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COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
E INCIDENTES DE
AVIACIÓN CIVIL

Report A-022/2018

Accident involving an Air Tractor AT-802 aircraft, registration EC-GVN, operted by Martínez Ridao Aviación S.L, in the Mediterranean Sea near the municipality of Pollença (Mallorca-Spain) on 12 June 2018

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Notice

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.5 of Regulation (UE) n° 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1, 4 and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

Contents

Abbreviations

°	Sexagesimal degrees
ºC	Degrees centigrade
AEMET	Spain's National Weather Agency
AESA	Spain's National Aviation Safety Agency
AT	Air Tractor
CPL(A)	Commercial pilot license (airplane)
DGAC	Spain's Civil Aviation General Directorate
E	East
FCU	Fuel control unit
FDV	Flow divider valve
FF	Firefighting
ft	Feet
ft/min	Feet per minute
GPS	Global positioning system
IBANAT	Institut Balear de la Natura
ICAO	International Civil Aviation Organization
IR(A)	Instrument rating (airplane)
kg	Kilograms
km	Kilometers
km/h	Kilometers per hour
kt	Knots
LESB	ICAO designator for the aerodrome of Mallorca/Son Bonet
m	Meters
MEP (land)	Multi-engine piston (land) rating
MHz	Megahertz
min	Minutes
N	North
P3	Air pressure at the gas generator outlet
PPL(A)	Private pilot license (Airplane)
SAR	Search and rescue
SEP (land)	Single-engine piston (land) rating
TCDS	Type certificate data sheet
UTC	Coordinated universal time
VFR	Visual flight rules
W	West

Synopsis

Owner:	Martínez Ridao Aviación, S.L.
Operator:	Martínez Ridao Aviación, S.L.
Aircraft:	Air Tractor AT-802
Persons on board:	1, pilot, fatal injuries
Type of flight:	Aerial work – Commercial – Aerial observation
Phase of flight:	En route – Cruise
Type of operation:	VFR
Date and time of accident:	12 June 2018, 18:04[1]
Site of accident:	2000 m off the coast of Cala Solleric, municipality of Pollença - Mallorca
Date of approval:	June 3, 2020

Summary of event

Aircraft EC-GVN was based at the aerodrome of Son Bonet (Mallorca) and was part of the aerial assets used to fire fighting. On 12 June 2018, it was doing an aerial observation flight planned by forests specialist of the regional government of the Balearic Islands; specifically, the route was along the Tramuntana Mountains, on the north of the island of Mallorca.

It took off at 17:20 from the aerodrome of Son Bonet, and approximately 44 minutes into the flight, the aircraft crashed into the sea. The impact killed the pilot and destroyed the aircraft. The wreckage was found three days later at a depth of 60 m

There were no messages during the flight involving any type of emergency in the aircraft or due to smoke or fire. The evidence also shows no signs of technical, meteorological or any other type of problem that might have occurred before or during the flight.

A GPS device was recovered from the aircraft wreckage that was used to determine the flight path until just before the impact with the water. Based on the records that were available, this report focused on analyzing the 23.5-km long flight segment from Cape Formentor until the impact, which stands out as it differs considerably from that of previous flights in the area.

[1] All times in this report are local (UTC+2)

Specifically, the investigators studied the actions of the aircraft during the maneuver prior to the accident, the findings of which are contained herein.

In the absence of specific information on the final seconds of the flight, the investigation has considered a scenario that is consistent with the evidence found in the retrieved wreckage and the environment in which the aircraft was flying.

The report indicates that the accident is consistent with a controlled flight into water preceded by a sudden descent, the cause of which could not be determined.

1. FACTUAL INFORMATION

1.1. History of the flight

On Tuesday, 12 June 2018 at 18:04, an Air Tractor AT-802, registration EC-GVN, operated by Martínez Ridao Aviación, S.L., crashed into the sea northwest of the municipality of Pollença (Mallorca) as it was engaged in an observation and surveillance firefighting (FF) flight for the Nature Institute of the Balearic Islands (IBANAT). The aircraft had been airborne for 44 minutes after taking off from the aerodrome of San Bonet, located on the island of Mallorca. The flight was being conducted under visual flight rules (VFR). The pilot, the aircraft's sole occupant, was killed in the event.

Aircraft EC-GVN was based at the aerodrome of Son Bonet (Mallorca) and was part of the aerial resources used to fight forest fires. On the day of the event, it was scheduled to do an aerial observation flight, as per the plan drawn up by the forests specialist at the Departement of the Environment, Agriculture and Fishing of the regional government of the Balearic Islands; specifically, along Route 3[2], which runs along the Tramuntana Mountains in the north of the island of Mallorca.

On 2 June 2018, ten days earlier, the pilot had begun the flight period associated with the 2018 summer season at the firefighting base of Son Bonet. This was his fifth summer season based on the island of Mallorca.

The pilot's activity in the days before the 12th had been limited. On the day of the event, he went on duty at 10:00, beginning with the pre-flight check of the aircraft. The rest of the day was uneventful.

At the scheduled time on the 12th, after the final pre-flight checks, the aircraft took off at 17:20 toward the west of the island. The weather conditions were not limiting, with barely any clouds and no convective activity.

Over the course of the flight, the only communication made by the pilot on the aviation frequency was in response to a call from the air resources communication aircraft to do a radio check and ask about the aircraft's position. That aircraft was also flying an observation mission, with that day's duty forest specialist on board. This communication was normal, and took place as EC-GVN was flying over the town of Valldemossa. The reply from the pilot of EC-GVN did not indicate anything out of the ordinary.

[2] Term used to designate different observation and surveillance areas on the island of Mallorca.

By 19:37, over an hour after the airplane's scheduled landing time[3], and with no messages from the pilot, the forest specialist on duty activated the regional government's emergency protocol.

The initial search focused on the last position given for the aircraft by the fleet management system's data recorder, since no signal was received from the emergency beacon on board the aircraft on either frequency, 121.5 or 406.0 MHz.

Two Spanish Navy ships joined the search efforts, and on 15 June, they located the aircraft wreckage on the ocean floor, at a depth of about 60 m and 2140 m away from the closest point to the shoreline.

The flight lasted 40 minutes and covered 150 km. Figure 1 shows the aircraft's flight path.

Figure 1: Aircraft's complete flight path

The pilot's body and the aircraft wreckage were recovered on the 17th.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Other
Fatal	1		1	
Serious				
Minor				
None				
Total	1		1	

[3] Flights along the accident route last about 55 minutes if no diversions in response to other circumstances are required.

1.3. Damage to aircraft

The aircraft was destroyed when it impacted the water.

1.4. Other damage

None.

1.5. Personnel information

Aircraft pilot

The pilot, a 46-year-old Spanish national, had two pilot licenses: a private pilot license (PPL(A)) issued on 23 February 1996, and a commercial pilot license (CPL(A)), issued on 30 September 1999, both by Spain's National Aviation Safety Agency (AESA).

He also had the following ratings:

- AT-4/5/6/8 SET, valid until 30 June 2018
- MEP (land), valid until 30 September 2018
- SEP (land), valid until 30 September 2019
- IR(A), valid until 30 September 2018

The pilot had a class-1 medical certificate that was valid until 17 May 2019.

He had a total of 2132 flight hours, of which 261 had been on the type. He had flown 13 hours in the last 90 days, 8 hours in the last 30 days, and none in the last 24 hours. He had flown 4:35 (hh:mm) since he began his shift on 2 June, and since that day, he had flown the same route as on the day of the accident on four occasions, the last on 9 June.

The operator's refresher training test and proficiency test were administered on 20 March 2018.

The pilot flew primarily in the Balearic Islands. During the last five summer seasons, he had worked in the Mallorca firefighting service for the same operator.

1.6. Aircraft information

The Air Tractor AT-802 aircraft, registration EC-GVN and serial number 802-0065, was entered in AESA's aircraft registry on 4 September 1998. It was a turboprop aircraft with a single Pratt & Whitney PT6A-67AG engine, serial number PCE-RD0010, and a fixed landing gear with a tail skid.

It had a restricted certificate of airworthiness issued by Spain's Civil Aviation General Directorate (DGAC). Its most recent airworthiness review was valid until 22 April 2019.

At the time of the accident, the aircraft airframe had a total of 2516:35 flight hours. On 25 January 2018, in keeping with the approved maintenance program (AMR-PM-AT-802, Ed. 2, Rev. 7, dated 7 December 2017), the last three maintenance tasks had been performed, namely the 50, 100, 200, 300 hour and 6, 12 and 24 month checks, with 2501:25 flight hours on the aircraft.

As for the engine, at the time of the accident it had a total of 2429:45 flight hours. The last maintenance tasks had been performed on 25 January 2018, with 2415:35 hours, and involved the 100, 200, 300, 400 hour and 12-month inspections.

The daily logbook did not have any entries on component failures. The flight logs also indicate that the usual pilot for the last three months had been the accident pilot.

1.7. Meteorological information

The closest weather stations to the accident site were as follows: Pollença (some 7 km south), Lluc (15 km south-southwest) and Escorca[4] in the Son Torrella Mountains (about 24 km southwest). The data recorded at the stations on Tuesday, 12 June 2018 at 18:02 local time were as follows:

Weather station	Temperature (°C)	Relative humidity (%)	Average wind (Km/h)	Maximum wind (Km/h or kt)
Pollença	27	41	8 southwest	16 (8.63) northwest
Lluc	21	39	5 west	18 (9.71) southeast
Escorca	19	54	-	-

Even though the closest station was in Pollença, it is subject to the influence of breezes from the Bay of Pollença/Alcudia, hence the difference in wind direction. According to AEMET data, there were hardly any clouds and the wind was generally light.

[4] Temperature/rain station does not provide wind data.

Moreover, according to the statement provided by a professional pilot who flew over the area of the Tramuntana Mountains minutes before the event, visibility was good since there were no clouds, and the sea was rough, with waves.

1.8. Aids to navigation

Not applicable.

1.9. Communications

The only message exchanged on an aviation frequency was with the fire coordination airplane, as described in point 1.1.

1.10. Aerodrome information

The aircraft was based at the aerodrome of San Bonet (Mallorca), ICAO code LESB, which is used as a base for the aerial observation, surveillance and firefighting assets of the Nature Institute of the Balearic Islands (IBANAT) on the island of Mallorca. It is an uncontrolled aerodrome.

1.11. Flight recorders

The aircraft did not have a flight data recorder and/or a cockpit voice recorder, as they were not required for the operation. The applicable aviation regulation did not require the airplane to have any kind of recorder.

1.12. Wreckage and impact information

As shown in Figure 1, the aircraft made a 180° turn over Cape Formentor and doubled back over the same north side of the Tramuntana Mountains. Upon reaching the municipality of Pollença, it turned right, going out to sea and eventually crashing into the water.

Figures 2, 3 and 4 show the condition of the aircraft when it was found on the seabed.

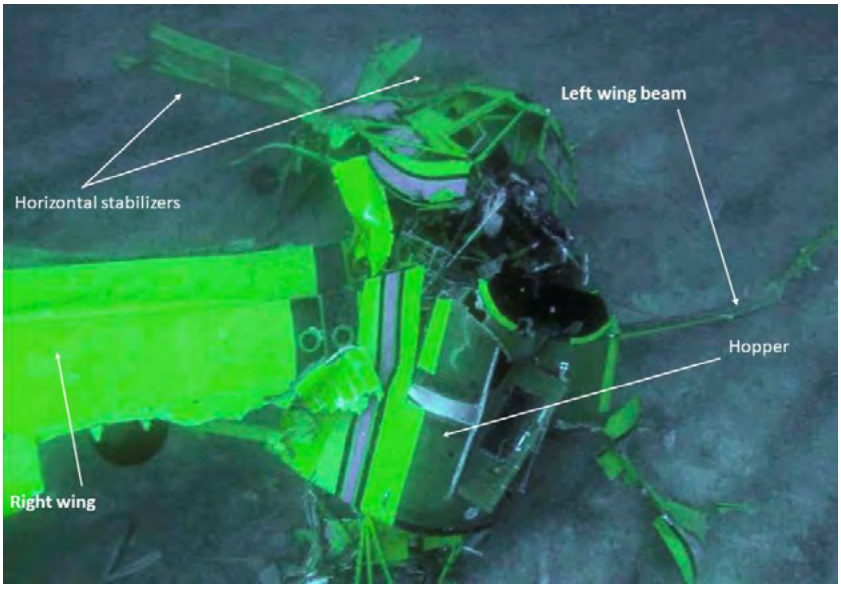

Figure 2: Front view of the aircraft

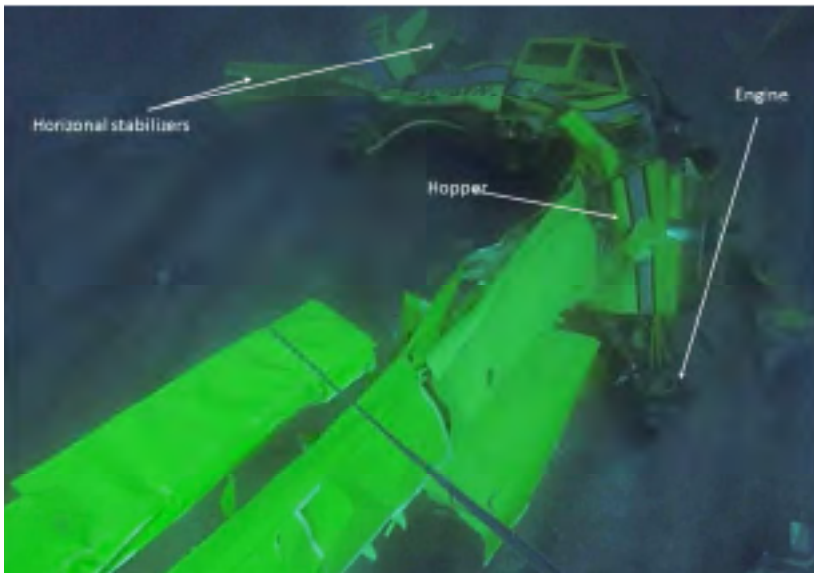

Figure 3: View of aircraft from front right quarter

The aircraft was heavily deformed, and as the above figures show, its tubular structure broke, dividing the aircraft into two sections, see Figure 3. The front section included the hopper, wing and engine. The rear section consisted of the cockpit and the rest of the airframe up to the tail.

The left wing only contained the main spar, and the right wing had lost various parts (flaps, leading edge, etc.). The pedals were visible in the cockpit, which was sheared at the control panel. The left side of the cockpit was crushed. The underside of the tailcone showed a significant impact. The horizontal stabilizers were bent upward, the bracing had detached and the right elevator had detached from its actuating shaft.

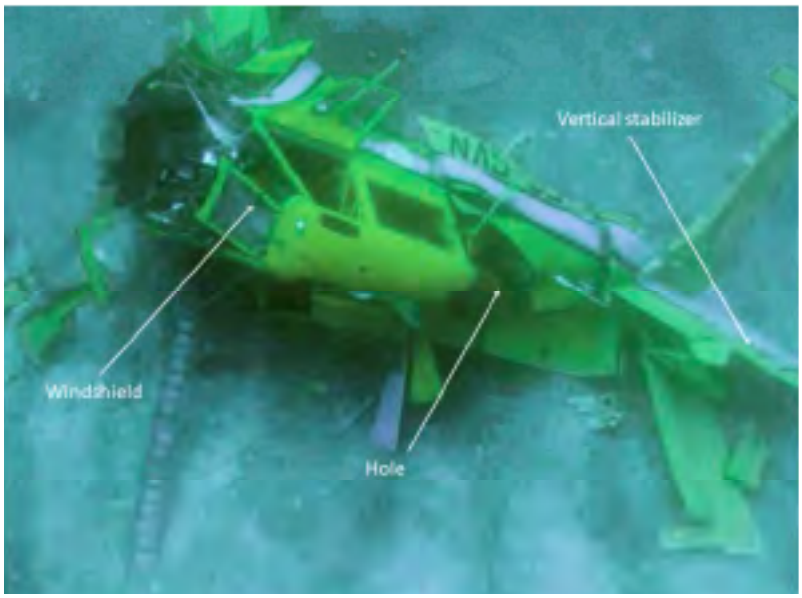

Figure 4: Overhead view of the aircraft

Located around the main wreckage were the propeller, with two of the five blades whole and attached to the pitch mechanism, part of the flap surfaces and the elevator, as well as various fragments of the wing and fuselage skin.

The wreckage was lifted from the seabed on 17 June. Fractures surfaces had undergone moderate corrosion, although the paint protected the remaining surfaces from rusting. Figure 5 shows the damage to the front of the aircraft, where the engine is located. There was an impact mark on the bottom left that directly affected the exhaust gas nozzle on that side, the engine mount and the partition that separates the engine from the hopper. The propeller detached, along with the second stage of the gearbox. At least two of the five propeller blades were distinguishable and had not detached.

Figure 5: Overview of the engine and propeller gearbox

The lower part of the cockpit had lost its integrity. The left side was open, and a strong impact toward the rear had removed the grip from the control stick. Only the tubular structure in the upper half maintained its integrity.

1.13. Medical and pathological information

The immediate cause of the pilot's death was determined to be the injuries that affected the nerve center that regulates vital functions.

The toxicological tests that were performed did not reveal any substances that may have limited the pilot's ability to fly.

1.14. Fire

None.

1.15. Survival aspects

1.15.1. Timeline of the search and rescue

12 June:

When the landing code set up at the operations detachment at the aerodrome of Son Bonet was not received, the specialist forest on duty activated the emergency protocol at 19:37, a little over an hour after the scheduled duration of the flight.

By 19:52, two aircraft, helicopter H-5, operated by the Spanish Air Force's Search and Rescue (SAR) service, and the surveillance airplane of the Mallorca firefighting service, had taken off in the direction of Tramuntana foothills. By 20:00, helicopter H-1, from the firefighting service, had joined them.

They did not see any signs of fire, nor did they receive warnings of fires that had broken out, during the time spent searching that day.

By 20:06, the last position recorded by the fleet tracking GPS device on board the airplane was available (39.931894°N 02.983056°E), placing it close to Pollença. These aerial assets remained in the air until sunset.

15 June:

SAR continued the search that had begun on the first day, while two Spanish Navy ships departed their base to join the efforts. The Tajo, a minesweeper, explored the area using its side-scan sonar, and around 15:00, the aircraft wreckage was located on the seabed, at coordinates 39.931894°N 2.983056°E. The pilot and aircraft were positively identified using an ROV.

16 June:

At 22:00, the Spanish Navy rescue ship Neptuno reached the area where the wreckage had been located to take charge of the rescue and plan the next day's operations.

17 June:

At 06:00, the rescue operation started, following a new inspection of the wreckage by an ROV. Navy divers then retrieved the pilot, which required diving to a depth of 60 meters. The pilot's body was retrieved at around 09:20.

The work continued until about 21:20, when the wreckage was recovered.

At 22:56, the rescue ship headed for port.

1.15.2. Survival

Inside the cockpit, the tubular structure that attaches the seat to the frame was in its position, but some joints had yielded (green circles in Figure 6). The seat had sunk to the left and the seatback was leaning forward. The retention system had kept the pilot in his seat, and the harness was fastened when the pilot's body was retrieved.

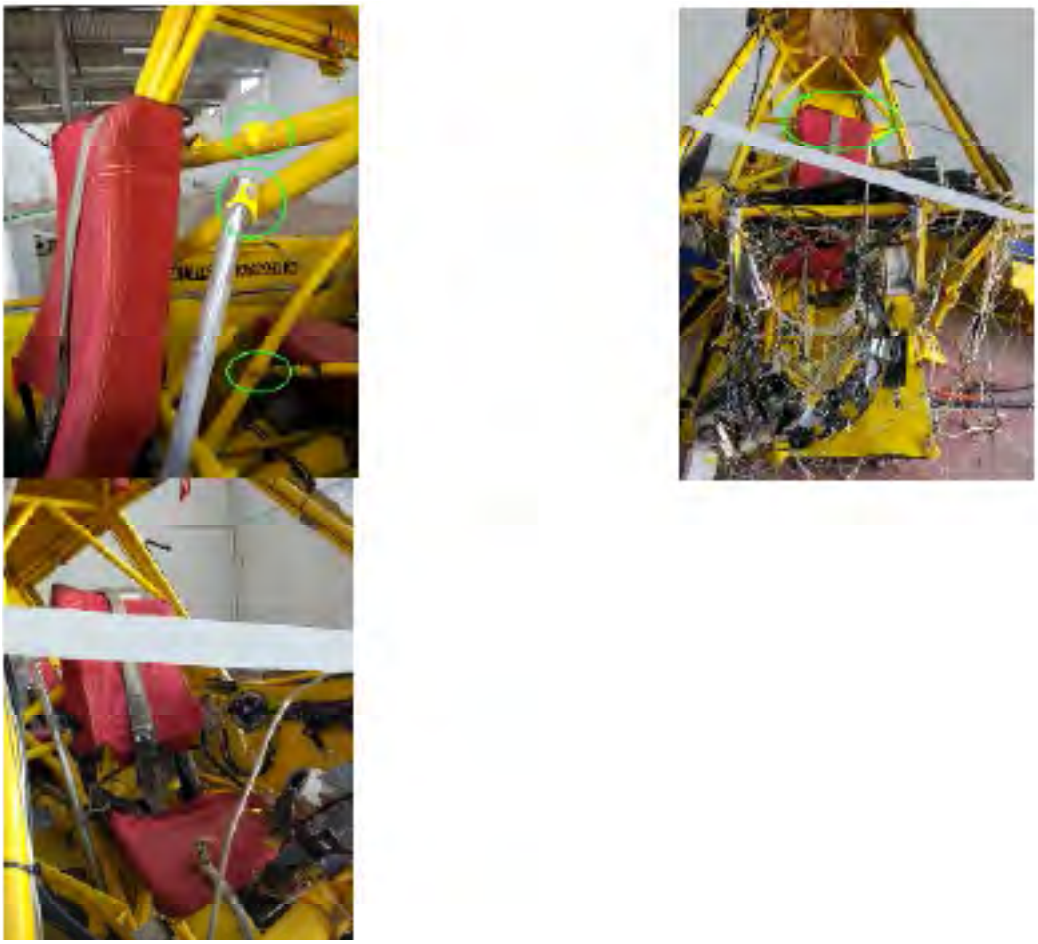

Figure 6: Cockpit of the aircraft

Figure 6 shows various views of the cockpit, seat and safety harness.

1.16. Tests and research

1.16.1. Information from the GPS

In addition to the fleet management system, there was a GPS unit inside the aircraft that was retrieved from the seabed. The Civil Guard laboratory was able to obtain from it the route of the accident flight. The length of the route recorded was longer than that in the fleet management system, although it was missing the final few meters with respect to the point where the wreckage was found.

The initial and final coordinates of the route were as follows:

	DATE	TIME	LATITUDE	LONGITUDE
Route start	12/06/2018	15:20:31	39.603429073467851	2.707971800118685
Route end	12/06/2018	16:04:04	39.925748286768794	2.98257602378726

The total distance recorded, shown in Figure 1, is 150 km long.

1.16.2. Description of the initial section

Figure 7 shows the initial section of the flight path, from the aerodrome of Son Bonet to Cape Formentor, a total distance of 136.5 km.

Figure 7 : Aircraft flight path to Cape Formentor

In this section, the data indicate that the aircraft first flew to the western tip of the island, where the town of Andratx is located, before proceeding along the north side of the Tramuntana Mountains.

From Andratx, the route continued to the town of Valldemosa, climbing through narrow valleys, but avoiding the highest elevations, which in this municipality reach 1067 m. It continued climbing to the municipality of Sóller, where the elevation reached just over 1000 m.

Once past Soller, the aircraft made a 270° left turn in order to gain elevation, which took it to an altitude of 1141 m (3743 ft), in order to fly over the foothills at 1067 m that surround the reservoir of Cuber, making this the highest elevation of any point in the flight.

After Cuber, the aircraft began to descend. It was at an altitude of 990 m as it flew past the peak of Puig Major, to its left, at an elevation of 1436 m. The aircraft continued descending, following the path of the Ma-10 road to the town of Pollença before eventually reaching Cape Formentor, where it made a 180º turn to continue with the return leg.

The route taken along the segment described did not cross over the coastline. The altitude profile reflected the elevation of the mountains and ensured sufficient separation.

1.16.3. Description of the second section

The final section was 23.5 km long, and corresponded to the part of the flight from Cape Formentor to the last recorded point.

Figure 8 shows how, after making the turn, the aircraft doubled back over the same route it had taken as far as Pollença.

Figure 8 : Aircraft's flight path from Cape Formentor

After that point, during the final 3 minutes of the flight, the orography became more abrupt, and the data show a constantly increasing altitude in an effort to clear the hills that were in its way.

Then, see Figure 9, the data show how in the vicinity of point B, the aircraft began a turn to the right of practically 90°, out toward the sea, flying over point C some 282 ft above the ground.

Between points C and D, the aircraft traveled 2330 m in 39 seconds on a heading of 307°, climbing a total of 82 m (269 ft), from 530 m to 612 m (2007 ft). After point D, the aircraft continued for a further 12 seconds, during which it descended while turning right, to an elevation of 231 m (757 ft), at which point the GPS recording ended.

The table below shows the values of the ground elevation and the aircraft's altitude.

SECTION	Ground elevation m (ft)	Flight level m (ft)
A	394 (1292)	480 (1574)
B	439 (1440)	499 (1637)
C	444 (1456)	530 (1738)
D	0	612 (2007)

The graph below shows the final 3 minutes of the flight.

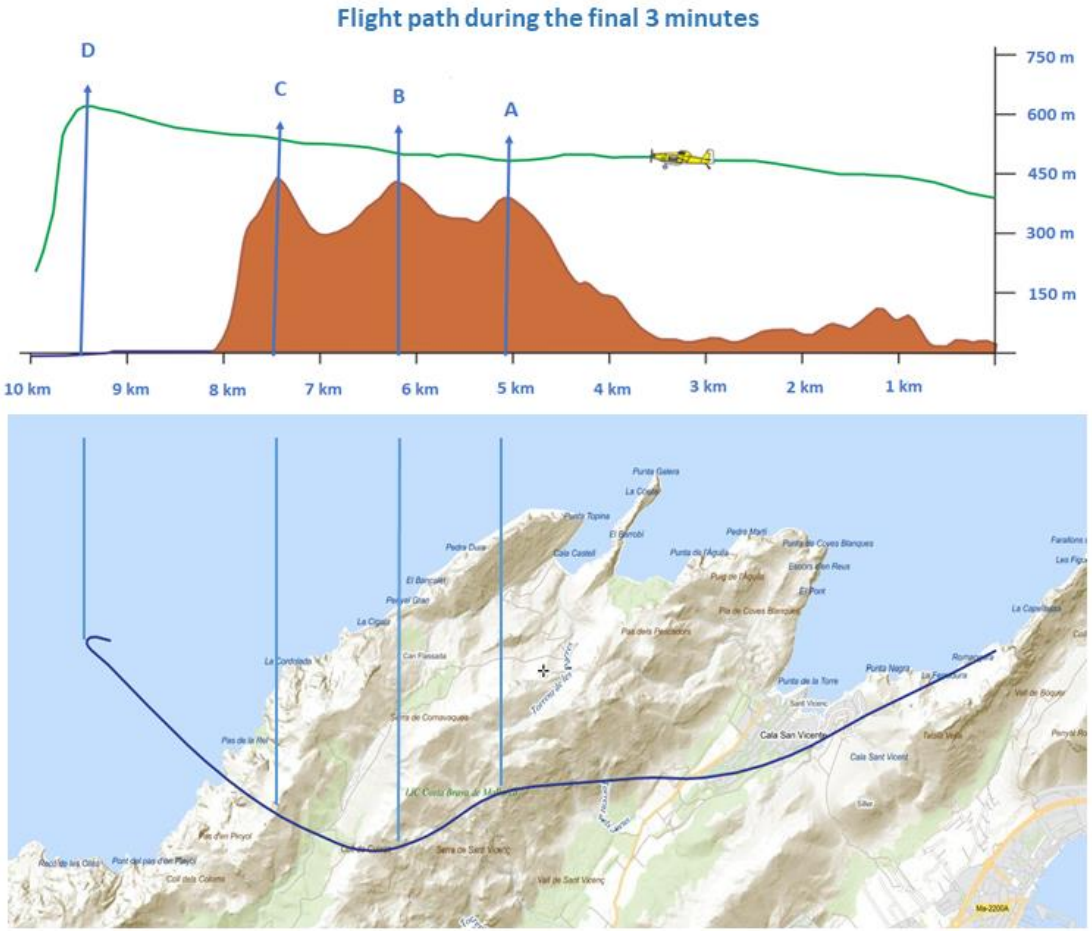

Figure 9 : Profile and plan views of the aircraft's flight path during the final 3 minutes

Figure 10 shows the data recorded from point C. Those following the aircraft's descent are highlighted in blue.

Aircraft altitude (m)	Distance traveled over the ground (m)	Altitude change (m)
Readings per second		
528.3	51	2.4
530.7	51	2.4
533.6	51	2.9
535.1	51	1.5
537.0	51	1.9
537.9	51	0.9
538.9	52	1.0
539.9	52	1.0
540.3	53	0.4
540.8	53	0.5
541.3	54	0.5
542.3	54	1.0
544.2	55	1.9
546.1	55	1.9
548.0	55	1.9
550.0	55	2.0
551.4	55	1.4
552.8	55	1.4
554.3	55	1.5
556.2	55	1.9
558.1	55	1.9
560.1	54	2.0
562.5	54	2.4
564.9	54	2.4
567.7	54	2.8
571.1	54	3.4

Aircraft altitude (m)	Distance traveled over the ground (m)	Altitude change (m)
575.0	53	3.9
578.3	53	3.3
582.2	53	3.9
585.0	52	2.8
588.9	52	3.9
591.8	52	2.9
595.1	52	3.3
598.0	51	2.9
600.9	51	2.9
603.8	51	2.9
606.2	50	2.4
609.1	50	2.9
611.5	50	2.4
612.9	50	1.4
610.5	50	-2.4
600.9	50	-9.6
584.1	51	-16.8
564.4	51	-19.7
539.9	40	-24.5
501.4	26	-38.5
429.3	33	-72.1
363.1	37	-66.2
296.9	55	-66.2
263.9	50	-33.1
230.8	50	-33.1
226.0	30	-4.8

Figure 10: Values recorded during the final minutes of the flight

The coordinates of the final position recorded by the GPS are 39.925451°N 2.9814474°E, and the wreckage was found at coordinates 39.931894°N 2.983056°E. These points are separated by 730 m. To follow this path, the aircraft had to turn left, toward the north, further out to sea.

1.16.4. Information on previous flights

In order to determine the usual practice when flying over the northwestern part of the island of Mallorca, investigators reviewed the flights made on Route 3 between June 2017 and the date of the event. The results show that over four and a half months of operations, 39 flights were conducted, 25 of them by the accident pilot.

The flights typically followed the pattern of traveling over the north side of the Tramuntana Mountains, starting at the western end and ending at Cape Formentor, and then flying back over the south side of the mountains to the firefighting base at the Son Bonet aerodrome.

Figure 11 shows the typical routes taken, with the one to the left being the most common one. These routes do not contain any segments over open water. Once Cape Formentor is reached, the return route is initiated by making a wide turn over the bays of Pollença and Alcudia and then heading southwest and flying over the town of Sa Pobla. The figure on the right shows an alternative route where the return involves making a tight turn and doubling back in the opposite direction as far as Pollença, leaving this town to the right (to the north) and then flying the route shown in the left figure, which travels close to the town of Sa Pobla.

Figure 11: Typical paths flown on Route 3

1.16.5. Wildlife in the Tramuntana Mountains

The black vulture (*Aegypius monachus*) is part of the wildlife that lives in the area of the accident that, due to its size and weight, could compromise the in flight safety of an Air Tractor AT-802.

The IBANAT Bird Control Service informed investigators that in the month of June on the north of the island, sightings of black vultures in the area overflown by the aircraft indicate a population of 20 to 30 specimens out of the total of around 200 specimens on the entire island. The weight of an adult bird is around 7-8 kg, and they fly at an altitude of some 100 m above the ground. They do not fly over the water. The nesting chicks had not yet started to fly. Figure 12 shows their distribution in the Tramuntana Mountains.

Figure 12: Range of the black vulture population in the north of Mallorca

Vultures fly in order to locate food, which is why they fly over land, and not normally over water.

1.16.6. Analysis of the engine

The aircraft's PT6A-67AG engine, serial number RD0010, was manufactured by Pratt & Whitney Canada. The entire engine-propeller assembly could not be recovered from the wreckage, since the propeller, the pitch control and the second stage of the gearbox detached from the main wreckage. The manufacturer took part in the investigation and inspected the engine components that were recovered.

External inspection

The external inspection of the engine showed that the first stage of the propeller gearbox and the accessory group exhibited the effects of salt water corrosion.

The fracture in the gearbox revealed that the bottom of the exhaust duct was bent inward all the way to the gas generator and inside the engine. The cover that spans the combustion section did not exhibit any significant damage.

The accessory gearbox had been generally corroded by the salt water. The connections powered by the engine and the fuel control unit were severed. The fuel control unit and the pump were in their positions, but the unit was cracked and the connections to the fuel control and flight control levers were severed.

The P3 pneumatic pressure lines (air discharge from the gas generator) were not damaged. Inside these lines there was magnesium residue, varying levels of chlorine, sodium and calcium. In the accessory gearbox, the oil filter and chip detector, although corroded, did not have any metal fragments.

The power turbine control (Py) line was secured and attached to the fuel control unit.

Internal inspection

At the compressor section in de gas generator case, a blade on the first stage integrally blades rotor was bent in the opposite direction of the rotor's rotation. Only particles with gray hues were found between the centrifugal compressor and the turbine section.

In the power stage, at the first-stage stator (compressor turbine), the gray particles were also found. Downstream, the tips of the compressor turbine blades had brushed against the top of the casing. This disk also exhibited a circumferential mark due to friction along the roots of the blades, which matched a similar mark found on the stator disk in the next stage (power turbine).

One after the other, the tips of the blades in the power turbine in the first stage had rubbed against the casing.

The bodies of the blades in the two turbine stages mentioned, and in the second stage of the power turbine, did not show signs of damage.

The ignition spark plugs did not show physical damage. The engine accessories did not show signs of a previous impact, although there was widespread corrosion.

Laboratory inspection

An analysis of the particles found inside the engine and other components revealed that they were made of magnesium and resulted from salt-water corrosion. Similarly, the remaining components inspected exhibited damage from being immersed in salt water.

The flow divider valve (FDV) was found with the transfer mechanism in the open position (fuel flow to the manifolds).

The fuel pump filter was in good condition, with clumps of fuel and salt, but nothing to prevent filtration. Inside the fuel pump, the pump gears and bearings did not show signs of having run without fuel.

In the body of the fuel control unit (FCU), the brake cables were still attached, the drive shaft was bent and turned freely. Internally, it exhibited salt-water corrosion. The housing of the P3 filter (air pressure at the outlet of the gas generator) only contained organic deposits, both internally and externally.

This implies that there was fuel pressure in the fuel manifold at the time of impact. The axial polish was present on the sealing surfaces on the primary and secondary valve.

The extent of the damage in the accessories prevented any determination as to possible malfunctions prior to the impact.

However, there was no evidence that the fuel pump components were starved of fuel. The bellows on the fuel control unit had no leaks and the flow divider and purge valve was found open to the manifolds (in the flow condition).

Conclusions drawn from the engine inspection

Areas were found with circumferential wear due to friction between both the compressor and power turbine rotors and the casing and their associated stators, which indicates that the engine was rotating at the time of impact.

The mostly grayish dust found along the inside of the engine was determined to be a corrosion product of magnesium, which is a component of various elements, and salt water. The water current is thought to have transported the corrosion products throughout the engine, even through the diffuser region and P3 conduit to the filter.

The damage to the engine accessories made it impossible to determine if anything malfunctioned prior to the impact; however, there is no evidence that any components in the fuel pump were starved of fuel, and the bellows in the fuel control unit was intact and showed no signs of leakage. The flow divider was open to the manifolds, meaning fuel was flowing.

There were no indications that any of the components examined had been damaged externally prior to the impact.

The absence of significant damage at the gas generator intake and the gas exhaust suggest that the engine was not operating at high power. The bent blade at the compressor inlet also indicates that the engine was turning when it went into the water. In short, it was concluded that the engine was running, albeit at low power, when the aircraft impacted the water.

1.16.7. Information on the beacon installed in the aircraft

The aircraft was equipped with an ACK E-04 ELT. According to the type certification data sheet (TCDS #EASA.IM.A.274), this beacon was optional. The signal from it was not received by the COSPAS-SARSAT Mission Control Center in Maspalomas, but it is not capable of transmitting underwater.

1.16.8. Information on the interviews conducted

Information was gathered from those individuals who had been in contact with the pilot in the last 24 hours. According to statements from his coworkers at the firefighting base, the pilot's behavior was normal. He and his roommates had dined together the night before and had planned to go out again the next day.

1.17. Organizational and management information

Not applicable.

1.18. Additional information

Not applicable.

1.19. Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

2.1. General

The aircraft operation entailed conducting a surveillance flight, scheduled by the forests specialist in the island of Mallorca and planned for the northern part of the island. The route normally used started at the base at the aerodrome of Son Bonet and traveled along the north side of the Tramuntana Mountains from west to east, and then returned along the south side back to the base.

The pilot had joined the firefighting campaign on the island of Mallorca on 2 June, as he had in the previous four years. On that very day, he flew 4 hours and 35 minutes. The day before the accident, he did not have to fly and at the end of the day he got together with other coworkers from the base, with whom he had planned to get together again the next evening.

He went on duty that day at about 10:00, with the daily inspection of the aircraft. He did not have any activities planned and he was not called out for forests specialist on duties that day.

As a result, the pilot is deemed to have had sufficient experience for the flight, knowledge about the operator's procedures, about the firefighting base and the operating environments. Even his coworkers were the same from previous years. He had also flown previously on the same aircraft along the same route in previous seasons, and even in the days before the accident. As a result of all this, the pilot is deemed to have been qualified to carry out the operation that ended in the accident.

The medical and pathological information analyzed during the investigation did not indicate any incapacitation before or during the flight.

As concerns the aircraft, the scheduled maintenance had been performed and the flight logs from the day before the accident did not indicate any problems with the aircraft. As usual, the pilot and the maintenance technician had inspected the airplane before being placed in service. No discrepancies were entered in the daily flight logs, and the aircraft remained on the stand, ready to be flown. The activity at the base, with no fires requiring the pilot's intervention, allowed for the monitoring flights to be flown as planned.

The weather conditions were such that the aircraft could operate without any limitations, even though the mountainous terrain of the area being monitored was prone to mountain turbulence. The flights of other aircraft in the area both before and after the event did not point to any problems in this regard.

2.2. Analysis of the aircraft wreckage

In light of location of the damage sustained by the aircraft and the degree to which the various components were affected after impacting the surface of the water, it was determined that the aircraft was likely making a left turn while descending at the time of impact.

Specifically, the left turn maneuver is suggested by the detached left wing spar, with no components attached to it (Figures 2 and 3), the twisted left wingtip as a result of the resistance encountered upon contacting the water, and the collapsed left side of the cockpit (Figure 6).

The pitch-down attitude of the aircraft is indicated by the fact that the propeller, three of its blades, the pitch control and the second stage of the gearbox all detached from the aircraft.

Other damage found, such as the detachment of the front of the airframe, behind the hopper, is explained by the distribution of loads along the hopper itself. The damage in the tail section, with the horizontal stabilizer bent upward and the right elevator dislodging from its shaft, is all the result of the impact with the water.

In general, the most significant damage was to the left side of the aircraft, as were the injuries sustained by the pilot.

2.3. Operating conditions of the engine-propeller assembly

Because it was immersed in salt water, it was impossible to make an accurate evaluation of the operation of the engine-propeller assembly. The inspection conducted, however, did provide a basis, based on the condition of the internal engine components, of its approximate power output at the moment of impact.

Section 1.16.6 describes the details of the engine inspection and the conclusions drawn. These include that the engine-propeller assembly did not exhibit any signs of external damage prior to the impact, and that the engine was running at low power when it impacted the water.

2.4. Analysis of the aircraft's flight path and maneuvers based on the GPS data

Sections 1.16.1, 1.16.2 and 1.16.3 present the evidence that the GPS data provided to the investigation into the event. The coordinates recorded allowed investigators to reconstruct the aircraft's flight with suitable accuracy in terms of its position over the ground, although less so in terms of the altitude. However, in light of the frequency at which the parameters were recorded (once per second) and of the absence of spurious readings, these data are deemed to be valid, and provided a basis for analyzing the aircraft's operations.

This analysis will focus on the section of the flight between Cape Formentor and the end of the recording some 7 minutes later. The section of the flight before the Cape contains no relevant information.

In order to analyze the final section, a correlation was established between the route taken by the accident aircraft and the routes taken in flights made during the firefighting campaigns in the previous two years. The number of observations made can be used to establish the routine way to operate in this segment by all the pilots on the base, including the accident pilot.

Figure 13 shows the two alternatives used to start the route along the south face of the Tramuntana Mountains, one in red and the other in blue. The bottom route, in blue, travels over the bays of Pollença and Alcudia en route to the south foothills of the Tramuntana range.

The alternative at the top, in red, employs a southwesterly course from Cape Formentor to the vicinity of Pollença. From there, it intercepts the blue route to the southwest. In the accident flight, the data show that the pilot, after reaching this locality, diverted from the usual route and proceeded to the northwest to fly over the foothills that are located to the north of Pollença, in the direction of the coast.

Figure 13: Description of the return routes

This last part of the flight, as shown in Figure 9, lasted about 3 minutes. The aircraft climbed gradually and constantly, to an altitude of 530 m above ground level before going over the coastline. It then continued its gradual climb over the sea on a heading of 307°, at which point the aircraft began to descend while turning to its right.
The known GPS data were used to make the table below, where each row corresponds to the readings provided each second by the GPS unit:

Point	Altitude (m)	Change in altitude per segment (m)	Net loss of altitude (m)	Horizontal distance traveled per segment (m)	Total horizontal distance traveled (m)	Heading at end of segment	
A	612.9	0.0	0	0	0	307	
B	610.5	-2.4	-2.4	50	50	307	
C	600.9	-9.6	-12.0	50	100	306	
D	584.1	-16.8	-28.8	51	151	306	
E	564.4	-19.7	-48.5	51	202	309	
F	539.9	-24.5	-73.0	39	241	316	
G	501.4	-38.5	-111.5	26	267	329	
H	429.3	-72.1	-183.6	33	300	006	
I	363.1	-66.2	-249.8	37	337	056	
J	296.9	-66.2	-316.0	55	392	095	
K	264.0	-32.9	-348.9	50	442	101	
L	230.8	-33.2	-382.1	50	492	101	
M	226.0	-4.8	-386.9	30	522	104	

Figure 14 shows an overhead representation of the values in the above table.

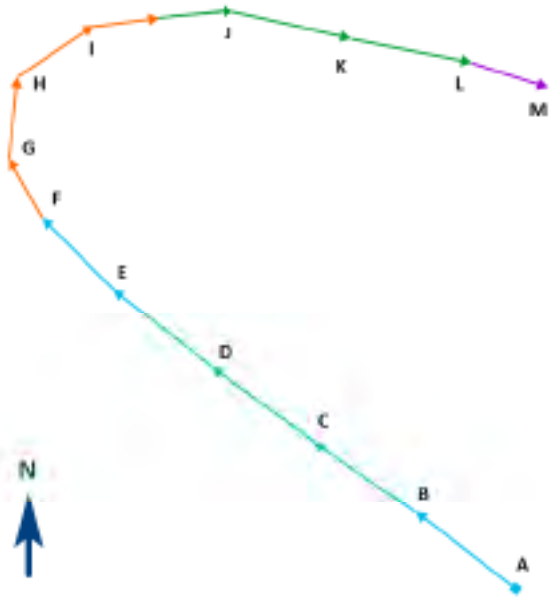

Figure 14: Flight path

Similarly, Figure 15 shows an approximation of the final flight path, again using the data in the table. The flight path obtained from the GPS is shown in blue, and in yellow one possible flight path it might have taken until impacting the water, assuming currents did not move the wreckage as it sank.

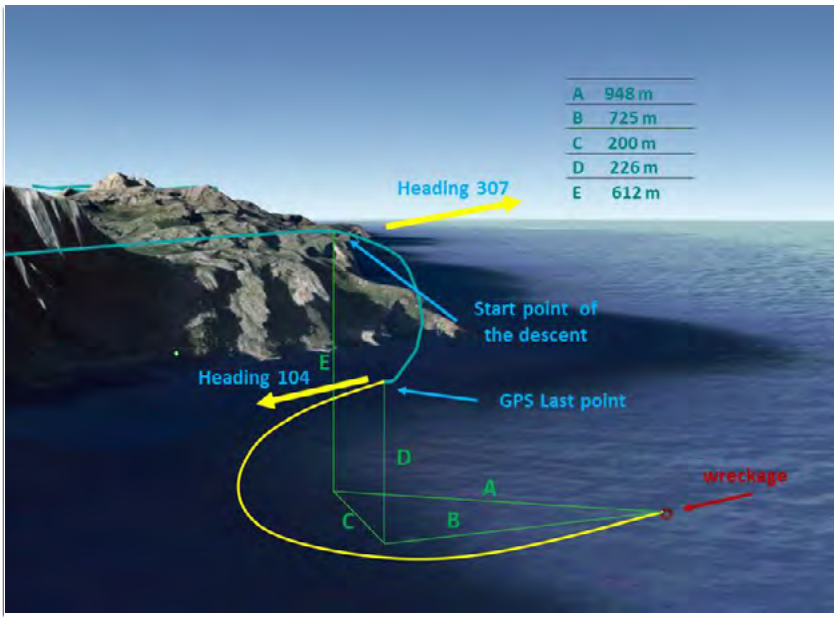

Figure 15: Flight path over the water

The data in the above table were used to evaluate the pilot's actions during the maneuver. To do so, as Figure 14 shows, the segments that comprise each row were grouped to create "Sections" based on the geometric and proportionality characteristics that relate the measured parameters to one another. This yields the following five groupings: Section A-F, Section F-I, Section I-J, Section J-L and Section L-M.

However, in order to optimize the calculation and have it fit the most realistic scenario, Section I-J was subdivided into two by adding point Q, thus yielding Section I-Q and Section Q-J. This creates Section F-Q, which would geometrically complete the sector of the flight path that fits a descending, helicoidal[5] motion.

The rest of the flight path is created by joining sub-Section Q-J to Section J-L to form Section Q-L, with more similar characteristics. As for Section L-M, the last recorded value is considered spurious because it diverges from the previous ones. The influence of the wind is also ignored.

The result is the following "Sections" with the following average values[6]:

- Section A-F[7]

Consists of five segments with a similar heading. This model shows that the aircraft descended on the course it had for 5 seconds at a descent rate of 2874 ft/min, a flight path angle of velocity vector Y= -16.6°, a negligible bank angle of velocity vector μ and an average airspeed of 99.4 kt.

- Section F-Q

This section consists of three segments plus semi-Section I-Q. The set comprises an arc of a descending helicoidal trajectory that takes place over 3.5 seconds. The calculation shows that the aircraft descended 210 m over the course of a 132° heading change, during which its flight path angle of velocity vector was Y= -57.26° and its bank angle[8] of velocity vector was μ= 68.9°. The resulting load factor was 1.5 with an aggressive descent rate of about 11,000 ft/min.

[5] Helicoidal motion results from combining rotational motion about a given axis with translational motion parallel to that same axis.
[6] When the segments are transformed into Sections, the result will be the value that provides the average.
[7] A negative sign for the flight path angle of velocity vector Y indicates pitch down.
[8] A negative sign for the bank angle of velocity vector μ indicates left roll.

- Section Q-L

Consists of two segments plus semi-Section Q-J. The resulting section shows a total change in heading of 13°, 7° of this in semi-Segment Q-J, 6° in section J-K and 0° in the last section, K-L. The calculations for the whole yield the following assessment: an average speed in Section Q-L of 124.4 kt; the average descent rate, although high, drops to just over 7,800 ft/min, as does the average flight path angle, Y= -38.66°; and finally, the bank angle of velocity vector decreases gradually to practically level in the final segment.

Given the way the various Sections representing the final 12 seconds of the flight were joined, it is concluded that the aircraft began to descend after the throttle lever was pulled back. This was followed by a coordinated maneuver, during which the aircraft adopted a strong pitch down and right roll attitude, causing it to descend in a helicoidal trajectory. Finally, the aircraft undid the above maneuver to presumably make a left turn.

Finally, Figure 15 shows one of the possible flight paths, in yellow, that would link the last GPS reading with the position where the wreckage was found. This part of the flight path is achieved after making a left turn, resulting in a more or less circular flight path that cannot be accurately determined.

2.5. Interpretation of the final minutes of the flight

The evidence found during the investigation indicates that the pilot did not report any problems for the duration of the flight. Moreover, the flight profile reflected the characteristics typical of observation and surveillance operations.

However, as the aircraft began the segment of the flight toward the south face of the Tramuntana Mountains, there was a change in heading to the northwest in the vicinity of Pollença that represented a departure from normal.

The heading change could have been required by the need to confirm some condition observed while flying over the area minutes area, while flying toward Cape Formentor. However, this course of action does not explain the reason for traveling 2330 m out to sea, nor does it seem to be related to any sign of a fire, since none were reported.

Another aspect to consider, given these data, is that once on the new course, the aircraft was climbing gradually at 414 ft/min with a ground speed of 104 kt, maintaining a suitable ground clearance. In this scenario, it is likely that the airplane could not have had any malfunction that would have allowed it to continue flying but not alter course. Moreover, the operation of the engine seems not to have affected the airplane's ability to fly until, at a certain point, it descended abruptly.

As for how the final segment evolved, initially there was a gradual descent while maintaining the same course. This was followed by a sharp, coordinated turn to the right that caused the aircraft to descend 386 m (1266 ft) in 12 seconds, at which time the GPS readings stopped, 226 m (741 ft) above the water. As analyzed in Section 2.4, this action is consistent with the execution of an aggressive maneuver in which the control stick is pushed forward in coordination with a steep roll to the right. The final maneuver levels the wings while lowering the descent rate.

This maneuver could be attributed to an impact with a vulture, resulting in damage to the aircraft and/or injuries to the pilot, perhaps with the loss of control. However, on the date of the accident, the vulture population was low, and the behavior of this species does not lend itself to flying over the ocean; therefore, the likelihood of a bird strike involving a vulture is remote.

Similarly, if a bird strike did occur, this does not seem to be reflected in the flight path that followed.

2.6. Evaluation of the final moments before the impact

The investigation was unable to determine the aircraft's flight path after the GPS unit stopped recording.

The setting for this final segment of the flight is as described in Figure 15. It started after the aircraft had leveled off and was descending with a Y value of approximately -33.4°. Based on the condition of the wreckage, it seems that the aircraft impacted the water with a slight left roll angle and the engine at a power below that needed to resume climbing.

The geometry of the scenario provides leeway for the possibility of the aircraft gaining altitude. At the same time, the flight path must have led it to the left, as this area was over the ocean and posed fewer problems to start climbing. Completing the flight path is not possible since, in order to reach the location of the wreckage, said path depends on the turn radius followed by the aircraft, which is unknown. However, it is safe to say that, in essence, the aircraft was not configured in a way that indicates that the pilot's intention was to climb.

3. CONCLUSIONS

The most important evidence used in this report is based on the information taken from the data recorded by a GPS device on board the aircraft, which were used to reconstruct the flight, and to analyze the maneuvers performed by the aircraft.

3.1. Findings

1. Involving the operation:

a. The pilot was qualified for the flight in question.
b. The aircraft had a valid certificate of airworthiness.
c. The flight had been planned as an observation and surveillance flight by the forests specialists who manage the firefighting assets of the Balearic Islands.
d. The pilot had flown the route four times in the last ten days.
e. The pilot had 261 flight hours on the type.
f. The weather conditions were not limiting for the flight.
g. The aircraft had a fleet tracking system on board and a separate, independent GPS device.
h. During the flight, the firefighting coordination aircraft and the accident aircraft were in radio contact.
i. There was no radio message warning of emergencies involving the aircraft or the operation it was conducting.
j. As the aircraft reached the farthest point on the route and was returning along the usual path, the pilot changed course and headed out to sea.
k. No signs of fire or smoke were found.
l. There are no indications that it struck a vulture.

2. Involving the rescue and the aircraft wreckage:

a. The search operation to locate the pilot and aircraft lasted three days.
b. The aircraft was found in water 60-m deep and 2140 m away from the closest point on the coast.
c. The pilot was in the pilot's seat, restrained by the safety harness.
d. The debris field on the seabed was small.
e. The propeller and second stage of the gearbox detached from the rest.
f. The damage observed in the wreckage was consistent with an impact with the water at a high left roll angle while descending.
g. When it impacted the water, the engine was operating at low power.

3. Involving the on-board GPS:

a. The GPS device was located with the wreckage.
b. It contained more information than that provided by the fleet management system.
c. The data indicate that the aircraft was climbing at about 414 ft/min until 12 seconds before the recording ended.
d. In the final 12 seconds, the aircraft performed an aggressive maneuver that combined a sharp descent rate and right roll for 3.5 seconds.
e. The final data show the aircraft descending with practically no roll angle.
f. The route recorded ends over the sea, a short distance away from the place where the aircraft wreckage was found.

4. Involving the aircraft's impact with the water and the surrounding area.

a. The maneuvers prior to the accident were performed over the surface of the water.
b. The aircraft did not show signs of regaining altitude.
c. The aircraft impacted the water in a clear downward attitude while turning left.
d. Flying over water alters the perception of visual references.

3.2. Causes/Contributing factors

The accident of aircraft EC-GVN is consistent with the characteristics of a controlled flight into water, preceded by a sudden descent, the cause of which could not be determined.

4. SAFETY RECOMMENDATIONS

None.