Limited review by Lt-Col (ret'd) Harry Horlings/ AvioConsult, graduate FTE of the USAF Test Pilot School (class 1985A) and former chief Flight Test of the Royal Netherlands Air Force. First text box is on page 15.

The sole objective of this review is the improvement of investigations of engine failure related accidents to prevent future accidents. It is not the purpose of this activity to apportion blame or liability.

ACCIDENT

Aircraft Type and Registration:	Cessna 310Q, G-BXUY
No & Type of Engines:	Two Continental IO-470-VO piston engines
Year of Manufacture:	1970 (Serial No: 310Q-0231)
Date & Time (UTC):	15 November 2013 at 1158 hrs
Location:	Hawarden Aerodrome, Chester
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	1,645 hours (of which 261 were on type) Last 90 days - 18 hours Last 28 days - 6 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was approaching to land at Hawarden Aerodrome at the end of a flight from Lognes-Emerainville Aerodrome near Paris. The aircraft deviated to the left of the runway on final approach and appeared to witnesses to become unstable before it pitched up and rolled to the left. It struck the ground in a steep nose-down inverted attitude. The investigation concluded that the left engine lost power at a late stage of the approach due to fuel starvation. The pilot probably attempted a go-around manoeuvre, but the speed fell below the minimum single engine control speed, causing him to lose control of the aircraft. The cause of the fuel starvation was attributed to mismanagement of the aircraft's fuel system.

Background to the flight

The pilot acquired G-BXUY in 2002. In September 2008, the aircraft began an extensive refurbishment programme at Hawarden and the pilot did not fly it again until August 2013, after the work was complete. At that time, he flew four flights in the aircraft with an instructor and examiner, when he renewed his Multi-Engine Piston (MEP) rating and passed a routine Licence Proficiency Check (LPC).

The pilot, who was from the Hawarden area but had a home in Andorra, flew G-BXUY to Seo de Urgel Airport in Catalonia, 12 km south of Andorra, arriving there on 12 August 2013. He then used the aircraft to fly between airfields in Spain and France before, on 7 November 2013, flying it from Seo de Urgel to Lognes-Emerainville Aerodrome, to the east of Paris.

History of the flight

Weather conditions on 15 November were fine. The pilot filed a flight plan for a departure at 0900 hrs, but this was subsequently delayed and the aircraft actually took off at 1001 hrs. The flight routed south of Paris before turning onto a north-westerly track which took it across the Channel towards Bognor Regis on the south coast. It then flew an approximately straight line to Hawarden, passing to the west of Birmingham. The aircraft initially flew at about 1,500 ft amsl (due to controlled airspace around Paris), before climbing to 4,500 ft over northern France, maintaining that altitude until nearing Hawarden.

The pilot was in routine contact with Air Traffic Control (ATC) during the flight and transmissions between the pilot and ATC were recorded and available for analysis. During the aircraft's progress through UK airspace, the pilot requested, and was provided with, a basic air traffic service from several ATC units: London Information, Farnborough West, Brize Norton, Shawbury, and Hawarden. The only non-routine radio exchange occurred when the Farnborough West controller noticed that the aircraft's altitude reporting transponder was giving ATC an erroneous altitude reading, requiring him to verify the aircraft's true altitude with the pilot. The pilot made no transmissions to suggest that the flight was not proceeding entirely normally.

When the aircraft was 12 nm from its destination, the pilot contacted Hawarden ATC and was informed that Runway 22 was in use. The surface wind was reported as being from 280º at 5 kt. Another light aircraft was in the circuit on a training flight; the instructor of that aircraft later commented that the conditions were good enough for his inexperienced student to make his first attempts at landing the aircraft. The training aircraft was downwind as G-BXUY turned on to final approach, and was not therefore in confliction. The pilot of G-BXUY called "FINAL" and was cleared to land. He acknowledged with the words "CLEARED TO LAND, GOLF UNIFORM YANKEE". This was the last transmission from the pilot, made just over a minute before the aircraft crashed. Again, all transmissions between the pilot and Hawarden ATC had been entirely routine; there were no unusual background noises on the pilot's transmissions and he seemed calm and collected.

The aircraft continued towards the runway, watched by staff in the control tower as well as other airfield personnel and a number of witnesses on an industrial site adjacent to the runway. The approach seemed normal until its late stages, when the aircraft deviated left of the runway centreline. When the aircraft was at a low height (witness estimates ranged between 10 ft and 50 ft), it seemed to become unstable. The Tower controller reported the wings rocking, as if the aircraft suddenly experienced buffeting from a strong wind, and generally having the appearance that something was not right. She thought it likely that the pilot would go-around[1] from the approach.

Of the other staff in the Tower, some saw the initial 'instability' (which appeared also to include a yawing element), and most described seeing the aircraft pitch to an unusually high nose attitude. The aircraft may have climbed a short distance, before the left wing dropped

Footnote

[1] A manoeuvre in which the landing is discontinued and the pilot applies power (typically full power) to climb.

and the aircraft rapidly rolled to the left, striking the ground to the left of the runway (viewed from the approach).

Other witnesses also variously reported yawing motions and wing rocking before a pitch-up and roll to the left. Some also likened it to the aircraft suddenly experiencing turbulence from a strong gusty wind, or as if a student pilot was attempting a first landing. Most of these witnesses were on the side of the runway on which the aircraft crashed (the opposite side to the control tower). Several reported that the aircraft was deviating to left of the runway centreline, and probably over the grass, before the pitch-up and left roll occurred.

Those witnesses who described unusual engine sounds reported apparent changes in engine or propeller speed. One witness reported hearing alternating high and low “revving” and on looking up saw the aircraft yawing from side to side and the wings rocking. Another witness, who only heard and did not see the aircraft, reported hearing what sounded like a very sudden increase in propeller rpm for no more than a second before suddenly reducing again. Other witnesses reported engine sounds increasing in engine volume immediately before the accident, although some reported nothing unusual.

Rescue activities

Aerodrome Rescue and Fire Fighting Service (RFFS) appliances were quickly on scene and their crews began life saving activities on the two occupants, who were exhibiting signs of life at this stage. Both occupants had been wearing seat belts and both were initially trapped in the wreckage and treated in situ until freed with the use of hydraulic rescue equipment. Local fire and ambulance vehicles also arrived on scene. Despite the efforts of the RFFS staff and the paramedics, the pilot died at the scene from his injuries. The passenger was taken by ambulance to Chester hospital but succumbed to her injuries a short while later.

Recorded data

The aircraft was not fitted with a Flight Data Recorder, nor was it required to be. However, the pilot was known to use a flight planning and navigation application on his tablet computer and apparently did so for the accident flight. Although the tablet suffered extensive damage, track points associated with the accident flight had been recorded and were successfully downloaded for analysis. The nature of the system that was gathering the position data is such that it can use different sources of data for position fixes. However, recorded accuracy figures indicate that the system was using GPS satellite data as the source of the positional information. The flight path of the final approach and accident sequence is shown in Figure 1.

Recorded data from the pilot’s tablet computer allowed a speed analysis of the latter stages of the flight. Speed and altitude data for the final approach and accident sequence is shown at Figure 2.

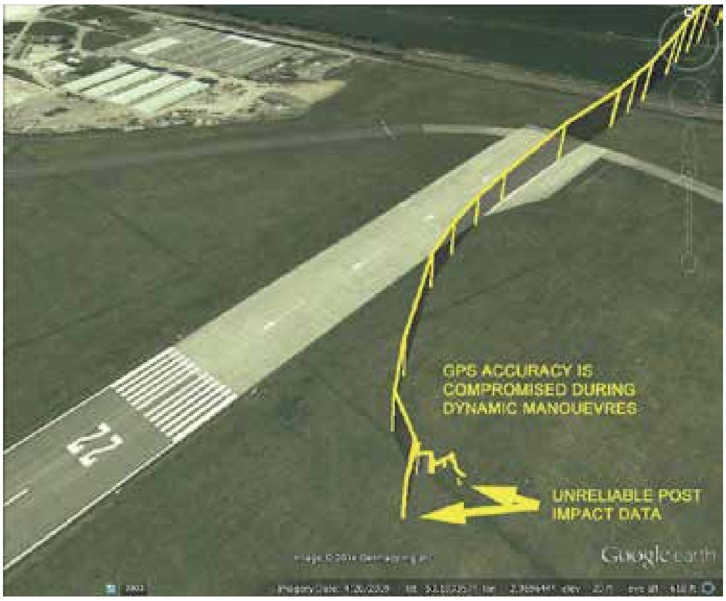

Figure 1

Recorded flight path: final approach and accident sequence

Aircraft information

The aircraft was a Cessna 310Q powered by two Rolls Royce Continental IO-470-VO engines. The fuel system for the aircraft consisted of four fuel tanks: two 51 US gallon (193 litre), wingtip-mounted, main fuel tanks and two 20.5 US gallon (78 litre) auxiliary fuel tanks in the outboard section of each wing (Figure 3). A pair of fuel selector switches, mounted on the cockpit floor, operated a fuel selector valve immediately outboard of each engine, which allowed each engine to receive fuel from its respective main or auxiliary tank, or to cross-feed fuel from the other main tank. The cross-feed, which was intended for emergency use, was the only interconnection between the left and right fuel systems.

The auxiliary tanks were designed for use in cruising flight so were not equipped with their own fuel pumps. For this reason, operation at less than 1,000 ft agl on auxiliary tanks was not recommended.

Each fuel tank is fitted with a capacitive sensor which provides fuel quantity readings to a pair of gauges in the cockpit. The gauges (Figure 4) automatically provide an indication of the fuel quantity in the fuel tanks selected by the fuel selector. A self-centring switch below the gauges allows the pilot to verify the contents of the other, non-selected tanks. Auxiliary tank indicator lights below the gauges illuminate when the associated auxiliary tank is selected for engine feed. The optional main fuel tank low quantity warning lights had not been fitted to G-BXUY. A dual fuel flow gauge was also fitted.

The aircraft had been fitted with two Hartzell PHC-C3YF-2UF three-bladed, constant speed propellers in accordance with Hartzell Supplementary Type Certificate SA234CH. Constant speed propellers and their control systems (governors) are designed to maintain the engine rpm selected by the pilot by automatic variation of propeller blade pitch angle. The propeller

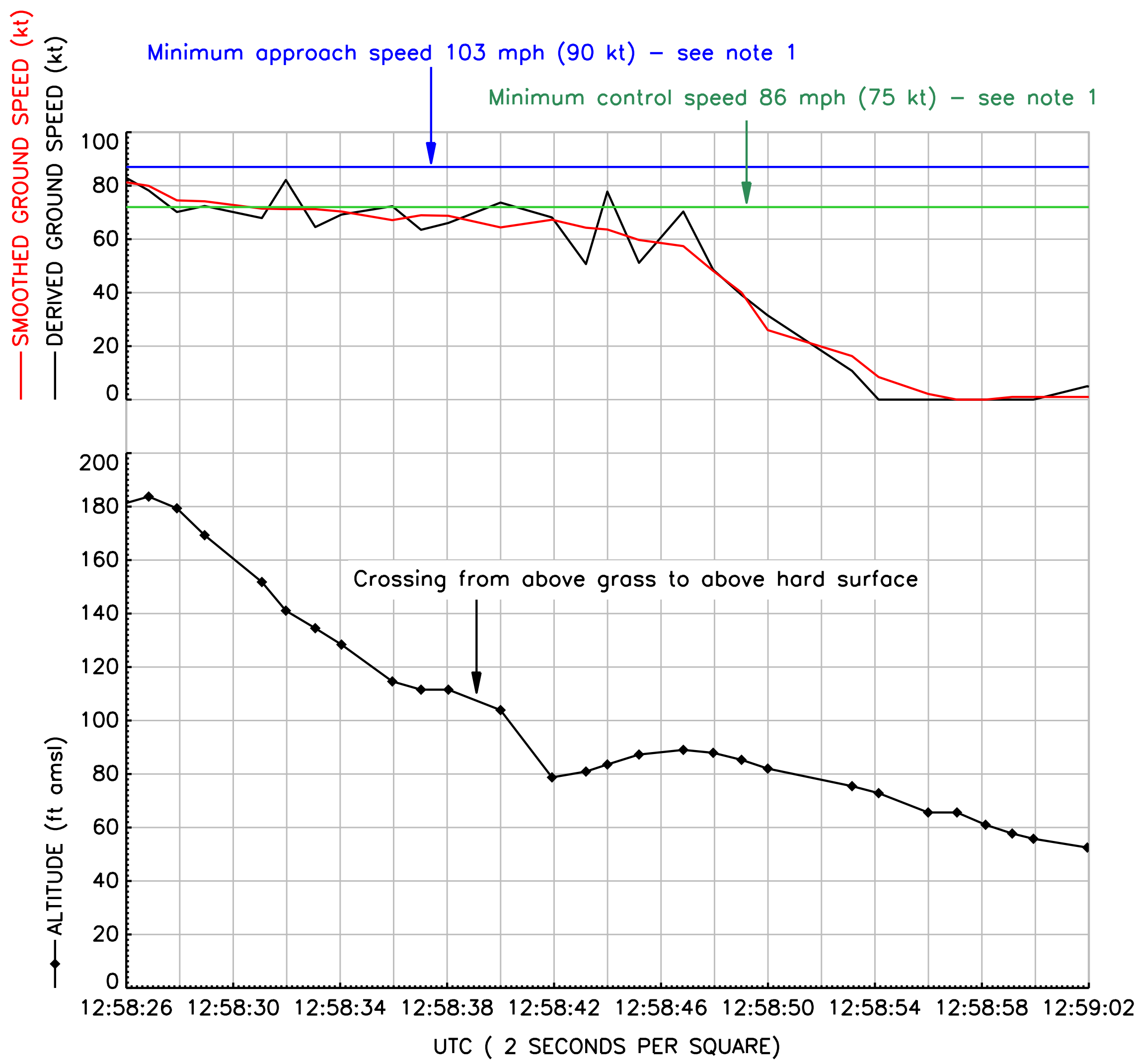

Figure 2

Recorded altitude data and derived speed

Note 1. A 3 kt headwind allowance is factored into the displayed minimum speed
Note 2. GPS accuracy is compromised during dynamic manoeuvres
Note 3. GPS altitude continued to drift down post-impact as altitude errors continued over time

governors supply metered high pressure engine oil to the propeller to control the propeller blade pitch. In the event of a loss of engine oil pressure the propellers fitted to G-BXUY would automatically move to the feathered position to minimise drag. When the engine is stopped on the ground, it is undesirable to feather the propeller, as the high blade angle will inhibit engine starting. To prevent this, the propellers incorporate a spring-operated pitch lock. If propeller speed falls below 800 rpm the spring force causes the latches to close and prevents the propeller blades from feathering during engine shutdown.

In the event that an engine begins to gradually lose power due to a fuel supply or mechanical problem, the propeller control system will automatically maintain engine speed by reducing the blade pitch until it reaches the FINE position. This may mask a problem with the engine until the propeller systems become unable to maintain the selected engine speed.

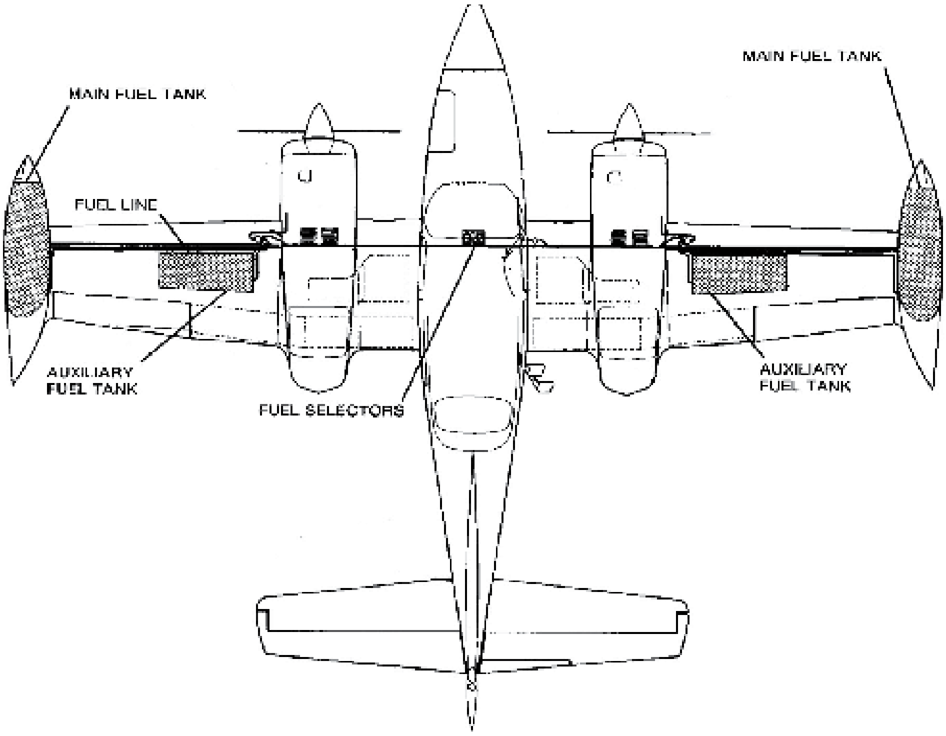

Figure 3
G-BXUY fuel system

Figure 4
G-BXUY fuel quantity gauge
(electrical power not applied)

Initial aircraft examination

Ground marks indicated that the aircraft first struck the ground inverted, in a steep nose-down attitude 115 m beyond the left edge of Runway 22 and 15 m before the threshold markings. After the initial impact the aircraft travelled backwards on its main landing gear for approximately 20 m before coming to rest (Figure 5). The fuselage of the aircraft had failed immediately aft of the main spar and the nose of the aircraft had been severely damaged. The right tip tank had ruptured and separated from the wing and the right wing exhibited compression damage to the outboard leading edge. The right propeller had dug into the ground during the initial impact which had resulted in a failure of the engine crankshaft and separation of the propeller. The left propeller remained attached to its associated engine.

Figure 5
Accident site

Inspection confirmed the continuity of all of the flying control circuits and that the flaps were deployed to a position of approximately 35°. The landing gear was down and locked. Both engine throttle levers were in the fully forward position, the propeller control levers were fully forward in the INC position and the fuel levers were in the FULL RICH position. These control positions corresponded to the positions of the engine throttle valves, the fuel mixture control and the propeller governor input levers on both engines. Both fuel tank selector switches were set to MAIN. The left main (tip) tank was undamaged but the quantity of fuel in the tank was too small to recover on site. The ruptured right main (tip) tank showed little evidence of the presence of fuel and there was no evidence of fuel spillage on the accident site. It was assessed that the tank was unlikely to have held more than about 10 litres of fuel, probably less. Fuel samples were taken from both engine fuel injection manifold valves. The right engine valve was found to be full of fuel, whereas the left engine valve was approximately 50% full. Approximately eight gallons (30 litres) of fuel was recovered from each auxiliary fuel tank.

Examination of the right propeller showed that rotation of the propeller during the initial impact had caused all three blades to dig into the ground; two of the blades exhibited significant rearwards bending of the blades at approximately half span as a result of rotation through the soil (Figure 6). The left propeller exhibited significantly different damage from the right; one blade had been bent backwards and the remaining two blades had been bent forward at mid-span. There was little evidence of rotational damage to any of these blades.

Figure 6
Left and right propellers

Maintenance history

Examination of the aircraft records showed that the aircraft was compliant with current UK airworthiness requirements. Between September 2008 and July 2013, the aircraft had undergone extensive maintenance as a result of scheduled structural inspections. This involved the replacement of a number of significant structural items including the wing spars. During this maintenance the aircraft fuel system was removed and inspected, the ignition systems, propellers and propeller governors were overhauled and the fuel quantity indication system recalibrated.

Detailed aircraft examination

The investigation focused on the aircraft's control systems, the fuel system, engines and propellers. No evidence of a pre-impact defect or restriction was identified within the aircraft's flight control circuits.

Testing of the aircraft fuel system confirmed that the cockpit fuel tank selectors and the respective fuel selector valves were correctly rigged and no evidence of a blockage or restriction was found in the aircraft fuel system. The left main fuel tank was disassembled and two litres of fuel were recovered. Both main fuel tank electric pumps were found to be operational. Tests carried out on the main fuel tank quantity sensors, the fuel quantity and fuel flow gauges confirmed that they operated normally and were correctly calibrated.

There was no evidence of a major mechanical failure in either engine and tests confirmed that both of the engines' ignition systems and propeller governors were operational. Examination of the failure surface of the right engine crankshaft showed that it had failed due to a combination of bending and torsional overload.

Two of the blades fitted to the right propeller showed chordwise witness marks and exhibited significant twisting and rearward bending along the span of the blade. One of these blades, the first to enter the ground, was found to be at a higher pitch setting when compared to the other two blades, which appeared to be at or close to the FINE pitch position.

The damage to the left propeller showed significant differences from that observed on the right. Damage to the propeller spinner was restricted to one third of the circumference, corresponding to the position of the propeller blade which had been bent backwards and little evidence of rotational damage was observed. All three of the blades on the left propeller appeared to be at or close to the FINE pitch position.

Both propellers were stripped and examined at an approved overhaul facility under AAIB supervision. Examination of the right propeller and its records confirmed that the No 3 blade was locked at a higher pitch angle than the remaining two blades and that it had been the first blade to strike the ground. Disassembly of the pitch change mechanism showed that the pitch locks had engaged and that the No 3 propeller blade pitch change knob, attached to the blade root, had failed in overload. This was consistent with having been caused during the impact sequence. A witness mark associated with the failure of the pitch change knob was found on the pitch change slot in the blade preload plate. Based on the position of the witness mark on the preload plate slot, it was estimated that the blade pitch when the pitch change knob failed was 27º. Additional witness marks on the faces of the preload plates, made by the pitch change fork, confirmed that at some point during the impact sequence all three blades had been at a pitch angle of 15º. Damage to the internal flanges of the propeller hub halves was consistent with all three blades being subject to a large rearward force. No evidence of a pre-impact failure or defect was found during the disassembly and inspection.

Discussion with the propeller manufacturer confirmed that the engine would have been capable of producing sufficient power at its maximum governed speed of 2,625 rpm to generate a propeller blade pitch angles of 15º during the early stages of a go-around. It was also determined that the engine would not be able to generate sufficient power to produce a blade angle of 27º in similar conditions.

Inspection of the left propeller confirmed that the No 3 propeller blade had been bent rearwards and the Nos 1 and 2 blades had been bent forward. Disassembly of the left propeller confirmed that there were no witness marks on the propeller pitch change mechanism which could give an indication of blade pitch at impact and the propeller blades had been prevented from feathering by closure of the pitch locks. Damage to the internal flange of the propeller hub halves was consistent with the No 3 propeller blade having been subject to a rearward force and the Nos 1 and 2 blades being subject to a forward force. No evidence of a pre impact defect or failure was identified within the propeller.

Pilot information

The pilot's flying licence, Class One medical certificate and aircraft class rating were all valid. He gained a PPL (Aeroplanes) in 1996 and subsequently took ownership of a Socata TB9 Tampico aircraft. In 2000, he also gained a PPL (Helicopters) and flew a mixture of fixed wing and rotary wing after that time. He gained a CPL (Aeroplanes) in November 2002 and a CPL (Helicopters) in June 2003. Although he held professional pilot qualifications, the pilot did not fly as a commercial pilot and only exercised the private pilot privileges of his licences.

The pilot first gained a multi-engine rating in October 1997 which he renewed in 2002, prior to taking ownership of G-BXUY. The pilot's MEP rating lapsed after G-BXUY began its refurbishment programme in 2008, but he renewed the rating at Hawarden on 6 August 2013, flying G-BXUY on its return to service. At the time of the accident, the pilot had flown 329 hours multi-engine, of which 261 hours were in G-BXUY. Between the pilot first flying G-BXUY post-refurbishment on 5 August 2013 and the day of the accident, he flew 20 flights in the aircraft, totalling 28 flying hours.

The examiner who flew with the pilot in August 2013 described the pilot's flying as competent, including his single engine handling. The examiner had needed to make only minor comments on the pilot's overall performance. The pilot's father, also an experienced private pilot, described his son as being competent and meticulous. With regard to fuel planning, the pilot was known for always using a dipstick to measure fuel quantities before flight rather than relying on fuel gauges, and would have been aware of the exact quantity of fuel required for a flight. The pilot was also described as being very sensitive to fuel economy and aware of fuel prices at different airfields. These comments were supported by an airline pilot who flew with the pilot in 2006. He reported that the pilot seemed very competent and spent considerable time in flight achieving the most economical running conditions for the engines.

It was established that the pilot telephoned Hawarden before the accident flight to enquire whether he could purchase fuel at a favourable rate, as he had flown at Hawarden for many years and was well known there. He established that he could, which would make the fuel available at Hawarden 9p / litre cheaper than that at Lognes-Emerainville.

Medical and pathological

The pilot was examined for his Class One medical certificate on 13 May 2013, which was valid for one year. He was described as being in good health and living an active lifestyle.

Post-mortem examinations of the pilot and his passenger revealed that each had died from injuries consistent with having been sustained during the accident sequence. There was no underlying natural pathology in the pilot which could have contributed to the accident. Toxicological investigations indicated that the pilot was not under the influence of alcohol, therapeutic or prescribed drugs nor illicit and abused drugs. His blood carbon monoxide level was low, indicating that he had not been exposed to the effects of carbon monoxide.

Navigation and route planning

Aeronautical charts covering the route from Longes-Emerainville to Hawarden were recovered from the aircraft. The charts were unmarked and there was no physical evidence of a prepared navigation log.

Tablet computer data

When the flight planning and navigation application on the pilot's tablet computer was accessed, an active route from Longes-Emerainville to Hawarden was present. It was a total of 410.9 nm long, and was predicted to take 2 hours 34 minutes and consume 206 litres of fuel. The predictions were based on a speed of 160 kt and a fuel consumption of 80 litres/hour, figures entered by the pilot and stored in memory (the cruise speed is consistent with that nominated by the pilot on his ATC flight plan). For individual flights, an optional average wind entry could be made. As found, there was no average wind entry, which thus defaulted to zero. It was established empirically that an average wind component, once entered, remained the default value, even if the tablet was switched off and on again. To illustrate the effect of wind entry, an average wind component of 020°/15 kt (based on the forecast winds taken from meteorological information issued on the morning of the accident) produced a revised flight time of 2 hours 41 minutes and a revised fuel burn of 215 litres.

The recorded route commenced 22 minutes after the reported takeoff time, when the aircraft was to the south of Paris. It was not established why the first part of the route was not recorded, but it may be that the tablet was switched off until that point.

A single planned flight existed in the tablet's memory for a flight from Seo de Urgel to Lognes-Emerainville, the route the pilot flew on 7 November 2013. The recorded actual flight time was 3 hours 5 minutes, which would have consumed about 247 litres at 80 litres/hour.

Flight planning calculations

The investigation reconstructed a flight planning sequence using the pilot's own performance data, the route data from the tablet computer and forecast wind information which would have been available to the pilot. This wind information, taken from Met Office Form 214 for the day of the accident, showed forecast winds at 1200 hrs of 040°/25 at 1,500 ft over northern France and the Channel, increasing to 050°/30 kt at 5,000 ft. Further north, over England, the wind at 5,000 ft gradually backed and reduced to 010°/10 kt. Using this data, the planned flight time increased to 2 hours 41 minutes, consistent with the tablet prediction with an average wind entered, but still considerably shorter than the actual time of 2 hours 57 minutes.

The time the route recording started was consistent with the expected time at that position. However, analysis showed the aircraft made slower than expected progress from that point during its flight over France and the Channel such that it was about 15 minutes later than expected crossing the south coast. For about the last 50 minutes of flight, the aircraft made progress approximately according to the calculation. Revised calculations for most adverse likely winds over France and the Channel failed to account fully for the extra time, so it was concluded that the aircraft probably flew more slowly than planned for some reason, before resuming planned cruise speed for the latter part of the flight.

The flight plan submitted by the pilot included his elapsed time estimates for entering the London Flight Information Region (FIR) and for arrival at Hawarden. These were 25 minutes and 2 hours 15 minutes respectively. These figures were inaccurate: the total time given was more consistent with a direct line routing in still air conditions, while the estimated elapsed time to the FIR boundary should have been about 1 hour 13 minutes.

Fuel planning

Fuel calculations during the investigation used the pilot's average planning figure of 80 litres/hour. Calculations assumed a serviceable fuel system with no leakage; the possibility of this not being the case is discussed in the analysis section of this report.

Assumed fuel quantities and distribution at the time of the accident are shown at Table 1. The figures are based on measured fuel quantities except for the right main tank, which was an estimated figure, based on the evidence from the accident site and assuming approximately equal fuel use from both sides during the flight.

Fuel tank quantities (litres)				
Left Main	Left Auxiliary		Right Auxiliary	Right Main
2	30		30	6
Total fuel 68 litres				

Table 1

Estimated fuel quantities at the time of the accident

Based on the actual flight time, the flight would have consumed about 236 litres. Thus, the aircraft would have taken off with about 304 litres of fuel (68 litres remaining, plus 236 litres trip fuel).

It was established that the aircraft was refuelled with 103 litres at Lognes-Emerainville on the morning of the accident, so the aircraft would have landed there with about 201 litres on board. The inbound flight from Spain, which took 3 hours 5 minutes, would have used about 247 litres. The aircraft therefore probably left Seo de Urgel with about 448 litres of fuel. This would be consistent with the last refuel before departure from Seo de Urgel, when 422 litres were uplifted.

The expected fuel consumption figure used by the pilot for deciding the fuel load for departure is unknown, but is likely to have been based on the tablet prediction for either still air (206 litres) or average wind (215 litres). The pilot would have added a suitable reserve fuel to his minimum requirement. Again, the figure used is unknown but a typical reserve fuel, sufficient for 30 minutes holding time at the destination, would be about 40 litres (including unusable fuel of about 7 litres). Using this information, three possible planning scenarios are presented at Table 2.

No	Option	Flight time (hr:min)	Trip fuel litres	Reserve fuel litres	Total fuel litres
1	Flight Plan estimate	2:15	180	40	220
2	Using still air conditions	2:34	206	40	246
3	Using forecast winds	2:41	215	40	255

Table 2

Possible fuel planning scenarios

Aircraft mass and balance

An aircraft mass and centre of gravity schedule was recovered from the pilot's documents. This was based on a weighing report dated 19 November 2004, which was the most recent available.

Calculations were performed to establish the aircraft's mass and balance condition at the time of the accident, using actual weights for the two occupants and actual weights for luggage and items of equipment not included in the weighing report. The estimated fuel load was as shown at Table 1 (small variations in quantity of fuel in the main tanks would not significantly affect the balance calculations due to the position of the tanks). Luggage and miscellaneous items in the cabin accounted for 105 kg. Although there was evidence that some of the luggage had been restrained, significant movement of luggage and equipment had taken place during the accident sequence. Therefore, two calculations were made, one based on an evenly spread load and a second based on the most adverse (aft) loading possible.

The aircraft weight at the time of the accident was calculated as 2,038 kg (4,494 lb). The maximum landing mass was 2,404 kg (5,300 lb). The centre of gravity for the evenly distributed case was 74% aft of the forward limit. The theoretical worst case loading scenario placed the centre of gravity at 81% aft of the forward limit. Thus, the aircraft was found to be within the mass and balance limitations, with a relatively aft centre of gravity.

How to read? Was the cg near aft limit?

meaning that actual Vmca was close to published Vmca (for cg location)

Aircraft performance

Conventional twin engine light aircraft such as G-BXUY are subject to the same principles of aerodynamics as single engine aircraft but there are differences which arise from the location of the engines on each wing. One advantage of wing mounted engines is that significant extra lift is derived from propeller slipstream over the wings. Like single-engine aircraft, twin-engine aircraft generally have left turning tendencies due to asymmetric propeller loading and torque, but this effect is greater in twin-engine aircraft, particularly during high angle of attack manoeuvres.

Only if props both turn clockwise.

When a twin-engined aircraft loses power on one engine, the asymmetric thrust that results requires positive and prompt pilot control inputs to counter the yawing and rolling tendencies, particularly if the operating engine is at a high power setting. The loss of power, combined with a significant increase in drag and loss of lift due to the reduced slipstream effect, may make sustained level flight impossible to achieve in some cases.

The (only one applies in-flight during takeoff and go-around - V_{MCA})

Aircraft manufacturers generally produce minimum and recommended speeds to fly with one engine inoperative. ~~A~~ minimum control speed (V_{MC}) represents the lowest airspeed that the aircraft can be controlled with one engine inoperative and the other at full power. It normally assumes a clean configuration, with the critical engine[2] failed (and its propeller feathered if an automatic feathering device is installed).

can maintain straight flight while banking 5° away inop engine.

For G-BXUY, the critical engine was the left engine, and the Vmc speed stated in the aircraft owners' manual was 86 mph (75 kt). The manufacturer's recommended safe single engine speed was 105 mph (91 kt), with a best single engine rate of climb speed of 116 mph (101 kt). The owners' manual stated:

V_{YSE}

V_{SSE} is for safely shutting down one engine in-flight for training purposes.
V_{YSE} + bank angle for max. range, V_{XSE} +bank for maintaining altitude.

> *'Although the aircraft is ~~controllable~~ at the minimum control speed, the aircraft performance is so far below optimum that continued flight near the ground* at V_{MC} *is improbable. A more suitable recommended safe single-engine speed is 105 MPH IAS since at this speed, altitude can be maintained more easily while the landing gear is being retracted and the propeller is being feathered.'*

Bank angle requirement missing for V_{MC} to be valid and minimum drag.

The manufacturer's minimum approach speed with 35° flaps was 103 mph (90 kt), with power being reduced only just before touchdown. In case of a single-engine go-around, the target speed was 116 mph (101 kt). =V_{YSE}

What is the definition of V_{MC} in the manual?

Analysis

Technical investigation

No pre-impact defects were identified within the aircraft flight control or fuel systems and there was no evidence of a pre-impact mechanical failure within either engine or propeller or their associated control systems.

The witness marks observed on the faces of the right propeller preload plates indicted that all three propeller blades were at the same pitch angle of 15° at the start of the impact sequence. The damage observed to the right propeller blades and the failure of the right engine crankshaft was consistent with the engine operating at high rpm at impact. Analysis of the blade pitch angle data by the propeller manufacturer confirmed that a blade pitch angle of 15° was consistent with a Continental IO-470-VO engine operating at its maximum governed speed of 2,625 rpm, as may be expected during the early stages of a go-around. Given that the No 3 blade of the right propeller was the first blade to enter the ground, it is thought that the forces acting on the blade were sufficient to twist the blade in the hub, resulting in the failure of the pitch change knob and an increase in blade pitch when compared to the remaining two blades.

The lack of rotational damage to the left propeller, and the deformation of its blades, was consistent with the left engine operating at low power at impact despite all of the engine controls being in the 'full power' position. The closure of the left propeller blade pitch locks

Hardly any difference with other failed engine.

Footnote

[2] The critical engine is the one whose failure most adversely affects the performance or handling characteristics of the aircraft.

For investigators this means that the actual Vmca was closer to the published Vmca than when the other engine would have failed. Published Vmca applies after failure of any engine. Don't mention this, because critical engine is for design and flight-test only.

indicated that the engine was operating and that the engine speed was at or above idle rpm at impact but no further estimation of the engine speed could be made.

The absence of fuel within the left main fuel tank and the limited quantity of fuel recovered from the left engine fuel injection manifold valve indicated that the probable reason for the difference in engine power was fuel starvation. Given the lack of evidence of fuel spillage from the right main fuel tank, it is considered that the right hand fuel system was also at a low level and that the right engine would also have begun to experience fuel starvation problems had the flight continued for any length of time.

The possibility of a fuel leak occurring during the flight was considered, but discounted for the following reasons: there was no physical evidence for a leak (other than the low fuel state); the pilot did not declare an emergency or change his course of action; and a leak would have had to affect both sides simultaneously, which was considered unlikely.

Final approach flight path

It is probable that G-BXUY's deviation to the left on final approach was a result of the left engine losing power, a situation which the properties of the constant speed propeller system may initially have masked from the pilot and which would have given rise to the apparent control difficulties described by all eyewitnesses. The aircraft drifted to the side of the runway, with very little height or time available to the pilot to correct. Faced with the alternative of landing on the grass, the pilot appears to have attempted to fly a go-around.

Given that the situation developed quickly, it is not certain that the pilot would have been fully aware of the exact nature of the problem, although he was probably aware (as discussed later) of the low fuel state in the main tanks. The speed had apparently been allowed to drop below the minimum approach speed, which may be due in part to the loss of power as the left engine became starved of fuel.

(or below V_{MC} for wings level)

All the available evidence is consistent with a go-around attempt, during which the pilot would have selected full power. It is possible (and there is some witness evidence to support the possibility), that the left engine responded to the pilot's selection, but only for a very short time. A fluctuating power delivery from the left engine would also account for the control difficulties seen at this time. However, the aircraft was by now at or below the minimum control speed, and would have slowed further as it pitched up. The reason for the exaggerated pitch attitude was not positively identified, but thought to be most likely due to a combination of increased engine power (which naturally produces a pitch-up on this aircraft type) and applied nose-up trim associated with the low speed. The increase of power on the right engine would have created an asymmetrical power condition, and the pilot would have been unable to control the resultant left yaw and roll.

With no indication from the pilot that he was experiencing a technical malfunction, the investigation sought to establish why the aircraft's main fuel tanks ran critically low on fuel on final approach, when there was sufficient fuel on board the aircraft for about another 45 minutes flying time.

Fuel load and distribution

An attempt was made to predict the likely fuel load and distribution at various stages of the two final flights. The results are shown at Table 3 and discussed in subsequent paragraphs.

Event	Total fuel litres	Fuel distribution			
		Left main	Left aux	Right aux	Right main
Refuelled with 422 litres					
Depart Seo de Urgel	448	193	31	31	193
Trip fuel 247 litres					
Arrive Lognes-Emerainville	201	70	30	30	71
Refuelled with 103 litres					
Depart Lognes-Emerainville	304	121	30	30	123
Trip fuel 236 litres					
Arrive Hawarden (accident)	68	2	30	30	6

Table 3

Estimated fuel quantities and distribution since departure from Seo de Urgel

The aircraft did not depart Spain with all tanks full, as it could then have reached Hawarden without refuelling. With an estimated 448 litres of fuel on board on leaving Seo de Urgel, 31 litres would have been in each auxiliary tank (normal practice would be to fill main tanks first). This correlates closely to the fuel quantity recovered from the auxiliary tanks (60 litres) during the investigation.

Refuelling with 422 litres at Seo de Urgel was only possible if fuel was put in the auxiliary tanks. This required a deliberate action, as the tanks were refuelled via separate filler caps, and indicates that the pilot regarded the auxiliary fuel tanks as usable at that stage. As a refuelling in Lognes-Emerainville was apparently planned, and each of the flights could comfortably be made with main tank fuel only (total capacity 386 litres), there would have been no need to load or use auxiliary tank fuel. The investigation therefore considered it likely that, at the planning stage, the pilot would have regarded the auxiliary fuel as a contingency fuel for unforeseen circumstances. In this case, it is more likely that he would originally have intended to use the fuel during the return journey to Spain rather than during the accident flight.

At Lognes-Emerainville there would have been ample capacity in the main tanks so the pilot would have had no reason to put any fuel in the auxiliary tanks. Therefore, it was concluded that the aircraft departed with 304 litres, consisting of 244 litres approximately evenly distributed in the main tanks, and the existing auxiliary tank fuel of about 60 litres.

Fuel plan for the accident flight

It was not possible to establish what fuel load the pilot would have regarded as a minimum for takeoff but, as he refuelled the aircraft on the morning of the accident flight, all necessary weather and wind information would have been available to him in order to decide on a suitable amount. Considering the pilot's known attitude to fuel prices, and the fact that he established cheaper fuel was available at Hawarden, it is unlikely that he would have loaded more fuel than he considered necessary, particularly as the auxiliary tank fuel was also available if needed.

The tablet computer, in its 'as found' state, did not included an average wind component, suggesting that the pilot may have used a still-air fuel prediction, a possibility supported by the close correlation between the estimated main tank fuel (244 litres) and planned fuel from Table 2 (246 litres). The only firm evidence regarding the pilot's expected flight is his estimate of a 2 hours 15 minutes flight time to Hawarden. Although this was a very inaccurate figure, and unlikely to be the basis for his fuel decision, it may indicate that the pilot expected a significantly quicker flight time than that achieved, possibly because the prevailing wind had not been taken into account.

If, as already discussed, the pilot's original intention was to regard auxiliary tank fuel as contingency fuel, he would have aimed to load sufficient fuel into the main tanks for the flight. The still-air fuel required was 206 litres and the fuel required when taking prevailing winds into account was 215 litres. Thus, with 244 litres in the main tanks, the investigation concluded that the pilot originally intended to complete the flight using fuel from the main tanks only, in the knowledge that auxiliary tank fuel was available if necessary.

Conduct of the accident flight

Had the pilot planned on using auxiliary tank fuel during the accident flight, it would have been normal practice to use it relatively soon after takeoff. Whether originally intended or not, had he tried to use the auxiliary fuel but been unable to for any reason, it may be expected that he would have made arrangements to refuel en-route, for which there were adequate alternative airfields.

The extra flight time, which was presumably unexpected, was incurred in the first half of the flight. Once the aircraft was over southern England, a comparison between expected and actual fuel load would have revealed that the aircraft would land with a low main tank fuel state unless the auxiliary tanks were used. However, without a prepared navigation log, the pilot would not have had a ready fuel reference during the flight that would allow such a comparison to be made, relying instead on mental calculations. Consequently, when the flight started to take longer than originally planned, it may not have been immediately apparent that the fuel in the main tanks might not be sufficient to complete the flight safely.

There was no reason to suspect that the pilot was not presented with accurate fuel quantity information in the cockpit. Even if this were not the case, he routinely used a dipstick to measure the fuel quantity before flight and (considering it was an aircraft he knew well and in which he had flown several long flights) he would have had an independent awareness that fuel in the main tanks would be very low on arrival.

Thus, as the aircraft neared Hawarden, it is most probable that the pilot was aware, either from the fuel gauges or by mental calculation, that fuel in the main tanks was running low. Even at that stage, he could have declared a low fuel state to ATC and possibly requested Runway 04 (a shorter routing), which may have altered the final outcome. It is possible he attempted to use some auxiliary tank fuel in the latter stages of the flight, in which case it is unlikely that a significant amount was used before the selectors were returned to main tanks for landing in accordance with normal procedure.

Conclusions

V_{MC} was 75 kt with 5° bank, approx. 85 kt with the wings level, very close to min. approach speed of 90 kt. A decrease of IAS below 90. or a little bank to the dead engine side would further increase V_{MC} to a value higher than IAS, after which heading cannot be maintained, sideslip increases and hence the drag. Gravity took control.

The engineering examination showed that the right engine appeared to be operating normally at impact while the left engine appeared to be operating at a lower power. The investigation did not identify a mechanical defect within the engines, the propellers or their control systems which could account for this difference.

In view of the lack of fuel recovered from the left main tank and the left engine fuel injection manifold valve it is considered that the probable reason for the differing engine power was fuel starvation of the left engine. The lack of evidence of fuel spillage from the ruptured right main fuel tank suggests that fuel starvation of the right engine may have been imminent.

The majority of usable fuel at the time of the accident was in the auxiliary tanks, which were not selected for engine feed. From the available evidence, it is probable that the pilot originally intended to complete the flight using fuel from the main tanks only, and loaded them with what he considered to be a sufficient quantity. However, the main fuel tank quantity was insufficient for safe completion of the flight. Options to use auxiliary tank fuel or to land and refuel would have been available to the pilot.

With no evidence of a prepared fuel plan, and in the absence of any obvious concern on the part of the pilot, he appears to have continued to believe that the fuel in the main tanks alone was sufficient, albeit with a greatly reduced reserve. Although he would not have intended or expected to land with such a low fuel state in the main tanks, the fine weather conditions of the day and his familiarity with Hawarden may have been factors in his apparent acceptance of the situation.

The accident occurred when the pilot lost control during a single-engine go-around manoeuvre, after the speed had fallen below the minimum control speed. The investigation concluded that the loss of power on the left engine just before landing was due to fuel starvation which resulted from mismanagement of the aircraft's fuel system.

The pilot (and the investigators) might not have been (made) familiar with the proper engine-out flight technique. No mention was made of the bank angle for which the published $V_{MC(A)}$ was valid, neither in the quote of the 'owners manual' on page 16, nor in the analysis of this accident.
The owners manual might not have published the constraints that come with the minimum control speed (straight flight with a bank angle of 5° into the good engine) and the requirement to bank 5 ° in the engine emergency procedures, both of which are required for maintaining control and for minimum drag as result of the tail design assumptions of the airplane, and as used during experimental flight-testing to determine V_{MCA}.

Recommended is to review the Airplane Flight and training Manuals for appropriate definitions and procedures on Engine-out flight.