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AAIB
Air Accidents Investigation Branch

AAIB Bulletin S2/2014 *SPECIAL*

ACCIDENT

Aircraft Type and Registration:	Eurocopter EC135 T2+, G-SPAO	
No & Type of Engines:	2 Turbomeca Arrius 2B2 turboshaft engines	
Year of Manufacture:	2007 (Serial No: 0546)	
Location:	Glasgow City Centre, Scotland	
Date & Time (UTC):	29 November 2013 at 2222 hrs	
Type of Flight:	Commercial Air Transport	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - 1 (Fatal)	Passengers - 2 (Fatal) Other - 7 (Fatal) 11 (Serious)
Nature of Damage:	Helicopter destroyed	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	51 years	
Commander's Flying Experience	5,592 hours (of which 646[1] were on type) Last 90 days - 38 hours Last 28 days - 19[2] hours	
Information Source:	AAIB Field Investigation	

Footnote

[1] 646 hrs are the hours on type the pilot had accumulated since 2010.
[2] Hours up to and including 26 November 2013.

Introduction

At 2222 hrs on 29 November 2013 a Eurocopter EC135 T2+ helicopter, operating in support of police operations, descended onto the roof of The Clutha Vaults bar, on Stockwell Street in central Glasgow. The roof collapsed and the helicopter came to rest embedded in the single storey building. The three occupants of the helicopter and six people in or adjacent to the bar were fatally injured. Thirty-two other people suffered injuries, twelve seriously. One of those seriously injured subsequently died of his injuries on 12 December 2013.

A team of AAIB Inspectors and support staff arrived in Glasgow at 0915 hrs the following morning to commence an investigation. The emergency services and the AAIB were presented with a very complex task, requiring a highly co-ordinated process to successfully meet the aims of the emergency response operation.

In accordance with established international arrangements, the Bundesstelle für Flugunfalluntersuchung (BFU) of Germany, representing the State of Design and Manufacture of the helicopter, the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) of France, representing the State of Design and Manufacture of the engines, and the National Transportation Safety Board (NTSB), representing the State of Design and Manufacture of the Full-Authority-Digital-Engine-Controls (FADECs) on the engines, appointed Accredited Representatives to participate in the investigation. They are supported by advisors from the BEA, the helicopter manufacturer and the engine manufacturer. The European Aviation Safety Agency (EASA), the UK Civil Aviation Authority (CAA) and the helicopter operator are also assisting the AAIB.

AAIB Special Bulletin S9/2013 was published on 9 December 2013 to provide initial information on the AAIB's investigation and the circumstances of the accident. This Special Bulletin is published to provide more factual information and an update on the progress of the investigation. No analysis of the facts is attempted.

History of the flight

At 2045 hrs on 29 November 2013, the helicopter departed Glasgow City Heliport (GCH), to support police operations. On board were the pilot and two police observers, each of whom was in possession of a set of Night Vision Goggles (NVGs). The helicopter had 400 kg of fuel on board, giving an endurance of approximately 1 hour and 35 minutes[3].

Initially, the helicopter tracked towards the Oatlands district of Glasgow, about 2 nm south-east of GCH. This was to assist in the search for a person believed to have been struck by a train. The helicopter remained in that area, at an altitude of approximately 1,000 ft amsl, for about 35 minutes. It then flew to Dalkeith, Midlothian, about 38 nm east of GCH, where it carried out a non-urgent task. It remained there for about four minutes, at various altitudes, before flying back towards Glasgow via Bothwell, South Lanarkshire, where it briefly carried out an observation task. It then flew to Uddington, South Lanarkshire

Footnote

[3] Using an average fuel consumption of 200 kg/hr and the operator's Final Reserve Fuel of 85 kg - Final Reserve Fuel being the minimum amount of fuel with which pilots should plan to land.

and Bargeddie, North Lanarkshire, where it carried out non-urgent tasks, orbiting in each location for less than five minutes (see Figure 1). At 2218 hrs, the pilot requested clearance from ATC to re-enter the Glasgow Control Zone, to return to GCH. This was approved. No further radio transmissions were received from the pilot.

Recorded data indicates that, in the latter stages of the flight, the right engine flamed out, and shortly after the left engine flamed out. The helicopter descended and struck the roof of The Clutha Vaults bar at a high rate of descent, in an upright attitude. Evidence indicates that the rotor blades and Fenestron tail rotor were not rotating at the moment of impact. The force of the impact caused the roof to collapse and the helicopter entered the building.

The last recorded radar position for the helicopter was at 2222:19 hrs, showing it at an altitude of approximately 400 ft amsl.

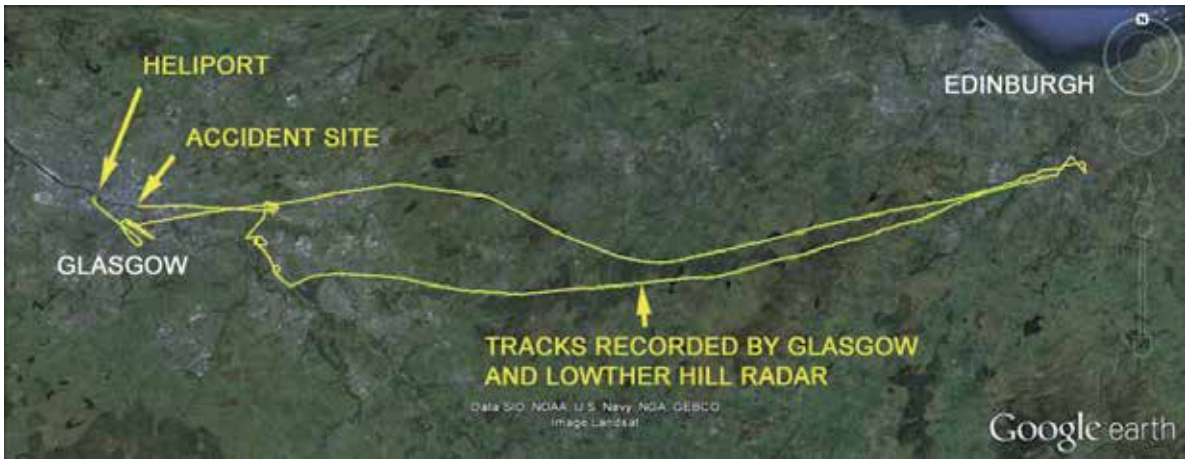

Figure 1

The helicopter's track, as recorded by radar

Weather and celestial information

The weather at 2220 hrs on 29 November 2013 at Glasgow International Airport, 4.5 nm west of GCH, was: CAVOK, surface wind from 300º at 7 kt, temperature 5ºC, dew point 2ºC and QNH 1025 hPa.

The moon set at 1402 hrs on 29 November 2013 and rose at 0449 hrs on 30 November 2013.

Engineering investigation

General

The helicopter was removed from the building in a co-ordinated and complex process to primarily meet the aims of the emergency response operation, while preserving the evidence. The subsequent engineering investigation has been following a methodical process examining the helicopter's systems in detail, as far as practically possible.

Fuel System

The helicopter's fuel tank group was drained and the contents were measured immediately after it was extracted from the building. It was found that the main fuel tank contained 76 kg of fuel, whilst the No 1 supply tank (left) contained 0.4 kg of fuel and the No 2 supply tank (right) was empty. It has also been confirmed, by examination and measurement of the internal design features, that this was the fuel disposition at the time of the accident. That is; fuel had not moved within the tank group whilst the helicopter was at rest in the building. Also, there was no evidence that fuel leaked from the helicopter before or during the impact with the building.

Since the helicopter's recovery to the AAIB facility, a very close examination of the fuel system has continued. It has been determined that the fuel tank group suffered sudden elastic compression during the impact, whilst retaining its basic shape. The compression was sufficiently severe to collapse all four internal fuel quantity transmitters, as they are designed to do, and the tank group bladders remained fuel-tight. Examination of all internal pipe work and transfer passages has not revealed any pre- or post-impact failure and all paths still permit uninterrupted fuel flow. It has been established that unrestricted flow was also available from each supply tank to the corresponding engine fuel control unit, through the relevant fuel shut-off valves which were found set to the OPEN position.

The fuel pump switches were examined at the accident site and it was found that the No 1 and No 2 prime pump switches (PRIME I and II) were set to the ON position and the fore and aft transfer pump (XFER F and A) switches were set to the OFF position.

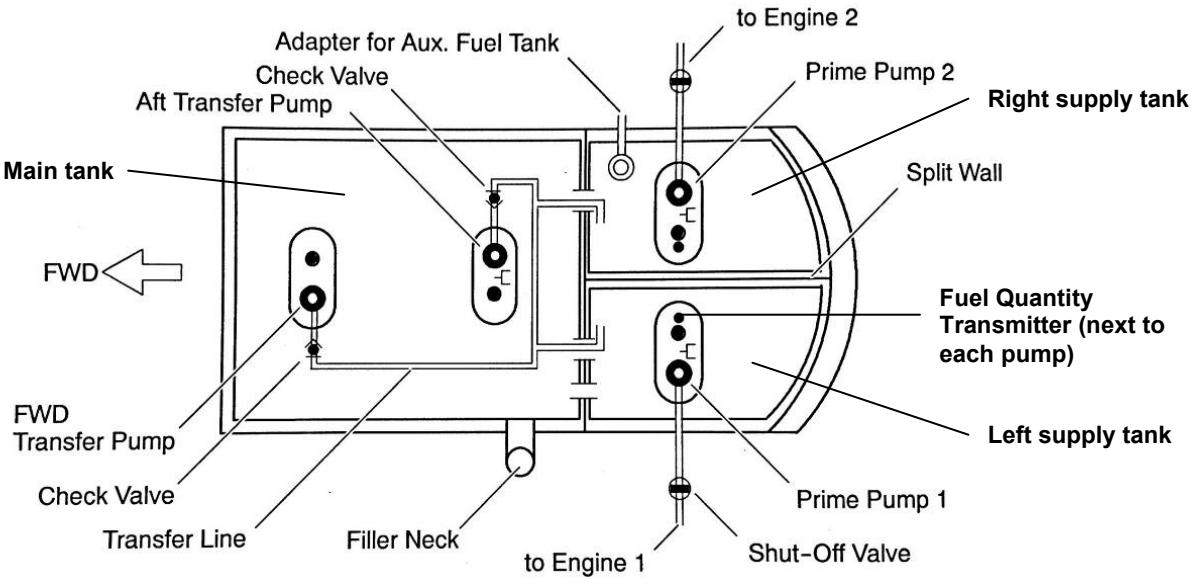

Figure 2

Fuel Tank Group Schematic

The forward and aft transfer pumps, situated in the main fuel tank, and the prime pumps in the No 1 and No 2 supply tanks were tested and found to operate correctly in accordance with their factory specification. The pump inlets and outlets were free from blockage or contamination. The No 2 prime pump and aft transfer pump housings had suffered minor damage, attributable to the tank compression during impact, but this had no effect on their operation under test.

Engines

Both engines were examined in the helicopter and later disassembled and examined at the engine manufacturer's facility. This was carried out under the direct supervision of AAIB investigators, representatives from the BEA and the helicopter manufacturer.

The engines were found to have suffered minor external damage as a result of the impact. Both engine gas generator cores, compressors and turbines, were free to rotate, as were the free power turbines, reduction gearboxes and output shafts. There was no evidence of foreign object damage or intake or exhaust blockage in either engine. Also, there were no signs of bearing or lubrication system failure, and the oil system chip detectors were clean and free from metallic particles. The No 1 (left) engine fuel filter was found to contain a small amount of fuel whilst the No 2 (right) engine was found to be empty of fuel. Both engine fuel control units were bench tested and found to be serviceable in all respects, producing fuel control, pressure and flow outputs within acceptable tolerance deviations, in accordance with the factory test protocol.

Both of the engine fuel valve assemblies were also tested on the bench, confirming that the engine electro-stop valves were fully open. These valves receive an electrical signal, to shut off the fuel to the engine, when selected by the pilot via the ENG I and II switches.

The engine control panel switches for the FADECs (Full-Authority-Digital-Engine-Control) were found set to ON and the ENG I and ENG II switches were guarded in the FLIGHT position. The engine mode select panel switches, ENG I and II were set to NORM and guarded and the ENG I and II VENT switches were set to OFF. This was the correct configuration for flight.

Transmission system, main rotor and Fenestron tail rotor

Examination at the accident site and further more detailed examinations at the AAIB facility in Farnborough have shown no evidence that the transmission system, main rotor, Fenestron tail rotor and associated drive shafts were rotating when the aircraft struck the roof of the building. The main rotor and Fenestron gearboxes had superficial external damage but were free from leaks. The main rotor gearbox lubricating oil filter was clean and the magnetic chip detector was free from metallic debris. All of the damage to the main rotor and Fenestron blades was attributable to impact with the building and supports the evidence that they were not rotating just before or at the point of impact. From the overall examination and assessment of the system no faults have been found with the transmission or rotor system.

Sub-systems

There is no evidence of hydraulic system or flying control failure in flight prior to the impact. The electrical power generation and distribution system appears to have been operating correctly prior to the accident. At the accident site the battery master (BAT MSTR) switch was found set to ON and the GEN I and GEN II switches found set to NORM. None of the helicopter circuit breakers, situated on the overhead panel, indicated pre-accident electrical overload failure of any of the vital electrical system devices. In summary, all of the damage and disruption to these systems was consistent with an impact sequence involving a very high energy deceleration.

The SHED BUS switch at the rear of the overhead panel was found guarded in the NORM position. The purpose of this switch is to give the pilot the ability to recover non-essential electrical services should both generators trip off line, such as in a double engine failure. Battery power is recovered to those systems when the guard is lifted and the switch set to EMERG. In this case, with the switch set to NORM, the radio altimeter and the steerable landing light would not have been available to the pilot. These two items are optional equipment and are not standard on the EC135 helicopter. However, a radio altimeter is required for UK police night flying operations, in accordance with Civil Aviation Publication (CAP) 612, *Police Air Operations Manual, Part One*.

Other evidence

There was no evidence of structural failure or in-flight fire and no evidence of damage caused by birdstrike or a foreign object hitting the aircraft whilst in flight.

Recorded data

Data from the helicopter

The helicopter was not required to have, and was not fitted with, flight recorders, nor did its systems provide a continuous recording of helicopter parameters. However, some of the installed helicopter systems recorded snapshots of limited sets of data, under specific circumstances, for engineering purposes.

The contents of the non-volatile memory (NVM) from the equipment known to record data have been successfully recovered and are being analysed. The majority of the recorded data have no form of time stamp. So, whilst the order of some of the snapshots can be determined, their relative timing is unknown. Other systems use time references but ones that are not directly linked to UTC.

The Warning Unit has provided information on the order in which warnings were triggered during the flight but not when they occurred. The unit recorded the normal warnings associated with starting the helicopter, followed by a warning free status. It subsequently recorded intermittent LOW FUEL 1 warnings for the left fuel supply tank, then a permanent LOW FUEL 2 warning for the right fuel supply tank. This was followed by a further temporary LOW FUEL 1 warning, before it became permanent for the remainder of the flight. These LOW FUEL warnings are triggered by thermal sensors in the supply tanks.

For this helicopter build configuration, they indicate when there is approximately 32 kg and 28 kg of fuel remaining in the left and right supply tanks, respectively. On receipt of these warnings, the manufacturer's flight manual for the helicopter instructs the pilot to '*LAND WITHIN 10 MINUTES'.*

An alarm gong was also recorded followed by intermittent warnings relating to low rotor rpm. The penultimate warning recorded related to the battery discharging, which occurs when there is insufficient engine-driven generator power. The last warning related to an autopilot system failure. Investigation into the possible causes for the individual warnings is continuing.

The Central Panel Display System (CPDS) displays cautions and fuel status information to the pilot. It also records internal display system faults but no information relating to its indications. The displays did record flight duration and work is being carried out to link this duration, and the conditions required to start and stop this recorded duration, to the flight path of the helicopter. A fault relating to one of the display systems was recorded and further work is being undertaken to establish the meaning and possible causes of the fault.

Each engine had a FADEC. The FADECs can record a limited number of maintenance reports relating to problems with the control and operation of the engines and instances when one engine is inoperative. Preliminary analysis of the FADEC data indicates that the right engine flamed out, followed, a short time later, by the left engine also flaming out. Since the maintenance reports only give timings relative to the moment the FADECs were turned on (which is not recorded), the exact times at which these flameouts occurred is unknown.

Externally recorded data

The continuous (timed) recordings identified so far are all external to the helicopter and are in the form of radar returns, radio transmissions and closed circuit television (CCTV) footage. No single source has provided a reliable link to all the on-aircraft sources of snapshot data.

The recorded radar track started just after the helicopter departed the heliport. The helicopter's altitude as it approached the area of the accident was approximately 1,000 ft amsl and its average groundspeed was approximately 105 kt. The last radar return reported an altitude of approximately 400 ft amsl, when corrected for ambient air-pressure.

CCTV recordings of the start of the flight are providing a means of linking some of the snapshot data from the helicopter's systems with the radar recorded flight path. However, no CCTV recordings have been obtained that capture the end of the flight.

The recorded radio transmissions do not contain any reference by the crew to difficulties with the aircraft.

Work on the recorded data continues.

Procedures

Fuel policy

The operator's operations manuals contained the following policy on fuel for the EC135 helicopter:

> *'Company Fuel Policy*
>
> *Company helicopters are operated under a principal of Minimum Land on Allowance (MLA), this figure is the minimum amount of total fuel at the point of landing.*
>
> *It is calculated as fuel remaining, not more than 10 minutes after the … FUEL caption (EC135) has illuminated….. and is included in the Final Reserve Fuel amount.'*

Final Reserve Fuel at night/in IFR was 85 kg. The operator advised its pilots that an emergency condition could be considered to exist if the commander believed that the helicopter would land below the MLA.

Emergency procedures

The operations manual provides pilots with guidance and procedures for use following a double engine failure. It states:

> *'Immediate Actions following total power loss in cruise or accelerative flight*
>
> - *Lower collective immediately and flare aircraft to conserve and/or recover NR*
> - *Select attitude for 75kt*
>
> *Selection of speed and RRPM* [Rotor RPM] *in Autorotative flight*
>
> - *Normal Autorotation 100% RRPM, 75kts*
> - *Range Autorotation 85% RRPM, 90kts*
> - *Min RoD [Rate of Descent]100% RRPM, 65kts*
>
> *EOL* [engine off landing] *over Land*
>
> - *At approximately 100' AGL (higher if heavy) initiate flare*
> - *Reduce groundspeed as much as possible*
> - *Level the aircraft and use collective lever to cushion landing*
>
> *EOL at Night or in IMC*
>
> - *Select and maintain 10° Nose Up until speed reaches 75kts and then re-adjust*
> - *Turn shortest arc into wind using ≤ 20° AoB* [Angle of Bank]
> - *Use RADALT* [Radio Altimeter] *to establish flare height*
> - *Progressively reduce flare until level at 10' RADALT height*
> - *Use collective to cushion landing'*

The operator teaches its pilots that, once a stable autorotation is established, the SHED BUS switch, in the overhead panel, should be switched from NORM to EMERG, if time is available, to power the steerable landing light and the radio altimeter during an autorotation.

Safety action

On 20 December 2013, the operator issued an amendment to its operations manual, replacing MLA with Final Reserve Fuel. It stated:

> *'An Emergency condition can be considered to exist if the Commander believes that the helicopter will land below Final Reserve Fuel (FRF).'*

The operator also issued the following safety notice to all its pilots on the same date.

> *'… we have conducted detailed examinations and tests on our fleet of EC135s. ……. As a result of these test it was deemed necessary to replace the sender units [fuel quantity transmitters] from the supply tanks on a number of our aircraft.*
>
> *Until such a time as we have an approved maintenance program* [from the manufacturer] *in place to perform functional checks of these units we have deemed it necessary to maintain a* ***Final Reserve Fuel (FRF) 90Kgs.*** *When completing fuel calculations …… please use 90kgs as the FRF for all flights (VFR & IFR) until further notice.'*

Ongoing investigation

The AAIB investigation continues to examine all the operational aspects of this accident and to conduct a detailed engineering investigation.

In particular, the investigation will seek to determine why a situation arose that led to both the helicopter's engines flaming out when 76 kg of fuel remained in the fuel tank group, why no emergency radio transmission was received from the pilot and why, following the double engine failure, an autorotative descent and flare recovery was not achieved.

The AAIB will report any significant developments as the investigation progresses.

Published 14 February 2014