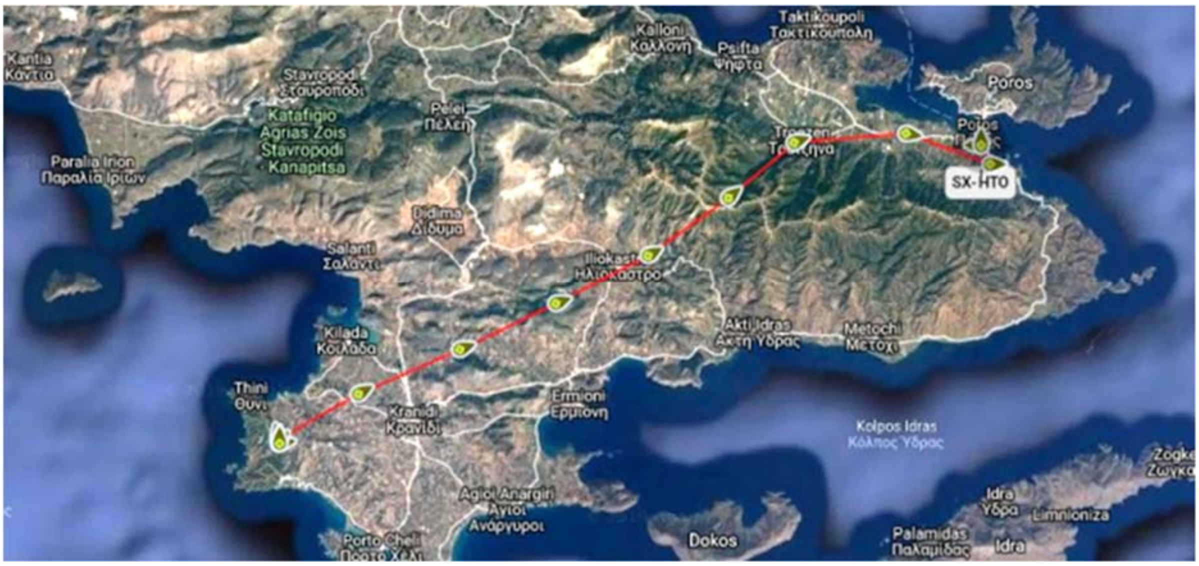


Fig. 3: The crossing points of the Helicopter from Kranidi to the Galata LF. The red line connecting the crossing points does not reflect the real course.

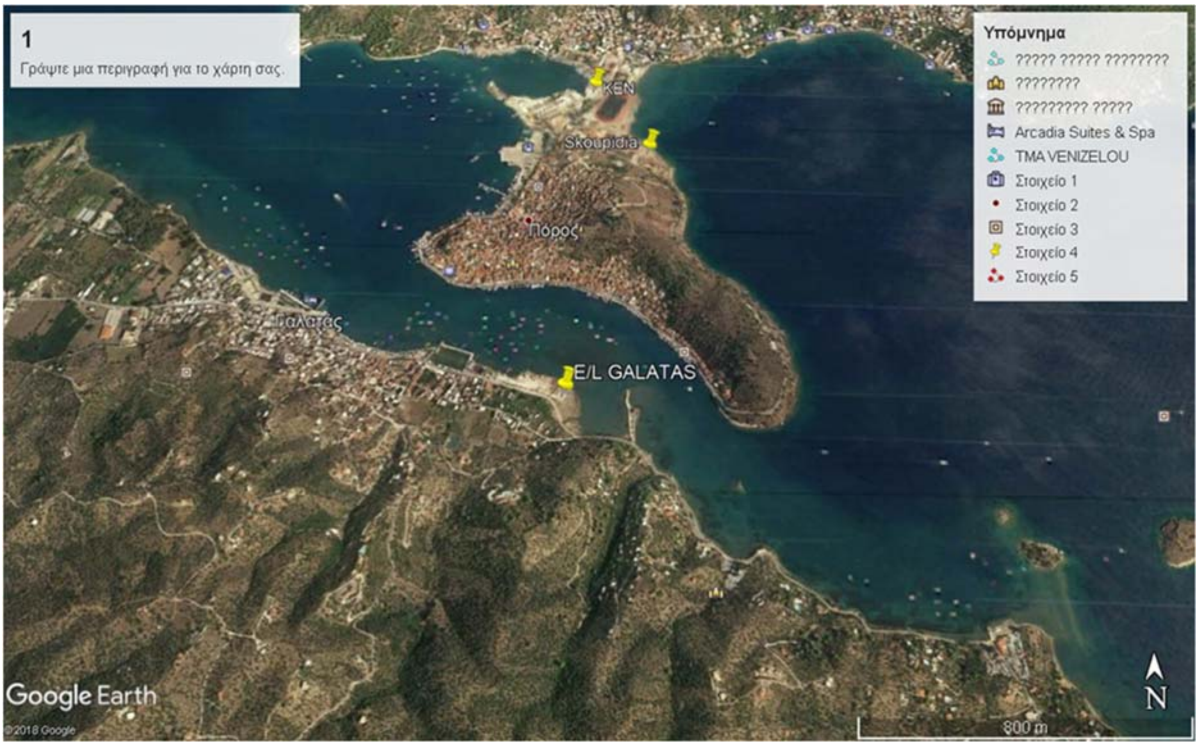


Fig. 4: The images sent to the Commander by the Operator on 20 AUG 2019 at 11:36 h.

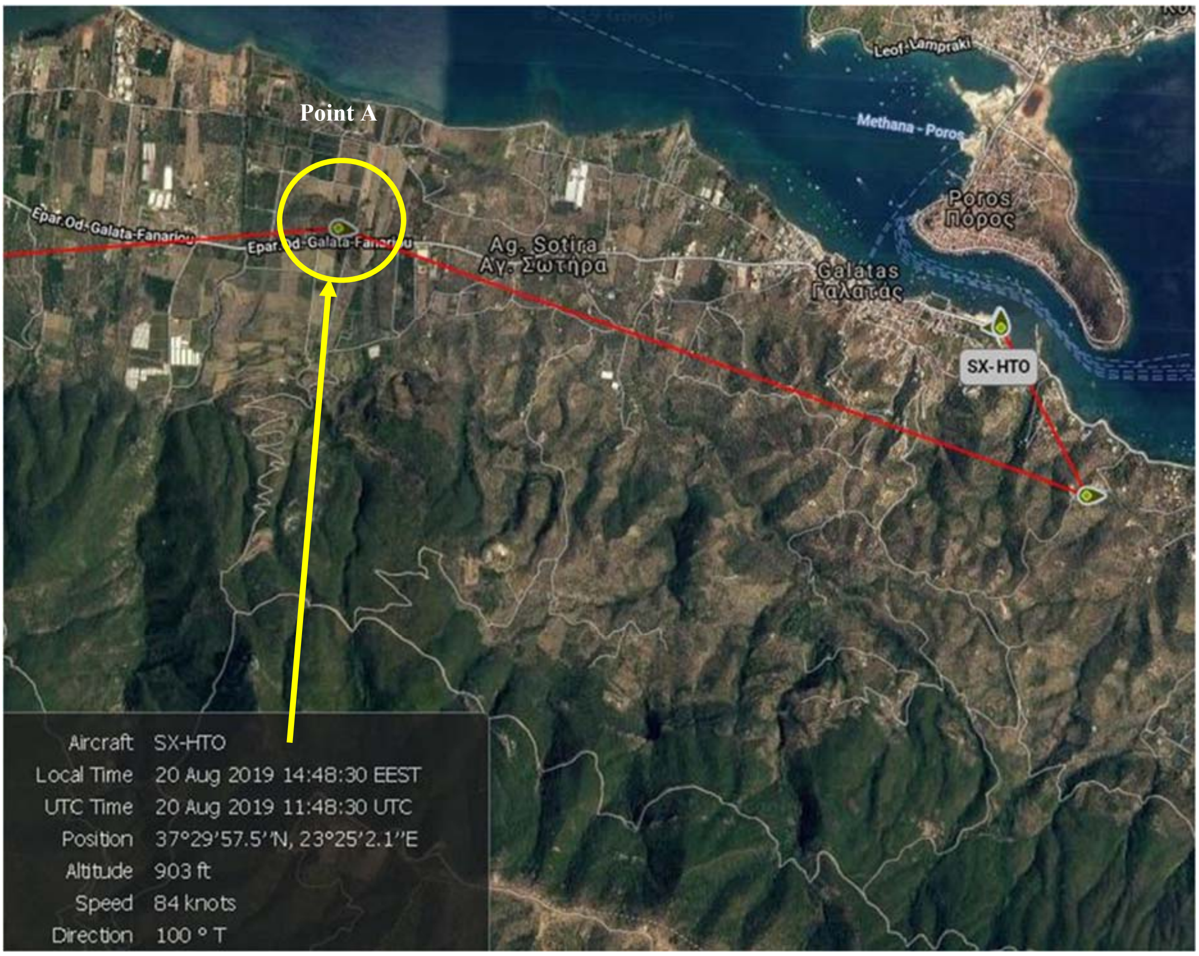


Fig. 5: The position of the Helicopter at 14:48:30 during its approach to the Galatas LF. The red line connecting the crossing points does not reflect the real course.

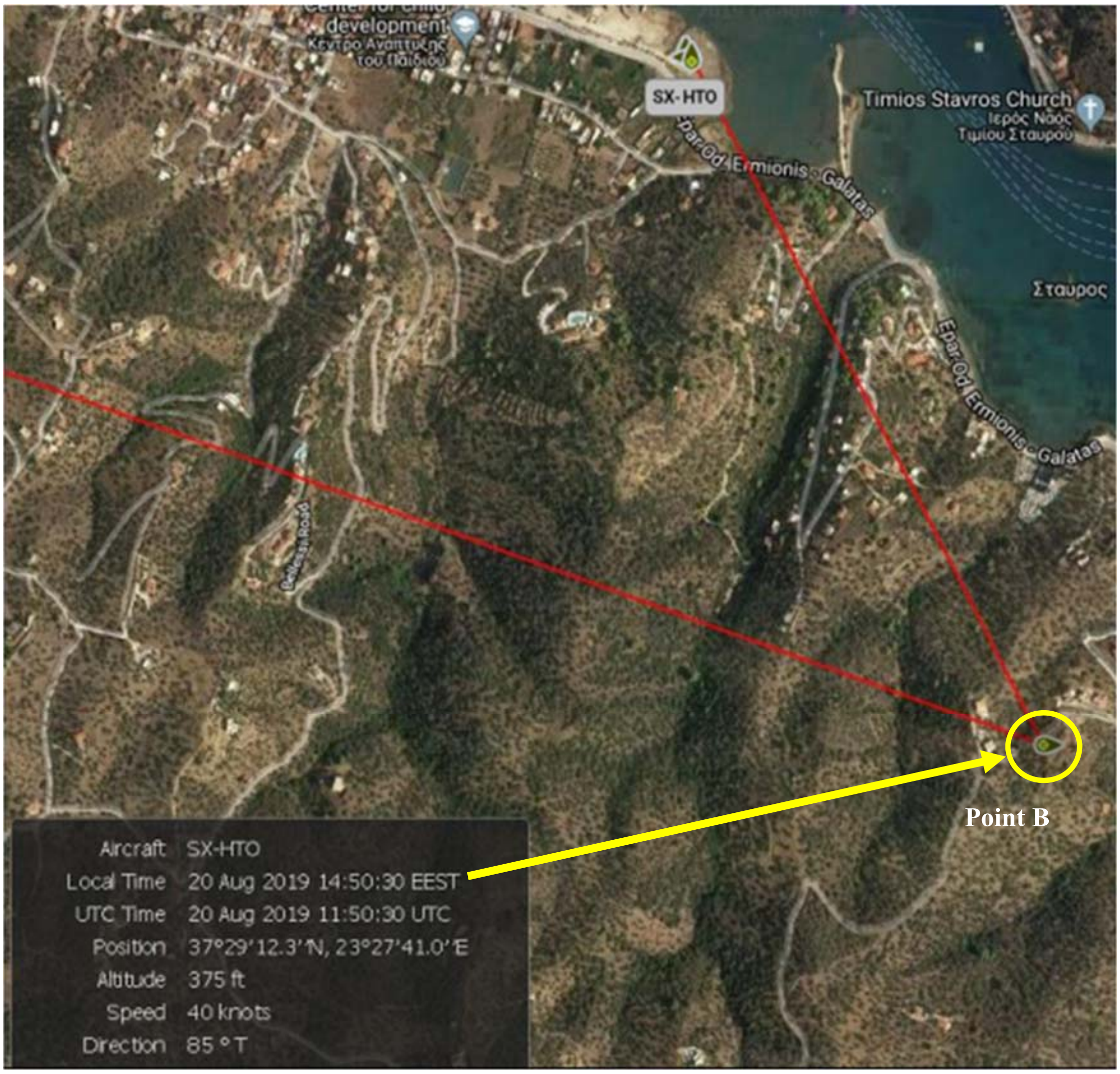


Fig. 6: The position of the Helicopter at 14:50:30 during its approach to the Galatas LF. The red line connecting the crossing points does not reflect the real course of the Helicopter.

**Fig. 7: Estimated Helicopter track during approach for landing at Galata LF.
The dotted line represents the flight under the Power Cables.**

Fig. 8: The Helicopter position at 14:52:30 above Galatas LF.

5.2 Simulation Flight

Photo 18: The Helicopter during the simulation flight at the point where Helicopter accident was at 14:48:30 of Fig. 6.

Photo 19: The Helicopter during the simulation flight following the estimated course of the accident Helicopter. In this photo, the Power Cables are not visible.

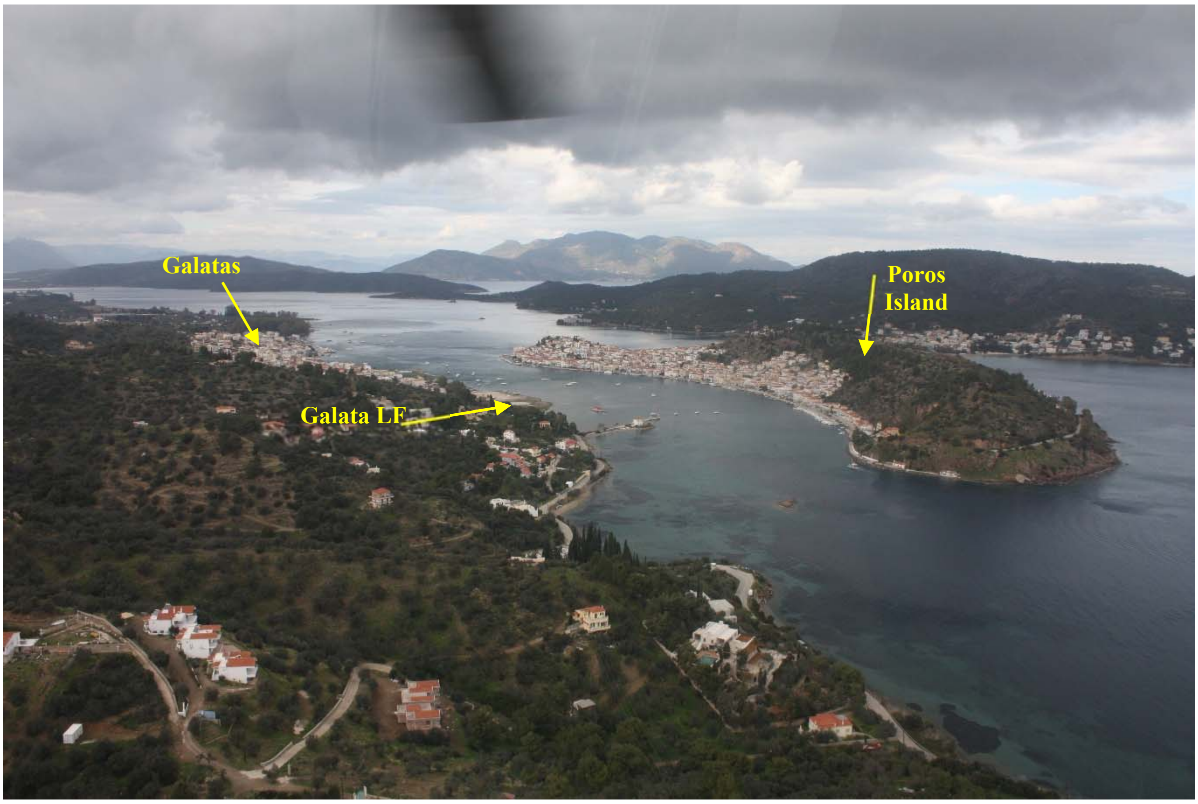


Photo 20: The Helicopter during the simulation flight near the point of the accident Helicopter at 14:50:30.

Photo 21: View of the area where the Power Cables are located when approaching the Galata LF, with a South direction from the side of Poros.

5.3 Characteristic points of contact of the Helicopter with the Power Cables

Photo 22: The points of contact of the Helicopter cockpit upper part with the Power Cables.

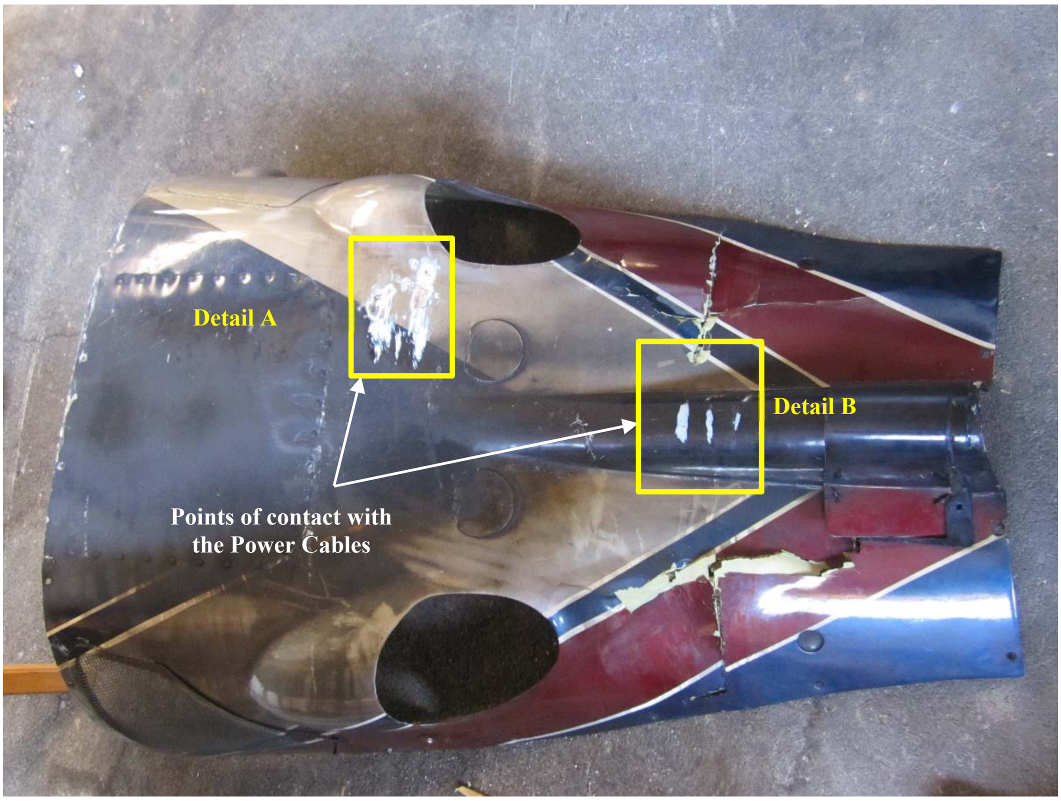


Photo 23: The points of contact and fracture of the outer oil coolers cover.

Phot. 24: Detail A

Phot. 25: Detail B

Phot. 26:Right engine cover.

Phot. 27: Detail A.

Photo 28: Detail B, the characteristic traces of the electric arc that was created between the metal cover and the Power Cables.

5.4 Tail section Deformation

Photo 29: Deformations of the vertical fixed tail section.

5.5 Imprints from the impact of the white blade on the tail section

Photo 30: The 5 cm length impact on the edge of the white blade and of the same dimension at the base of the bearing support of tail rotor shaft.

Photo 31: Imprint on the blade from the Helicopter color with the tail section (yellow arrow).

Photo 32: The tip of the white blade with the existing deformations.

Photo 33: The tip of the white blade with color imprints from the impact on the tail section (red arrow).

5.6 Right engine fuel shut off valve switch, control panel and Collective control lever

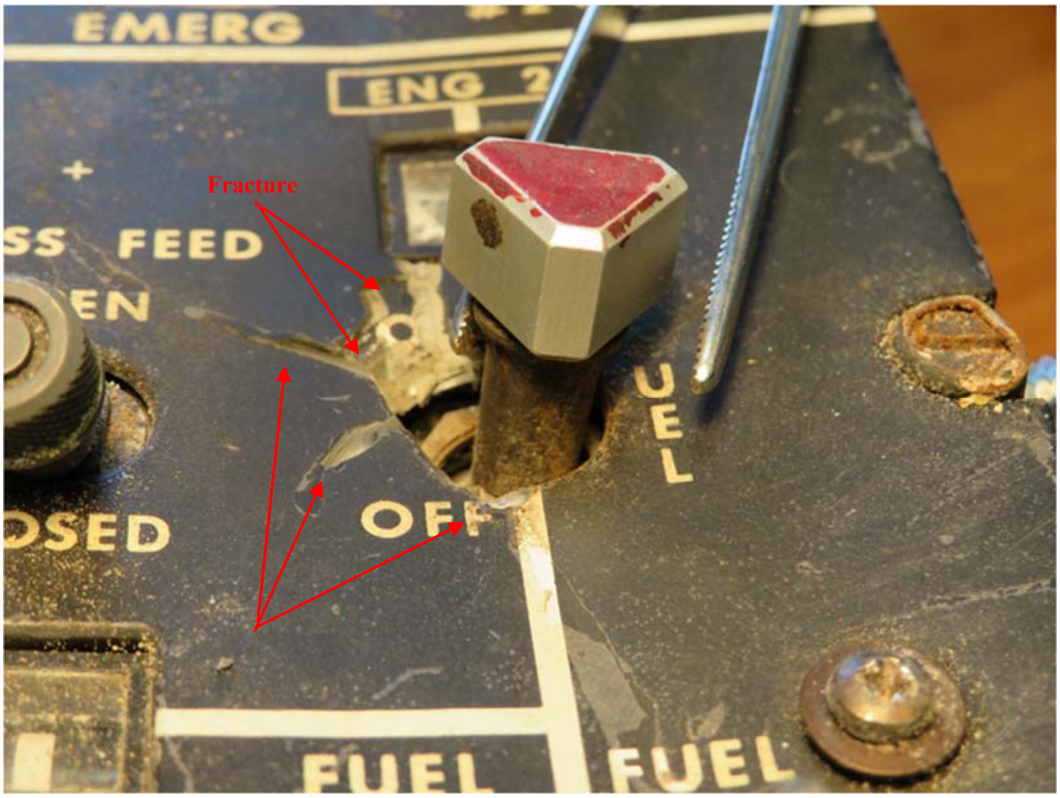


Photo 34: Abrasions and breaks on the switch control surface.

Photo 35: The control panel after removing the switch.

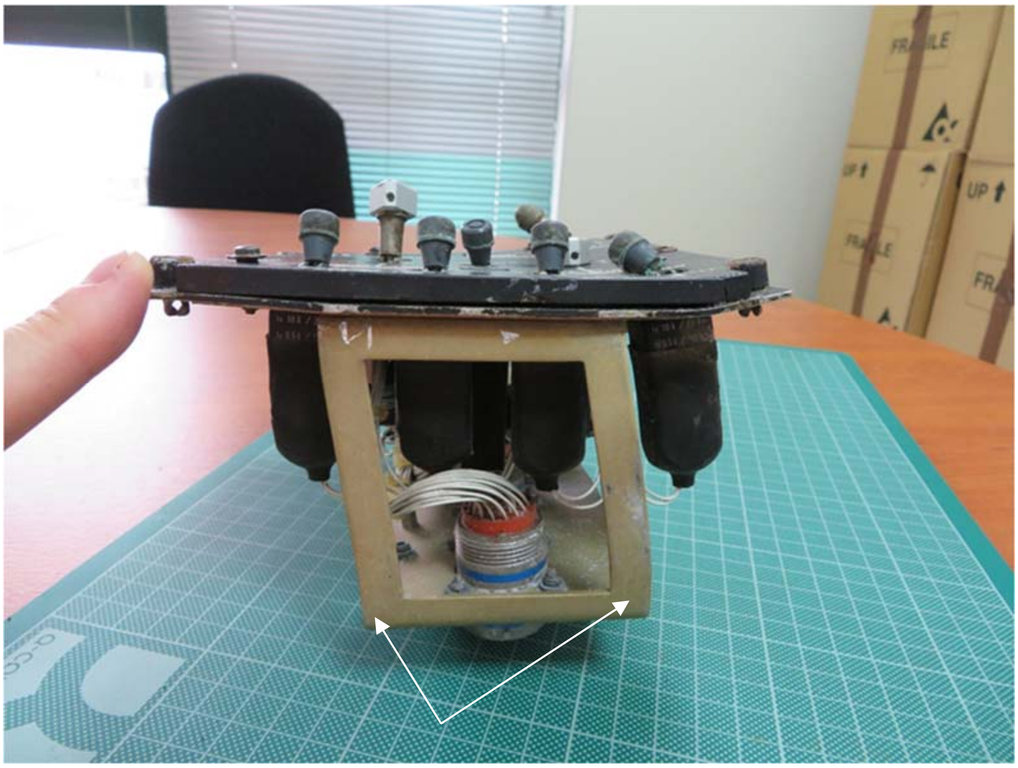


Photo 36: The distortion of the control panel frame.

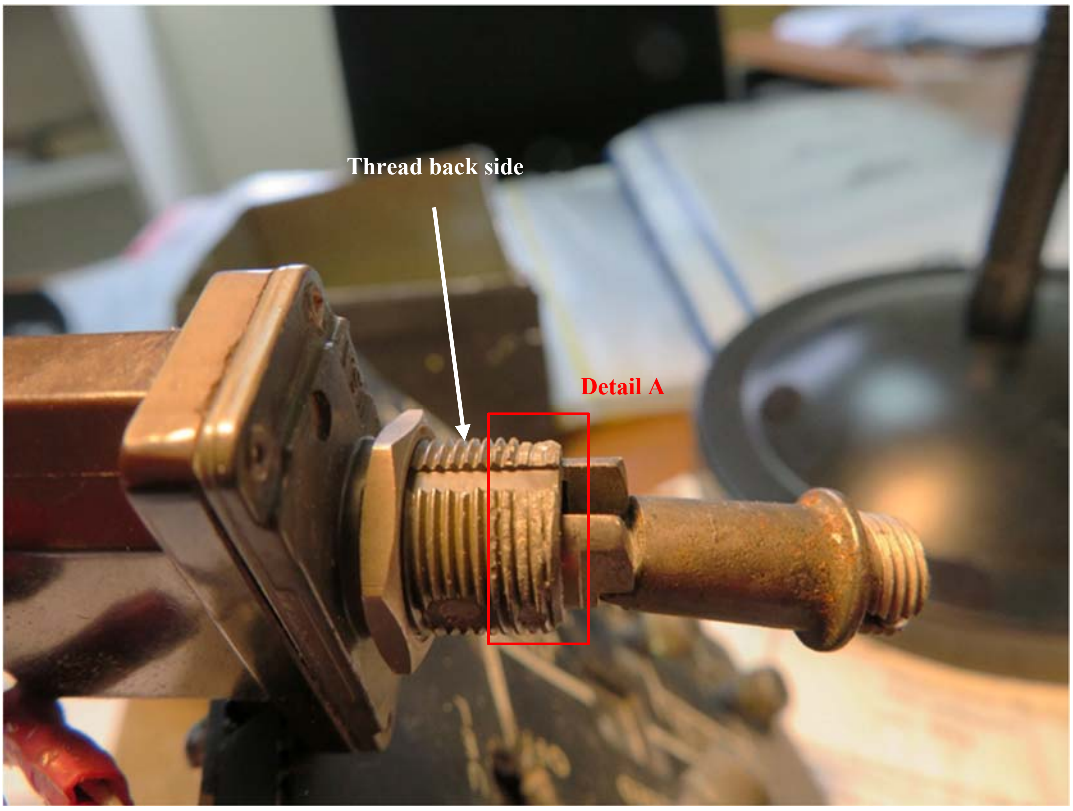


Photo 37: The thread on the rear section of the right engine fuel shut off valve switch.

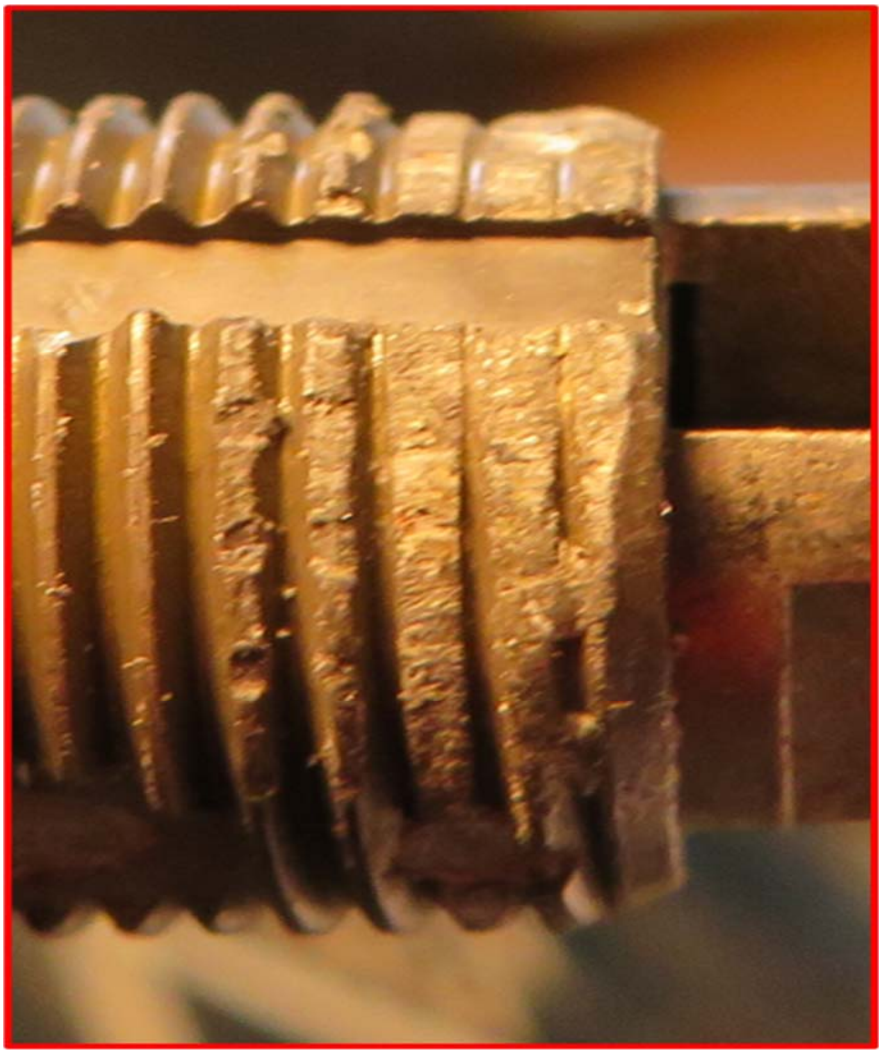


Photo 38: Detail A showing the wear of the rear side of the thread.

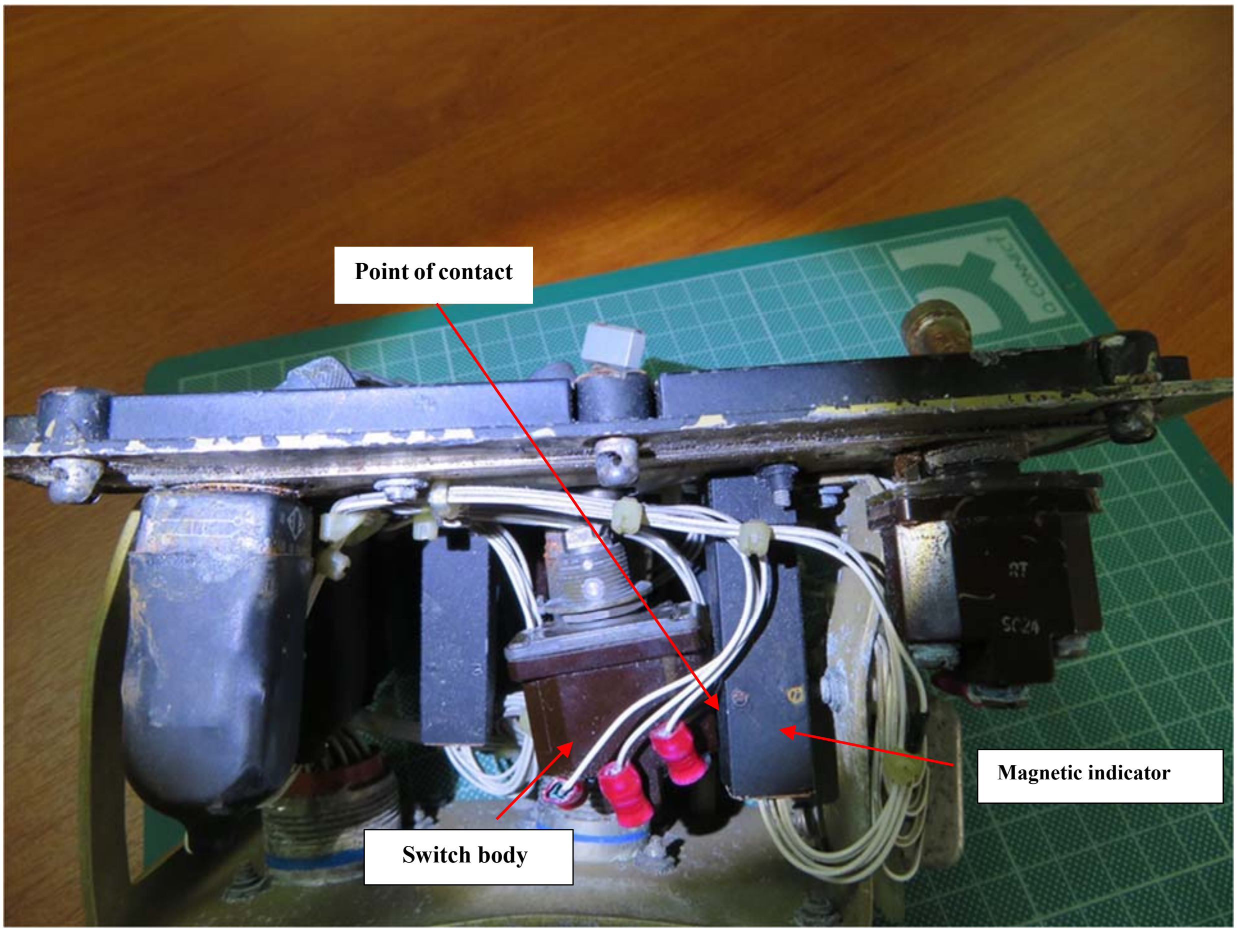


Photo 39: The body of the right fuel shut off valve control switch and its contact with the body of the valve's position magnetic indicator.

Photo 40: Collective control lever perforation.

5.7 Numbering of engines in Power levers

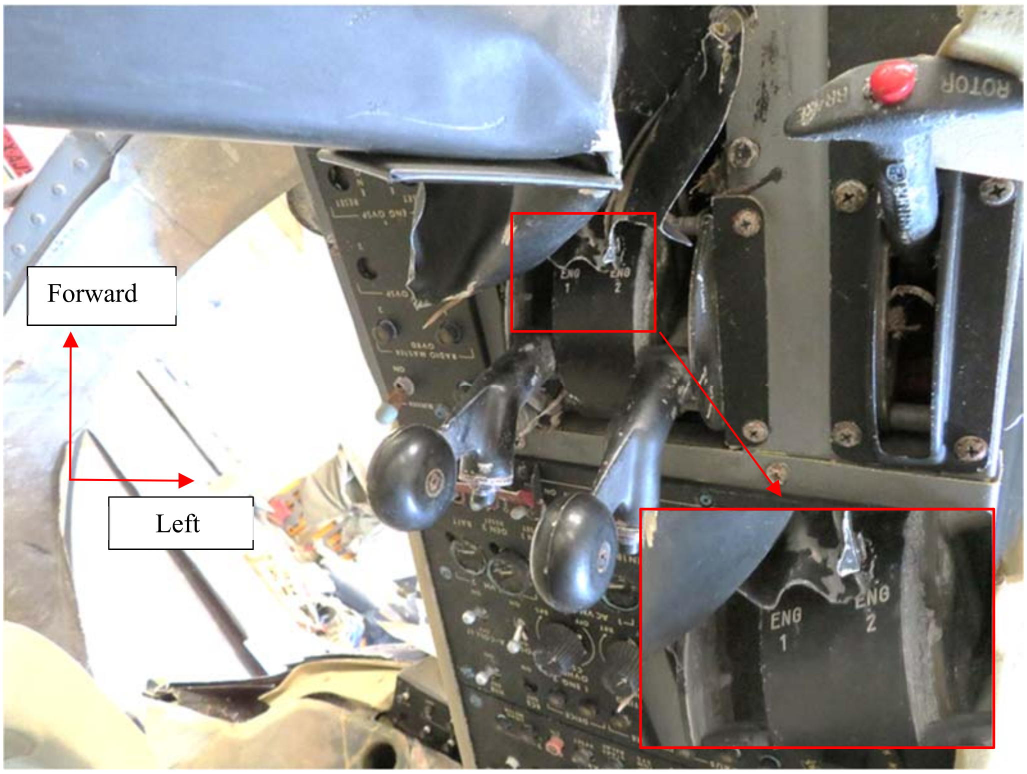
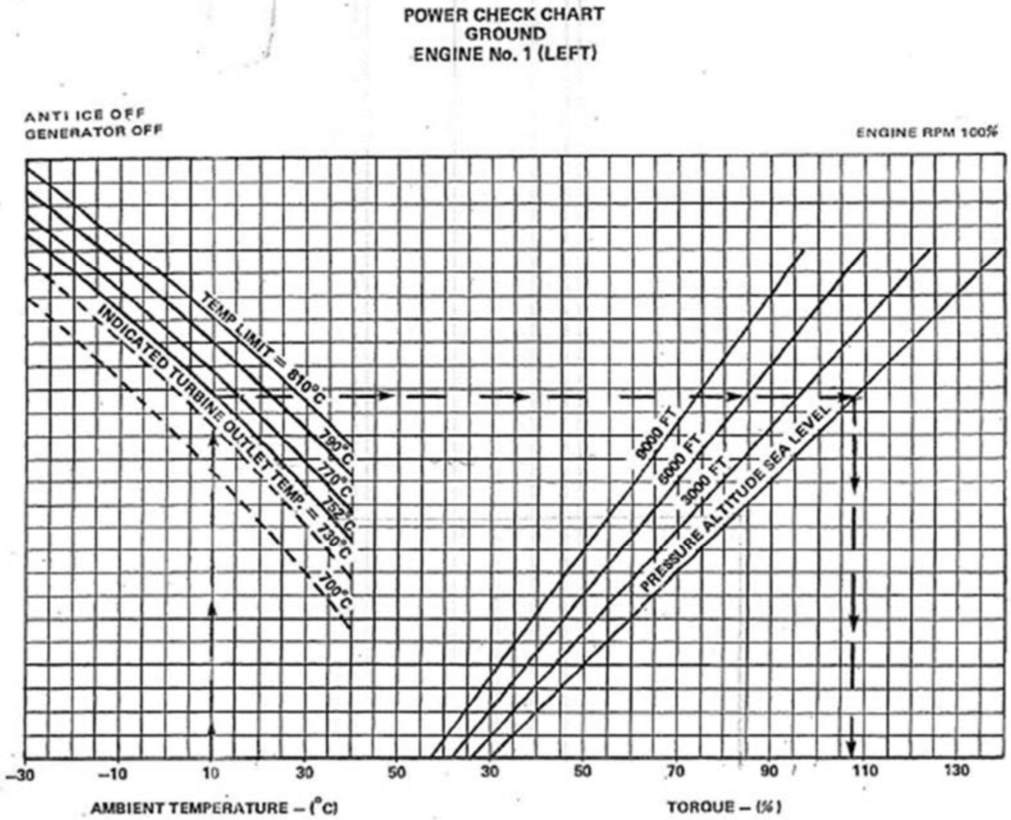
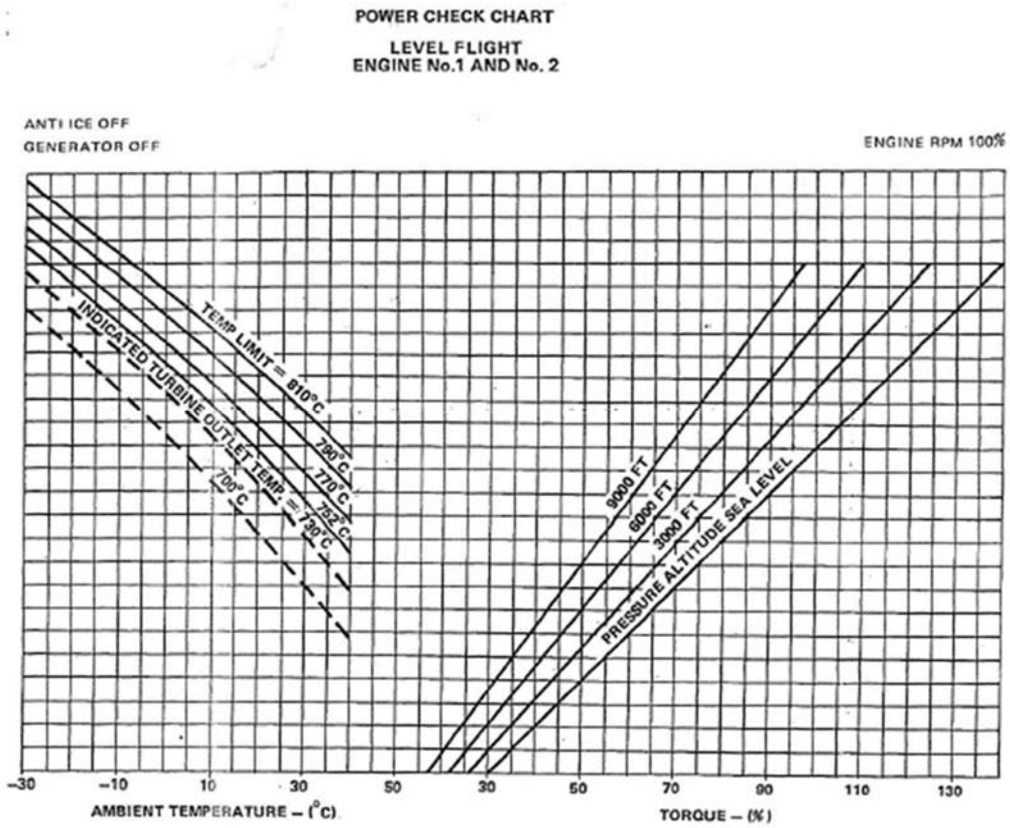


Photo 41: The numbering of the engines in the Power levers.

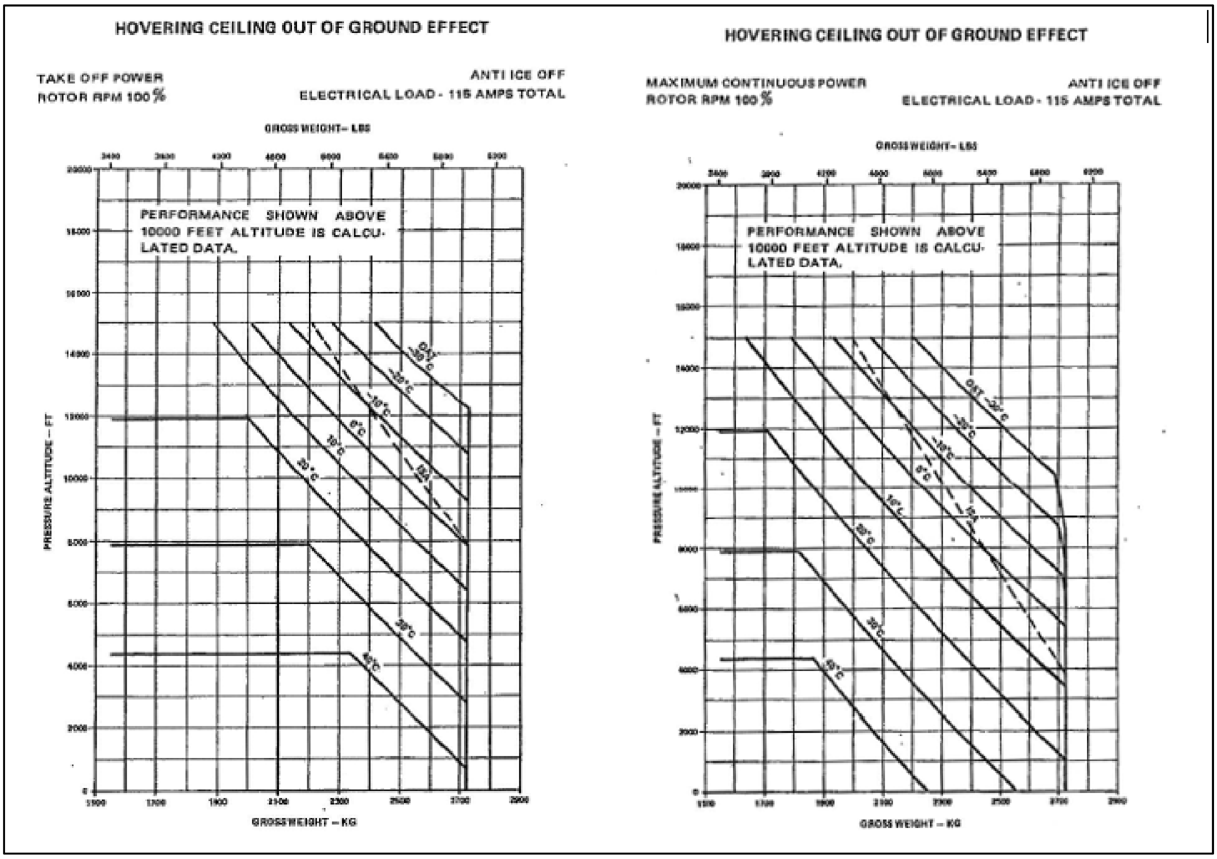
Photo 42: The numbering of the engines in the instrument panel.

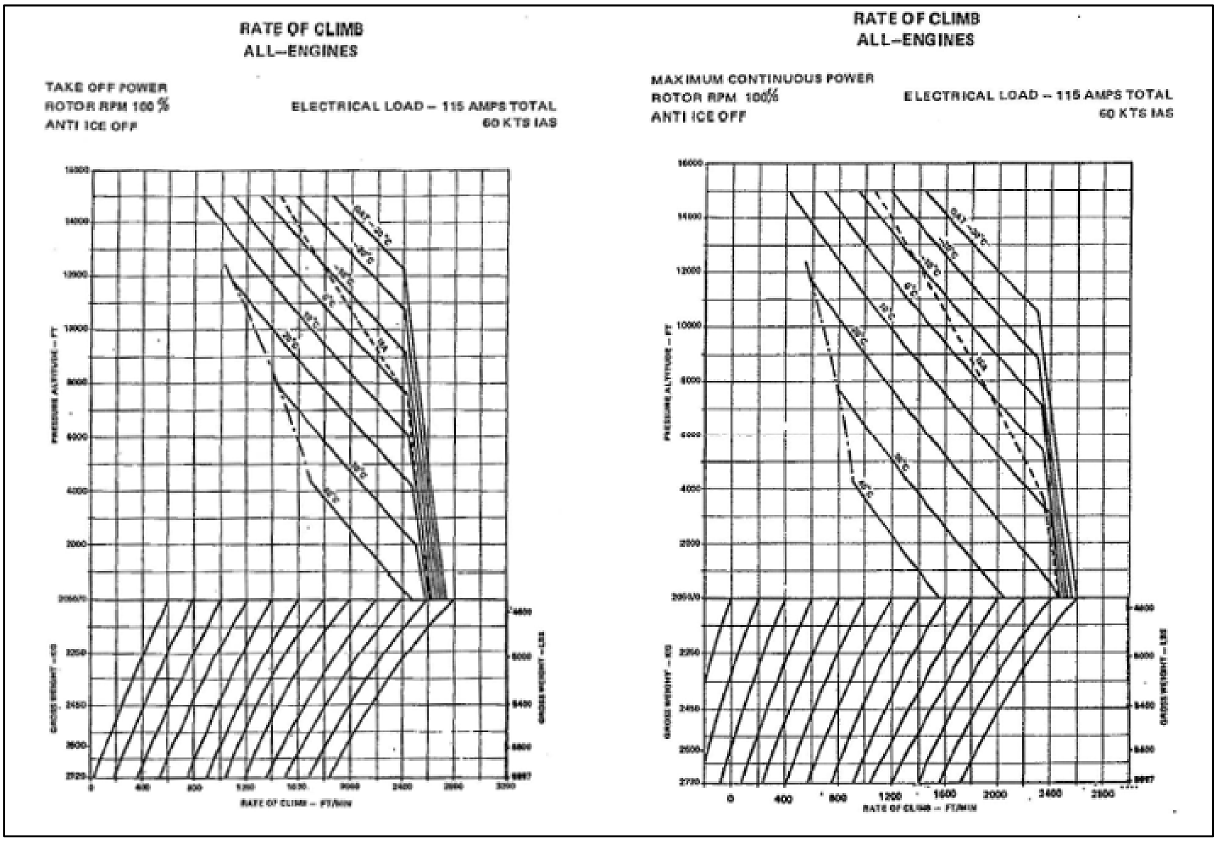
5.8 Engine Power control diagrams





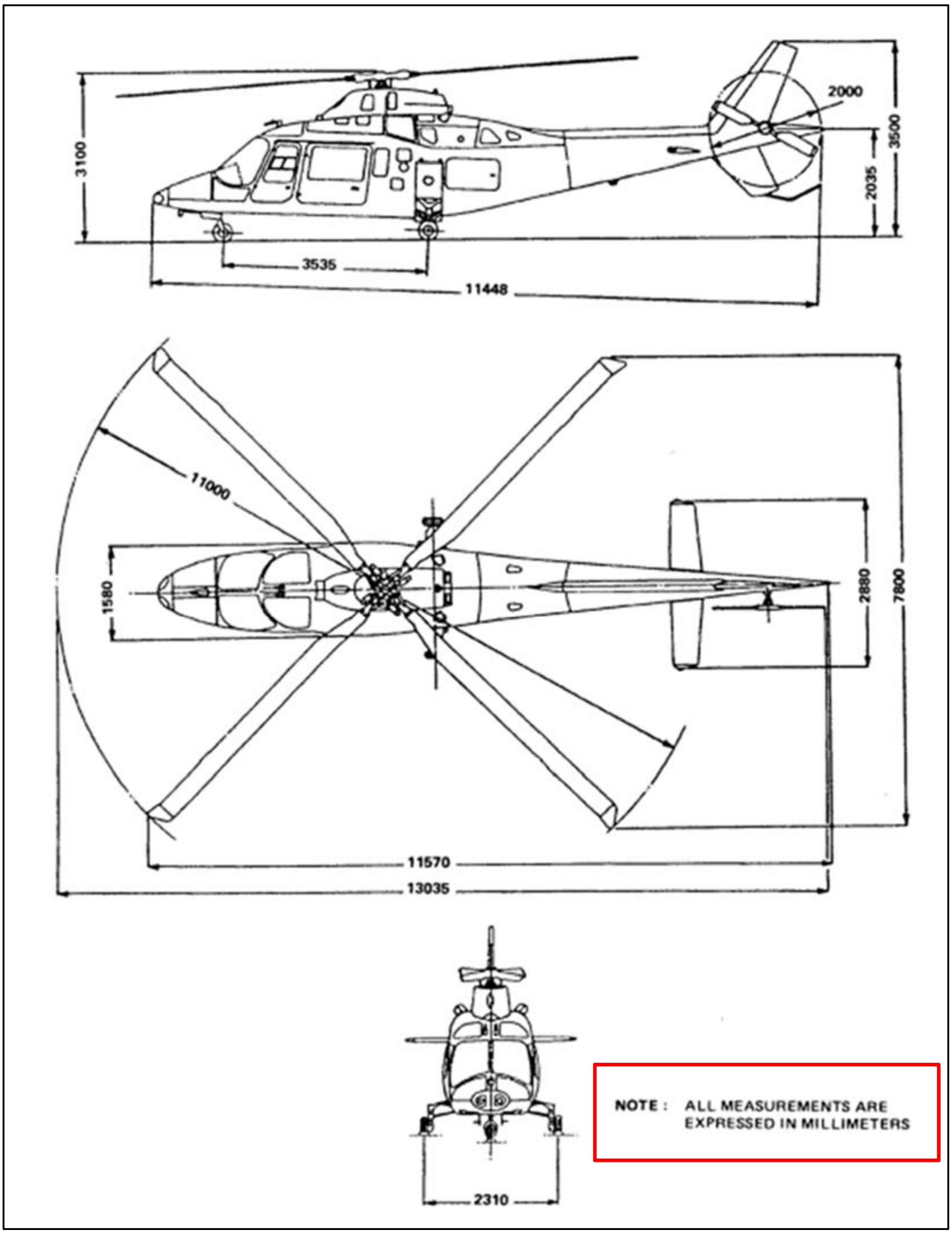
5.9 Weight Hovering and rate of climb diagram



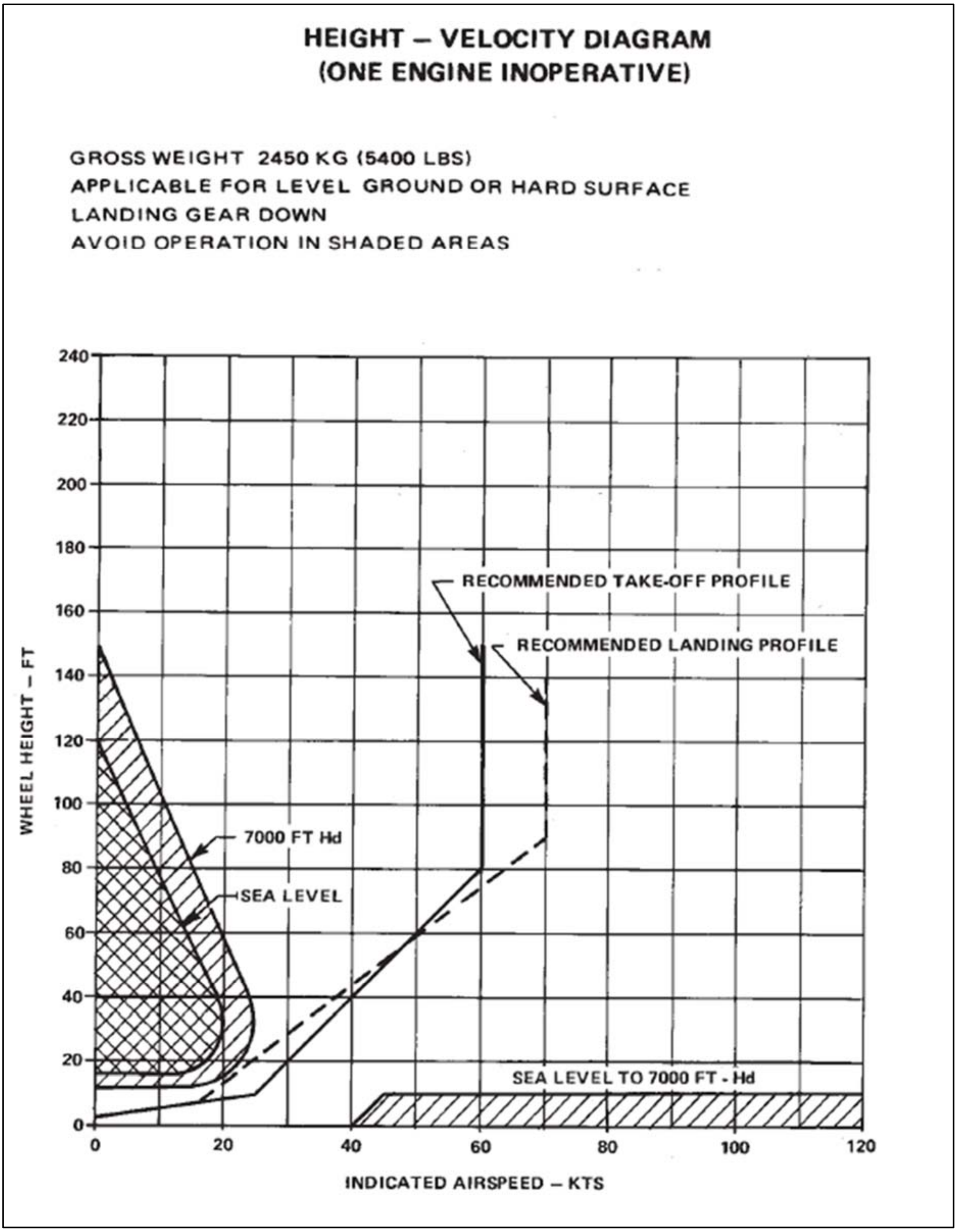


5.10 Helicopter Basic Dimensions

The Helicopter basic dimensions as mentioned in the Maintenance Manual, chapter 06-10.



5.11 Helicopter Height – Velocity Diagram



5.12 Push – Pull Rods

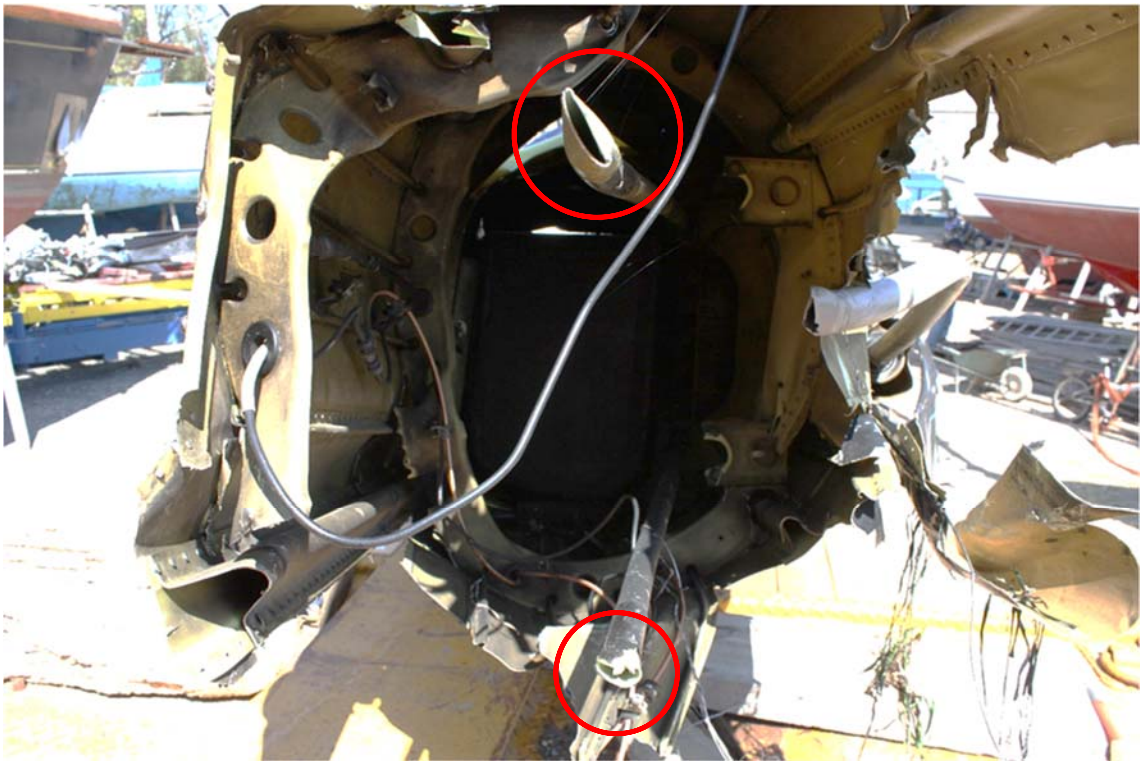


Photo 43: The fractured points of the two Push-Pull Rods

5.13 Translational Lift

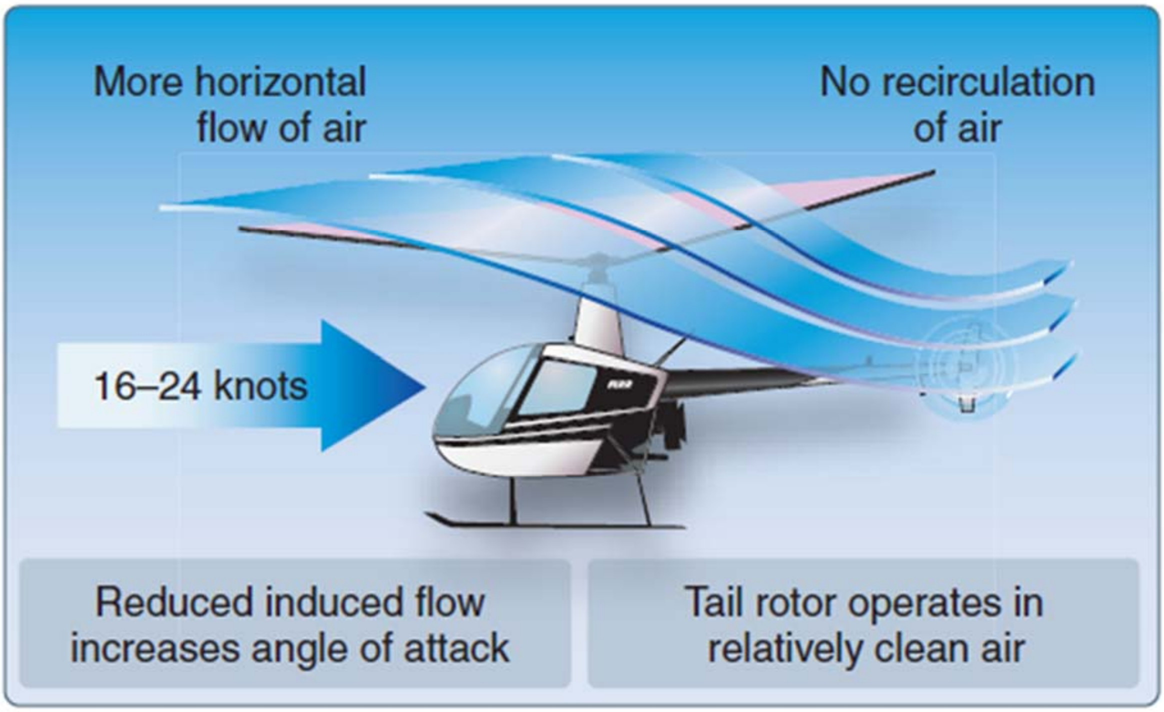
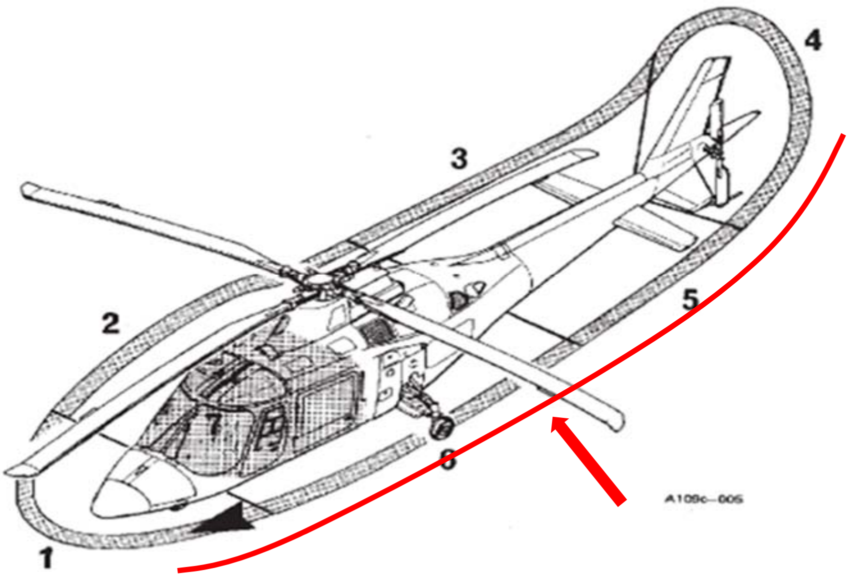


Fig. 9: Air flow around the rotor during translational Lift with speed between 16-24 kts.

5.14 Position of a yacht at the time of the Helicopter take-off

5.15 Pre-Departure Inspection course



5.16 Engine bleed air Cabin heating system

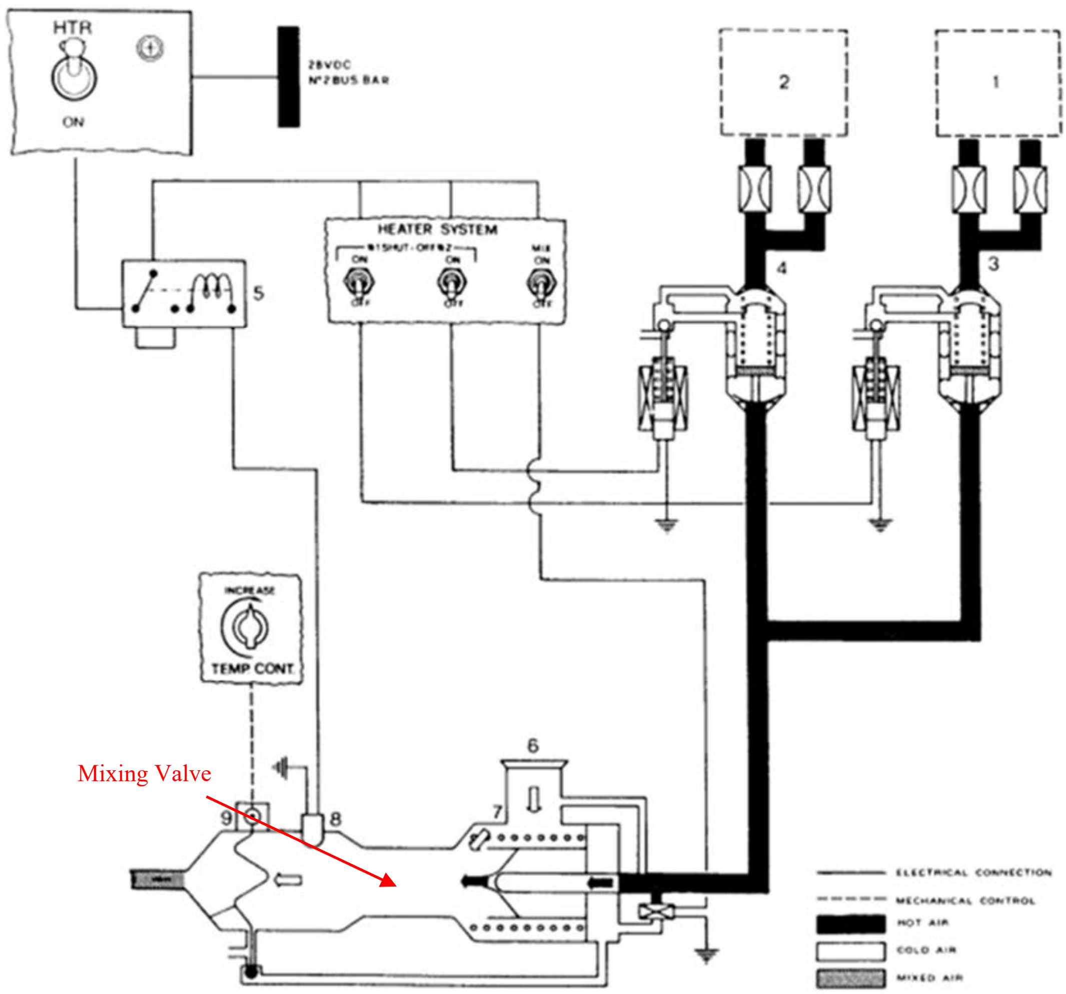


Fig. 10: Schematic of the cabin heating system by means of engine bleed air.

5.17 Rotating Scissor and attachment to the hub

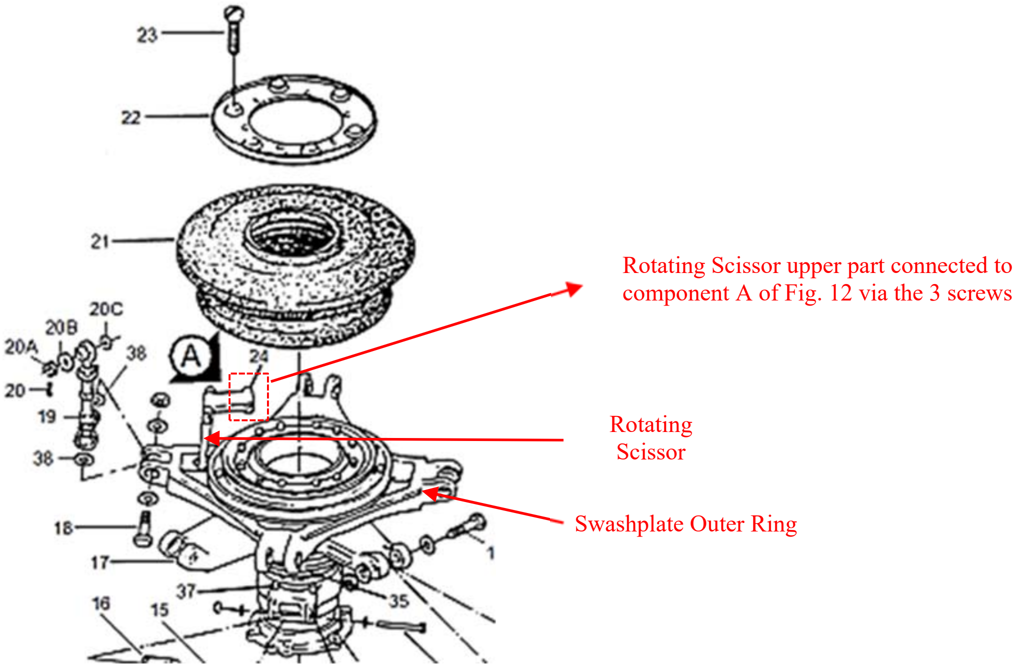


Fig.11: Rotating Scissor

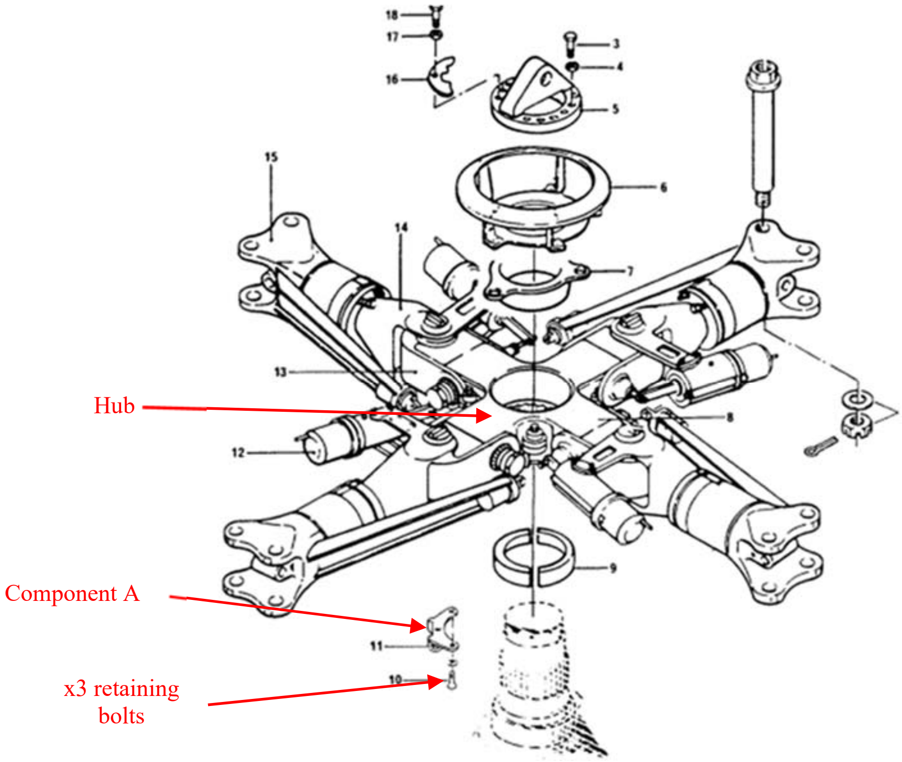


Fig. 12: The component A that connects the top of the Rotating Scissor to the Hub via the three screws.

5.18 Results of Helicopter performance evaluation by the Manufacturer

Table 1

Maximum Hovering weight out of ground effect with take-off Power.	2720 kg
Maximum Hovering weight out of ground effect with Max Continuous Power	2500 kg

Table 2

Both engines rate of climb with Max Continuous Power	1306 fpm
Both engines rate of climb with Take-off Power	1773 fpm

Table 2 Rate of Climb values of are modified in relation to the corresponding ones resulting from the diagrams of App. 5.9, due to the differentiation of the validation data of the diagrams of App.5.9. Table 2 values consider the presence of tail wind at the time of the take-off, of maximum estimated speed 10 kt and the fact that the indicated speed of the in the period of 3 s was evaluated to be 50 kt, 10 kt less than the speed value of the Rate of Climb diagrams of App.5.9 validation

Also, the above values are based on the worst-case scenario where the available engine Power is equal to the minimum determined by the Flight Manual

Table 3

Rate of Climb (fpm)	Height Increase (m) in the last 3 s
885	13.5
1306	19.9
1773	27.0

Note:

- *According to the estimated values of the average wind direction (270^0) and the Helicopter course (113^0), a relative angle of 157^0 is created between them. In the context of the performance evaluation, the assumption of the worst-case scenario was considered, with a relative angle of 180^0 (full tail wind).*
- *The Helicopter speed was calculated from the difference between the ground speed and the wind speed.*

5.19 Results of Helicopter performance evaluation by the investigation team.

In the context of the investigation, a Helicopter performance evaluation was made, based on the tables presented in App. 5.9.

The evaluation was based on the following data:

- OAT: 31^0 C.
- Pressure altitude: -79 ft.
- Engine Anti-ice: OFF.
- Climb time 9 s and horizontal flight time 3 s.
- Helicopter altitude after 9 s climb: 134.5 ft (41m).

According to the above data and in combination with the diagrams of App.5.9, an evaluation of the maximum hovering weights was performed, in out of Ground Effect conditions.

Also evaluated the Helicopter average rate of climb during the 9 s climb, the height that the Helicopter would have climbed if in the last 3 s its climb had been discontinued and its ground speed before the impact with the first Power Cable based on the distance travelled in the last three seconds of the flight.

According to the above, the following emerged:

- Evaluated ground speed: 60 kts
- Average rate of climb 885 fpm, acquired in the 9 s climb to 41 m.

Table 4

Engine's Power	Maximum hovering weight (kg)
Take off Power	2720
Max Continuous Power	2520

Table 5

Climb Rate	Increase in main rotor height in the last 3 s	Net passage height above Power Cables
885 fpm, 4.5 m/s	44 ft, 13.5 m	34 ft, 10.4 m

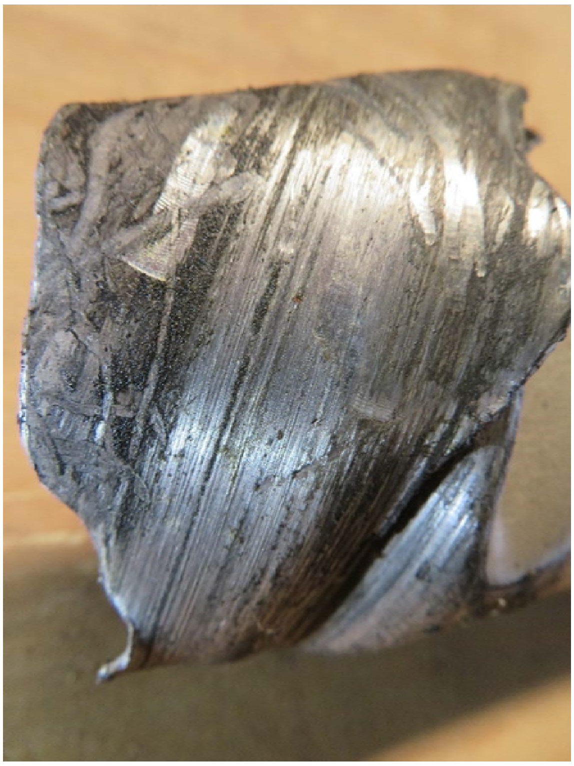
Note: The net height over the Power Cables results from the difference of the height increase (second column of table 5) and the distance of 3.1 m (10.17 ft) between Main Rotor Hub and the Helicopter wheels (App. 5.9, Fig.13).

5.20 Tail rotor shaft

Photo 44: The twist of the rotation axis of the tail rotor (red arrow).

Photo 45: The breaking point of the tail rotor shaft.

Φωτ. 1: The tail shaft's forward section fracture point



Φωτ. 2: Abrasions on the tail rotor shaft surface at the point of fracture.

5.21 Detailed recording of the cockpit switches position

- The landing gear lever was in the down position.
- The four fuel pumps switches were in the "open" position, while the No. 4 fuel pump switch was distorted to the left (Photo 48).
- The left engine's fuel shut off valve switch was in the 'open' position as well as its position indicator. (Photo 48 B).
- The cross-feed valve switch was in the off "closed" position as well as its position indicator (Photo 48 C).
- The actuation switch of the hydraulic systems 1 and 2 was in ¨Both On¨ position, Photo 48 D and was distorted to the left.
- The switches of the two shut-off valves for the flow of air from the Engine Shutoff valve to the cabin heating system were in the 'open' position, while the mixing valve switch was in the 'closed¨' position.
- In the autopilot panel, switches SAS 1, SAS 2 were in the 'closed' position while the ATTD HOLD switch was in the 'open' position.
- The positions of switches GEN 1 BUS, GEN 2 BUS were in the "closed" position while the switches GEN 1, GEN 2, BAT and INV 1, INV 2, INV 3 were in the "open" position.
- The Power lever of the right engine was in the ¨Idle¨ position while that of the left engine was slightly behind the middle position between ¨Idle¨ and ¨Flight¨.
- The position of the engine anti-icing switches was in the "closed" position.
- The pitot static probes heating switches were in the ¨closed position.
- The numbering of the engines in the Power levers was reversed and opposite to the numbering of the engines in the instrument panel (Par.5.7, Photos 41, 42).

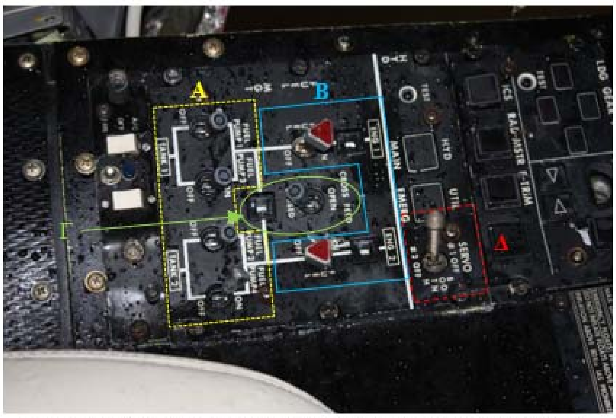


Photo 48: Cockpit view showing the positions of the fuel system switches and the hydraulic systems.

Photo 49: The cabin heating system switches.

5.22 Detailed description of fuselage findings

- On the outside of the cockpit, forward of the two Pitot probes, there are obvious traces of contact with the Power Cables (App. 5.3, Photo 22).
- The Emergency Locator Transmitter (ELT) switch was in the ¨MAN RESET¨ position.
- The landing gears were extended.
- In the area of the main gearbox (Photo 7), the following were found:
  - Fracture of the hydraulic systems lines and loss of No. 2 hydraulic system tank.
  - Fracture of the oil supply lines from the oil tanks to the engines and loss of the two engine oil tanks.
  - Fracture of the four connecting rods of the gearbox with the Helicopter fuselage. All four connecting rods have static fracture characteristics due to the abrupt detachment of the gearbox.
  - Fracture of the two gearbox antitorque plates with static fracture characteristics. The right plate was detached, removing part of the fuselage structure.
  - Fracture of the cabin air conditioning ducts.
  - In the Bell crank of the right engine Power lever linkage, a Push - Pull rod fracture was observed, which is located between the Bell crank lever and the engine with static fracture characteristics.
  - The connection linkage from the left engine Power lever to the engine's fuel control unit was continuous.
- The oil coolers outer cover located aft of the engines had characteristic traces from the contact with the Power Cables, App. 5.3, Photo. 23, 24, 25.
- The engine compartment did not show any signs of fire.
- The red circular discs indicating the expansion of the fire extinguishers were intact. The pressure gauges on the fire extinguishers were 400 psi on the left and 700 psi on the right.
- The tail rotor shaft together with the roller bearings had free rotation.
- The two Push - Pull Rods, for the tail rotor pitch change and the two tail balancing surfaces movement, showed characteristics of static fracture (App.5.12, Photo 43).
- The fuel tank was broken and part of it was outside the fuselage.
- The seat belt of the right passenger had obvious traces of tensile load due to the impact of the Helicopter.

5.23 Detailed description of findings on the main rotor

- All four blades of the main rotor were deflected vertically upwards.
- In the main rotor blue blade there was a fracture at a length of 1.00 m from its root. The blade end is missing in a length of 0.75 m.
- In the yellow blade there was a fracture at a distance of 1.10 m from its root. After the above fractured point, there was a detached part at a length of 3.55 m. The metal tip of the blade is missing.
- In the red blade there was a fracture at a distance of 1.10 m from its root.
- In the non-Rotating Scissor, the connecting rod was deformed and statically fractured. Also, the upper and lower rod ends were unbroken and secured.
- In the red blade Flap Restrainer, the Outer Cam was broken while one of the two springs was missing.