CIAIC

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Report A–025/2015

Accident involving a WSK PZL-M18B aircraft, registration EC-FBJ, operated by Servicios Aéreos y Tratamientos Agrícolas S.L., in Castro Caldelas (Ourense-Spain) on 27 August 2015

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MINISTERIO DE FOMENTO

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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) nº 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.

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Abbreviations

ºC	Degrees centigrade
AESA	Spain's National Aviation Safety Agency
AEMET	Spain's National Weather Agency
AGL	Above Ground Level
AMA	Aviation Weather Self-Service
ATPL	Airline transport pilot license
CAMO	Continuing airworthiness maintenance organization
CAS	Calibrated airspeed
CIAIAC	Spain's Civil Aviation Accident and Incident Investigation Commission
COE	Special operator's certificate
COPAC	Official Association of Commercial Aviation Pilots (Spain)
CPL	Commercial pilot license
CRM	Crew resource management
ELT	Emergency locator transmitter
FF	Fire Fighting
ft	Feet
GPS	Global Positioning System
hr	Hours
IAS	Indicated AirSpeed
kg	Kilograms
km	Kilometers
Km/H	Kilometers per hour
kt	Knots
l	Liters
m	Meters
METAR	Aerodrome weather report
min	Minutes
MTOW	Maximun take off weight
N	North
Nº.	number
RCA	Restricted certificate of airworthiness
RCC	Rescue Coordination Center
RD	Royal Decree
SAETA	Servicios Aéreos y Tratamientos Agrícolas (Aerial Services and Agricultural Treatments)

S/N	Serial number
SMS	Safety management system
SOP	Standard operating procedures
TAFOR	Aerodrome forecast
VFR	Visual flight rules
VHF	Very high frequency
W	West
WSW	West-Southwest

Synopsis

Owner and operator:	Servicios Aéreos y Tratamientos Agrícolas S.L. (SAETA)
Aircraft:	WSK PZL-M18B, registration EC-FBJ
Date and time of accident:	Thursday, 27 August 2015 at 15:47 local time[1]
Site of accident:	Castro Caldelas (Ourense-Spain)
Persons onboard:	1 pilot, seriously injured
Type of flight:	Aerial work - commercial - firefighting
Phase of flight:	En route
Date of approval:	28 September 2016

Summary of the event:

On Thursday, 27 August 2015 at 15:47, a PZL-M18B aircraft, registration EC-FBJ, was engaged in firefighting activities when it experienced an uncontrolled impact against the ground after a possible stall while turning to avoid crashing into mountains. During the turn the aircraft banked at an angle of almost 90°, during which the pilot made the water drop. Despite the high energy impact that took place, the pilot was able to exit the aircraft under his own power. The aircraft was destroyed. The search and rescue process was commenced immediately.

The investigation determined that the accident took place when the pilot lost control of the aircraft due to a stall that occurred while making a turn at low altitude to avoid crashing into a mountain. The following contributed to the accident:

- The possible prioritization of the water drop phase over the other phases of flight, which could have affected the pre-flight planning.
- The formation flight, which could have resulted in:
  - Incomplete pre-flight planning that did not consider the flight levels and the weather forecast along the route.
  - The hasty takeoff of aircraft EC-FBJ, which was second in the formation, and which forced the climb phase on the runway heading to be shortened, resulting in EC-FBJ not reaching the same altitude as the lead aircraft.

[1] All times in this report are local.

  - A delay in the pilot's decision to remedy the altitude problems that were present from the start of the flight.

- The pilot's limited experience with the aircraft.

This report contains two safety recommendations for the operator, Servicios Aéreos y Tratamientos Agrícolas S.L. (SAETA).

1. FACTUAL INFORMATION

1.1. History of the flight

On Thursday, 27 August 2015 at 15:47, while flying toward a forest fire, a PZL M-18B aircraft, registration EC-FBJ, impacted the side of a mountain in the vicinity of Castro Caldelas (Ourense).

The aircraft, operated by the company SAETA[2] as part of the regional Galician government's 2015 forest firefighting campaign, was based in Doade[3] (Lugo), as were two other aircraft from the same company[4]. At 15:27[5], the base was asked for units to aid in fighting a fire that had broken out 18 km southeast of the base in Chandrexa de Queixa[6] (Ourense). All three aircraft were mobilized.

At 15:41, the mobilization of the aerial units stationed at the base in Doade was recorded in the base's log. Their callsigns were Doade 1 and Doade 2 (EC-FBJ). Aircraft Doade 2 took off second, at 15:42, behind Doade 1, both from runway 26. After taking off, they had to turn left to the southeast and climb.

At 15:45, an eyewitness located in Castro Caldelas (9 km southeast of the base) saw the two aircraft flying by the town, the first of them fairly higher than the second. The next information on the status of aircraft EC-FBJ comes courtesy of two photographs taken by the same eyewitness shortly before the impact. The first photograph shows the aircraft at a steep left bank angle while dropping the water. In the second photograph, the aircraft is upside down on a nearly vertical trajectory. The aircraft crashed to the ground seconds after this second photograph was taken.

Figure 1 shows the two photographs taken by the eyewitness, the first on the left and the second on the right. Figure 2 shows a view of the terrain where the accident took place. Indicated on the figure are the position of the eyewitness, the impact point and the estimated flight path, based on the photographs taken by the eyewitness.

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[2] Servicios Aéreos y Tratamientos Agrícolas S.L.

[3] The base, located at an elevation of 587 m, has one runway in an 08/26 orientation.

[4] The operator had three aircraft at the Doade base, two PZL M-18B firefighting aircraft (EC-FBJ and EC-EVQ) and one Vulcanair P68TC coordination aircraft (EC-KYY).

[5] Time obtained from the base log, where the times of the calls made to the base were recorded, along with the takeoff and landing times, number and type of units mobilized and type of product to be used on the fire.

[6] The fire area was at an elevation of 1000 m.

Figure 1. Photographs[7] taken by the eyewitness in Castro Caldelas

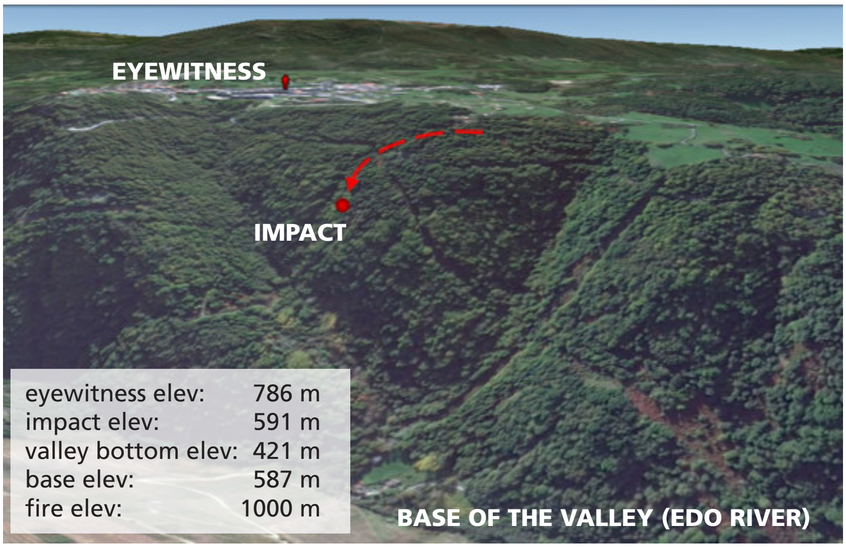

Figure 2. Positions of the impact and eyewitness and estimated flight path based on the photographs

1.2. Injuries to persons

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

[7] These are cropped images taken from each photograph. The originals show a wider view of the area.

1.3. Damage to aircraft

The aircraft was destroyed by the impact. For the most part, the damage affected the front and right side of the aircraft. The engine detached, the right wing was almost completely separated from the fuselage, the left wing lost an aileron and its wingtip was punctured. The bottom of the fuselage and the tail assembly exhibited significant damage, but less than the front of the aircraft. The cockpit seemed to be intact.

1.4. Other damage

The aircraft's impact affected four trees.

1.5. Personnel information

The pilot, a 34-year old Spanish national, had a commercial pilot license (CPL(A))[8] issued by Spain's National Aviation Safety agency (AESA). He also had instrument, single-engine and multi-engine ratings that were valid at the time of the accident [9], as well as a medical certificate[10]. He had taken a firefighting course on recognisance, coordination and airplane waterdroping airplane[11], and he had a certificate of firefighting proficiency for patrol, coordination and airplane water drop activities involving the Vulcanair P68, Cessna 337 and PZL M18 airplanes[12].

He had a total of 1600 flight hours[13], of which 15:50 hours had been on the type. He had been working for this operator for nine years, and this was his first campaign flying this airplane. He was familiar with the area since he had been flying in Galicia for four campaigns, two of them based in Xinzo de Limia and two in Doade.

1.5.1 Training

The pilot took the following training courses from April to June 2015[14]:

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8 The operator required pilots to have an ATPL or CPL license to fly the PZL (M18 or M18/BS).

9 Multi-engine and instrument valid until 31/03/2016. Single-engine valid until 31/03/2017.

10 Valid until 18/02/2016.

11 Issued by Martinez Ridao Aviación ES.COE.A.05, on 31/05/2015.

12 Issued by SAETA, ES.COE.A.06, on 19/05/2015.

13 The Operations Manual (Part A, Section 4), a literal transposition of the requirement contained in RD 750/2014, stated that the experience required to fly as the pilot in command during water drop operations was 500 hours as the pilot in command, 50 of which had to be in activities of similar characteristics and 50 in aircraft of similar characteristics.

14 As per the qualification requirements specified in the Operations Manual.

Agricultural:

- 23/03/2015: proficiency check for the agricultural pilot rating in a PZL M18BS aircraft.

On Vulcanair (patrol and observation aircraft):

- 27/03/2015: refresher training on fire surveillance, patrol and coordination[15] with the P68TC aircraft.
- 27/03/2015: operator's proficiency check on the operator's multi-engine, single-pilot land airplanes with the P68TC aircraft.
- 27/03/2015: Vulcanair (P68) familiarization training.

On Cessna 337 (patrol and observation aircraft):

- 27/03/2015: Cessna 337 familiarization training (C337).
- 27/04/2015: refresher training on fire surveillance, patrol and coordination with the C337 aircraft.
- 28/04/2015: operator's proficiency check on the operator's multi-engine, single-pilot land airplanes with the C337 aircraft.

On PZL M-18BS (water-dropping airplane):

- 4 and 5/05/2015: refresher firefighting training[16] with the PZL M-18BS aircraft.
- 06/05/2015: operator's proficiency check on the operator's single-engine, single-pilot land airplanes with the PZL M-18BS aircraft[17].

General:

- 17/06/2015: RD750/2014 course.
- 17/06/2015: course on regulation 1178/2011.
- 18/06/2015: area/aerodrome training.

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[15] This is a one-hour course with three landings and takeoffs and 15 exercises. The exercises include slow flying, approach to and recovery from stalls, 30° and 45° turns, flying at different speeds while maintaining altitude and steep turns over a point.

[16] This is a three-hour course with 11 landings and takeoffs. It has 28 exercises, which include slow flying, approach to and recovery from impending stalls and spins, turns, obstacle-avoidance techniques, mountain flying, normal and emergency drops during firefighting operations.

[17] This is a one-hour course with three landings and takeoffs. It has 23 exercises, including flying (VFR) in the following situations: flight at critically low speed with or without flaps, steep turns (360° at a 45° bank angle), stall and recovery (clean full, during descending turn, with approach configuration and power, with landing configuration and power, in climbing turn with takeoff flaps and climb power).

- 19/06/2015: training on and verification of emergency and safety systems.
- 19/06/2015: safety management system (SMS).
- 19/06/2015: crew resource management (CRM).
- 19/06/2015: conversion training.
- 22/06/2015: hazardous materials course.

1.5.2 Recent activity

The pilot had been assigned to the firefighting campaign in Galicia since July. Before being transferred there, he had been in Palma de Mallorca, where he was involved in firefighting activities:

- 1 to 10 June: activity with the Vulcanair P68OBS2 aircraft at the base in Palma de Mallorca.
- 11 to 30 June: rest and transfer to the base in Doade.
- 1 to 20 July: activity with the Vulcanair P68TC aircraft at the base in Doade.
- 21 to 30 July: rest.
- 31 July to 8 August: activity with the Vulcanair P68TC aircraft.
- 9 to 16 August: rest.
- 17 to 27 August[18]: activity with the accident aircraft.

The work shifts lasted 12 hours. On the day of the accident, he had gone on duty at 09:45 and it was the first flight of the day. He had flown 23 hours in the last month.

1.6. Aircraft information

The aircraft, initially manufactured as a WSK PZL-M18A, S/N 1Z021-25 in 1991, was owned by Martinez Ridao Aviación S.L. and operated by SAETA. It had a PZL KALISZ ASZ-62-M18 engine[19], S/N K18536666C, and a LEKKICH (CNPL) AW-2-30/SP.00-001-00 propeller[20]. In 2007, the aircraft was transformed into a PZL-M18B model[21] and a VHF transmitter was installed for communicating with the ground.

[18] His work schedule ran through on 30 August.

[19] Installed on the aircraft on 13/09/2006.

[20] Installed on the aircraft on 24/03/2009.

[21] This modification included changes to several surfaces on the aircraft and to the controls. In addition, the aircraft's maximum takeoff weight was increased to 5300 kg (compared to the 4200 kg MTOW of the original model).

In May 2015 a McMurdo Kannad 406 ELT (emergency locator transmitter) was installed.

At the time of the accident, the aircraft had 1652 total flight hours and the engine 3153 hours. Starting in October 2014, it was idled for 10 months until it was returned to operations again on 24 June 2015. Between then and the accident date, the aircraft had been at the base in Doade and had flown 71 hours.

The aircraft was maintained by SAETA[22]. The CAMO (Continuing Airworthiness Maintenance Organization) was Martínez Ridao Aviación[23]. The last maintenance inspections had been in May 2015, before the start of the firefighting season. The engine had undergone a 300-hr inspection, the aircraft a 100-hr/annual inspection, the ELT was installed and the engine was reinstalled after being overhauled. All of the tasks were performed at SAETA's facilities. On 5 August 2015, after the campaign started, a 50-hr check of the aircraft and engine was performed at the base in Doade.

The aircraft had a valid restricted certificate of airworthiness (RCA) and insurance certificate[24] on the date of the accident.

The aircraft was used by SAETA to engage in firefighting activities using water drops. SAETA was authorized by AESA as an aerial work company and had a valid special operator's certificate (ES.COE.A.06) at the time of the accident to carry out these activities[25].

1.7. Meteorological information

Information about the weather conditions during the flight was obtained from three different sources:

- From the descriptions from the three pilots who flew in the area on the day of the accident, who said that:
  - On the runway at Doade, an hour before takeoff, the wind was lined up with runway 26 (from approximately 80º) at 10-15 kt and gusting up to 20 kt. On takeoff, the wind was strong, gusting up to about 20-25 kt.

[22] Maintenance organization authorized by AESA ES.145.195.

[23] Continuing airworthiness maintenance organization authorized by AESA CAMO ES.MG.106.

[24] The RCA was valid until 15/03/2016 and the insurance until December 2015.

[25] Certificate issued on 03/07/2015.

  - In the Edo River canyon, where the accident occurred, the wind was from the east (same as at the base) and there was turbulence and downdrafts that hampered flying at low speed and altitude.

- From the two photographs taken by the eyewitness, which show weather conditions suitable for visual flight.

- From Spain’s National Weather Agency, which reported that:

  - A cold front was approaching Galicia on the day of the incident, but at the time of the incident, the cloud cover associated with the front was still over the Atlantic Ocean and had not reached Galicia. In the northwest of Galicia there was storm also associated with the front.

  - Radar for La Coruña indicated there was no precipitation in the area of the incident.

  No intense downdrafts were reported[26].

1.8. Aids to navigation

Not applicable.

1.9. Communications

There is no record of the communications between the aircraft during the accident. The information available is from the descriptions provided by the pilots of Doade 1 and Doade 2, which indicate that the following communications took place:

- The pilot of Doade 1 informed Doade 2 when over the Sil River that he was switching to the coordination frequency for the province of Lugo. The next message from Doade 1 was as it was approaching the fire.

- The pilot of Doade 2 instructed Doade 1 to reduce power and wait because he was not gaining altitude. This report was not heard by Doade 1.

[26] The data from the station closest to Castro Caldelas (Montforte de Lemos, 17 km away) indicated good visibility, no significant phenomena or precipitation, few clouds, 24° C temperature, 64% humidity and wind from the WSW (about 250°) at variable speeds (16 km/h) and gusting up to 30 km/h. Because of the distance and geography differences, these data are not considered representative of the weather at the accident site. In fact, the wind direction is opposite to that reported by the three pilots for the base and the accident area.

1.10. Aerodrome information

The base at Doade has one runway in an 08/26 orientation. The base has a wind measuring system that is used to determine actual wind conditions, but only at the base. Information on the weather along the route is obtained by using the internet connection that is available at the base.

1.11. Flight recorders

The aircraft had a fleet tracking system installed made by the company Heligraphics. This system consisted of an onboard unit that recorded the time, position and altitude of the aircraft every 6.7 seconds. The system used this information to calculate the speed and heading.

This system was used to obtain the flight path for both EC-FBJ (Doade 2) and the aircraft ahead of it (Doade 1)[27]. Figures 3 and 4 show the flight paths taken by the two aircraft (Doade 1 in blue[28] and Doade 2 in red) and the altitude of EC-FBJ versus the elevation of the terrain. Also included are the positions of the eyewitness who took the two photographs and the point of impact.

The recorded data indicate that the flight of EC-FBJ progressed as follows:

- Segment 1-4: takeoff, turn to southeast (course 120º) and climb.
- Segment 4-5: segment in which the aircraft's altitude stabilized or even dropped off. The speed[29] remained between 150 and 160 km/h.
- Segment 5-6: climbing on course 120º. The speed increased momentarily to 174 km/h before falling to 150 km/h.
- Segment 6-9: segment with three course changes (first to the right[30] and then to the left), during which the aircraft did not manage to gain altitude. This segment saw several changes involving the altitude and speed:
    - Segment 6-7: drop in altitude and speed (to a minimum of 127 km/h at point 7) and course change to the right.

[27] The fleet tracking system also recorded the flight of the coordination aircraft that was mobilized after the two Doade flights. These data are not relevant to the accident analysis and are not shown.

[28] The flight path of Doade 1 is not shown in its entirety.

[29] The speed values given in this section are ground speed, since they are calculated based on position and time data recorded by the fleet tracking system. To calculate the wind, and thus the indicated airspeed, the wind for each phase of the flight was estimated based on the description of the pilots, who said the wind was from 80º (like at the base) at between 10 and 20 kt.

[30] The "left" and "right" references are from the pilot's point of view.

- Segment 7-8: Increase in altitude and speed and course change to the left.
- Segment 8-9: loss of altitude, sudden drop in speed (from 162 to 142 km/h) and new course change to the left.

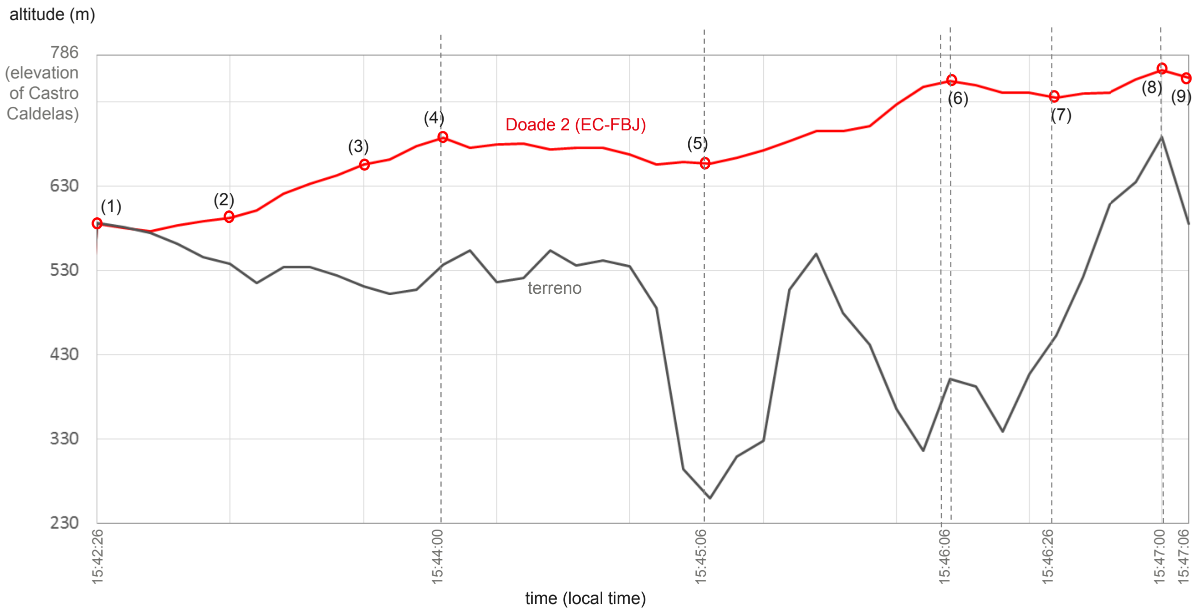

Figure 3. Flight profile of aircraft EC-FBJ (Doade 2)

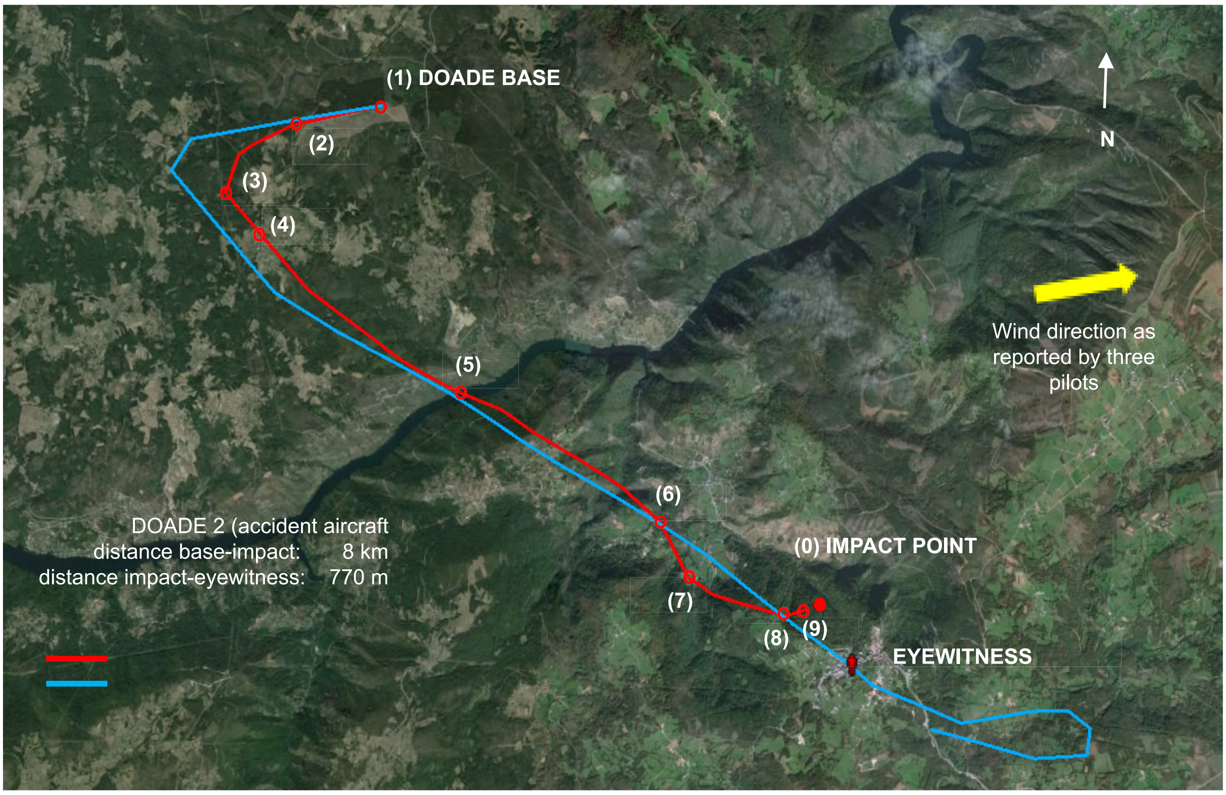

Figure 4. Flight paths of EC-FBJ (Doade 2) and Doade 1

The figures show a total of 10 important points on the flight path. The first nine are from data recorded by the fleet tracking system, and the tenth is the crash site.

(1): 15:42:26: takeoff from base.

(2): 15:43:00: start of turn to the southeast. The aircraft was 55 m AGL at 138 km/h[31]. From there it began to climb. Doade 1's climb on the runway heading was longer and it started to turn to the southeast when it was 188 m AGL; in other words, when it was 133 m higher than Doade 2.

(3): 15:43:33: end of turn and start of segment on southeasterly heading (120º), which it maintained until 15:46:06 (point 6)[32].

(4): 15:44:00: end of climb phase. The aircraft was at 688 m (155 m AGL) and 138 km/h. From this point on, the aircraft's altitude stabilized, or even decreased.

(5): 15:45:13: aircraft above the Sil River at 657 m (398 m AGL) and 154 km/h. Doade 1 had passed over that same point 48 m higher than Doade 2 and at 169 km/h. Here it began to descend.

(6): 15:46:06: end of climb. The aircraft was at 755 m (354 m AGL) at 153 km/h. Doade 1 had passed over this same point 109 m higher than Doade 2 and at 177 km/h[33]. At this point it started making a series of changes to its course, the first to course 150º.

(7): 15:46:26: the aircraft had descended to an altitude of 735 m and its speed had fallen to 127 km/h. A new course change saw it turn left to course 100º.

(8): 15:47:00: the aircraft had climbed to 768 m but the ground elevation was also higher (it was approaching Castro Caldelas), meaning the aircraft was 79 m AGL. Doade 1 had passed over this same point 115 m higher. The speed over this point was 162 km/h (Doade 1 was flying at 175 km/h). The last course change started here with a turn to 67º.

(9): 15:47:06: last data point. The aircraft had descended with respect to the previous point and was flying at 142 km/h, 20 km/h slower than in the previous point (6.7 seconds earlier). It was turning left toward

[31] It is estimated that in the takeoff segment, it had had a headwind between 18 and 36 km/h. This would translate into an IAS of between 156 and 174 km/h.

[32] Assuming the wind en route was the same as at the base, the aircraft is estimated to have had a tailwind of between 14 and 27 km/h during the segment when it was on course 120º.

[33] By this point, Doade 1 was already flying 78 m above the elevation of Castro Caldelas (786 m).

an area with a lower elevation. Its altitude was 759 m (173 m AGL).

(10): 15:47:00: point of impact, 150 m past the previous data point. The point of impact was along the same course as the previous two data points.

The flight of Doade 2, compared to that of Doade 1, showed that:

- Doade 1 was flying faster than Doade 2.
- Due to the fact that Doade 1 had taken off earlier, there was a difference in distance between both aircraft of 1 km in the first phase of the flight (from base to Sil River). Doade 2 was 60 m lower that the Doade 1 and 10 km/h slower (in the same point).
- From the Sil River onward, the differences in altitude, speed and distance increased. Doade 1 averaged 20 km/h faster and 90 m higher than Doade 2 at the same points. The distance separating them increased from 1 km to 1.7 km.

1.12. Wreckage and impact information

The wreckage was located in an area called "Souto do Conde", part of the municipality of Castro Caldelas (Orense), at coordinates 42º22'47.0" N 7º25'25.3" W. It was on the south face of the valley, which is some 1500 m wide and faces east-west. The Edo River flows through the valley. It had crashed practically halfway up the mountainside, at an elevation of 591 m. The wreckage was facing southwest (220º) and uphill. The area was mountainous, with a steep slope (45%). It was covered by a dense forest with scrubland vegetation and trees (primarily birch, chestnut and oak) ranging from 10 to 15 m in height.

The impact affected four trees, two of them during the initial fall and two more as the airplane slid down the hill.

The initial impact affected the top branches of an oak tree (identified as no. 1 in Figure 5).

The second impact was against a birch tree (no. 2 in Figure 5), 15 m away from the first tree and at a higher elevation. The tree consisted of several vertical branches sprouting practically from a common trunk on the ground. Just four of these branches were torn off. Two of the branches were found next to the tree, and the other two next to the aircraft, one driven into the front of the aircraft and the other underneath the left wing.

The next impact was against the ground, next to tree no. 2. The impact left deep marks in the ground, indicative of a hard impact. Between this spot with the hard impact and the place where the main aircraft wreckage was found there were shallower marks indicating that the aircraft had slid along the ground.

As the aircraft slid downhill from the birch tree, the outer edge of the left wing struck another tree (no. 3 in Figure 5), penetrating almost halfway through the wing and bending the wingtip upward. The aileron from that wing detached and was found 5 m downhill. The aircraft's cockpit was in good condition, with no apparent damage. The cockpit compartment was not breached and the window glass (front and side) was intact.

The aircraft stopped at that point, next to trees 3 and 4, with the right wing practically detached from the structure and rotated with respect to its longitudinal axis. The left wing was in better condition than the right and remained attached to the fuselage. The left wingtip had practically separated from the wing due to the impact with tree no. 3. The engine and propeller were found down the hill, stopped against a tree trunk.

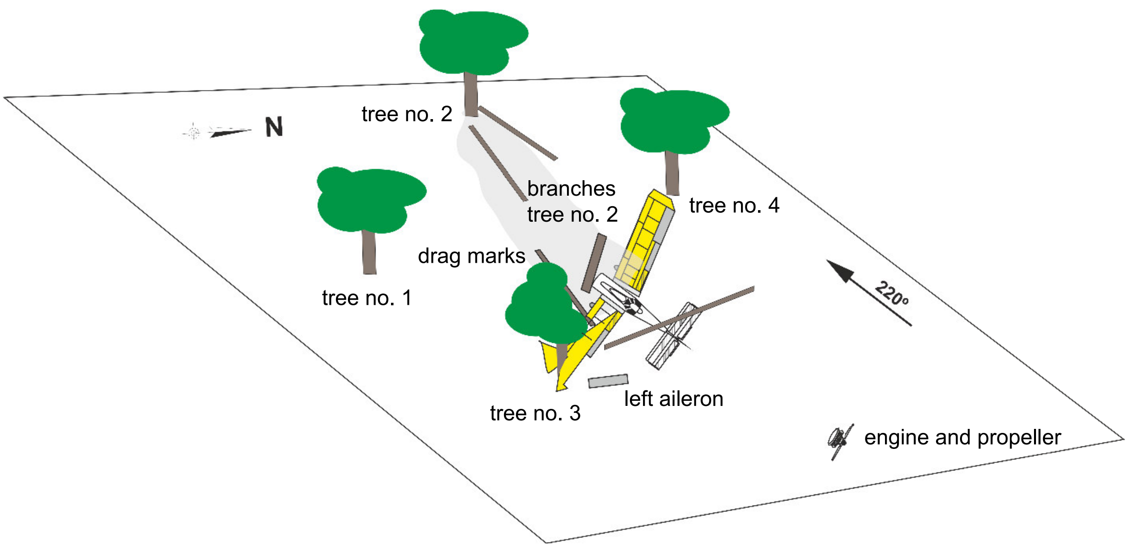

Figure 5. Debris field of aircraft EC-FBJ

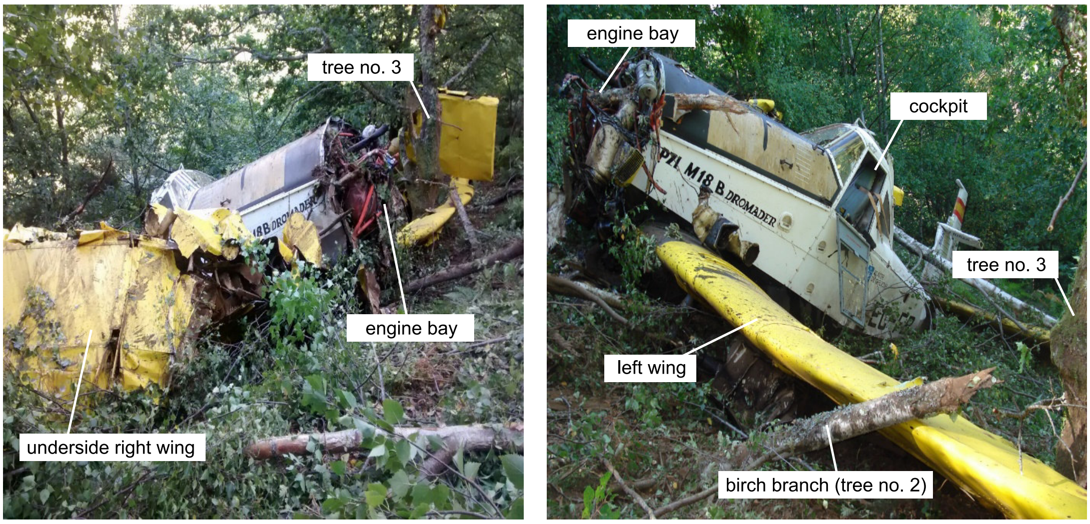

Figure 6. Aircraft EC-FBJ after the impact

1.13. Medical and pathological information

The pilot was taken to a hospital where he was admitted and treated for chest trauma.

1.14. Fire

There was no fire.

1.15. Survival aspects

The cockpit compartment retained its integrity, which helped the pilot avoid more serious injuries. The pilot's harness was fastened, and both the harness and the seat supported the impact, thus fulfilling their safety function.

The pilot managed to exit the aircraft under his own power. He was later found outside the aircraft.

The emergency locator (ELT) also worked following the impact and activated properly. In addition to the ELT, since the aircraft was flying in formation and the accident was seen by an eyewitness, the search and rescue process was begun immediately. By 15:50, within three minutes of the impact, the 112 emergency services center had already received calls reporting the accident, which the center relayed to RCC Madrid and to other agencies, triggering the search process. Initially involved in search and rescue efforts were two aerial units from the firefighting detachment.

The aircraft and pilot were found at 16:30.

1.16. Tests and research

1.16.1 Statement from the pilot of Doade 2

The pilot stated that it was a very windy day. After taking off from the base in Doade, he felt strong wind gusts of around 18-24 kt, and a steady wind of 10-15 kt. Since the wind was lined up with the runway, it helped with the takeoff, after which they turned left to proceed to the site of the fire. He had problems climbing because of the gusts, but he was able to climb over the first hill and reach the Sil River. He had the throttle fully open but he was unable to climb. He had a tailwind. At that point the aircraft started losing altitude due to wind and turbulence. He realized that if things continued like that, he would be unable to make it past Castro Caldelas, so he decided to make a slow 180° left turn into the wind to try to gain altitude and climb above the hill he had in front of him. At the start of the turn he was hit by another gust that made him bank left 30 to 40°. The airplane destabilized and he started to drop the water. After the water was released, the airplane made a sudden left turn that practically put him in an inverted position with the nose facing down. He tried to stabilize the aircraft and make an emergency landing. He impacted a tree, and the next thing he recalled was the sound of people looking for him. It took them 20-25 minutes to find him.

That day he filled the water tank in the morning, with the fuel tank full. Since he took on too much water, he had to remove about 200 l[34].

During the flight he called Doade 1 telling him to slow down and wait for him because he was unable to climb.

1.16.2 Statement from the pilot of Doade 1[35]

They received a call about the fire, whose location was reported using coordinates on a grid map[36].

[34] This information was confirmed by the pump operators at the base who are responsible for this task.

[35] This pilot had been working for the operator since 2006. He took off ahead of the accident aircraft.

[36] There is a grid map in the office, with the Doade base at its center, which features a scale in miles that is used to determine the distance and heading to the fire.

The pilot, who stated he had considerable experience in Galicia and who knew perfectly well the area they were headed to, explained that the terrain southeast of the base was mountainous, and you had to gain altitude before reaching it. They took on water[37], held the briefing and decided that he would take off first, since he knew the area better, followed by Doade 2.

After taking off, he extended the upwind leg a little to give Doade 2 time to take off. At the base the wind speed was 20-22 kt, and gusting even higher. They had a headwind, which helped them. He did not have any problems taking off, and it seemed that Doade 2 did not either. When he estimated that Doade 2 had taken off, he turned to set course for Castro Caldelas. During the turn he looked toward the base and saw Doade 2 flying toward his position.

Before reaching the Sil River, he spoke with the pilot to coordinate the radio frequency change[38]. He changed frequencies and shortly after flying over Castro Caldelas he called the pilot to ask if he was close to him[39]. There was a lot of turbulence in the canyon (before reaching Castro Caldelas). He figured that in that area, he was flying some 100 to 200 m above the top of Castro Caldelas.

The pilot of Doade 2 did not answer this call. He repeated the message several times without receiving a reply. He decided to go back to look form him and when he did, realized there was no aircraft on the horizon. He reported on the radio that he had lost Doade 2 and was starting to look for it. He decided to release the water east of Castro Caldelas. He flew toward the part of the valley between Castro Caldelas and the Sil River. The tree cover in the area was dense, making it difficult to locate a downed aircraft. There was a lot of turbulence, which hampered flying at a low altitude and speed. The low-wing design of the aircraft also limited his downward visibility, so he decided to return to base[40].

[37] The operation at the base is as follows:

- The aircraft are loaded with fuel but not water. When an alert is received, the water is loaded (a process that takes very little time). The water is pumped in once the pilot is in the cockpit, since it is the pilot who signals the pump operators when to stop the pump. On the first flight, they always leave with full fuel tanks, around 720 l, and with 1600-1700 l of water (about 200 l below the maximum load). On subsequent flights, when some of the fuel has been burned, they take on maximum water. They refuel during the break they take every two hours.
- Before taking off they hold a mini-briefing where they discuss the characteristics of the fire zone and how they are going to proceed. The pilot with more experience in the area flies at the front, setting the course and altitude, and the other aircraft follows, mirroring the actions of the first.
- They navigate with help from GPS unless they know the route, in which case no navigation aids are needed. They also have maps onboard in case they need to check them.

[38] Each province has its own frequency on which to coordinate firefighting activities. The base in Doade and the fire were in different provinces, with the Sil River marking the boundary between the two.

[39] They have to arrive at the fire with little distance between them, no more than 1 km, in order to make consecutive drops.

[40] The arrival of this aircraft was recorded in the base log at 15:56.

1.16.3 Statement from the pilot of the VULCANAIR P68 aircraft

He was dispatched several minutes after the Doade pilots. As for the weather conditions, he stated that around one hour before he was activated, he had been taking wind readings with a hand-held anemometer they have at the base. The wind speed was 10-15 kt, gusting to 20 kt. The wind speed was increasing throughout the day, and was even higher when they were activated.

As he was flying toward the fire zone, he was told that Doade 2 had disappeared, so he started looking for it.

He was flying inside the canyon (lower than usual), trying to maintain his line of flight. He then realized that the aircraft was gradually but steadily descending, which indicated the presence of downdrafts.

Suddenly he felt a strong downdraft and the aircraft started to descend at a rate of about 1000 ft/min. He had to use the full thrust of the aircraft to stop descending and exit the canyon.

He then realized that the weather and geographical conditions were not suited to searching for the airplane, and that the search had to be conducted from a helicopter. Just then a helicopter arrived from the base at Marroxo, which located the aircraft wreckage.

1.16.4 Statement from the eyewitness in Castro Caldelas

The eyewitness who took the two photographs of the accident was in the kitchen in his home in Castro Caldelas. The third-floor home faced northwest and offered a very good view of the accident area. He stated it was 15:45 and he was in the kitchen. He heard an airplane and looked out the window. He saw an aircraft flying to the east, and estimated that it flew over the north part of the town. Since he knew that another one would follow it, since there were always at least two, he took his telephone and got ready to take pictures of it. He was looking at the screen on his cell phone when the aircraft fell to the ground. He called 112 to report what he had seen.

As for the altitudes, he said that the first aircraft was considerably higher than the second one.

1.16.5 *Inspection of the aircraft*

Inspection of the fuselage, wings and cockpit:

- There was continuity in the rudder and elevator controls. The rudder cables were stuck and the bar on the elevator was bent, which made it impossible to move. In the left wing there was continuity in the bank controls up to the point where the wing was broken.
- The left side of the rear of the fuselage was in better condition than the right side.
- The bars in the tail assembly were broken and bent by the impact.
- The left horizontal stabilizer and the left elevator were in better condition than their counterparts on the right side.
- The vertical stabilizer was broken from the middle to the end.
- The seat did not exhibit any damage.
- The seatbelts were in perfect condition.
- Inside the cockpit, the ELT light indicated the ELT was armed and activated, the emergency fuel pump was OFF, the fan, lights and generator were ON, magnetos 1 and 2, propeller pitch was at maximum and the throttle control in GAS.

Inspection of the engine and propeller:

- The engine detached when its mount broke.
- Three of the four blades showed bending and marks consistent with an impact at power. The fourth blade was not bent but it did have marks.
- The fuel pump shaft rotated freely.
- There was continuity in the carburetor actuator connections.
- The engine ignition wiring showed nothing out of the ordinary other than wires broken by the impact. The connections to the spark plugs were intact.
- The exhaust system and the intake manifold were crushed or broken, and their detached parts were scattered along the path of the aircraft, all as a result of the impact.

1.16.6 *Information in the flight manual*

There is a published basic flight manual for the PZL M18 aircraft, as well as a specific supplement, number 17[41], for the modified version, the PZL M18B. In the introduction to this supplement (Section 1 - General. Part 1.1, Introduction) is the information that amends or complements that contained in the basic manual for operating the M18B aircraft, with its increased 5300-kg MTOW. The information shown below, which is of relevance to the accident, is taken from the basic manual and from supplement 17.

- The increased MTOW and the M18A to M18B modification affects the restriction involving the bank angle during turns, which had been limited to 30°.
- The maximum allowed headwind was the same at 29.5 kt.
- In order to take off with a maximum weight of 5300 kg, it states that after the rotation, a climb angle should be established such that the airplane is flying at 155 km/h after 15 m (50 ft).
- After the first 15 m (50 ft), the aircraft should climb at a speed of 160-165 km/h for a maximum weight of 5300 kg.
- The minimum flight speed when loaded is 175 km/h (CAS).
- As for the steps to take in the event of an inadvertent spin (emergency procedures), no guidelines are given concerning the load.
- As concerns the normal firefighting procedure, it states that:
  - The airplane should be in level flight during the drop.
  - The aircraft will immediately pitch up after the drop. This must be offset by pushing the control stick forward.
  - NOTE: the drop duration does not exceed two seconds. After the drop, the altitude will increase by 30 m and the speed will drop by 30 km/h.
- For a MTOW of 5100 kg[42], with no engine and no flaps at a bank angle of 60°, the stall speed is around 195 km/h. For a 30° angle, the stall speed is 150 km/h and for a 40° bank angle, it is 160 km/h.
- As for the operational center of gravity in a firefighting configuration, the operator had created a table as part of the flight manual for pilots to use as a quick guide for loading the aircraft. This table showed the amount of fuel and

[41] Supplement 17: M18B AIRPLANE OPERATION.

[42] The takeoff weight of EC-FBJ was estimated based on the information provided by the pilots and the pump operators.

water that could be loaded onto aircraft EC-FBJ without exceeding its MTOW. For example, with 100% fuel load, the operator allowed a maximum of 1874 liters of water to be loaded[43].

- The aircraft's weight[44] was used to calculate the variations in the weight, the position of the center of gravity (left) and the moment of the center of gravity (right) in two scenarios: at takeoff with three quantities of water (1874, 1700 and 1600 l)[45] and after the water drop[46]. In every situation, the aircraft is within the envelope.

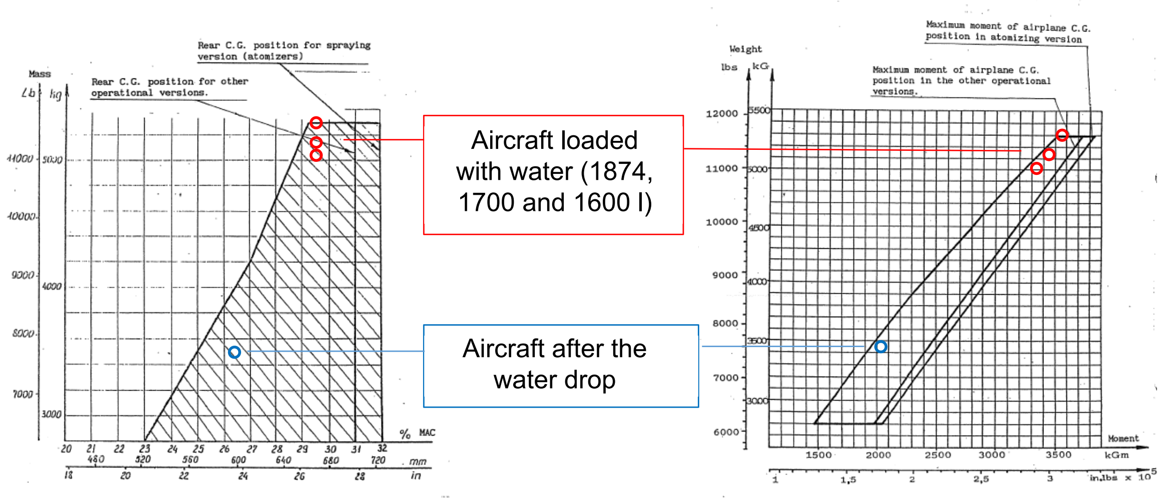

Figure 7. Change in the position and moment of the center of gravity during the flight

1.17. Organizational and management information

The operator had an Operations Manual[47] that incorporated the regulatory requirements specific to this type of operation[48] , as well as annexes that contained the procedures specific to each aircraft, task and area. These annexes included the Standard Operating Procedures (SOP) for dropping water from an airplane during firefighting (FF) operations[49]. Both documents were specific and adapted to the

[43] These were the reference values given by the pilots during the interviews. In fact, so as not to have the aircraft fully loaded, if the fuel tank was full, they would take on 1600-1700 l of water, 200 l less than the maximum allowed.

[44] Taken from the weight and balance report written in 2007 after the M18B modification.

[45] 1874 l is the maximum weight of water with which it could have taken off. 1700 and 1600 l are the amounts that the pilots said the actually took on (200 l below the maximum allowed). This means that the takeoff weight would have been between 5026 and 5126 kg.

[46] For the same fuel weight.

[47] Approved by AESA. Published on 29/05/2015.

[48] RD 750/2014 of 5 September, which regulates aerial firefighting and search and rescue activities, and specifies the airworthiness and licensing requirements for other aviation activities.

[49] This document included several of the aspects contained in the report written by COPAC (Official Association of Commercial Aviation Pilots) on aerial firefighting operations. This document defined generic operational procedures

types of operations and aircraft used by the operator. The operator had also identified the dangers and risks and created mitigative measures in an effort to make flights involving water drops from airplanes safer.

Both documents, and in particular parts A of the Operations Manual and the SOP-FF annex, contained constant references to:

- The importance and benefits of standardizing and implementing operational procedures.
- The unique features of firefighting flights, emphasizing aspects such as:
  - Special atmospheric conditions with turbulence,
  - Low-altitude, low-speed flying,
  - Fast decision making,
  - Heat stress and stress associated with the workload in a single-pilot airplane,
  - Turbulence that hampers climbing,
  - Maneuvering a loaded airplane near its stall speed,
  - Mountainous areas.
- It analyzed the various scenarios that could take place in this type of flight and identified which scenarios and conditions were complex and which were not. Of relevance to this accident, the following were considered complex:
  - Flying in mountainous areas, and
  - Flying in areas with microclimates and suddenly changing weather conditions.
- It analyzed flights with water drops as a series of seven phases, each one preceded by adjustments, checks and checklists. The seven phases were: pre-flight planning at the base, pre-flight, loading, flight, drop, flight and post-flight.
- Of relevance to the accident, it stated that during the flight planning phase at the base:
  - The captain must gather and analyze all the relevant aviation information, including an online check of weather information. The general and specific conditions forecast are to be presented at a weather briefing at the start of the day and include METARs, TAFORs and significant weather maps drawn up internally or, failing that, using AMA resources. The forecast for turbulence, mountain waves and high temperatures must be considered due to their direct effect on the airplane’s performance.

for aerial firefighting activities for both airplane and helicopters.

- The captain shall familiarize himself with the geography of the area and with the minimum elevations to be cleared. In these mountainous areas, the captain must be aware of the effect of local winds, leeward winds, etc.

• In the pre-flight phase, it mentioned the need to gather information on special weather conditions. This section emphasized that "in single-pilot airplanes, the pilot must be particularly critical of himself and question the suitability of the actions he is carrying out at all times". It also noted that "we all make mistakes, the important thing is to have routines so that we can identify and correct those mistakes".

• For the flight phase, it specified that:

  - The turn after takeoff shall be into the wind regardless of the location of the fire. If the geography requires turning away from the wind, increase the speed margin before the turn and bank as little as possible. Do not exceed the maximum bank angle.
  - The flight toward the fire shall be at a minimum safety altitude of 500 ft[50] AGL.

• The procedures for aircraft departing from the same base state that the aircraft must maintain separation. If an aircraft is left behind, the pilot should ask the pilot of the lead aircraft to reduce power in order to maintain separation before reaching the fire. When flying to the fire, set the throttle at 90%.

1.18. Additional information

In 2014, an aircraft from the same operator suffered an accident during a flight to drop water. This accident was investigated by the CIAIAC[51] . The aircraft, an Air Tractor 802, crashed while making an evasive maneuver forced by the proximity of a mountain that posed an imminent collision risk. Though the circumstances of this accident were different from those of EC-FBJ, in both cases, though for different reasons, at one point in the flight the pilots found themselves flying near a mountainside at a low altitude and made water drops while banking at angles that exceeded the aircraft's operating limits.

1.19. Useful or effective investigation techniques

Not applicable.

[50] Equivalent to 152 m. If flying over populated areas, the altitude shall be 1000 ft.

[51] A-009/2014. Accident involving an Air Ttractor AT-802, registration EC-LCA, while fighting a fire in the vicinity of Serón (Almería) on 25 May 2014.

2. ANALYSIS

On 27 August 2015, a PZL-M18B aircraft, registration EC-FBJ, crashed into the ground as the result of being at a bank angle of nearly 90° while turning to avoid impacting a mountain. The investigation analyzed both the impact itself and the events leading up to it that caused the aircraft to be in this situation. This approach resulted in the analysis being divided into four areas:

Of the impact:

- The attitude of the aircraft on impact (Section 2.1).
- The crash sequence, in particular an analysis of the motions and positions of the aircraft before coming to a stop (Section 2.2).
- There is also a separate section that considers the suitability of dropping the water in an effort to regain control of the aircraft in extreme situations (Section 2.3).

Of the conditions prior to the impact:

- The preliminary flight, which analyzes the possible reasons why the aircraft was flying at a low altitude and that gave rise to the turn that triggered the accident (Section 2.4).

As a result of the analysis in Sections 2.3 and 2.4 two safety recommendations have been issued to the operator, SAETA.

2.1. Aircraft's attitude on impact

The attitude of aircraft EC-FBJ was analyzed by considering the following significant facts gleaned from the crash site:

- only two trees, 15 m apart, were affected by the aircraft while it was airborne,
- of the second tree impacted (tree no. 2[52]), only some of the branches were affected, with the rest remaining intact,
- branches from tree no. 2 were lodged in the area that houses the engine, and
- the marks on the ground indicated a high impact energy and a very short travel distance on the ground, meaning the impact was energetic but confined.

[52] References from Figure 5.

Based on this information, it was determined that:

- the aircraft's flight path was nearly vertical,
- the horizontal speed component was practically zero, and
- the aircraft crashed at a significant nose-down angle.

These findings regarding the aircraft's attitude immediately prior to the impact are consistent with the two photographs taken by the eyewitness, which show the aircraft descending practically vertically in an inverted position (Figure 1). The little to no horizontal velocity it had on impact and the fact that the aircraft's wings were not level indicates that the pilot had not managed to recover, at least fully, from the stall that was affecting the aircraft prior to the impact. The pilot had, however, corrected the inverted position since when the aircraft impacted the trees, the cockpit was above the landing gear.

2.2. Impact sequence

Based on the damage to the aircraft and on the marks on the ground, the investigators concluded that the impact sequence was as described below.

The aircraft's attitude when it went into the trees was nearly vertical, breaking small branches from the top of tree number 1.

The front of the fuselage (the nose), which was the part closest to the ground, then impacted tree number 2. One of the branches on this tree pierced and was embedded in the engine bay. This impact had two effects: it reduced the aircraft's speed, and it caused a rotation that slightly straightened out the aircraft longitudinal axis. This is probably also the impact that damaged the engine mount.

The impact with the ground followed quickly afterwards. The engine mount finished breaking and the engine started rolling downhill. During this impact, the part that struck with the most force was the right wing, causing it to almost detach completely from the fuselage.

The aircraft, now resting on its belly on the ground, started sliding downhill. During this slide, the aircraft's longitudinal axis must have been facing south, such that the left wing was pointing toward the valley floor. The aircraft slid a few meters until the outer edge of the left wing struck tree number 3. The wing dug into the tree and the aircraft pivoted about the tree, coming to a stop after rotating clockwise, as seen from above, a small distance.

The position in which the aircraft was found and the distance from the last recorded point are consistent with the last two data points in the fleet tracking system.

Despite the high energy impact against the trees, its cushioning effect, along with the aircraft's structure, limited the injuries to the pilot, which would have been more serious given a different scenario or a different aircraft. In fact, the cockpit retained its integrity and the harnesses and seats absorbed the impact. The components used to locate the aircraft also worked properly. In all, no significant aspects were identified involving the response of the aircraft during the impact sequence.

Search and rescue efforts were begun immediately not only because the ELT activated, but because the accident was seen by an eyewitness. The aircraft was also flying in formation. It took approximately 40 minutes to locate the aircraft. The process was hampered by the small number of trees affected and by the density of the tree cover.

2.3. Suitability of dropping water as an emergency measure

The aircraft's attitude on impact was the result of the previous maneuver, captured in the two photographs taken by the eyewitness. From the first photograph, which shows the aircraft banking at an angle of nearly 90° in the middle of a water drop, and considering the water dispersion patterns and the duration of the water drop process, it may be concluded that the drop had been initiated less than a second before the photograph was taken, and that therefore at that point, the aircraft would have had a bank angle very close to 90°. This means the aircraft was performing a maneuver that greatly exceeded the 30° bank angle approved for this aircraft.

In this situation, with the aircraft at an excessive bank angle and laden with water, the aircraft must have stalled, becoming practically uncontrollable. The pilot's decision to drop the water in this position is viewed as a learned response that has been internalized by pilots engaged in this type of flight who think that when faced with any emergency, the water should be dropped in an effort to regain control of the aircraft. This measure seems logical since the reduced weight increases the maneuvering margins (when banking, for example). But it is not directly applicable to every emergency situation or abnormal aircraft attitude. A water drop maneuver results in an abrupt and instantaneous shift in the aircraft's flight conditions. There is a sudden and large shift in the center of gravity, and the instantaneous loss of one-third of the aircraft's weight. The aircraft moves in a direction opposite to the water discharge and the angle at which the wind is striking the wings is subject to change, possibly resulting in a stall profile that did not exist before the drop. For all of these reasons the flight manual specifies that water should be dropped with the aircraft level, and never during a turn.

Based on the aircraft's behavior during this process, it is questionable to think that a water drop during a sharp turn with a nearly 90° bank angle is going to improve the situation or the aircraft's maneuverability. Aircraft EC-FBJ would have been thrown to the left, to the inside of the turn, reducing the turn radius, losing height due to the position it was in and causing the aircraft to stall if it was not already stalled.

This reflection on the suitability of releasing the water or not must be put in the context of the flight at hand. In this case, when the pilot decided to discharge the water, he was in a highly compromised flight position. He probably did not have control of the aircraft and the position of the surrounding terrain did not offer him any alternatives. Trying to level the aircraft without dropping the water would have required horizontal and vertical clearances that he did not have. The collision with the mountains in front of him was imminent since he was not high enough to clear them. Therefore, with or without the water drop, the outcome of the situation would have been the same or similar, and so the option to discharge undoubtedly made the pilot think that it might offer a way out of the situation.

This situation involving aircraft EC-FBJ had already occurred before with another of this operator's aircraft. In both accidents, though for different reasons, the aircraft were making sharp turns and the pilots decided to dump the water while in the turn as a desperate measure to regain control of the aircraft. Since a water drop, depending on the aircraft's position, may not only not help the situation but make it worse, a safety recommendation is issued to the operator to have it study, evaluate and incorporate into its training and procedures those situations in which water drops are beneficial or detrimental, based on the aircraft's position.

2.4. The preliminary flight

As noted earlier, the situation facing aircraft EC-FBJ immediately prior to the impact likely did not offer any options due to the proximity of and the altitude over the surrounding terrain. Despite discussing the suitability of the water drop maneuver, which may prove to be useful information in the decision-making process in other situations, it is necessary to delve into the reasons why the aircraft ended up in this situation.

Prior to the drop, the aircraft was in a high left bank angle position while making a turn commanded by the pilot in order to correct the low altitude at which it was flying.

2.4.1 Bank

No data point or record was available to confirm the reason why the aircraft was at such a high bank angle. The pilot stated that it was a gust of wind that caused the bank. The statements from the crews of the two aircraft engaged in the search after the accident, and who were flying at a low altitude in the area, confirmed this information. They also noted the presence of turbulence and downdrafts.

The information provided by AEMET rules out strong downdrafts in the area, though this does not mean there were not lower intensity downdrafts present. Flights in mountainous areas are more likely to encounter changing weather conditions. In fact, the operator regards the accident flight as a doubly complex flight, both because it took place between mountains and because it took place in an area subject to changing local weather conditions. Furthermore, flying in mountainous areas at low altitudes makes it even more likely to encounter sudden, localized changes due to the mountains, which in effect act as obstacles. In fact, the turbulence and downdrafts had a greater effect on the search helicopter while it was flying between the mountains at low altitude.

In addition to the effect of the weather conditions, the aircraft's speed could also have played a role in the final outcome of the flight. The speeds recorded by the fleet tracking system showed ground speeds on the order of 150 to 160 km/h. Though the wind speed or direction during the flight could not be determined exactly, calculations assuming a wind similar in direction to that at the base at speeds ranging from 10 to 20 kt show that the aircraft's indicated airspeed could have been below that specified in the flight manual for those conditions. The pilot did not report any engine problems that could have explained such a low speed. The lead aircraft, with the same characteristics and with the same load, had a ground speed that was 10 to 20 km/h faster than that of EC-FBJ. Again, the reason for the accident aircraft's low speed could not be determined or accurately confirmed.

2.4.2 Altitude

The low altitude at which the aircraft was flying is believed to have been a consequence of the following conditions:

- The possible prioritization of the water drop phase over the phases of flight prior to and after the drop.
- The fact that the aircraft was part of a formation following another aircraft, which could have had a negative effect at various times:
    - During pre-flight planning, as concerns the altitudes necessary based on the elevation of the terrain.

  - During pre-flight planning, as concerns the weather conditions expected on the flight.
  - During takeoff, by minimizing the climb on runway heading segment.
  - During the flight, by delaying the decision-making process.
- The pilot's limited experience on the aircraft.

Water-drop flights, as is the case with other types of aerial work flights, often involve two very different flight phases: those dedicated to the activity itself, in this case dropping water over a fire, and all the other phases prior to and after the primary activity. The drop phases proper tend to be highly complex and require considerable concentration and effort from crews, while the other phases, because they are not as complex, are more likely to be less worthy of the pilot's attention during the flight and of his time to plan them prior to the flight. The pressure that exists during these flights to reach the fire site quickly is another factor that can affect the amount of time dedicated to pre-flight planning, time that is necessary for every phase of the flight.

The accident of EC-FBJ took place precisely during one of these lower complexity phases, the preliminary flight. This phase of flight, as specified by the operator in its procedures, requires planning at the base prior to takeoff. While it is true that both pilots stated they held a briefing prior to takeoff, it is possible that the changing elevations were not discussed as much as they should have been. The fact that they were flying in formation, along with the pressure to reach the fire site quickly, could also make the pilot flying behind the lead aircraft relax or become complacent, making him paying less attention to information than if he were flying solo or in the lead position.

The elevation of the terrain from the base at Doade to the fire site sloped up. The base was at 587 m and the fire at 1000 m. Castro Caldelas was at an elevation of 786 m. In other words, Castro Caldelas, which is fewer than 9 km away from the base, was already 200 m above the base. And the fire, 18 km away, was 400 m higher. In other words, the pilots should have realized they needed to gain altitude from the start, since the terrain sloped up the entire way.

The pilot did not find himself at a low altitude before the impact due to a sudden or abrupt maneuver. The records from the fleet tracking system show that the aircraft had problems gaining altitude from the start of the flight. On the initial climb, when the wind was lined up with the runway, offering an ideal opportunity to gain altitude, the pilot started a turn immediately after takeoff. The lead aircraft, however, extended this segment and managed to climb 133 m higher. This higher altitude just after takeoff made all the difference in how the flights of these two aircraft, both with similar characteristics and weights, unfolded. The operator's procedures also state that if a turn away from the wind is made after takeoff, the speed has to be increased. That did not happen in this case and EC-FBJ flew lower and slower than the lead aircraft and than was required for the flight.

The decision to start the turn and not prolong the takeoff was probably conditioned by the fact that the lead aircraft had already taken off and was waiting for EC-FBJ. This may have subconsciously introduced an element of haste into the takeoff. Hence the importance of pre-flight planning. If the pilot of EC-FBJ had considered the need to gain altitude as quickly as possible, he would probably have made a different decision at that point in the flight.

The weather conditions also affected the outcome of the flight. Although the exact weather conditions encountered by the aircraft along the route could not be determined, the weather conditions at the base were known. If these conditions persisted near the base, then the aircraft would have had a tailwind while en route to the fire, as turned out to be the case. A tailwind does not affect an aircraft's ability to climb; in other words, the climb rate is not affected, but it does lead to a higher horizontal distance traveled in less time than with a headwind. In this case, the wind along the route made the aircraft approach Castro Caldelas faster. This information regarding the wind along the route should have underscored even more the need to gain altitude as quickly as possible. Thus, the increased elevation of the terrain and the tailwind component they could expect during the flight, at least initially, should have been discussed during the pre-flight planning at the base so as to increase the pilots' awareness of these two factors.

The progress of the flight after takeoff showed, as noted earlier, that one minute and a half after takeoff, the aircraft stopped climbing. From then on, not only did it not gain altitude, it actually lost altitude over the next minute. When it was over the Sil River, after descending, the aircraft climbed again, taking it to point 6 (Figure 4), located a little over 2 km away from Castro Caldelas. The lead aircraft, Doade 1, was above the elevation of Castro Caldelas by the time it reached point 6, and thus had no problem clearing the mountains that Doade 2 crashed into. Doade 2, in contrast, was 30 m below that elevation. Despite this, the pilot continued with the flight and kept losing altitude as he neared the mountains. This shows how already from an early phase in the flight, the aircraft was below the altitude necessary to clear the first obstacle, which was 200 m higher. And yet the pilot continued with the flight. In his statement, the pilot said he was aware of the problem he was having gaining altitude and that at one point, he thought he would not be able to resolve it. His assessment of the situation was correct, but he acted too late, especially in light of his limited speed.

Turning in a mountainous area, flying between mountains, where the effects of wind changes are greater, and with a tailwind pushing him toward the mountains, with an upward sloping terrain, at a low speed and with the aircraft loaded did not leave much room for error. As noted earlier with the hasty turn, it is very likely that flying in formation delayed the pilot's resolve to address a problem that he seemed to have been aware of from the start. The decision to make a turn leads to delays in reaching the fire site and interrupts the planned flight, which in turn affects the formation as a whole since the arrival at the fire has to be coordinated in order to make the water drops more effective. This interruption, therefore, and the ensuing delay it would entail undoubtedly influenced the pilot's delayed decision.

Lastly, as concerns the pilot's prior experience, his training record and flight hours show that he was an experienced pilot who was familiar with the operator's procedures and methods, since he had been on the operator's staff for many years. He had experience fighting fires and he had experience in the area, with this being his second year flying out of that base. The pilot was qualified and had had recent training on the aircraft on topics required by regulations and by the operator's training plan.

This experience, however, had been gained primarily on other types of aircraft with characteristics that differed considerably from those of the accident aircraft, and on flights involving fire observation and coordination, and not so much water drops. Even though he had received training recently on the aircraft on techniques and maneuvers involving approach to and recovery from impending stalls and spins, turns, slow flying, mountain flying and obstacle avoidance, it was not enough. From the start of the firefighting campaign he had been flying other aircraft and making observation and coordination flights, not water drops. As a result, the pilot's lack of experience on the aircraft could have contributed to some extent to his inability to maintain a higher speed and to assess the aircraft's maneuvering capabilities.

In light of all the factors that may have played a role in the accident, a safety recommendation is issued to the operator to have it enhance the pre-flight planning phase and the assertiveness skills of its pilots.

3. CONCLUSIONS

3.1. Findings

General:

- The aircraft had all the licenses required to make the flight.
- The pilot had the licenses, experience and training required to make the flight.
- The investigation was unable to confirm the weather conditions during the flight, though it is very likely that there was a 10-20 kt tailwind and low-level turbulence and downdrafts.
- The pilot had considerable experience flying and in observing and coordinating firefighting activities.
- The pilot had very limited experience on the aircraft.
- Since the start of the firefighting campaign, the pilot had been flying two other aircraft with very different characteristics from those of the accident aircraft. He had been flying this aircraft for 10 days.
- The pilot was familiar with the base and with the operator's procedures.
- The pilot had been trained as per the operator's training plan.

Regarding the impact:

- The aircraft was banking left at an almost 90° angle. It was in that position that the water was dropped.
- Seconds before the impact, the aircraft was photographed descending practically vertically in an inverted position. The pilot was unable to recover from the stall before crashing, though he had managed to right the airplane.
- The aircraft impacted the ground at a very high nose-down attitude, with a highly vertical flight path and with little to no horizontal speed.
- It was a high energy impact.
- The contact with the trees and the aircraft's structure helped to limit the pilot's injuries.
- No foreign object penetrated the cockpit and the pilot survived the impact.
- The harnesses, seat and ELT worked correctly.
- The pilot exited the aircraft under his own power.
- The search and rescue process began immediately. The small area of trees

affected by the impact and the density of the forest hampered efforts to locate the crash site.

- The possibility that glare might have contributed to the event has been ruled out.

Regarding the flight prior to the impact:

- The aircraft took off from the base after an aircraft with the same characteristics and with the same load.
- The aircraft's weight and balance were within limits.
- After taking off, the aircraft turned downwind at the speed specified in the manual. The speed margin specified in the operator's procedures was not considered.
- The accident pilot turned after takeoff earlier than the lead aircraft.
- After takeoff, the aircraft flew slower and lower than the lead aircraft.
- An estimate of the aircraft's IAS shows that it is likely that the aircraft was flying slower than specified in the manual.
- The horizontal separation between the two aircraft increased during the flight.
- Within one minute of taking off, the aircraft was already having problems gaining altitude.
- The pilot realized that his altitude was insufficient to clear the Castro Caldelas mountains, but he waited too long to take action.
- The turn to avoid impacting the mountain was made at a low altitude and probably at a low speed, with turbulence, downdrafts and a laden aircraft.
- The engine did not play any role in the accident.

3.2. Causes/Contributing factors

The accident took place when the pilot lost control of aircraft EC-FBJ during a probable stall while turning at low altitude to avoid impacting a mountain. During the turn, the aircraft was banking at an angle of almost 90º.

The following factors contributed to the accident:

- The possible prioritization of the water drop phase over the other phases of the flight, and which could have affected the pre-flight planning.
- Flying in formation, which could have led to:
    - Incomplete pre-flight planning that did not consider the flight levels and the weather forecast on the route.
    - The hasty takeoff of aircraft EC-FBJ, which was second in the formation, and which forced the climb phase on the runway heading to be shortened, resulting in EC-FBJ not reaching the same altitude as the lead aircraft.
    - A delay in the pilot's decision to remedy the altitude problems that were present from the start of the flight.
- The pilot's limited experience with the aircraft.

4. SAFETY RECOMMENDATIONS

REC 78/16. It is recommended that, for its water drop firefighting flights and for each of the models it operates, Servicios Aéreos y Tratamientos Agrícolas S.L. (SAETA):

- Analyze those situations in which doing an emergency water drop is adequate and helpful to recovering or improving control of the aircraft, and that it
- Incorporate this analysis into its operating procedures and into the training courses it gives its pilots.

REC 79/16. It is recommended that Servicios Aéreos y Tratamientos Agrícolas S.L. (SAETA) review and incorporate into its procedures and pilot training the following aspects involving formation flights during firefighting activities:

- Pre-flight planning for formation flights: The importance of doing pre-flight planning before taking off to ensure that:
  - every phase of the flight is briefed completely and in detail,
  - all the pilots are mindful of aspects that are important to the flight, and
  - this phase is not delegated or ignored by virtue of flying second in the formation.
- Assertiveness in formation flights: The importance of assertiveness during formation flights so as:
  - not to delay decisions,
  - not to be influenced by virtue of flying in formation, and
  - to report any problem during the flight, even if it means delaying the arrival at the fire.