SERIOUS INCIDENT

Aircraft Type and Registration:	BN2T-4S Islander, G-CGTC
No & Type of Engines:	2 Rolls Royce M250-B17F/1 turboprop engines
Year of Manufacture:	2013 (Serial no: 4019)
Date & Time (UTC):	12 November 2020 at 2055 hrs
Location:	City of Derry Airport, Eglinton, Londonderry
Type of Flight:	Emergency services operations
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Undamaged
Commander's Licence:	Commercial Pilots Licence/Instrument Rating
Commander's Age:	59 years
Commander's Flying Experience:	8,325 hours (of which 3,153 were on type) Last 90 days - 31 hours Last 28 days - 10 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft suffered a double engine failure, likely due to intake icing, while operating in IMC at approximately 7,000 ft amsl. After an initial glide descent both engines were successfully restarted and the aircraft made a powered landing at Eglinton. The operator has taken safety action related to winter operations, use of anti-icing systems and pilot wellbeing.

History of the flight

The plan was to depart Belfast Aldergrove Airport and route to an operating area, climbing to an altitude of approximately 10,000 ft amsl. The crew consisted of the pilot and two observer passengers. Before flight the crew conducted a briefing in which the meteorological information was an area of particular concern as a cold front was approaching the operating area bringing extensive cloud and reducing temperatures. The pilot was conscious of the risks of airframe icing and during the brief decided to operate the aircraft below the 0°C isotherm.

The aircraft taxied at approximately 1950 hrs for departure from Runway 17 at Aldergrove. While taxiing, the aircraft was given a different ad hoc task. The pilot informed ATC of the change and arranged a new departure clearance. Shortly afterwards the pilot was told by one of the observers that the new task had been resolved and therefore the aircraft was to revert to its original plan. The pilot requested an appropriate departure clearance, but the aircraft was then required for the ad hoc tasking once again. The pilot again requested a change of departure clearance and stated he felt somewhat exasperated by the frequently changing situation.

Figure 1
Britten-Norman 2T-4S Islander

The aircraft took off from Runway 17 at 2005 hrs and routed to the new operating area. This tasking was at lower levels, so the pilot climbed to approximately 1,600 to 1,800 ft amsl. The lower altitude allowed the aircraft to operate clear of cloud, and icing conditions were not an issue. The task was concluded at 2025 hrs and the aircraft was released to continue with the originally planned operation. The pilot set course for the operating area and requested clearance to operate up to FL 090.

During the transit the pilot decided to stop the climb at approximately 7,000 ft amsl to remain below the 0°C isotherm. At 7,000 ft he recalled that the air temperature was +1°C. During the transit the aircraft entered cloud and as it did so the pilot recalled selecting the engine anti-icing ON. The aircraft reached its operating area at approximately 2045 hrs.

After around five minutes on task the pilot noticed that the torque indications for both propellers were reducing, with a related decrease in airspeed. He therefore increased power to restore both torque and airspeed. A short time later the pilot again noticed a drop in both torque and airspeed. The aircraft needed "more and more power" to maintain the required performance and the pilot became concerned that something was amiss. He then noticed that the turbine gas temperature (TGT) on both engines had reached the limit of 927°C.

At this point the pilot reduced power to keep the TGT within limits. He informed the rest of the crew that there was a technical issue with the aircraft and that his intention was to return to Aldergrove. The pilot recalled that during the subsequent left turn the right engine failed, stating, "I was so startled I did not do any immediate drills but concentrated on maintaining control of the aircraft." Given the already evident engine issues he was now concerned that the second engine would also fail. He recalled that as he thought this, the left engine failed.

The pilot was aware of the aircraft's position and decided that his only option was to try to glide to the nearer City of Derry Airport, Eglinton. He established the aircraft in a glide and then completed the engine shutdown and propeller feathering drills. He declared MAYDAY to Aldergrove ATC and asked for vectors toward Eglinton. He was aware that Eglinton was closed so asked Aldergrove ATC if they could do anything to get the airfield lighting switched on.

The aircraft's topographical moving map display is role equipment and requires electrical supply from the generators and so was lost when the engines stopped. The pilot had an iPad with a mapping application but this also was not working. The observers also had iPads with mapping applications and one of them went to the cockpit to assist.

During the descent the pilot attempted to restart the engines and 1 minute 30 secs after the second engine failure he was able to restart the right engine at approximately 2,100 ft amsl. The aircraft had cleared cloud and the pilot could now see nearby cultural lighting. From the observer's iPad he could see the aircraft was over Loch Foyle. At approximately 1,500 ft amsl he then attempted a restart of the left engine. The first attempt was unsuccessful, which he attributed to not having selected the left engine igniters ON. On what he recalled was the second attempt the left engine also restarted.

The pilot decided to continue to land at Eglinton. Using the iPad map, and with the observer assisting with navigation, he flew the aircraft towards the airport. The pilot recalled that the wet runway surface at Eglinton became visible in reflected cultural lighting as the aircraft flew overhead at approximately 900 ft agl. Considering that this was too high for a safe approach he flew a left hand circuit to reposition on the centreline for Runway 26. The aircraft descended during the circuit and the pilot recalled seeing the runway from a height of approximately 350 ft agl. He then made a powered landing on the unlit runway. After landing the pilot taxied the aircraft to the main parking area and completed the shutdown checks. All on board were uninjured.

Recorded information

G-CGTC was not fitted, nor required to be fitted, with a flight data or cockpit voice recorder but recorded information was obtained from the following sources.

Flight Management Computer

G-CGTC was fitted with a Universal Flight Management Computer (FMC) that, when powered, continually recorded data to internal non-volatile memory[1]. The FMC was

Footnote

[1] This functionality is only available on some Universal FMCs, running certain software part numbers, and records data for the last 20 hours that the FMC is powered.

downloaded by the AAIB and the recovered data, which contained the incident flight, was decoded by the manufacturer. Data from the FMC, which is primarily used for navigation and flight guidance, included the aircraft's position, altitude, details about the aircraft's operating environment such as the Static Air Temperature (SAT) and the engaged flight guidance modes. The FMC data also included fuel consumption for each engine, derived from a fuel flowmeter mounted on each engine, and a calculated value for the total fuel on board[2]. In addition, the FMC memory recorded the pilot's interaction with the FMC.

The data showed that, after the first tasking was completed at approximately 2025 hrs, the aircraft climbed to a pressure altitude of 7,400 ft (equivalent to 7,000 ft amsl), reaching this altitude at 2035 hrs, and tracked from the general vicinity of Aldergrove towards the west. As G-CGTC climbed, the SAT decreased from 8°C to 1°C. Eight minutes after levelling off, at 2043 hrs, while maintaining a westward track the SAT reduced further to 0°C and a marked decrease in the right engine's fuel flow was seen on the data, without a notable change in G-CGTC's flightpath or performance. Ten minutes later, at 2053 hrs, after a descent to a pressure altitude of 7,000ft (equivalent to 6,600 ft amsl) and while G-CGTC performed the flight's second tasking, the left engine's fuel flow reduced to zero as the engine flamed out.

G-CGTC entered a descent, at up to 1,500 ft/min, and its true airspeed increased to 150 kt. A minute later, at 2054 hrs, the right engine's fuel flow reduced to zero as this engine also flamed out. (The data showed that the engines did not fail in the order recalled by the pilot). G-CGTC then entered a steeper descent, during which the true airspeed (which after the first engine flameout had reduced to 120 kt) again reached 150 kt, the SAT rose rapidly and a peak rate of descent of approximately 3,300 ft/min was recorded.

The right engine was successfully restarted 74 seconds after it flamed out and at a pressure altitude of 2,500 ft (2,100 ft amsl), at which point G-CGTC's flight path began to stabilise with a reduction in both the rate of descent and true airspeed recorded. The data then showed two unsuccessful attempts were made to restart the left engine, while the aircraft was in a shallow descent towards Eglinton, before it was successfully restarted at a pressure altitude of 1,200 ft (800 ft amsl) 8 minutes 27 seconds after it had failed. G-CGTC landed at 2109 hrs, with both engines operational, after one circuit flown at approximately 500 ft agl. An annotated copy of this data is shown in Figure 2 below.

Terrain Awareness and Warning System

G-CGTC was fitted with a Universal Terrain Awareness and Warning System (TAWS). The data recovered from the unit showed that several 500 ft agl call-outs were issued by the TAWS, as the aircraft positioned and then flew a single circuit to land at Eglinton, followed by a sink rate alert which occurred on short final. The sink rate alert was triggered by a descent rate of 990 ft/min, when G-CGTC was 91 ft above ground and had a true airspeed of 82 kt. The terrain and obstacle data used by the system was found to be significantly out of date.

[2] The FMC calculates the total fuel on board by totalising the fuel used during the flight and subtracting this value from a pilot-entered value at the start of the flight.

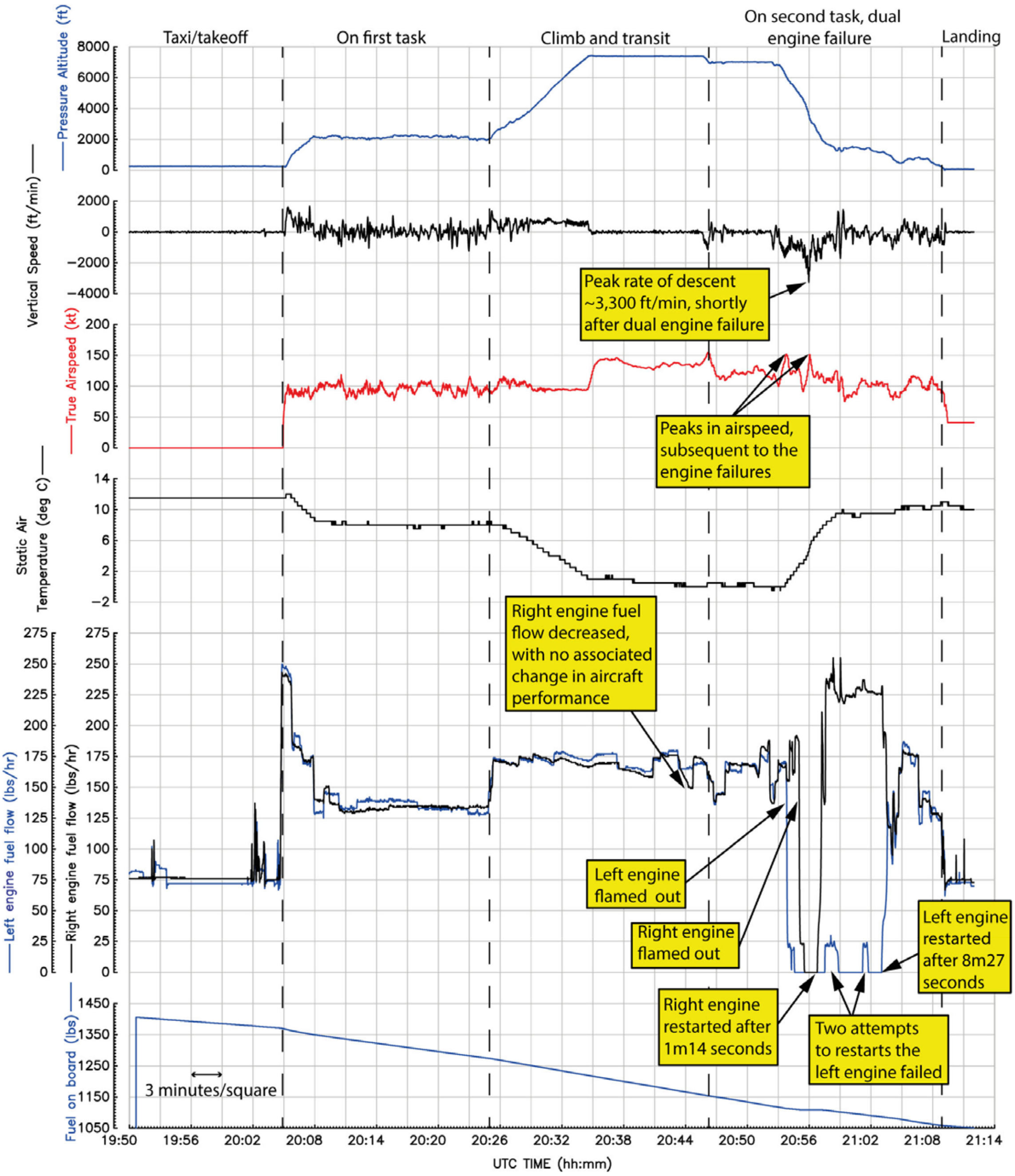

Figure 2

FMC data for the incident flight

Radar recordings

Radar and RTF recordings of the incident flight were available, radar coverage being lost because of terrain masking as the aircraft descended.

Miscellaneous recorded data

Flightpath data recovered from the observer's iPad agreed with data recovered from the FMC and is not presented here.

Aircraft information

Originally derived from the BN Islander aircraft, the BN-2T-4S Islander has a stretched fuselage, an enlarged wing, a new nose structure capable of accommodating a sensor turret and radar, and an increased payload. The aircraft is powered by two Rolls Royce M250-B17F/1 turboprop engines rated at 450 shaft horsepower (shp) but derated to 400 shp for integration into the Islander platform. Each engine is fitted with a Hartzell three-bladed, constant speed, oil/gas operated, fully feathering propeller.

Rolls Royce M250-B17F/1 engines

The Rolls Royce M250-B17F/1 is a hydro-mechanically controlled engine consisting of four modules: a four-stage axial and single stage centrifugal compressor, a reverse flow combustor, a gas generator and power turbine, and reduction gearbox modules. Air flows through the axial and centrifugal compressors and is ported rearwards via two transfer pipes from the centrifugal compressor discharge (Diffuser scroll). The transfer pipes turn the air through 180° and connect to the rear of the combustion chamber. The expanding combustion products power the high pressure (HP) turbine to drive the compressor module and the power turbine which drives the propeller via the reduction gearbox.

Anti-ice system

The aircraft is cleared for flight into known icing conditions. The wing and tail leading edges are fitted with a pneumatic de-icing system. Powerplant icing is considered a risk with visible moisture in the air at temperatures of +5°C or less[3].

The powerplant anti-ice system activates two distinct sub-systems. One powers electrically heated spraymats[4] on the engine intake ducts and electrical heater elements bonded to the propeller blades. The second diverts hot bleed air from the compressor discharge to the compressor front support structure to heat the surfaces of the static structure reducing the likelihood of ice accretion. The engine igniters are automatically switched to continuous operation when the anti-ice system is ON, to help prevent water from melted ice or snow interrupting the combustion process. A green L.ENGINE ANTI-ICE or R.ENGINE ANTI-ICE caption illuminates on the cockpit central annunciator panel when the respective anti-ice system is selected.

Once activated, intake duct heating is cycled on and off by a controller circuit depending on the surface temperature of the duct. At 60°C or below, the heating elements will activate and warm the intake surface to 110°C. On reaching this temperature, the control circuit will deactivate the heater until the surface cools again to 60°C, when the circuit is reenergised. The operation of the electrical anti-ice circuits can be monitored on an ammeter located in the pilot's instrument panel just above the anti-ice switch panel. A four-position rotary switch selects left or right intake or propeller electrical current indication. If the ammeter

Footnote

3 Pilatus BN Pilot's Operating Handbook and CAA Approved Aircraft Flight Manual (AFM/2T-4S) section 2 'Limitations', paragraph 2.9d.

4 A spraymat contains heating elements and a thermistor sensor for detecting the spraymat's surface temperature.

needle is within the green band marked 'Intake' or 'Prop' it shows that the current drawn is within the circuit's electrical operating limits.

When anti-ice is selected ON, an engine mounted solenoid valve is de-activated[5] allowing hot bleed air to be diverted from the diffuser scroll to the compressor front support structure (Figure 3). Feeding hot air to the front of the engine causes a slight increase in the TGT which can be observed on the respective engine's TGT indicator located on the cockpit centre instrument panel. The increase in TGT results in a small reduction of available torque. Diverting air from the compressor also reduces the engine's efficiency and power. In addition, the current drawn by the anti-ice heating system increases the load on the engines from the electrical generators, compounding the reduction in engine torque.

The Pilatus BN Pilot's Operating Handbook and CAA Approved Aircraft Flight Manual (AFM/2T-4S), (AFM), contains the following caution:

> *'The formation of intake ice may cause rapid power loss. Selecting Power ENGINE ANTI-ICE to FAST or SLOW, after intake ice has formed, may cause engine flame-out.*

If icing conditions are inadvertently encountered, or intake icing is suspected, immediately select ENGINE ANTI-ICE to FAST or SLOW for the selected engine. Confirm correct operation of the selected engine for approximately ten seconds before repeating the ENGINE ANTI-ICE selection for the other engine.'

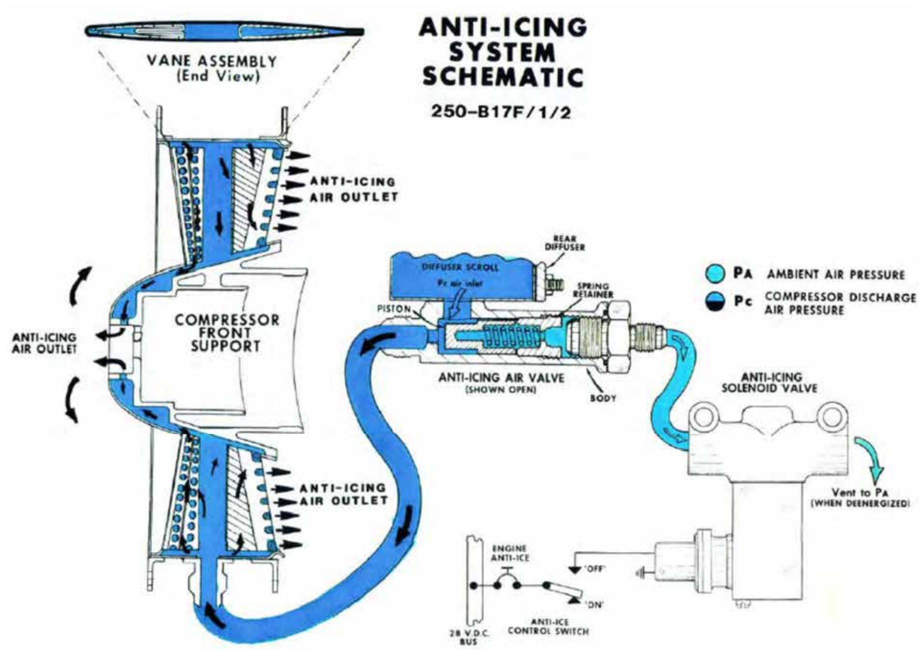

Figure 3

Schematic of the engine anti-ice bleed air system

Footnote

5 With the anti-ice off, power is supplied to the solenoid valve, the valve closes and activates a piston mechanism to prevent bleed air from reaching the front support assembly.

Aircraft examination

Fuel

The aircraft's maintenance organisation took fuel samples from its main bulk fuel supply bowser and from the bowser used to refuel G-CGTC. Visual examination of the samples showed the fuel to be clear, bright, the correct colour and with no visible debris, contamination, or water. Testing using water sample capsules showed the dispersed water content was less than the maximum limit of 30 parts per million as recommended by the International Air Transport Association. The samples were sent for forensic examination.

The aircraft fuel gauges showed approximately 240 US gallons of fuel, 120 US gallons in each side, remained in the aircraft fuel tanks. The left and right engine driven fuel pump filters were replaced with new items and the removed filters quarantined. As the aircraft was parked in a location that was exposed to poor weather conditions, it was taxied at low power to a local maintenance hangar for storage and further examination. There were no anomalies reported with the aircraft systems or engines during this process.

Ten fuel samples were taken from the aircraft (5 from each wing) and sent for forensic examination to assess the fuel type, content, additives, potential contamination, and quality. The quarantined filters were also sent for debris analysis. There were no significant anomalies. Very small amounts of debris were found in the filters but no microbiological growth.

Engines

An initial borescope inspection was made of the engine compressors' first stage rotors and guide vanes to look for obvious signs of soft body damage[6] caused by any contact with ice. The first stages of each engines' HP and power turbines were borescoped via the combustion chamber igniter plug ports and the exhaust ducts. The combustion chambers, inner liners and the first stage turbine nozzle shields were also visually examined. No obvious signs of damage were evident on the first stages of the compressors, the turbines, nozzle shields or combustion chambers and liners.

Powerplant anti-ice system

To determine the operational status of the powerplant anti-ice systems, the engines were started, the engine anti-ice systems selected ON and the left and right engine anti-ice ammeter switches set to 'Prop' and 'Intake' in turn. In most cases, the ammeter indications were within their respective green bands. The ammeter showed that the heating element on one of the three blades on the left propeller was inoperative. With the engines at idle, the respective TGTs increased by 30 to 50°C when anti-ice was switched on and returned to their original temperatures when switched off, indicating the system was functioning as expected. The appropriate green anti-ice warning caption illuminated when the system was selected.

The engines were removed for further examination and component testing.

Footnote

[6] Soft body damage is caused when material that is softer than the blades causes damage such as bending of the aerofoil surfaces during impact.

Examination of the engines

Both engines were examined and dismantled together so comparisons could be made if potential issues were found. No external damage was visible other than fraying of an igniter cable braided metal outer sheath. No anomalies were found when the magnetic chip detectors were removed and examined.

When the axial-flow compressor casings were unbolted and split in half to view the rotor wheels and stator stages, there were signs of slight rubbing of the tips of the rotor blades.

Figure 4

Some of the corrosion found on the left engine axial compressor wheel hubs

Further detailed examination of the left engine's rotor wheels showed there was heavy corrosion present on their hubs (Figure 4). Despite these issues, there was no damage that could be attributed to ice ingress, a potential overspeed or overheat event during the roll-back and shutdown of the engines.

When the centrifugal compressors were removed from the engines, and the outer diffuser casings removed, both the impeller blades and inner casing abradable surfaces showed signs of rubbing. The maintenance organisation and the subsequent report by the engine manufacturer[7] stated that the wear was typical of normal engine deterioration.

Following engine disassembly, the main ancillary components were bench tested to determine their operational status. Some of the pass-off settings[8] of both fuel control units were found to be slightly out of limits. The maintenance organisation considered the out of tolerance settings to be normal for in-service items.

The fuel nozzles were placed in a test chamber and a metered, substitute fluid used to show their spray pattern. Minor voids were present in the left nozzle's spray pattern caused

Footnote

[7] Thomas, A (2021), *ASI0213 Dual Engine IFSD of BN Islander G-CGTC,* edition 01, Rolls Royce.

[8] Pass-off settings are the fine tolerances required to certify a repaired or overhauled fuel control unit as serviceable.

by small amounts of carbon build-up partially blocking the nozzle holes, but they were not considered to have been a factor in the engine failures.

No faults or anomalies were found with the remaining engine parts or ancillary items during bench testing.

Core lock

Thermal lock or core lock is a result of the differing cooling effects of air on various rotating metal engine components. Tolerances between moving and stationary turbine parts can be compromised by differing rates of thermal contraction as the engine cools following an in-flight shutdown, causing them to temporarily lock together to prevent engine rotation.

Meteorology

Across Northern Ireland, the meteorological conditions on the evening of 12 November 2020 were characterised by an active cold front crossing from the west. This brought a band of rain, heavy in places, across the region as shown in Figure 5.

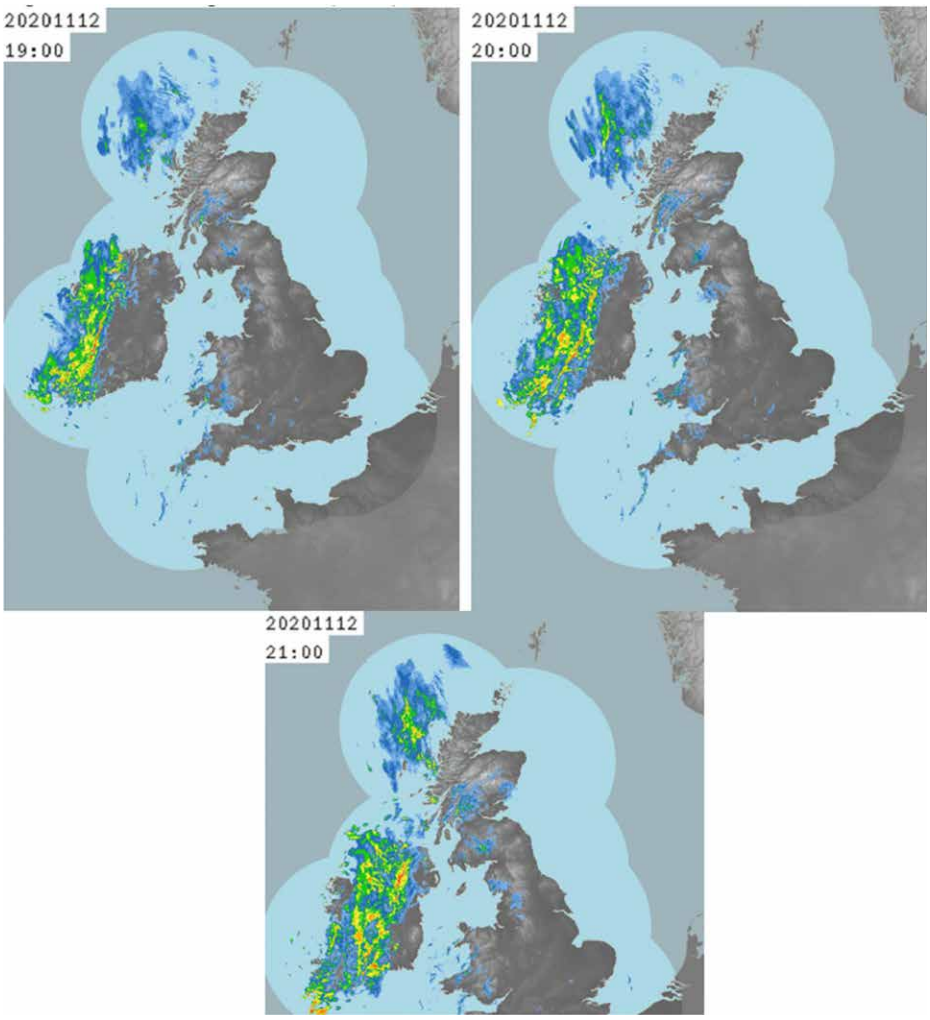

Figure 5

Met Office radar images for 1900, 2000 and 2100 hrs

Thick layers of cloud existed within this frontal zone from around 1,500 ft amsl, occasionally lowering to 700 ft amsl, with cloud tops up to 16,000 ft amsl. Analysis of a radiosonde ascent showed the 0°C Isotherm was around 8,500 ft and the +5°C Isotherm around 4,500 ft. Due to the very high liquid water content in the atmosphere, sustained flight in or around the 0°C Isotherm could lead to a risk of severe airframe icing developing.

The relevant from F215 (Figure 6) forecast the presence of moderate icing with a risk of severe icing on the cold front.

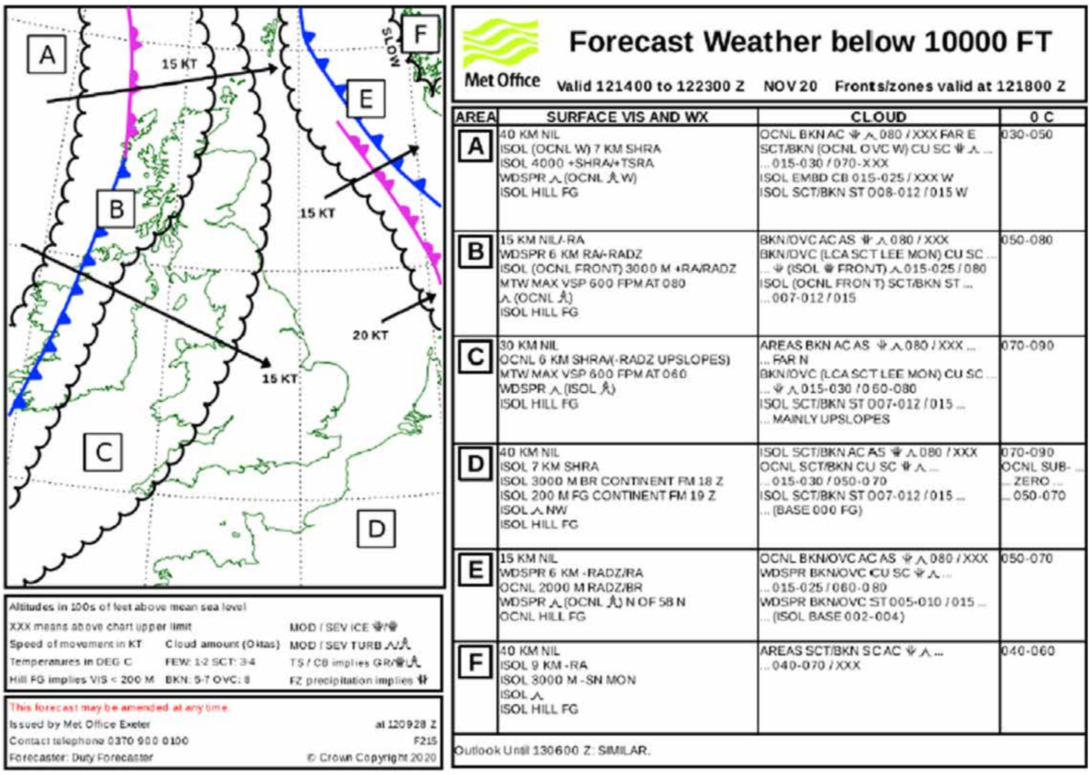

Figure 6

Met Office F215 forecast Weather Below 10,000 ft

Airfield information

Eglinton, (Figure 7) is a regional airport on the south bank of Lough Foyle. Runway 08/26 is 6,460 ft long and has an asphalt surface.

The runway is equipped with an ILS for both landing directions and there is an NDB on the airfield. The NDB radiates 24 hours a day and the ILS is left radiating on whichever runway is in use at the close of the ATC watch. When the ATC watch closed on 12 November 2020 the ILS was radiating on Runway 26.

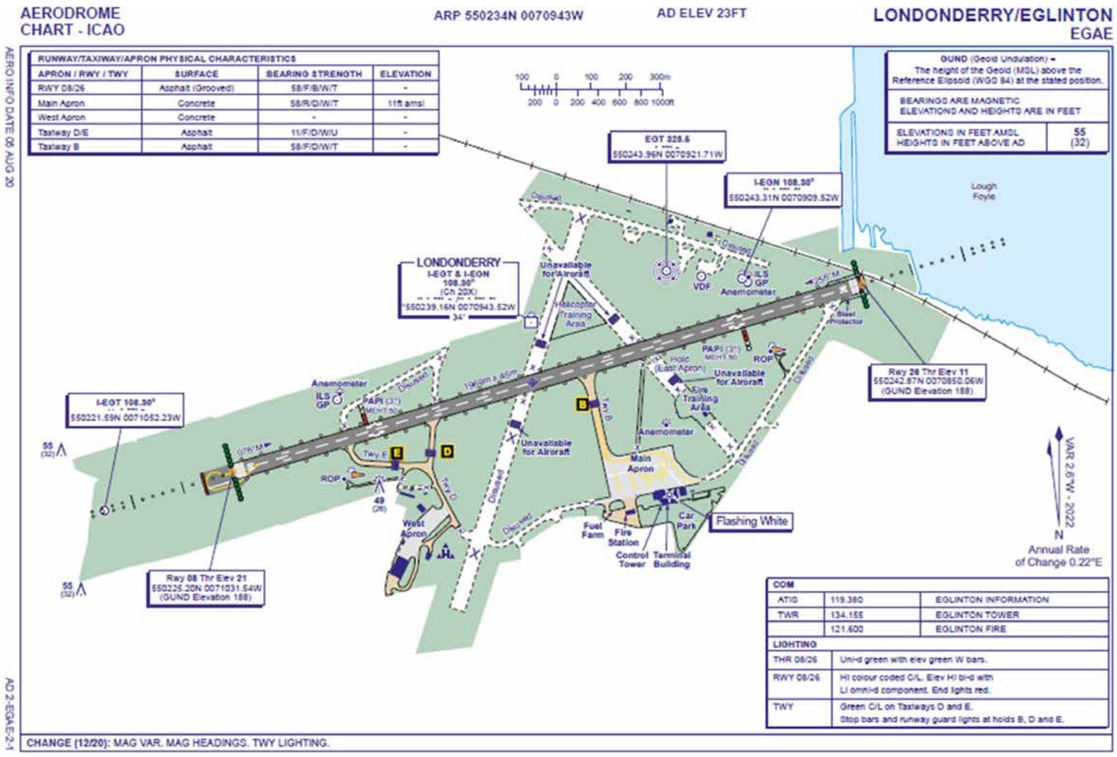

Figure 7

Eglinton Airport diagram

While not intended for use out of aerodrome operating hours the ILS would have provided guidance in azimuth and elevation and could have been of assistance in locating the runway.

Personnel

Pilot

The aircraft was operated by a single pilot. Under current regulations a pilot must cease commercial single-pilot operations at age 60. The incident pilot was 59 at the time of the event and was aware that once he reached age 60 he could no longer be employed as a pilot. His contract indicated he would be offered alternative employment until a retirement age of 67 and he intended to continue in employment until then. He had raised the matter through the unit's chief pilot. The operator had approached its parent organisation's human resources (HR) department in October 2019 to seek guidance on what employment would be available to the pilot after his 60th birthday. Although repeated requests had been made before the event, which occurred two months before the pilot's 60th birthday, there had been no offer of alternative employment. The pilot stated during interview that the uncertainty over his future, and other personal stressors, had contributed to him feeling worried and had caused his sleep pattern to be badly disrupted. He stated that the stress he was experiencing had the effect of making him feel angry more easily, but he had not thought it would affect his flying performance and had not considered seeking any kind of emotional or psychological support.

Sleep history

The commander's description of his sleeping patterns indicated that he usually gave himself sufficient sleep opportunity but suffered disturbed sleep, with early waking or periods of wakefulness on the four nights prior to the incident. The pilot slept for about six hours on the night immediately before the incident, compared to his reported sleep need of approximately nine hours.

Observers

The observers, though necessary for the operational role, were carried aboard the aircraft as passengers and not as technical crew. They were not therefore subject to flight time limitations or other crew regulations. However, the operator had embarked on a Crew Resource Management programme to enhance the integration of the observer activities with the overall operation of the aircraft, which included some simulator training on the operator's helicopter types.

Checklists

The aircraft was routinely operated by a single pilot. Consequently, all the normal and abnormal checks were conducted by the pilot without assistance from or monitoring by anyone else. The operator's Operations Manual stated the following about use of the aircraft checklists.

> *'For normal operations, the Flight Crew adopt a flow system. For each phase of flight, the Flight crew member actions the relevant switches and required configurations using a well-practiced route and order around the flight deck. They will then follow up with "Set-Up Redundancy," using the Normal Abbreviated Checklist, to check the relevant actions and configurations have been completed. All Emergency and Abnormal checks should be carried out using the appropriate checklist. Items printed in bold on the aircraft Emergency and Abnormal checklist MUST be committed to memory.'*

Reference is made to checks for icing in the pre-takeoff, climb and cruise checklists but these checks relate to particular flight events. There was no procedure specified in the operator's manuals for entry into IMC or icing conditions, so selection of ice protection required pilots to recognise if such conditions existed. The aircraft's Primary Flight Display and Multi-Function Display show total air temperature, indicating when the temperature is in the band for icing to occur, but there is no colour change or other warning to draw the pilot's attention. There was no system fitted to the aircraft specifically to detect or alert the pilot to the existence of icing conditions.

The AFM Supplement covering flight into known icing contained a checklist for entry in IMC:

Flight In Visible Moisture, OAT less than 5 deg C

Before entering cloud:

1. Engine Anti-ice switches. . . . . .FAST or SLOW, as required
2. Condition Levers . . . . .MAX RPM
3. Pitot/Stall Warning Heater switches . . . . .ON
4. Engine Anti-ice Ammeter & TGT Indicators . . . . .Checked
5. Ice Light . . . . .ON, if required (night operation)
6. Cabin Ventilation/Heating Windscreen De-misting. . . . .ON

Figure 8

Checklist for entering cloud

The pilot stated that he was aware of this checklist but had not used it during the incident flight. It was not a part of the normal checklist card carried in the aircraft cockpit.

The aircraft checklist contains actions for the failure of both engines:

3.3.c. **FAILURE OF BOTH ENGINES EN ROUTE**

If both engines fail en route, carry out the following procedure:

Immediate action to attempt quick restart

1	Both power levers	IDLE
2	Both igniter switches.	ON CONT

Secondary action if quick restart is unsuccessful

3	Fly and trim the aircraft at the recommended gliding speed of 90 kts IAS	
4	Both condition levers	FUEL OFF FEATHER
5	Both generator switches	OFF
6	Attempt a normal air start on either engine	
7	If start is unsuccessful, attempt a normal air start on the other engine	

Follow up action

If neither engine can be started after repeated attempts carry out a Landing Without Power (Ref Para 3.13.b).

When one or both engines have been restarted carry out normal after start checks including operation of the powerplant anti-ice system, if appropriate

WARNING...
APPROXIMATELY 1000 ft WILL BE LOST DURING THE EXECUTION OF EACH RESTART ATTEMPT

Figure 9

Failure of both engines checklist

This is an emergency checklist intended to be completed from memory by the single pilot. Should the first two items not result in an immediate restart then the remaining items prepare the engines for an air start. The AIR START checklist is shown in Figure 10.

AIR START

1. Generator switch for Inoperative engine . OFF
2. Select and hold starter switch lever towards the engine to be started.
3. As N_1 speed accelerates through 12 to 15 per cent, move the condition lever forward to MIN RPM. *This avoids momentary propeller overspeed and minimises drag surge as the propeller unfeathers.*
4. De-energize the starter when 58 per cent N_1 speed is reached.
5. A positive indication of oil pressure must be obtained when 60 per cent N_1 is reached.
6. The start is completed when a stabilized N_1 speed of 60 to 65 per cent is reached, the propeller has unfeathered and has stabilized at 59 to 69 per cent N_2.

Notes...

To assist in starting the other engine, the generator on the operating engine may be switched ON, but an N_1 speed of 70 per cent or greater must be set.

Depending upon conditions the starting cycle takes approximately 15 to 45 seconds for each engine.

CAUTION...

Due to thermal change within the turbine, the gas producer section of the engine may lock up after an inflight shutdown. This is a temporary condition which exists after the engine has been shut down for approximately one minute and which may continue for up to ten minutes following the shutdown. In an emergency, air starts may be attempted during the time period between one minute after shutdown and ten minutes after shutdown but restart cannot be guaranteed.

Figure 10

Air start checklist

The pilot stated that after both engines failed he was "shocked and confused." His immediate feeling was to fear for the lives of all onboard. His initial focus was on the possibilities for a forced landing. As a result, he did not attempt an immediate relight but began the AIR START procedure once established in the glide.

Organisational information

Most of the operator's flights were conducted in VMC. While all the operator's pilots had instrument ratings, they exercised them less frequently than would be usual in some other commercial aviation environments.

The operator had two similar aircraft, but differences between them had led to different clearances for operating in known icing conditions. While the incident aircraft was cleared for unrestricted flight in icing conditions the other aircraft was not cleared for flight in airframe icing. There had been frequent discussion about the icing clearance and the issue had led to a drop in confidence among the crew about operating in such conditions. For example, during the incident flight the pilot chose to operate below the 0°C isotherm even though there was no technical requirement for the incident aircraft to remain clear of airframe icing conditions.

The operator did not include specific training in winter operations in its recurrent programme.

Stress, fatigue and performance

CAP 737 – *Flight-crew human factors handbook*[9] defines stress on a human being as:

> *'The body's non-specific response to demands placed upon it, whether these demands are pleasant or unpleasant.' and 'An unresolved pressure, strain or force acting upon an individual's mental or physical systems which, if continued, will cause damage to those systems.'*

It states that continued stress can create physical symptoms such as insomnia and irritability. The document also lists some performance and behaviour issues associated with stress, including omitting to carry out actions.

CAP 737 lists the effects of fatigue, including '*easy distraction*', '*increased slips and mistakes*' and '*abnormal mood swings.*'

Fatigue is defined by the International Civil Aviation Organisation (ICAO) as:

> *'A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase or workload (mental and physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties.'*

The ICAO Fatigue Management Guide[10] summarises the scientific principles of fatigue management and states:

> *'losing as little as two hours sleep on one night will reduce alertness the next day and degrade performance on many types of task.'*

Support for pilots

Negative life events and stressors can have a detrimental effect on anyone's wellbeing. Pilots are not immune and may need support in times of stress. Common options including seeking support from a line manager, HR department or doctor may not appeal if the individual is concerned about confidentiality or fears the loss of their licence or medical certificate and therefore livelihood.

Footnote

[9] Civil Aviation Authority (2014) CAP737 Flight-crew human factors handbook. https://publicapps.caa.co.uk/docs/33/CAP%20737%20DEC16.pdf [accessed on 30 April 2021]

[10] International Civil Aviation Organisation (2015) *Fatigue Management Guide for Airline Operators.* https://www.unitingaviation.com/publications/FM-Guide-Airline-Operators/#page=1 [accessed on 30 April 2021]

Confidential peer-to-peer support programmes are considered particularly suitable support mechanism for pilots. Pilots are considered more likely to be open with a fellow professional who does the same job and understands the unique stresses and demands of it. A pilot peer support programme can be described as follows:

> *'A structure whereby a pilot can get confidential help with mental wellbeing or life stress issues, either for themselves or for a colleague. The confidentiality of the process is absolute, except for certain clearly defined circumstances which are standard medical practice. At the heart of the programme are Pilot Peers: ordinary line pilots who are trained in basic listening and counselling skills, and who have extensive knowledge of company policies which can assist the pilot in addressing their problems. These Peers are trained, mentored and supported by a suitably qualified Mental Health Professional (MHP)'*[11]

Pilot peer support programmes also provide anonymised data to operators to feed into the safety management system. This can help an organisation to identify and manage risks associated with poor mental wellbeing.

The investigation did not find any published evaluations of pilot peer support programmes.

Pilot support guidance and practice in the UK

There are no regulations in the UK requiring commercial air transport operators to provide access to a support service specifically for pilots.

The CAA has been encouraging operators to implement pilot support for several years and published *CAP 1695 Pilot Support Programme – Guidance for Commercial Air Transport Operators*[12] in September 2018. Several larger operators within the UK have implemented in-house pilot support programmes and many smaller UK operators have contracted third parties to provide them.

In July 2020, the CAA issued Safety Notice SN-2020/014[13] that stated:

> *'Support Programmes are key. It remains essential that senior management of all aviation stakeholders, mental health professionals, trained peers, and in many cases representative organisations of crew members and safety sensitive personnel work together to enable self-declaration, referral, advice, counselling and/or treatment, where necessary when mental or wellbeing issues arise. CAT operators are strongly encouraged to continue with their maintenance of or preparations for introducing Support Programmes.'*

Footnote

11 European Pilot Peer Support Initiative (2019). *Pilot peer support programmes: The EPPSI guide*. https://www.ifalpa.org/media/3519/eppsi-guide-v81.pdf [accessed on 26 April 2021]

12 https://publicapps.caa.co.uk/docs/33/CAP1695%20-%20Pilot%20Support%20Programme_SEP18.pdf [Accessed on 15 March 2021]

13 *https://publicapps.caa.co.uk/docs/33/SN%20-%20The%20Effect%20on%20Mental%20Health%20From%20Return%20To%20Work%20Due%20to%20Covid%2019.pdf* [accessed on 17 March 2021]

In January 2021, the CAA issued Safety Notice SN-2021/004[14] which stated:

> *'CAT operators are strongly recommended to continue to introduce Flight Crew Support Programmes as required by the Regulation [Regulation EU 2018/1042] and to maintain existing programmes despite a deferred implementation date.'*

Pilot support regulation and guidance in the EU

Regulation EU 2018/1042 introduced requirements in commercial aviation for pilot support:

> *'The operator shall enable, facilitate and ensure access to a proactive and non-punitive support programme that will assist and support flight crew in recognising, coping with, and overcoming any problem which might negatively affect their ability to safely exercise the privileges of their licence.'*

Implementation was postponed from 14 August 2020 until 14 February 2021 by Commission implementing Regulation (EU) 2020/745 of 4 June 2020 to account for delays caused by public health restrictions. Consequently, the new regulations were not in force and applicable before the UK left the EU on 31 December 2020 and were not therefore automatically applicable in the UK at the time of the occurrence.

The CAA stated that the Statutory Instrument necessary to implement Regulation EU 2018/1042, in whole or in part, is intended to be laid before parliament on 31 October 2021. The Statutory Instrument will come into force (as UK law) 21 days later, and the CAA would expect applicable operators in the UK to be fully compliant with the requirements within 90 days of the law coming into force.

Educational aspects of pilot support

Santilhano (2019)[15] found in her research that,

> *'the historical emphasis in aviation on identifying physical symptoms of incapacitation may contribute to pilots' lack of understanding or awareness of their emotional and psychological well-being, subsequently failing to see it as impacting their fitness to fly.'*

The Acceptable Means of Compliance[16] that accompanied Regulation EU 2018/1042 specified that the support programme should contain as a minimum:

> *'procedures including education of flight crew regarding self-awareness and facilitation of self-referral' and 'involvement of trained peers, where trained peers are available.'*

Footnote

[14] Safety Notice SN-2021/004 *Update to the introduction of UK Regulation No. 2018/1042 of 23 July 2018 and 2020/745 of 4 June 2020 amending Regulation No. 965/2012* http://publicapps.caa.co.uk/docs/33/SafetyNotice2021004.pdf [accessed on 17 March 2021]

[15] Santilhano, W., Bor, R. and Hewitt, L.M.M. (2019). The role of peer support and its contribution as an effective response to addressing the emotional well-being of pilots. *Aviation Psychology and Applied Human Factors, 9(2),* 67-76

[16] AMC3 CAT.GEN.MPA.215 Support Programme.

The guidance material[17] suggested that the education of flight crew should include:

'Positive impacts of a support programme

Awareness of job stressors and life stressors – mental fitness and mental health

Coping strategies

Early recognition of mental unfitness

Principles and availability of a support programme'

The AAIB observed an example of an introductory education module for UK aviation personnel that covered these aspects. At the end of the module, participants were asked if they would now feel confident contacting the peer support service. Of 23 responding, two said '*I still have concerns about using the service*', 11 that '*I already knew about the service and am happy to use it*' and 10 said '*I wasn't aware of the service but am happy to use it.*'

Support at the operator

The parent organisation of the operator offered a self-referral confidential counselling service for all employees, intended to provide support with worry and stress. The service was publicised in emails from the occupational health and wellbeing department of the parent organisation, but the pilot was not aware of it before the occurrence.

The operator did not offer a support service specifically for pilots. The operator reported that it had been encouraged by the CAA to implement one but, at the time, felt that the informal support offered within its small pilot community was sufficient. However, public health restrictions meant there was little contact between pilots at the unit in the lead-up to this incident. Consequently, there was little opportunity to seek or offer informal support.

A representative of the operator's HR department explained that staff shortages and pressures created by public health restrictions, as well as the legal complexity of the situation, had hampered the resolution of the pilot's employment status.

Analysis

Introduction

The investigation found no evidence of defects in the aircraft engines, anti-ice systems, fuel system or the fuel itself that could have caused the double engine failure.

Operation of the aircraft

The pilot was particularly concerned by the threat of airframe icing conditions, which he covered in his pre-flight briefing. At that briefing he had decided to operate the flight below the 0°C isotherm to avoid the risk of airframe icing. After the initial low level tasking the aircraft climbed to higher altitude to undertake its originally planned tasking. During that

Footnote

[17] GM3 CAT.GEN.MPA.215 Support programme, training and awareness

climb the pilot recognised that the aircraft would enter IMC conditions and recalled selecting the engine anti-icing ON before entering cloud. However, he did not recall the existence of the ENG ANTI-ICE captions and could not confirm if they illuminated. It is likely therefore that he did not select the engine anti-icing system ON before entering engine icing conditions despite his recollection that he did so. A build-up of ice in the engine intakes would then have precipitated the failure of both engines.

The operator's pilots were more familiar with operating in VMC and it is likely they had a lower awareness of the risks posed by operating in engine icing conditions than if they had done so more frequently. In this single-pilot operation there was no challenge-an-response process for entry into IMC, and no means of trapping an omission to select engine anti-icing. It therefore represented a single failure path to double engine flameout.

After the engines failed the pilot promptly established the aircraft in a glide descent toward Eglinton. He asked for assistance from Aldergrove ATC, who were able to provide vectors but unable to assist with reopening Eglinton in time for a landing there. The loss of engine driven generator power following the engine flameouts resulted in failure of many electrical services, including the topographical map display. The pilot's iPad also failed and initially he found himself with limited navigation information. Aldergrove ATC lost radar contact as the aircraft descended. One of the observers recognised that the pilot was in difficulty and immediately went to the cockpit to assist, taking with him an iPad with a mapping application that he and the pilot used to navigate to Eglinton. His presence and support to the pilot assisted in the conduct of the restart drills and the approach to Eglinton.

During the descent the right engine restarted on the first attempt. The left engine required three attempts to restart. The pilot attributed this to the igniters not being selected, though it is possible that the left engine was also affected by the core lock phenomena. Once both engines had restarted the pilot and observer used the iPad to position for a landing at Eglinton. The observer was not aware that the ILS would be radiating, and this was not considered by the pilot. Because it was unlit the crew identified the aerodrome quite late in the approach and flew a circuit to land. The pilot began a descent from the circuit based on the position shown on the iPad and only positively identified the aerodrome visually on the approach at approximately 300 ft agl. The rate of descent was variable and much higher than usual during the latter stages of the approach, but a safe landing was achieved.

Although both engines had restarted the pilot was sufficiently concerned about the prospect of further engine issues that he rejected the option of a transit to Aldergrove. This would have offered a fully lit airfield, ATC assistance and approach aids, but would have extended the flight by approximately 20 minutes.

Pilot wellbeing and support

The unit's chief pilot had attempted to resolve the pilot's contractual situation. The operator's HR department stated that staff shortages and public health restrictions in place at the time had hampered their efforts. The delay meant that the pilot had been uncertain about his future for about a year at the time of the incident, and he stated that the stress he was experiencing disrupted his sleep.

In the days leading up to the event the pilot stated that he had suffered a period of disturbed and restricted sleep which he considered arose from various stressors, primarily his contractual situation and the lack of a resolution to it. On the night before the incident, he had lost approximately three hours sleep and his sleep quality on the preceding three nights was poor.

One effect of both stress and fatigue is irritability or difficulty regulating mood. The commander described his exasperation at the repeated change of tasking instructions during the departure, and the stress and fatigue he reported may have been a factor in this.

The pilot reported that he considered his flying performance would not be affected by the worry he was feeling about his future or the effects of disrupted sleep, and he did not consider seeking assistance. It was not possible to determine whether stress and fatigue were a factor in the pilot omitting to turn on the engine anti-ice system, but the relationships between stress, disrupted sleep and impaired human performance are well established and are acknowledged hazards in aviation.

The limited social contact at the unit in the period leading up to the incident provided little opportunity for others to notice any observable symptoms, and the ad hoc social support that the unit relied on was also not readily available. The pilot was not aware of the confidential self-referral counselling service that was available to all the company's employees.

There was no applicable regulatory requirement for a pilot support programme at the time of the incident, though the CAA had encouraged all CAT operators to introduce one. Following the model of Regulation EU 2018/1042, such a programme would include education to raise pilot awareness of and access to confidential peer support. The incident pilot did not identify in himself the effects of the various stressors or recognise that they might represent a flight safety hazard. The example training observed as part of this investigation appeared effective in raising awareness that a confidential support facility was available, helping pilots to recognise the hazards and refer themselves for assistance if necessary.

The CAA stated that the Statutory Instrument necessary to implement Regulation EU 2018/1042, in whole or in part, is intended to be laid before parliament on 31 October 2021. The Statutory Instrument will come into force (as UK law) 21 days later, and the CAA would expect applicable operators in the UK to be fully compliant with the requirements within 90 days of the law coming into force.

Engines

During examination of the engine components and operational testing, voids were found in the left fuel nozzle's spray pattern due to carbon build-up. The engines' fuel control unit idle speeds were slightly out of tolerance, there was some wear of the axial and centrifugal compressor blades, and there was corrosion present in the left engine's axial compressor wheel hubs. However, these issues were attributed to normal wear and tear typical in use. There was no evidence of damage to the engines that may have been caused by ice, overtemperature or overspeed events.

The results of fuel testing and forensic analysis of the fuel samples and filters indicate that the fuel system and contents were not a factor in this incident.

The failure of the heating element on one of the propeller blades would not have caused the engines to fail, and there was no other evidence of mechanical or electrical defects that would have caused or contributed to the incident.

The AFM caution in paragraph 2 of section 4.17.e '*Use of Engine Anti-ice System*' is informative:

> '***Caution…***
>
> *The formation of intake ice may cause rapid power loss. Selecting Power ENGINE ANTI-ICE to FAST or SLOW, after intake ice has formed, may cause engine flame-out.'*

It is likely that the initial loss of propeller torque observed by the pilot was a result of ice forming on the engine intake ducts. The absence of soft body damage on the axial compressor blades does not necessarily mean that ice was not present: the ice may have melted or softened sufficiently to avoid damage to the compressor when it was released from the intake ducts.

If anti-ice was selected after ice had formed, it would have melted and loosened the ice causing a combination of water and ice to enter the engines' compressors and progress into the combustion chambers. This could have interrupted the combustion process, however, when anti-ice is selected the igniters operate continuously to maintain combustion and resist engine roll-back.

If the pilot did not select powerplant anti-ice, it is likely that a rapid build-up of ice formed around the engine intake ducts when the aircraft entered cloud, choking the engines of air resulting in roll-back and shut down. The fact that both engines shut down within a short time of each other adds weight to this possibility. As the aircraft descended and the outside air temperature increased, the ice may have melted sufficiently to unblock the ducts enabling the pilot to restart the right engine. It took some time to restart the left engine, and thermal (core) lock may have been a factor.

Conclusion

It is likely the engine anti-icing system was not selected ON before entry into cloud with an outside air temperature less than 5°C. A build-up of ice in the engine ducts probably caused the engine symptoms noted by the pilot and the subsequent rollbacks and flameouts. The investigation found that the pilot's limited recent experience in icing conditions was likely to have been a contributory factor, and that circumstances causing stress and fatigue could have affected his performance. Both engines were relit during the descent and a safe landing was made at Eglinton, although the airport was closed.

Safety action

The operator has taken the following action:

Introduced a standard system of icing conditions briefing and checks for all the operator's flights. This includes pre-flight briefing of icing conditions along with actions required and the impact of any aircraft system unserviceabilities. Inflight use of a standard response to any change of altitude such as "Levelling FL70, temperature 2°C, engine anti-icing is on."

Emphasis on 'Standard' climb and descent checks.

Secured funding to provide an update to the TAWS database on the incident aircraft.

Introduced icing checklists that can be called for by either the pilot or the observers.

Introduced biannual ground training days for all pilots.

Re-issued a winter operations briefing to all pilots.

Enhanced training for individuals based on examiner, management pilot and individual input.

Produced cockpit aide memoires to cover icing related issues.

Increased communications with pilots relating to mental wellbeing and access to a specific aviation-focused peer support programme within the flying operation in addition to the confidential counselling service already available within the parent organisation.

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