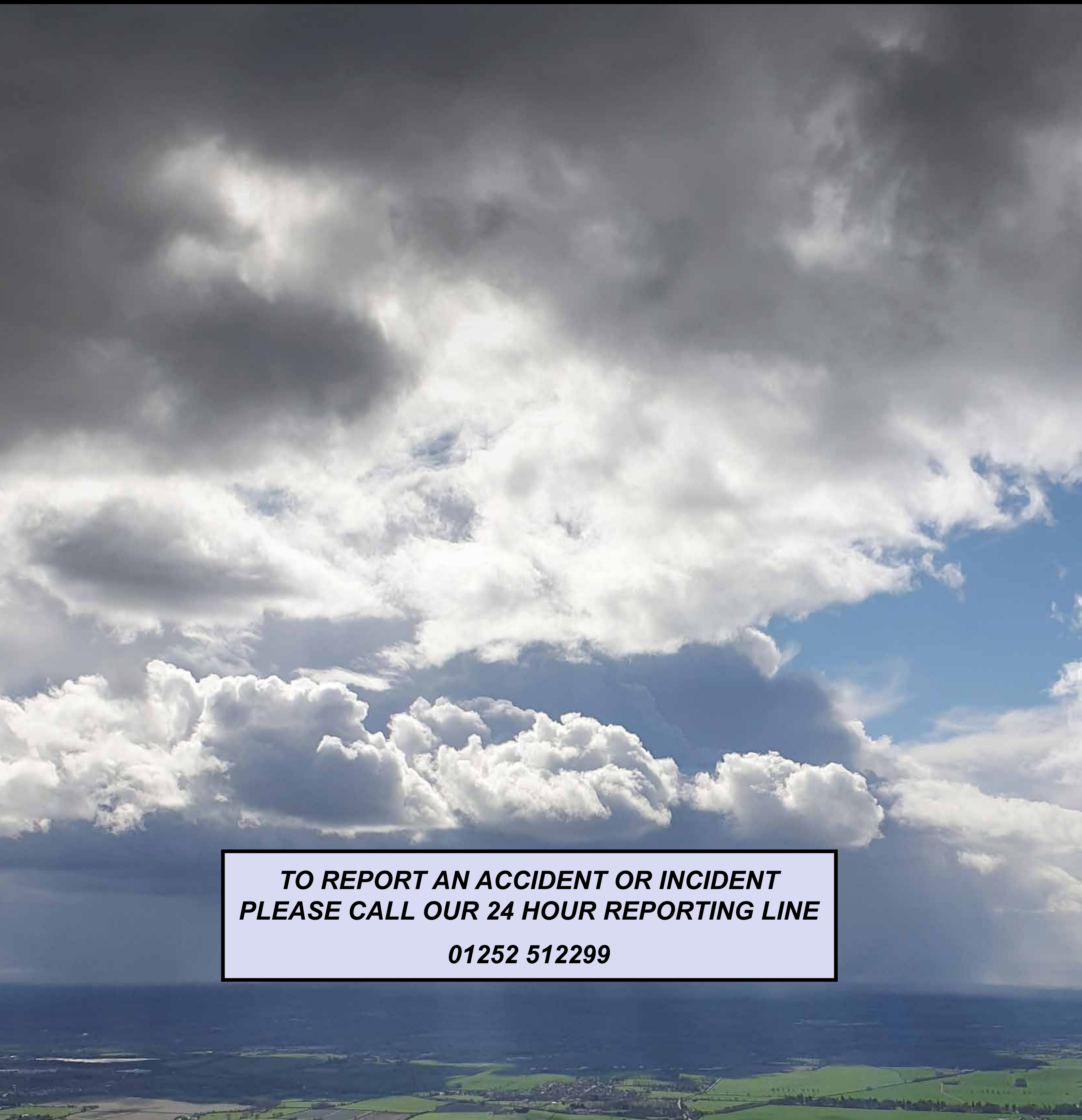
AAIB
Air Accidents Investigation Branch

AAIB Bulletin 10/2021



TO REPORT AN ACCIDENT OR INCIDENT PLEASE CALL OUR 24 HOUR REPORTING LINE

01252 512299

Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
Aldershot
Hants GU11 2HH

Tel: 01252 510300
Fax: 01252 376999
Press enquiries: 0207 944 3118/4292
http://www.aaib.gov.uk

AAIB investigations are conducted in accordance with Annex 13 to the ICAO Convention on International Civil Aviation, EU Regulation No 996/2010 (as amended) and The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018.

The sole objective of the investigation of an accident or incident under these Regulations is the prevention of future accidents and incidents. It is not the purpose of such an investigation to apportion blame or liability.

Accordingly, it is inappropriate that AAIB reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

AAIB Bulletins and Reports are available on the Internet
http://www.aaib.gov.uk

Published 14 October 2021

Cover picture courtesy of Stephen R Lynn LRPS
(www.srlynnphotography.co.uk)

ISSN 0309-4278

Published by the Air Accidents Investigation Branch, Department for Transport
Printed in the UK on paper containing at least 75% recycled fibre

CONTENTS

SPECIAL BULLETINS / INTERIM REPORTS

None

SUMMARIES OF AIRCRAFT ACCIDENT ('FORMAL') REPORTS

None

AAIB FIELD INVESTIGATIONS

COMMERCIAL AIR TRANSPORT

FIXED WING

ROTORCRAFT

None

GENERAL AVIATION

FIXED WING

None

ROTORCRAFT

None

SPORT AVIATION / BALLOONS

None

UNMANNED AIRCRAFT SYSTEMS

None

AAIB CORRESPONDENCE INVESTIGATIONS

COMMERCIAL AIR TRANSPORT

GENERAL AVIATION

CONTENTS Cont

AAIB CORRESPONDENCE INVESTIGATIONS Cont

SPORT AVIATION / BALLOONS

UNMANNED AIRCRAFT SYSTEMS

None

RECORD-ONLY INVESTIGATIONS

MISCELLANEOUS

ADDENDA and CORRECTIONS

None

(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Field Investigation Reports

A Field Investigation is an independent investigation in which AAIB investigators collect, record and analyse evidence.

The process may include, attending the scene of the accident or serious incident; interviewing witnesses; reviewing documents, procedures and practices; examining aircraft wreckage or components; and analysing recorded data.

The investigation, which can take a number of months to complete, will conclude with a published report.

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.

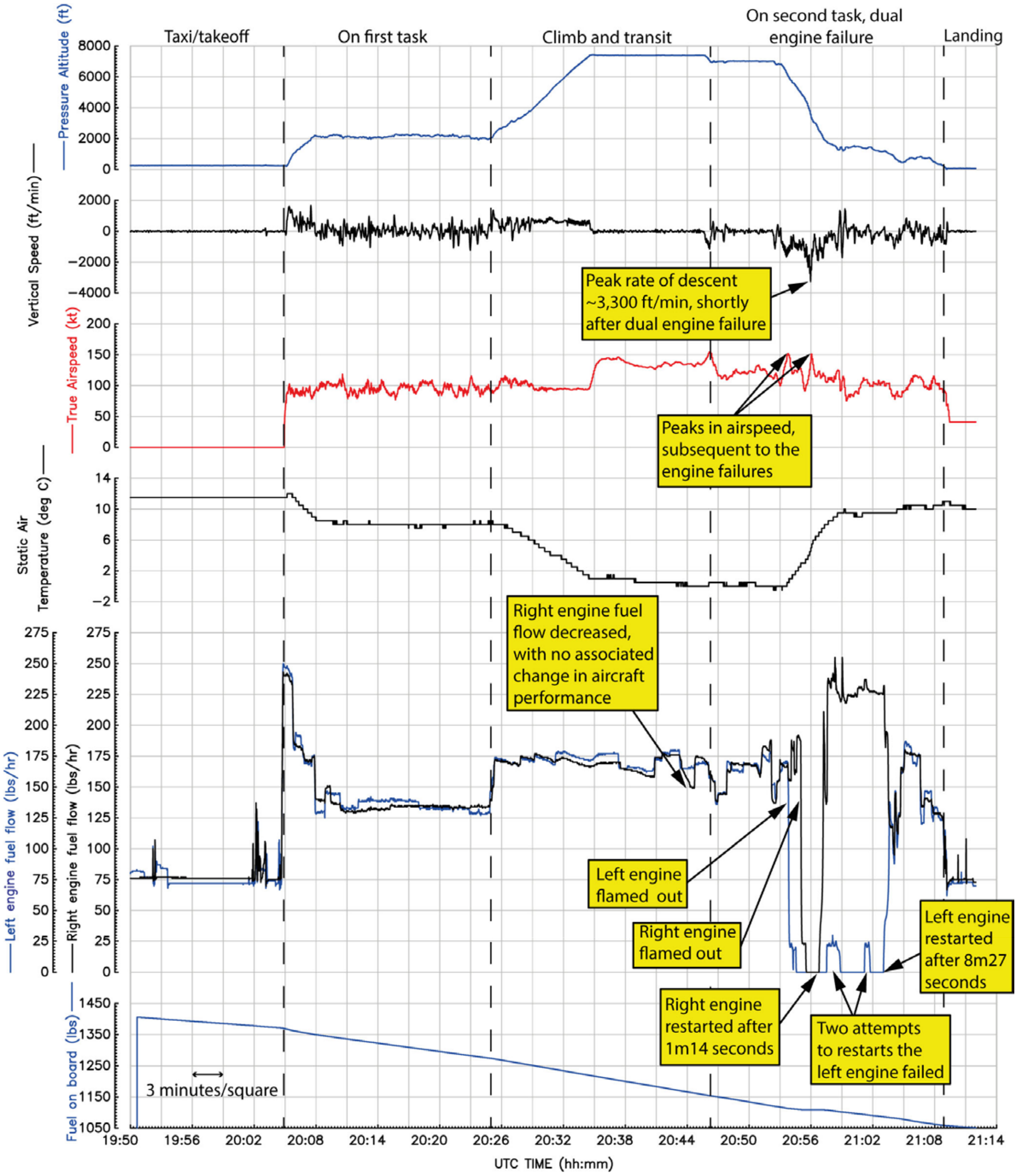
The right engine was successfully restarted 74 seconds after it flamed out and at a pressure altitude of 2,500 ft (2,100 ft amsl), at which point G-CGTC's flight path began to stabilise with a reduction in both the rate of descent and true airspeed recorded. The data then showed two unsuccessful attempts 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.



Peak rate of descent ~3,300 ft/min, shortly after dual engine failure

Peaks in airspeed, subsequent to the engine failures

Right engine fuel flow decreased, with no associated change in aircraft performance

Left engine flamed out

Right engine flamed out

Right engine restarted after 1m14 seconds

Two attempts to restarts the left engine failed

Left engine restarted after 8m27 seconds

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.’

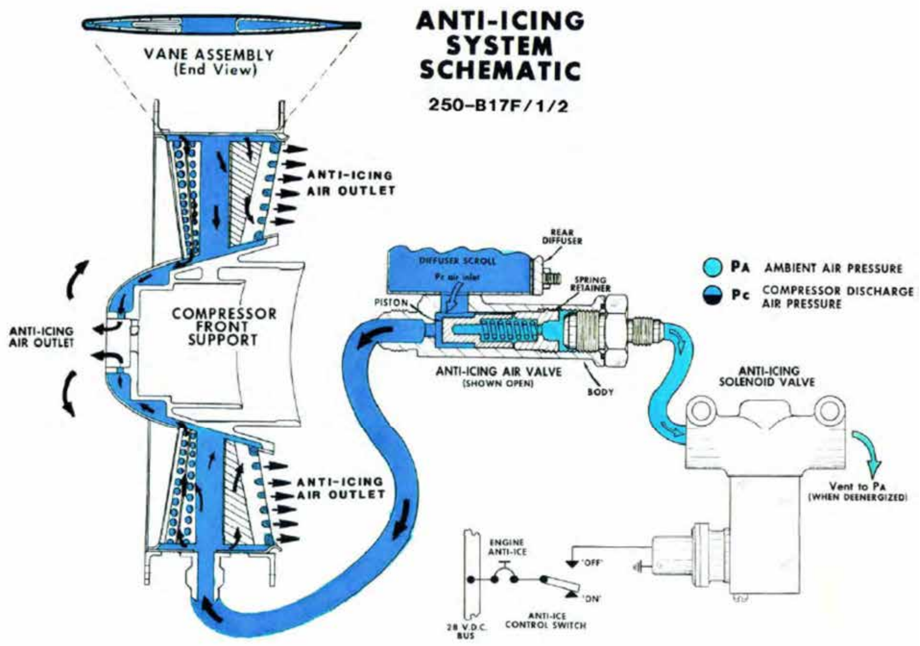


Figure 3

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.

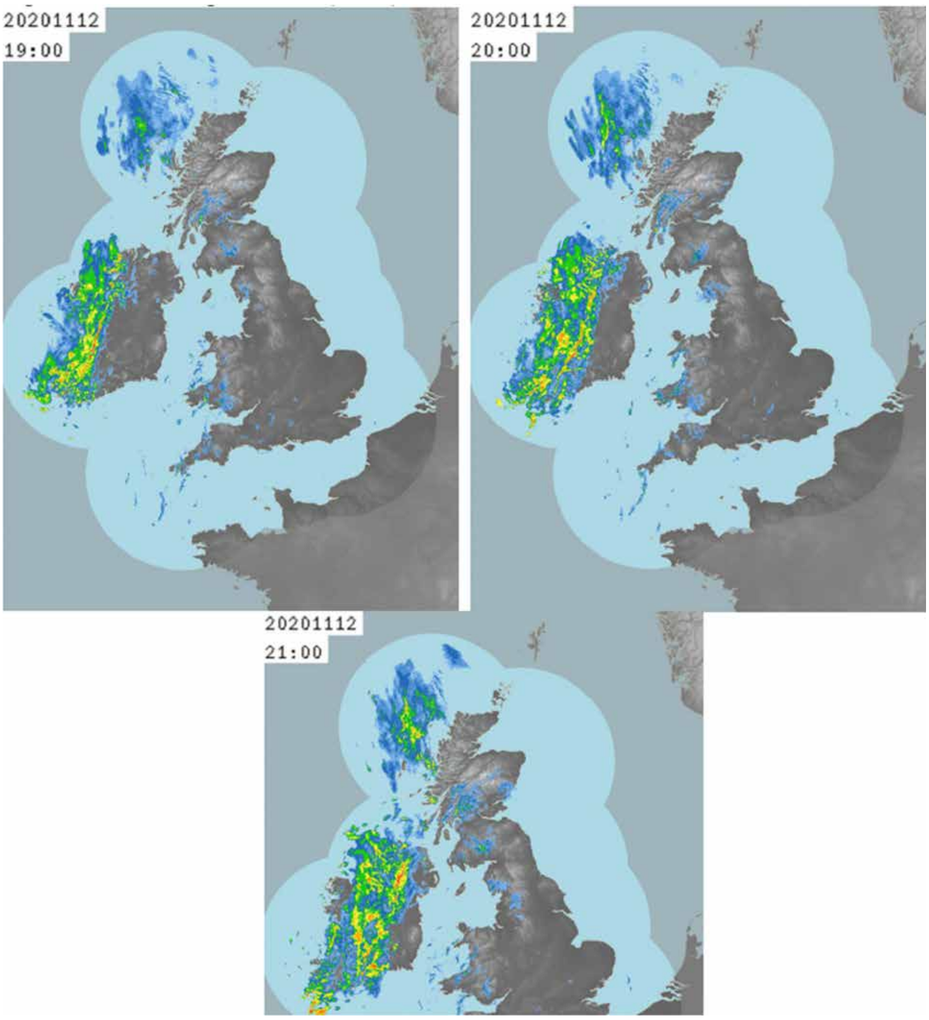
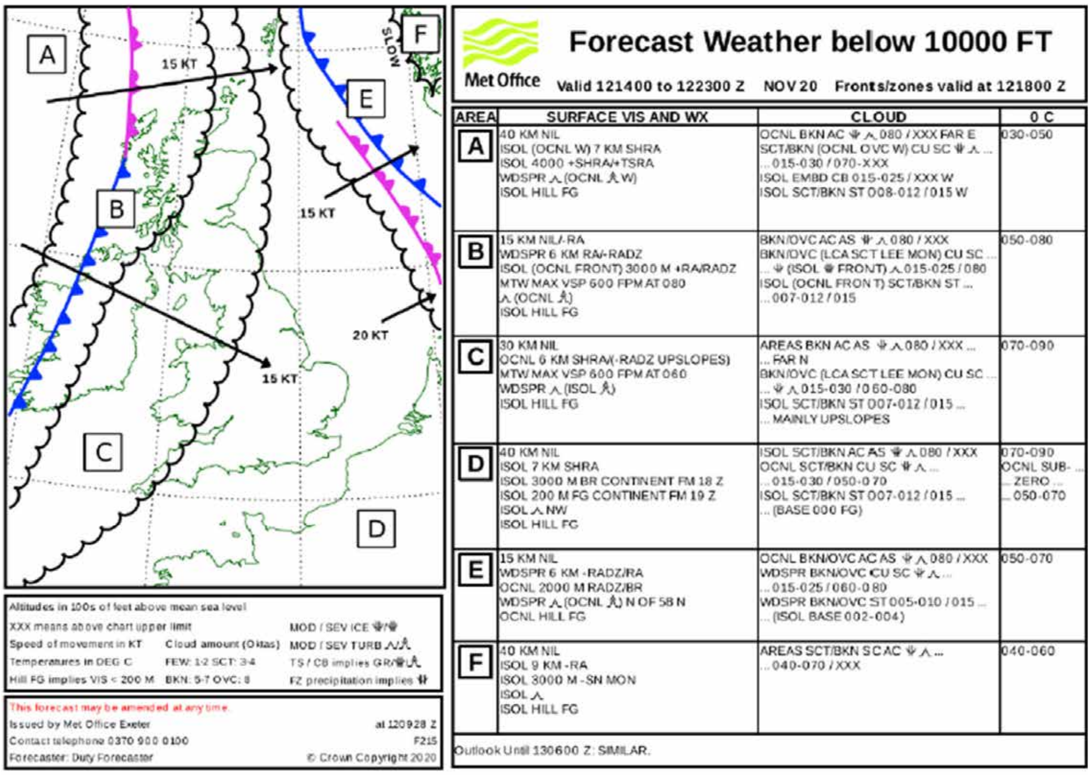


Figure 5

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.



Forecast Weather below 10000 FT

Met Office Valid 121400 to 122300 Z NOV 20 Fronts/zones valid at 121800 Z

AREA	SURFACE VIS AND WX	CLOUD	0 C
A	40 KM NIL ISOL (OCNL W) 7 KM SHRA ISOL 4000 +SHRA/+TSRA WDSPR ⋀ (OCNL ⩓ W) ISOL HILL FG	OCNL BKN AC Ψ ⋀ 080 / XXX FAR E SCT/BKN (OCNL OVC W) CU SC Ψ ⋀ ... ... 015-030 / 070-XXX ISOL EMBD CB 015-025 / XXX W ISOL SCT/BKN ST 008-012 / 015 W	030-050
B	15 KM NIL/-RA WDSPR 6 KM RA/-RADZ ISOL (OCNL FRONT) 3000 M +RA/RADZ MTW MAX VSP 600 FPM AT 080 ⋀ (OCNL ⩓) ISOL HILL FG	BKN/OVC AC AS Ψ ⋀ 080 / XXX BKN/OVC (LCA SCT LEE MON) CU SC ... ... Ψ (ISOL ♆ FRONT) ⋀ 015-025 / 080 ISOL (OCNL FRONT) SCT/BKN ST ... ... 007-012 / 015	050-080
C	30 KM NIL OCNL 6 KM SHRA/(-RADZ UPSLOPES) MTW MAX VSP 600 FPM AT 060 WDSPR ⋀ (ISOL ⩓) ISOL HILL FG	AREAS BKN AC AS Ψ ⋀ 080 / XXX ... ... FAR N BKN/OVC (LCA SCT LEE MON) CU SC ... ... Ψ ⋀ 015-030 / 060-080 ISOL SCT/BKN ST 007-012 / 015 ... ... MAINLY UPSLOPES	070-090
D	40 KM NIL ISOL 7 KM SHRA ISOL 3000 M BR CONTINENT FM 18 Z ISOL 200 M FG CONTINENT FM 19 Z ISOL ⋀ NW ISOL HILL FG	ISOL SCT/BKN AC AS Ψ ⋀ 080 / XXX OCNL SCT/BKN CU SC Ψ ⋀ ... ... 015-030 / 050-070 ISOL SCT/BKN ST 007-012 / 015 ... ... (BASE 000 FG)	070-090 OCNL SUB- ... ... ZERO 050-070
E	15 KM NIL WDSPR 6 KM -RADZ/RA OCNL 2000 M RADZ/BR WDSPR ⋀ (OCNL ⩓) N OF 58 N OCNL HILL FG	OCNL BKN/OVC AC AS Ψ ⋀ 080 / XXX WDSPR BKN/OVC CU SC Ψ ⋀ ... ... 015-025 / 060-080 WDSPR BKN/OVC ST 005-010 / 015 ... ... (ISOL BASE 002-004)	050-070
F	40 KM NIL ISOL 9 KM -RA ISOL 3000 M -SN MON ISOL ⋀ ISOL HILL FG	AREAS SCT/BKN SC AC Ψ ⋀ ... ... 040-070 / XXX	040-060

Outlook Until 130600 Z: SIMILAR.

Altitudes in 100s of feet above mean sea level
XXX means above chart upper limit
Speed of movement in KT
Temperatures in DEG C
Hill FG implies VIS < 200 M
Cloud amount (Oktas)
FEW: 1-2 SCT: 3-4
BKN: 5-7 OVC: 8
MOD / SEV ICE Ψ/♆
MOD / SEV TURB ⋀/⩓
TS / CB implies GR/♆/⩓
FZ precipitation implies Ψ

This forecast may be amended at any time.
Issued by Met Office Exeter at 120928 Z
Contact telephone 0370 900 0100 F215
Forecaster: Duty Forecaster © Crown Copyright 2020

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.

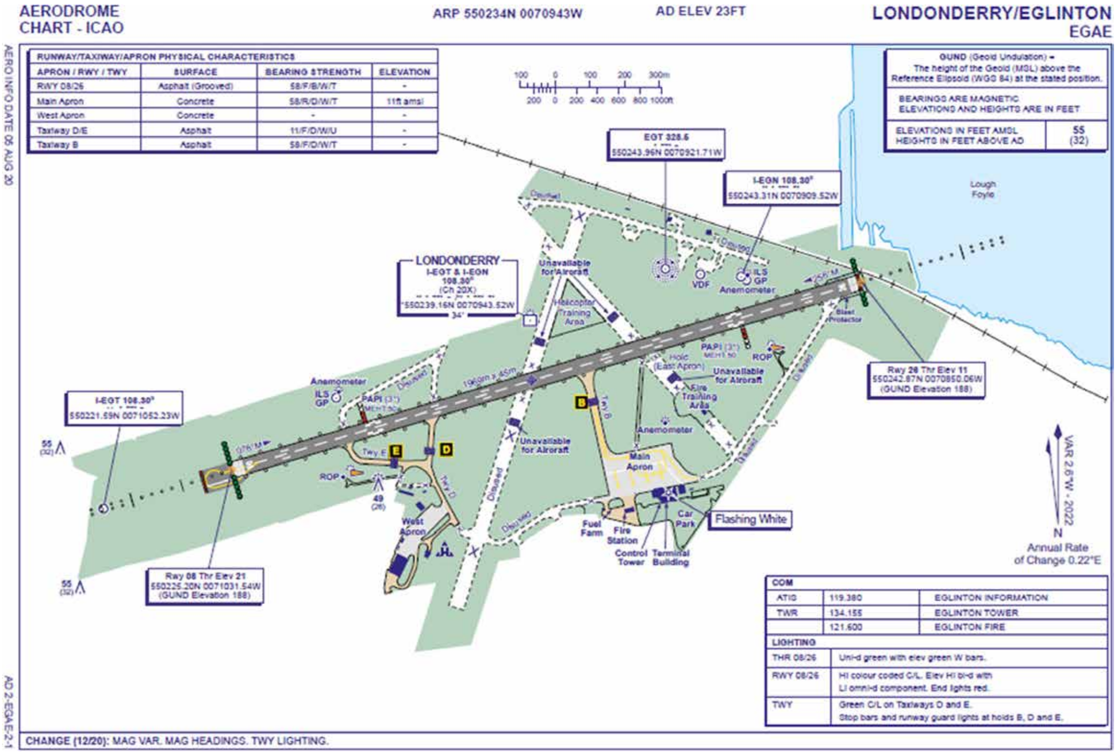


Figure 7

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.

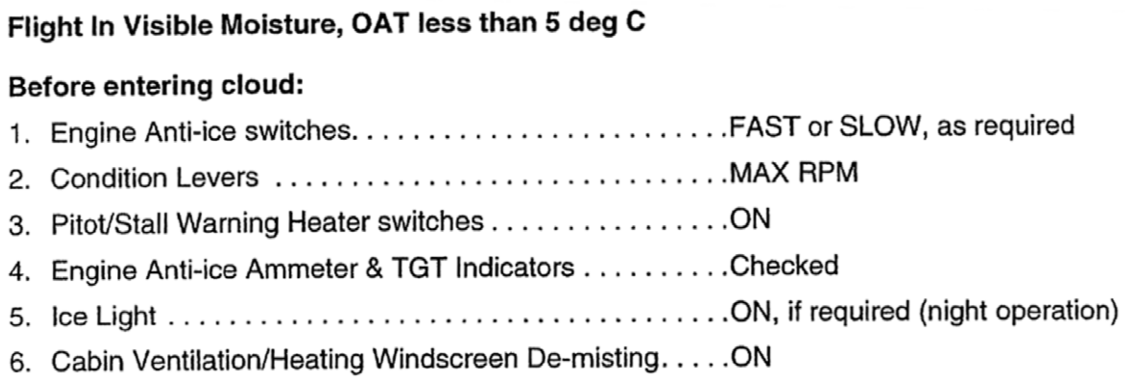
Checklists

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:

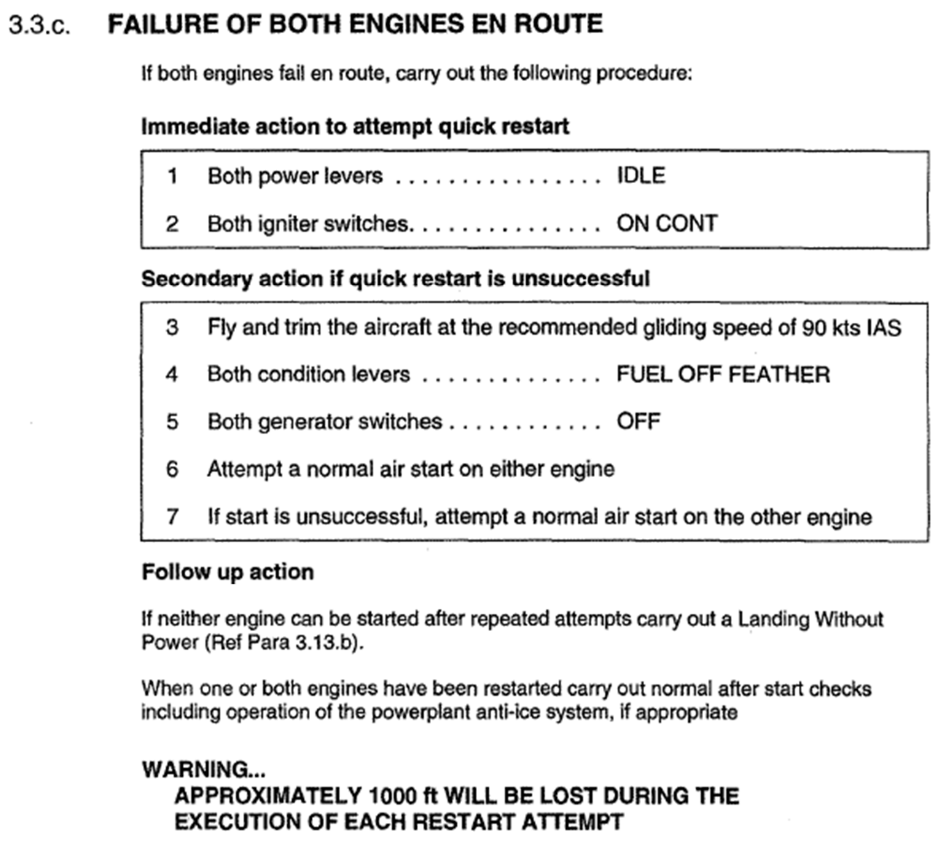
1. Engine Anti-ice switches. . . . . .FAST or SLOW, as required
2. Condition Levers . . . . .MAX RPM
3. Pitot/Stall Warning Heater switches . . . . .ON
4. Engine Anti-ice Ammeter & TGT Indicators . . . . .Checked
5. Ice Light . . . . .ON, if required (night operation)
6. Cabin Ventilation/Heating Windscreen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

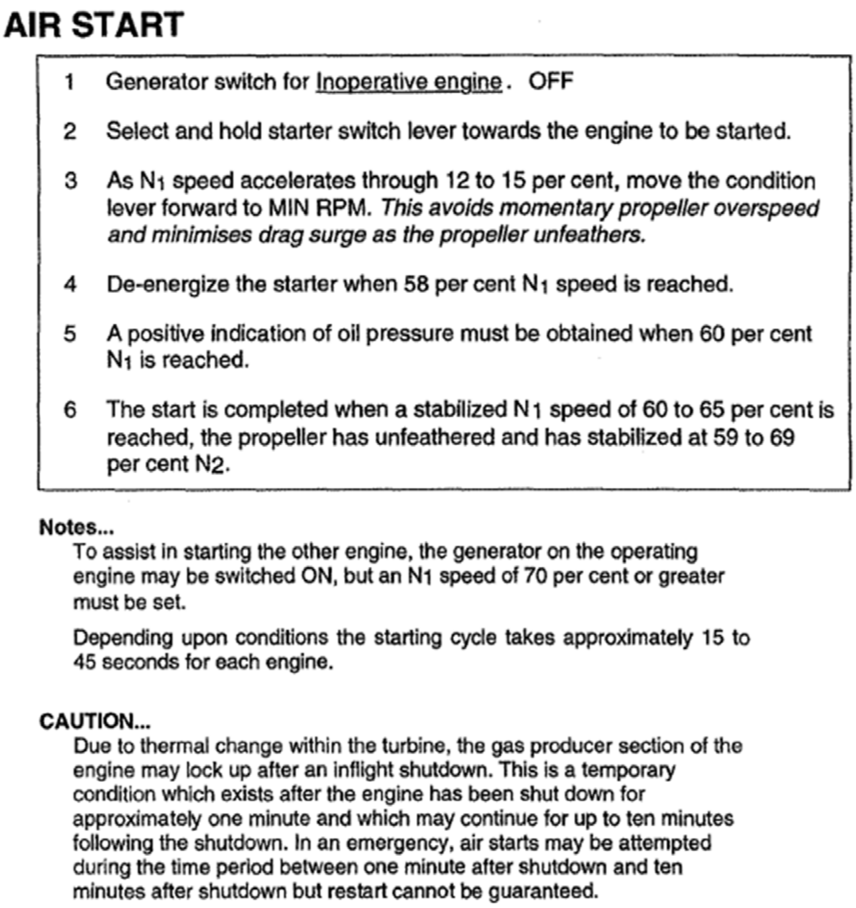
When one or both engines have been restarted carry out normal after start checks including operation of the powerplant anti-ice system, if appropriate

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.

Published: 16 September 2021.

ACCIDENT

Aircraft Type and Registration:	Hawker Sea Fury T Mk.20, G-INVN	
No & Type of Engines:	1 Pratt & Whitney R2800-CB3 radial piston engine	
Year of Manufacture:	1951 (Serial no: 41H-636070)	
Date & Time (UTC):	4 August 2020 at 1518 hrs	
Location:	Harston, Cambridgeshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Serious)	Passengers - 1 (Serious)
Nature of Damage:	Forward fuselage and wings detached from engine and tail section. Extensive internal engine damage	
Commander's Licence:	Air Transport Pilot's Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	3,508 hours (of which 31 were on type) Last 90 days - 15 hours Last 28 days - 8 hours	
Information Source:	Field Investigation	

Synopsis

During the aircraft's second flight following maintenance, its engine oil temperature rose and the oil pressure started to fluctuate. The engine then seized, forcing the pilot to make a landing in a field. The aircraft was extensively damaged and both occupants suffered serious injuries.

Examination of the engine revealed extensive internal damage which resulted from the failure of a main engine bearing. The cause of the bearing failure could not be identified but the investigation determined that contamination of the oil system was the most likely cause.

History of the flight

G-INVN had been undergoing an annual maintenance check for the previous nine months. Completion of the maintenance check had been delayed while a new engine oil cooler and tailwheel fork were manufactured. Engine ground runs were conducted during the week prior to the accident.

On the morning of the accident flight, the pilot flew the aircraft for a post-maintenance test flight. During his pre-flight checks he noticed the rudder trim had been rigged incorrectly and arranged for this to be rectified before the flight. He flew the aircraft for 15 minutes, completing several stalls, checking the trim and completing some general handling. He reported that the aircraft was "wonderful", the engine was "smooth" and there were no problems.

Weather conditions were good, with a light south-easterly breeze, CAVOK and temperature 22°C.

A second flight was planned with a journalist, who had been invited to fly as a passenger in the Sea Fury. The journalist, who was also a qualified pilot, was writing an article about it. The flight was intended to last approximately 20 minutes.

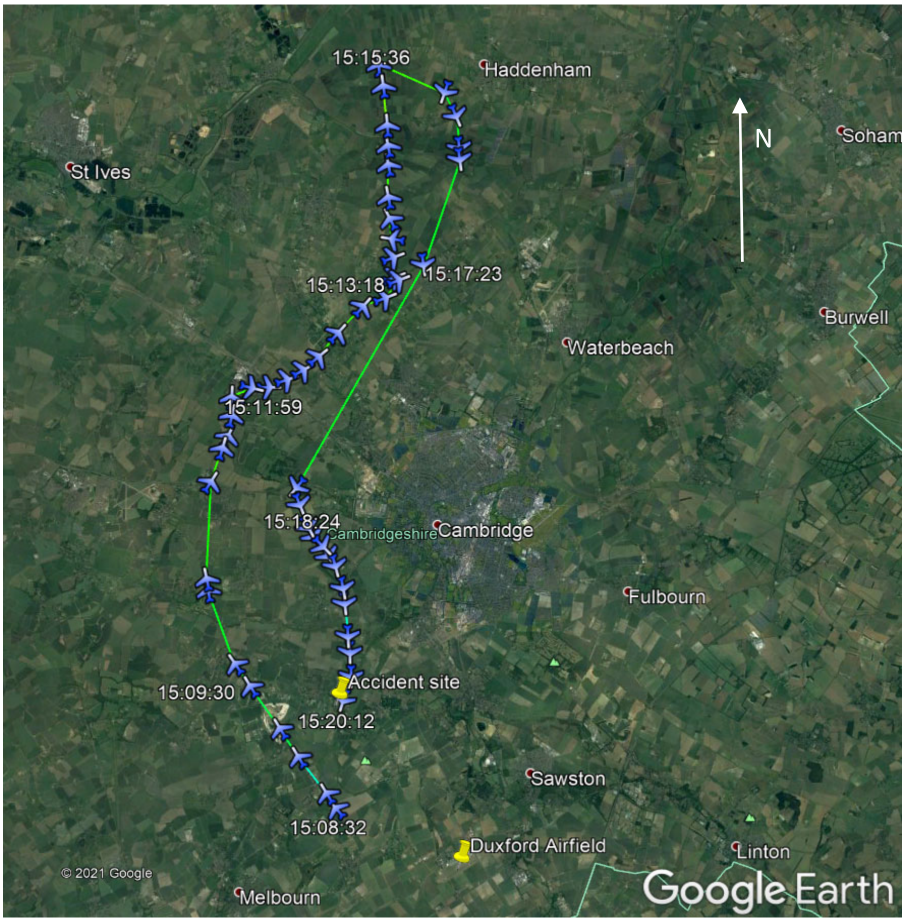


Figure 1

Accident flight track recorded by Flightradar24

The aircraft took off from Duxford for the second flight at 1508 hrs and climbed to approximately 4,500 ft. As it climbed through 1,000 ft the pilot passed control to the passenger so he could experience flying it. As they had briefed, the pilot retained control of the throttle and rpm lever. They flew to the north conducting several turns, rolls, stalls and a loop. The track recorded by Flightradar24 is shown in Figure 1. Both the pilot and passenger reported that the aircraft was flying very well and they both recalled monitoring the engine instruments and seeing all parameters "in the green".

The first indication of a problem occurred as they were flying back towards Duxford, passing abeam Cambridge at 2,000 – 2,500 ft. The pilot noticed that the engine oil temperature was rising. He asked the passenger to check the gauge in the rear cockpit, and the passenger confirmed it was also showing the temperature rising. At this stage the temperature was still “in the white” (being above the green band but below the second red line). The pilot manually selected the oil cooler flap to OPEN (by holding the switch to the OPEN position for 12 - 15 seconds) and increased airspeed to increase the cooling airflow. Approximately 20 seconds later the oil temperature passed the upper red line and the oil pressure started to fluctuate.

Figure 2

Oil temperature gauge (top) and oil pressure gauge (lower left)
(indications shown do not represent the accident flight)

At 1618:25 hrs the pilot transmitted a MAYDAY call to Duxford:

G-INVN - “MAYDAY MAYDAY MAYDAY SEAFURY INDIA NOVEMBER VICTOR NOVEMBER, GOT ENGINE ISSUES”

Duxford - “GOLF INDIA NOVEMBER VICTOR NOVEMBER, ROGER, CIRCUIT IS, ER, TRAFFIC IS JUST CLIMBING OUT, THERE IS NOTHING LINED-UP, WE WILL CLEAR THE CIRCUIT, REPORT FINAL FOR EITHER RUNWAY, THE SURFACE WIND TWO THREE ZERO DEGREES TEN KNOTS”

G-INVN - “COPIED, WE SEEM TO BE LOSING OIL PRESSURE, TEMPERATURE RUNNING HIGH, WE MIGHT NOT MAKE IT THERE”

He considered diverting to Cambridge Airport, but discounted this because of a large built-up area in that direction. The passenger recalled that the engine was now starting to run rough, and he could smell oil and see oil on the windscreen. He looked over the side and could see smoke. The engine speed then increased beyond the 2,800 rpm takeoff limit, to 3,600 rpm. The pilot brought the throttle and rpm levers fully back to contain the overspeed, reducing the rpm to 2,900 rpm. The pilot recalled the airspeed reducing but the engine was running fast, which felt counter-intuitive, and he remembered seeing brown smoke to his right. The engine and propeller then stopped rotating.

The pilot lowered the aircraft's nose and found that it required an attitude of approximately 45° nose-down to maintain airspeed. He maintained 135 kt and remembered thinking "just keep it flying". The aircraft was descending rapidly, which he considered gave him limited options, and his view forward was restricted by oil on the windscreen. He selected a brown field slightly to the right and at 1619:26 hrs transmitted a final call to Duxford:

> "JUST LOST THE ENGINE, MAKING A FORCED LANDING"

He kept the landing gear up as he believed this was the safest option for an off-airfield landing. He selected the flaps DOWN, though unsure if there was enough hydraulic pressure for them to travel. He did not have time to select the fuel or magnetos OFF nor to open or jettison the canopy. The passenger did briefly consider jettisoning his canopy but thought he did not want to create extra drag.

Nearing the ground, the pilot flared the aircraft to reduce the rate of descent but did not hold it off. The aircraft hit the ground and bounced, then hit again and skidded across the field. The aircraft slid into a tree on the far side of the field, which spun it around, and it came to rest in a hedgerow (Figure 3).

Figure 3

G-INVN after the accident

The pilot and passenger were able to climb out and move away from the aircraft. Local residents arrived quickly, and the pilot and passenger told them to stay away from the aircraft as there remained a risk of fire from the fuel on board. Another pilot who was flying nearby and heard the pilot's transmissions was able to locate the wreckage and pass the location to Duxford. Emergency services from Duxford arrived shortly afterwards.

The pilot and passenger were taken to hospital, both having suffered broken vertebrae.

Witnesses

Several people saw or heard the aircraft in flight. One witness, located north-west of Cambridge, heard it pass over heading north. He tracked the aircraft on Flightradar24 and, when he saw it was coming back overhead, went to look for it. When he heard it for the second time, he described it as "sounding totally different, clattery, not missing, sounding rough".

Several people in villages near the accident site reported hearing and seeing the aircraft before the accident. They reported hearing a rough running engine and seeing smoke coming from the aircraft. Several of them heard the engine stop. Video footage and several still photographs supplied to the AAIB showed a smoke trail coming from the aircraft (Figure 4). A witness who was close to the accident site saw the aircraft flying towards him. He described seeing "thick black smoke coming from both sides" and that "the propeller was rotating but then stopped and the nose dropped".

Figure 4

G-INVN in flight just prior to the accident with smoke trail visible
(Photograph used with permission)

Accident site

The aircraft touched down mid-way across a smooth ploughed field travelling in a south-westerly direction and continued until it reached a dense hedgerow with trees (Figure 5). It did not slow significantly, travelling approximately 160 m, with the landing gear raised, over the dry hard earth. After the initial impact there was a second impact impression and thereafter a debris trail of small metallic items, remains of antennas and part of an engine mount.

The left wingtip struck the hedge first and caused the aircraft to rotate anti-clockwise (as viewed from above) whilst travelling along the hedge line. The aircraft came to rest in three pieces: the engine, the forward fuselage with wings, and the rear fuselage. The engine had detached from its mountings during the ground slide but was still attached to the airframe by several large-diameter electrical cables. The fuselage had broken just aft of the front windscreen, which coincided with the rear of the wing structure.

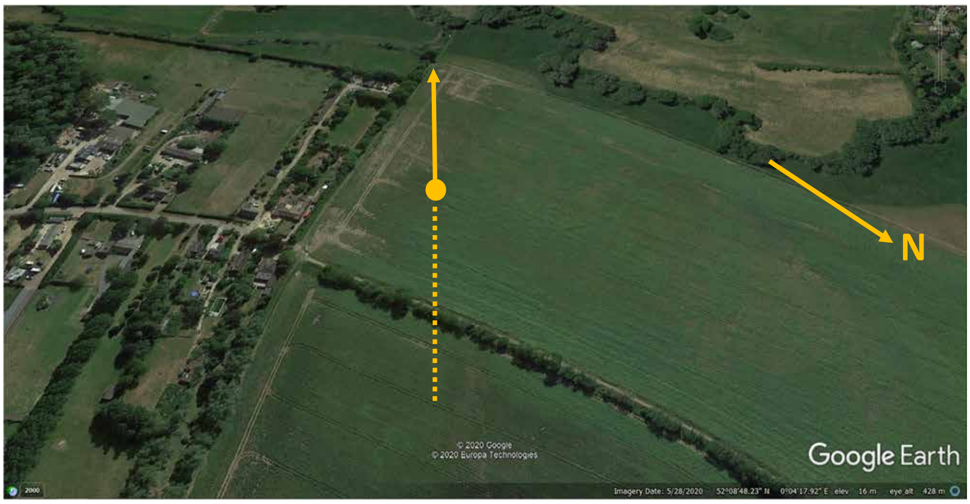


Figure 5

Accident location

Recorded information

Video footage of the morning flight included the start-up, taxi, takeoff and landing, and showed a smoke trail from the aircraft on takeoff. Several people watched this takeoff and opinion was divided as to whether the smoke trail was normal.

The image in Figure 6 was taken after the flight and showed an oil streak along the left side of the aircraft. The oil streak appeared to emerge from the crankcase breather duct positioned beside the cowling flaps.

Figure 6

G-INVN after the first flight showing an oil streak on the left side
(Still photograph taken from video used with permission - Sky High Films)

Further video footage showed the start-up, taxi and takeoff of the accident flight. During the pre-flight checks, smoke could be seen coming from the exhaust for the No 9 cylinder (rear bank, master cylinder) (Figure 7). No smoke was observed coming from any other exhaust. The footage also showed a smoke trail during the takeoff, and there appeared to be more smoke than was visible on the first flight.

Figure 7

G-INVN before the accident flight showing smoke from No 9 exhaust
(Still photograph taken from video. Image used with permission)

Aircraft information

G-INVN was a Hawker Sea Fury T.20 two-seat training aircraft originally built in 1951. The aircraft was used in a variety of roles until, in 1990, it suffered an engine failure and forced landing in which it was significantly damaged. It was rebuilt and returned to the UK in 2009. During the winter of 2017/2018 the Bristol Centaurus engine was removed and replaced by a Pratt & Whitney (P&W) R2800-CB3 18-cylinder radial engine. The five-bladed propeller was replaced by a 4 m diameter four-bladed propeller from a Grumman Guardian. The engine had been overhauled in 2016 and had completed 86 flying hours before the accident flight. The aircraft was used for private flights, display flying and recreational flights within the Safety Standards Acknowledgement and Consent framework[1].

Engine

The P&W R2800 engine has two banks of nine cylinders driving a single crankshaft. The crankshaft drives a supercharger to compress the fuel/air mixture from a carburettor mounted on the upper rear crankcase. Aft of the supercharger is an accessory gearbox to which the oil pumps, filters, an electrical generator and a starter motor are attached. The front of the crankshaft drives another accessory gearbox for magnetos, an oil pump and the reduction gearbox for the propeller. The engine has an oil-fed propeller governor to control the pitch of the propeller blades. Cylinder numbering is shown in Figure 8 with the engine viewed from the front.

Footnote

[1] Safety Standards Acknowledgement and Consent (SSAC) | UK Civil Aviation Authority (caa.co.uk) [accessed January 2021]. SSAC is a risk analysis framework that allows operators to offer fare-paying recreational flights in certain aircraft that are unable to meet commercial safety standards. An operator intending to offer SSAC flights must ensure that the risks to both participants, third parties and other airspace users have been considered.

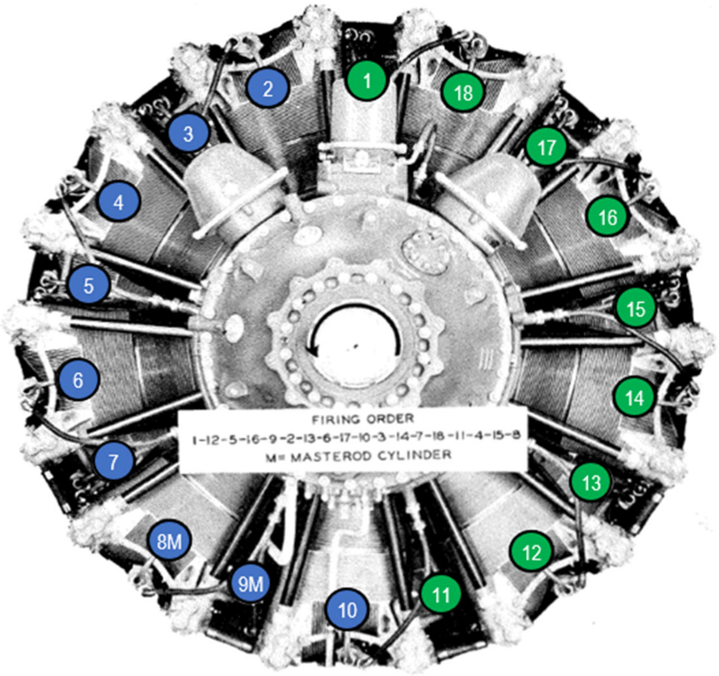


Figure 8

Cylinder numbering (Pratt & Whitney)

The design of the crankshaft evolved throughout the life of the R2800 programme, with the CB3 crankshaft one of the last iterations. The crankshaft is made up of three sections, split at the forward and rear crankpins to facilitate assembly, and is structurally stiff along the axis of the shaft. This inherent stiffness results in a lower load on the centre of three plain crankshaft journal bearings (Figure 9), which are steel shells with silver plating on the internal and external faces. There are locking tabs on the bearings which engage in the crankcase to prevent rotation.

Each bank of nine pistons is connected to the crankshaft by a master connecting rod and eight link connecting rods (Figure 10). The master rod bearing and the eight link pins are held by two retaining plates. The master cylinder (in which the master rod is located) is No 8 in the front bank and No 9 in the rear bank. The master rod bearings are silver-plated steel plain bearings with a lead-indium coating on the internal bore. The crankpin bearing faces are nitrided to harden the surface, with case hardening approximately 0.76mm (0.030 inch) thick. During the engine overhaul in 2016, all the crankshaft bearings were inspected and the lead-indium coating on the two master rod bearings was re-plated.

Each cylinder has two poppet valves, one for inlet and one for exhaust. These are opened and closed by rockers and pushrods driven from a cam ring inside the front and rear crankcases. There are external pipes for the fuel/air mixture from the supercharger and each cylinder has its own exhaust pipe. With reference to Figure 8, cylinder Nos 2 to 10 (in blue) exit on the right side of the airframe, and cylinder Nos 11 to 18 and No 1 (in green) exit on the left side.

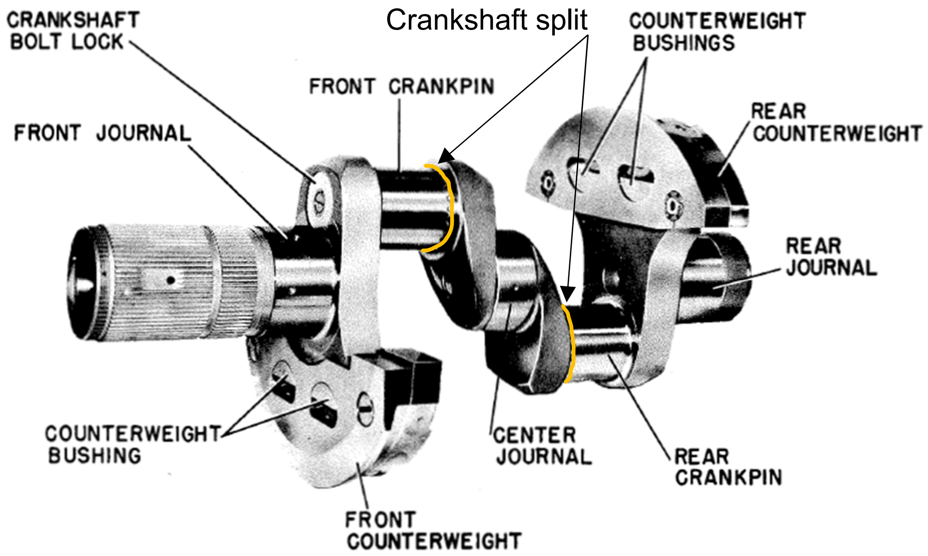


Figure 9

Crankshaft (Pratt & Whitney)

Figure 10

Master connecting rod assembly (Pratt & Whitney)
Master rod bearing (Photograph used with permission)

The pistons are manufactured from aluminium and have five piston rings: three compression rings, a dual oil control ring and a fifth scraper ring at the bottom of the fullskirt.

Oil system

The engine oil lubrication system installed in G-INVN was a hybrid system using some parts from the original Bristol Centaurus installation and other parts specific to the R2800 (Figure 11). The oil tank was fitted to the cockpit firewall and comprised original equipment modified to allow additional clearance from the starter motor on the rear of the engine. The outlet pipe from the tank fed the pressure oil pump on the engine rear accessory case, providing the primary oil pressure for the system.

Within the engine, oil from the pressure oil pump passes through the pressure oil strainer and then into seven individual oil pathways to ensure complete lubrication. Oil to the rear crankshaft journal is supplied by a short pipe from a pocket in the centre of the rear crankshaft. Oil passes through the centre of the crankshaft to the front of the engine, lubricating the crankshaft, pistons and master rod bearings. Another pump in the front accessory case boosts the oil pressure to the propeller governor. Oil is returned to the rear of the engine by the front scavenge oil pump and then pumped out of the engine by the main scavenge oil pump. Oil from the rear of the engine passes through the rear case drain screen before joining the scavenge system.

The oil pressure gauge in each cockpit was connected to a common pressure tapping on the rear engine case. The oil temperature gauge in the front cockpit was connected to a sensor in the oil outlet pipe, whereas the rear cockpit gauge was connected to a sensor in the rear accessory case. They were both protected by the same circuit breaker (CB) labelled 'OIL TMP'.

Scavenged oil passed through a metal mesh Cuno[2] pressure filter mounted on the engine firewall and then to a bypass valve. The Cuno filter replaced the original suction filter which was installed between the oil tank and the engine. The pressure oil strainer was fitted with a bypass valve which operated if the filter became blocked. The outlet pressure of the scavenge pump was unregulated, so a bypass valve provided over-pressure protection for the oil cooler and was set to open at 100 psi.

Oil cooler system

An oil cooler was installed in the left wing root and used the airflow of forward flight to cool the oil (Figure 12). Air entered the cooler through a slot in the wing leading edge and passed through the cooler core, which was made up of 5.2 mm diameter copper alloy pipes. Heated airflow exited through the lower wing surface and was regulated by a movable flap. A cockpit switch allowed the flap to be manually opened, closed, switched off, or to operate automatically. The switch was sprung to OFF, in which the flap would remain in its current position, and it was necessary to hold it in either the OPEN or CLOSE position to manually adjust the flap. The switch was normally placed in AUTO. The flap was opened and closed by an electrical actuator and used a temperature sensor in the cooler outlet in the AUTO mode. The circuit was protected by a CB labelled 'OIL CLR'.

Footnote

[2] A Cuno filter is a cartridge oil filter made up of alternating metal woven mesh disks and spacers. Contamination is caught on the mesh.

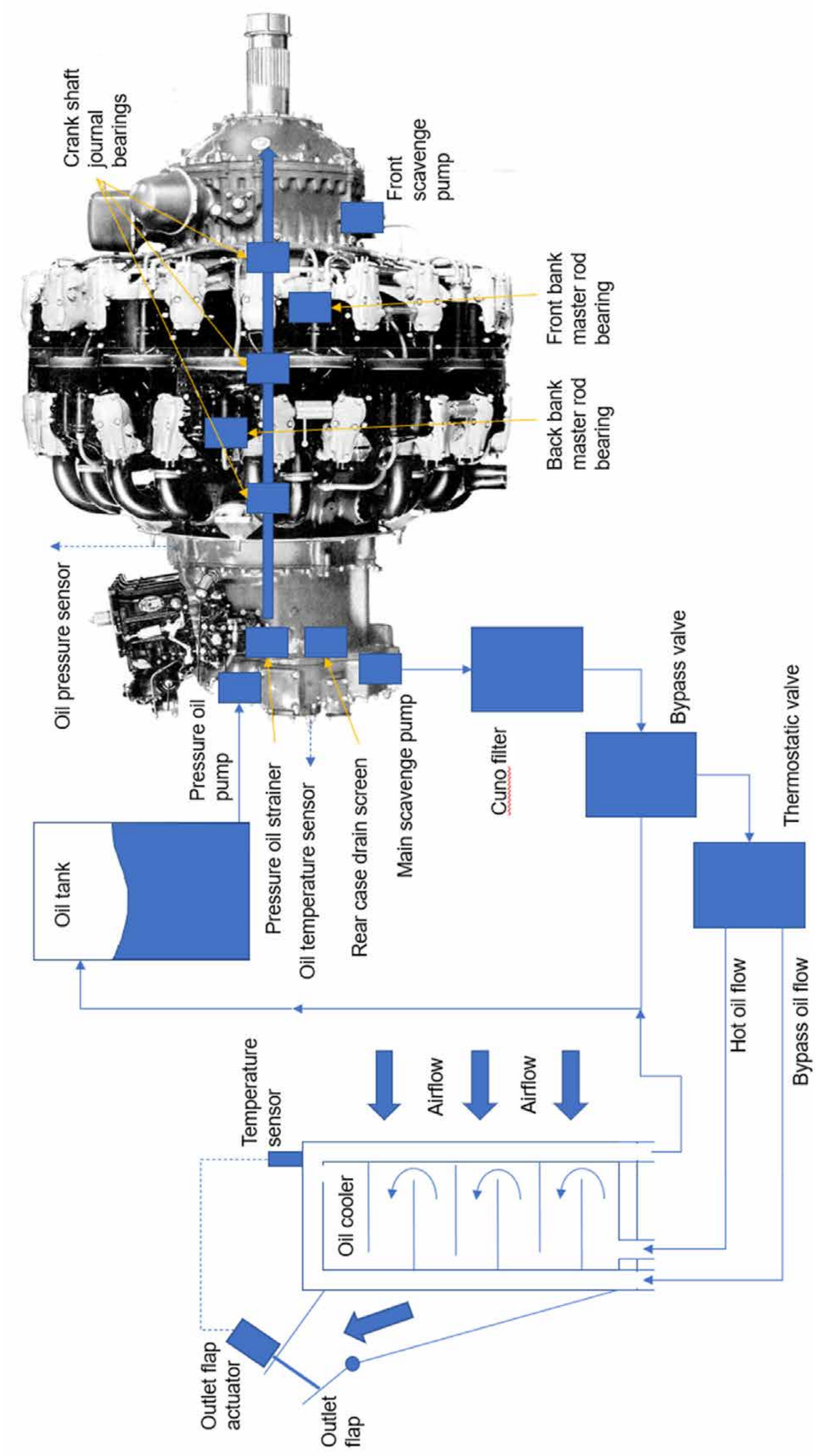


Figure 11

Oil system schematic

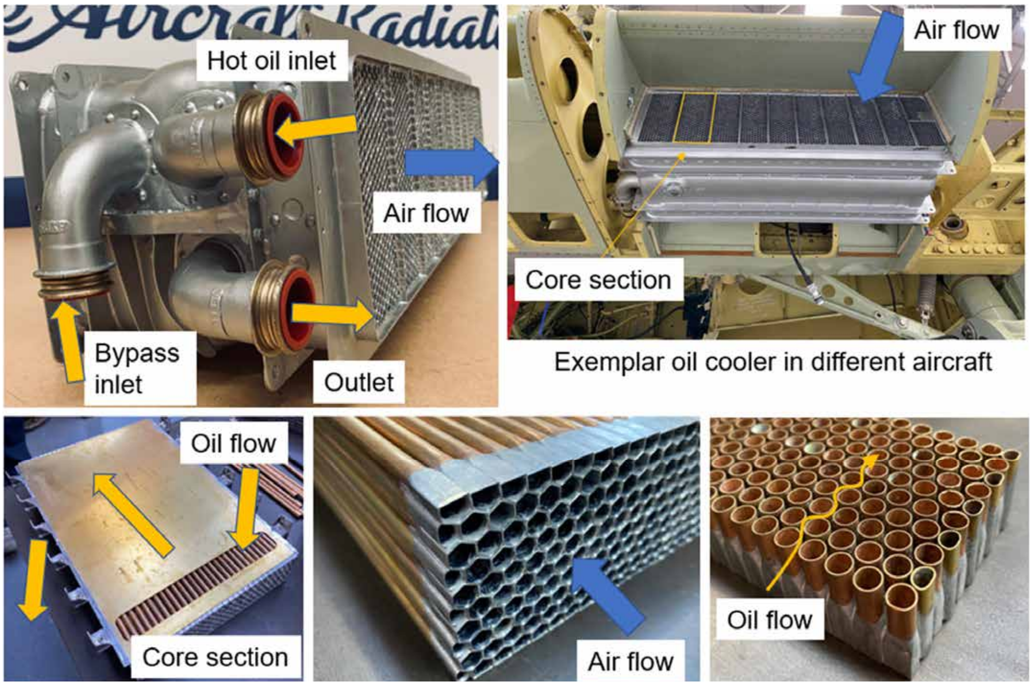


Figure 12
Oil cooler

If the oil temperature was lower than 50°C the thermostatic valve diverted the oil to the bypass inlet of the cooler, where it flowed around the cooler frame and back to the oil tank. The valve would gradually open as the oil temperature rose from 50°C to 95°C, allowing hot oil to flow into the cooler core and over the matrix of copper alloy pipes. The core was made up of ten sections with internal baffles, forcing the oil to travel back and forth across the core sections to maximise contact with the air-cooled pipes. At the end of the core the oil joined the bypass flow in the frame of the cooler and returned to the tank.

Several entries made in the aircraft maintenance log in 2019 referred to the oil cooler leaking. Each entry was closed stating that the cooler had been repaired. During annual maintenance in October 2019 it was noted that the cooler was leaking again. The cooler was removed and sent to a specialist to manufacture new core sections and replace them in the original frame. The cooler was then flushed and pressure tested to ensure integrity prior to completion. The rebuilt cooler was fitted in July 2020.

Crankcase breather

In all piston engines there is some leakage of combustion gases past the piston rings into the crankcase. To allow these gases to escape without damaging the engine there is a ventilation system in the crankcase. The internal volume of the engine, from the propeller reduction gearbox to the supercharger, is interconnected and allows free passage of oil and gases. On the front face of the supercharger diaphragm there are four orifices located on the periphery of the casing which lead through internal passages in the crankcase to two ports on the rear of the crankcase. These ports are connected by pipes to ducts mounted on the side of the engine cowls (Figure 13).

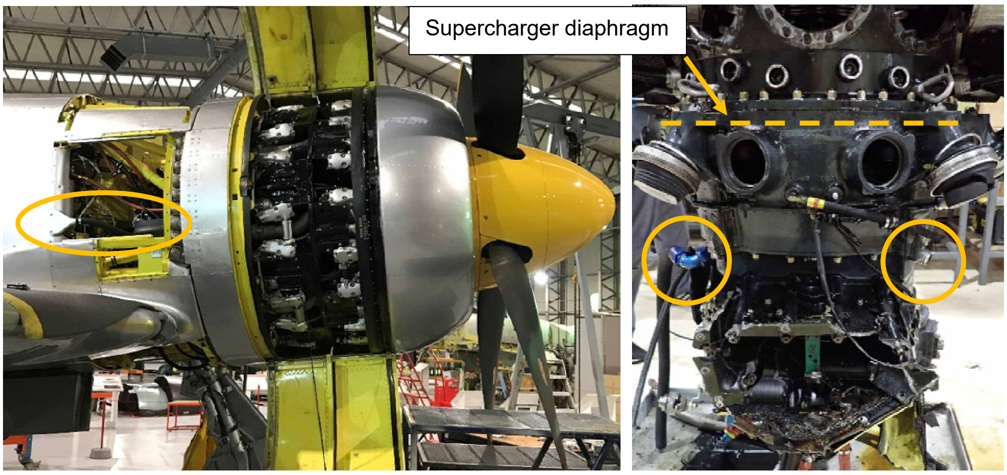


Figure 13

Crankcase breathers
(Photograph (left) used with permission - Aerotech (Suffolk) Ltd)

Oil priming process

G-INVN had last flown on 28 October 2019, before the maintenance check. The engine was not run again until 3 August 2020 due to the oil cooler replacement. The engine oil was replaced and the filters were cleaned in January 2020. The engine was not inhibited whilst waiting for the new cooler.

Before the engine was started after the maintenance check, the oil which had collected in the engine was drained and an oil priming rig was attached to the oil pressure tapping on the rear case. The oil priming rig was used to heat approximately two gallons of engine oil to 60°C and then pump it into the engine at about 80 psi using an electric pump. This process was intended to ensure that all the bearings were lubricated before the first engine start after being dormant. The priming oil was pumped through the engine and the other system components and added to the oil already in the tank. The propeller was rotated by hand during priming, with one spark plug removed from each cylinder to ensure that no hydraulic lock[3] occurred.

No written procedure was available for the operation of the priming rig but the person operating it had been trained by those familiar with it.

After completion of the priming process, the engine was run on the ground to verify system functionality. High power ground runs, the first flight and the accident flight were all made the following day.

Footnote

[3] Oil can enter the lower (inverted) cylinders of an engine by seepage past seals and piston rings. A hydraulic lock occurs when the volume of any incompressible fluids in a cylinder approaches the volume remaining as the piston moves towards top dead centre. If the engine is rotated past this point, mechanical failure can occur, usually manifesting as damage to the connecting rods.

Propeller pitch control

Pressurised oil from the front accessory case pump is fed to the propeller governor to control the pitch of the propeller blades and maintain the selected engine rpm. Aerodynamic loads on the blades tend to move them to 'fine' pitch to align with the blade rotation. In fine pitch the load on the engine decreases and the speed of the propeller increases. When the blades are rotated to 'coarse' pitch their angle of attack increases, increasing the load on the engine and reducing the speed of rotation.

Aircraft examination

Initial inspection

An inspection of the aircraft at the accident site revealed the damage sustained either whilst travelling cross the field or during the impact with the hedge. Two propeller blades were bent backwards and had scratches consistent with scraping across the ploughed field. One blade had detached at the blade root and had failed in bending, and there was evidence of it having struck a substantial tree trunk in the hedge. The engine had become detached from the mounting structure and had pitched nose-down as it travelled across the field. This motion had caused the starter motor to rupture the engine oil tank, so it was not possible to determine the amount of oil remaining in the system before impact. The rear of the engine bay was covered in oil and there was evidence of oil contamination on the ground. The carburettor, generator, one magneto and other engine ancillaries had suffered impact damage during the accident.

The fuselage had split to the rear of the windscreen and the gap between the two sections was approximately one metre. The sheet metal on the left side of the break showed signs of compression buckling and tearing in tension whereas the right side showed only tearing in tension. The cockpit instrument panels were largely intact, but the transponder had become dislodged and was found several metres to the right of the fuselage. All the CBs were closed (in) except the 'OIL CLR' and 'OIL TMP'. There was evidence of oil streaking along the side of the fuselage from each of the crankcase breather ducts (Figure 14).

Figure 14

Oil streak from crankcase breather ducts

The left wing was significantly damaged by the impact with the hedge, with multiple tears, and the tip structure had detached (Figure 15 left). The right aileron was significantly damaged and was deformed by a large tree. The flap lever was in the fully DOWN position and the flaps had partially deployed. The landing gear lever was in the UP position with the landing gear retracted, but the landing gear was not locked and the legs extended freely during the recovery. The tail structure was intact and the right tailplane had dug into the ground. The partially deployed tail wheel had scribed an arc in the grass (Figure 15 right).

Figure 15

Engine section, aircraft forward and aft sections

The oil cooler inlet cowling was deformed and the front of the cooler was clogged with earth. The outlet flap was closed but the actuator arm had penetrated through the surface, indicating that the flap had been at least been partially open and was forced closed during the ground slide (Figure 16).

Figure 16

Oil cooler outlet flap

Preliminary engine strip down

The engine was disassembled under AAIB supervision. Initial inspection showed that no external components were missing from the engine, there were no signs of component failure, it was still seized and all visible external damage had been sustained during the ground slide.

The engine had seized with the No 1 piston (rear bank) at or near top dead centre (TDC). Correspondingly the No 10 piston (front bank) was also at or near TDC. All the rear bank pistons were damaged below the scraper ring groove and the scraper rings were partially lost (Figure 17 left). Around the periphery of the piston crown it was evident that some pistons had struck the top of their cylinders (Figure 17 centre) and there were indentations from the inlet valves in all the piston crowns. The side of all pistons showed evidence of abrasion and the compression rings were entrained in the grooves of the master piston (Figure 17 right).

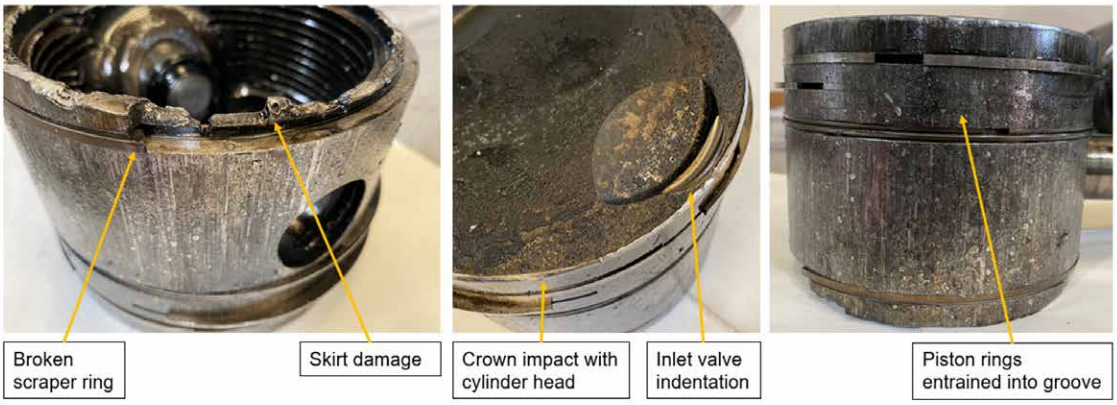


Figure 17

Rear bank piston damage (Piston No 9 shown)

There was considerably less damage to the front bank pistons, with only abrasion damage to the skirts and some pistons retaining metal fragments inside the rear of the piston. There was evidence on some piston crowns, in each bank, of a grey powder deposit (Figure 18). A sample was removed, analysed, and found to contain aluminium, carbon, oxygen, lead and bromine.

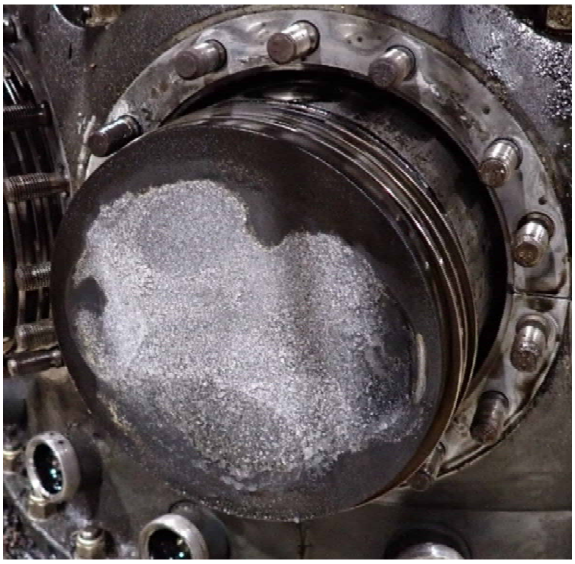


Figure 18

Piston crown deposit (piston No 13 shown)

Some cylinder barrels had impact damage to the flange which engages inside the crankcase. The shape and size of the damage was inconsistent: whilst most flared outwards (Figure 19), one cylinder was flared inwards.

Figure 19

Cylinder flange impact damage (cylinder No 15 shown)

The pressure oil pump was removed and could be turned by hand. There was evidence of fine metallic debris in the oil passageways. The front scavenge pump would not turn by hand but there was no evidence of damage to the drive gears. The pump was disassembled, and metallic debris was found within the gears, preventing them from turning (Figure 20). No other damage was observed.

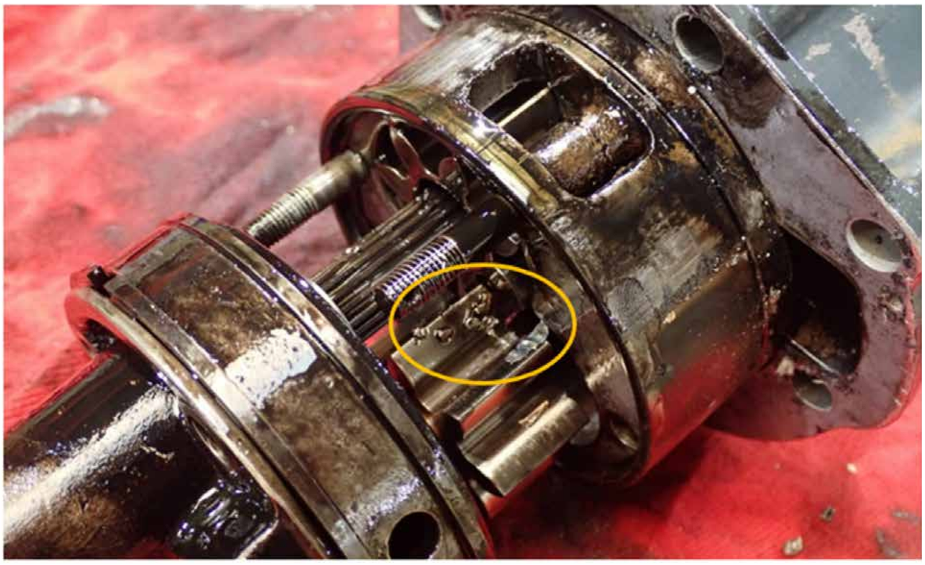


Figure 20

Front oil scavenge pump

The two engine oil filters and the Cuno filter were removed and their contents examined. The metal mesh filters contained a large amount of fine metallic debris whereas the rear case screen contained a quantity of large metallic fragments (Figure 21). These fragments were identified as broken pieces of piston skirt and piston ring. The fine metallic debris was analysed and was found to be silver, iron, aluminium and copper.

Figure 21

Left – pressure oil strainer. Right – debris from rear case drain screen

Crankcase strip down

The propeller reduction drive gearbox, front & rear accessory cases and the supercharger were removed from the crankcase. More metallic debris was found inside all sections, similar to that found in the oil filters. None of the components were significantly damaged and all were present and correctly located. On all internal faces the coating of oil was heavily laden with fine metallic particles and there were indications that the oil had reached an abnormally high temperature.

An inspection of the front and rear crankcases revealed evidence that the front and rear crankshaft journal bearings had rotated in the crankcase. The locking tabs of both bearings had dragged in the casing (Figure 22) with the front bearing having rotated approximately three to four degrees. The rotation of the rear bearing was at least 120° as there was continuous mechanical damage between the locking tab slots. It was not possible to determine if the bearing had rotated more than 120°. The bearing surfaces were heavily scored (Figure 23) and there was evidence that the silver had melted and solidified. The centre crankshaft bearing showed no evidence of rotation but some evidence of scoring. The silver bearing material was largely intact.

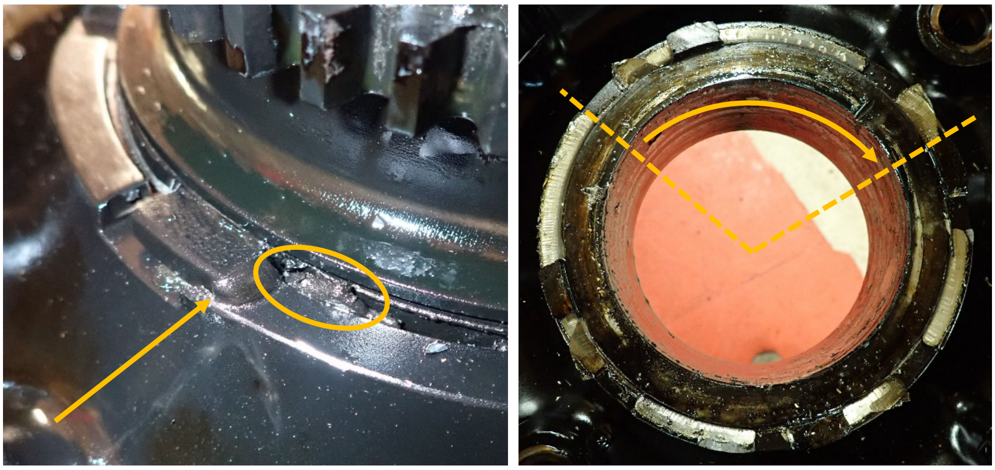


Figure 22

Left – Detail of front bearing rotation (arrowed) and molten metal (circled).
Right – Detail of rear bearing rotation

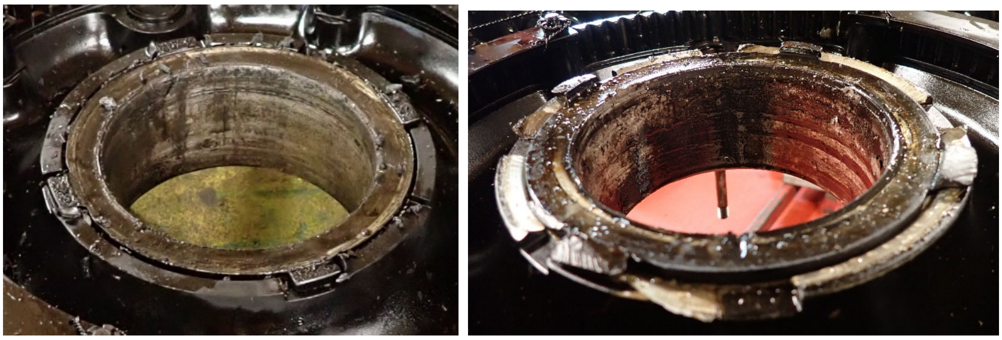


Figure 23

Left – Front crankshaft journal bearing
Right – Rear crankshaft journal bearing

Crankshaft

The crankshaft journals were heavily scored and there was evidence in the journal oil holes of a build-up of fine metallic particles (Figure 24). When the supercharger output shaft was removed from the rear of the crankshaft, the metallic particles retained in the crankshaft pocket were found on the end of the shaft (Figure 25). The oil pipe to the rear bearing was blocked and the rear secondary counterweight bearing showed evidence of running without lubrication. The front journal bearing hole was partially blocked restricting the supply of oil to the bearing.

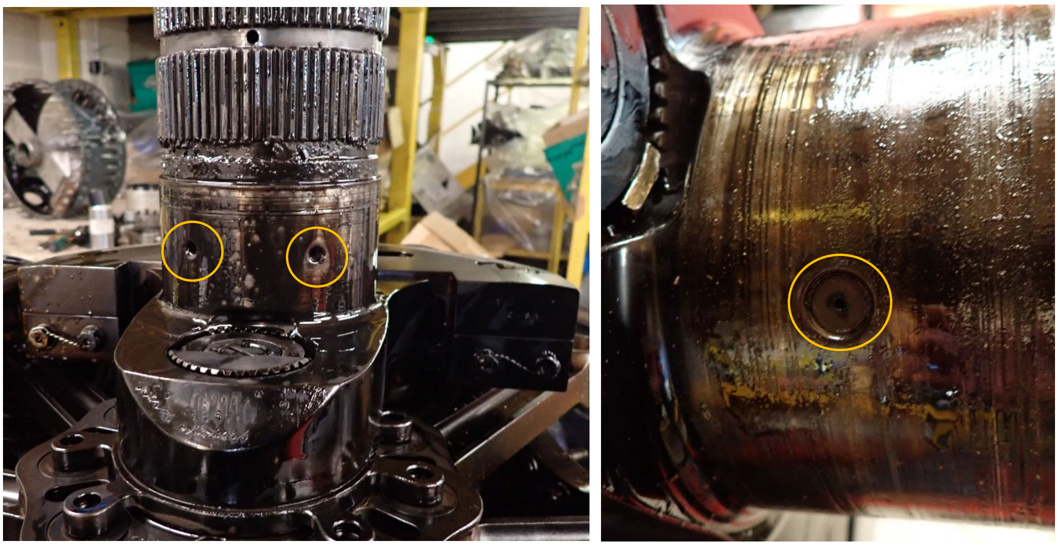


Figure 24

Left - Front crankshaft journal (oil holes circled)
Right - Rear crankshaft journal (oil hole circled)

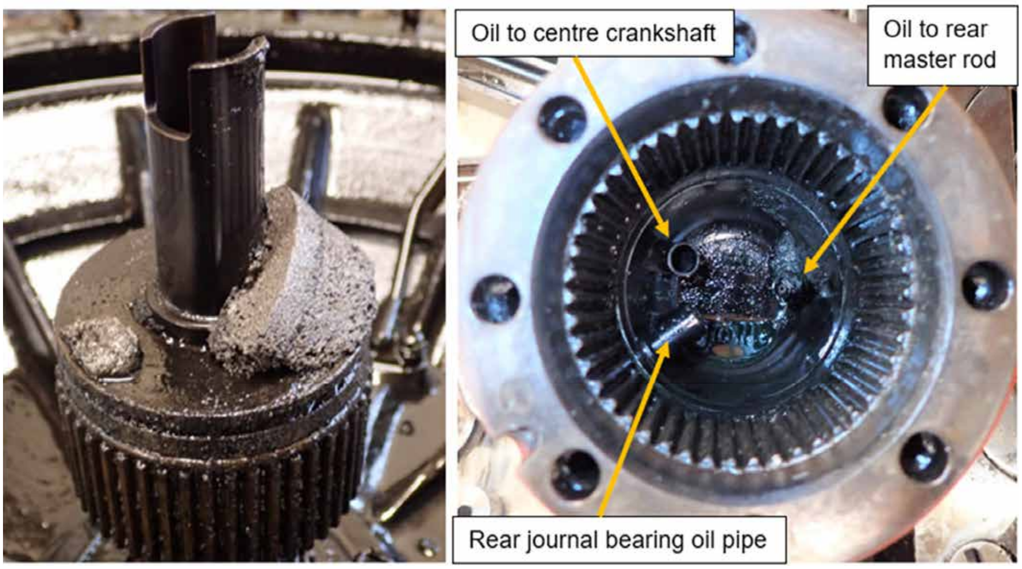


Figure 25

Metallic particles filling the rear of the crankshaft
Supercharger output shaft – Left. Crankshaft pocket – Right

The crankshaft was split into its three sections and the master rod assemblies were removed. Both crankpins were deeply scored and one side of the rear crankpin was heavily worn. The nominal diameter of a crankpin is 89.027 mm (3.505 inches) and Table 1 shows the diameter with reference to Figures 26 and 27 for the rear crankpin. Front crankpin wear was similar to the rear but to a lesser extent, with the smallest diameter of 88.519 mm across the same line as the rear crankpin (A-E).

Measurement (mm)	1	2	3	4
A-E	84.328	84.074	84.023	84.455
B-F	86.665	86.360	86.436	87.757
C-G	89.408	88.773	88.265	88.900
D-H	87.173	86.157	85.344	85.852

Table 1

Rear crankpin diameters

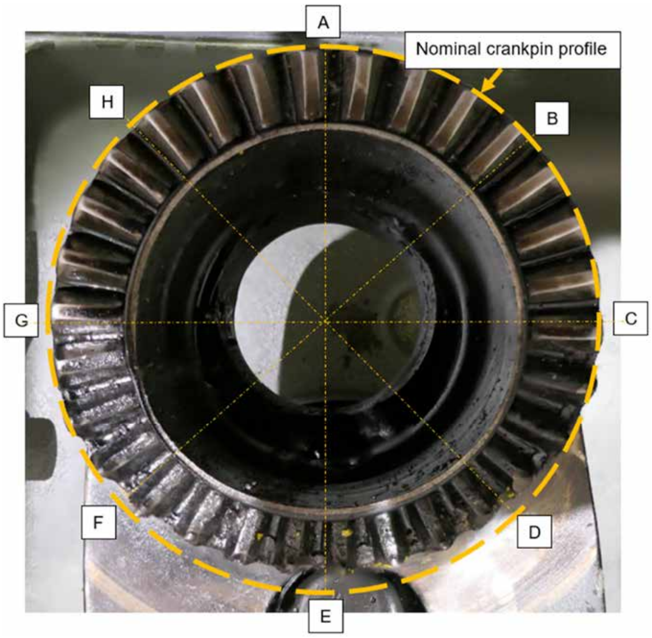


Figure 26

View looking aft on rear crankpin (centre crankshaft removed)

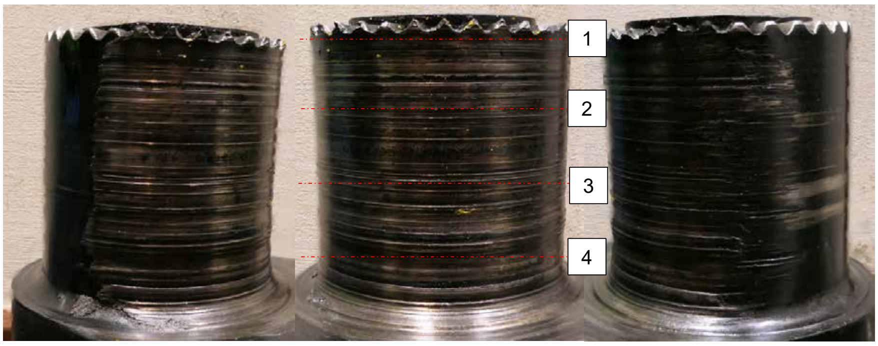


Figure 27

Side view of rear crankpin (centre crankshaft removed)
Left - view on G. Centre – view on E. Right – view on C

Master rods

The front master rod assembly was removed and there was evidence of extensive bearing material erosion and scoring of the bearing face. The bearing faces were wet with heavily contaminated oil indicating that the bearing was being lubricated until the engine stopped.

The rear master rod assembly also showed evidence of heavy scoring with very little of the bearing material remaining (Figure 28). There were also substantial amounts of loose, metallic particles on the bearing face. The castellations on both ends of the bearing had been significantly damaged along with the corresponding castellations of the retaining plate. The castellations had become swaged together and had to be cut away to enable the bearing to be pressed from the master rod. No defects or bending were found on the link rods of either master rod assembly.

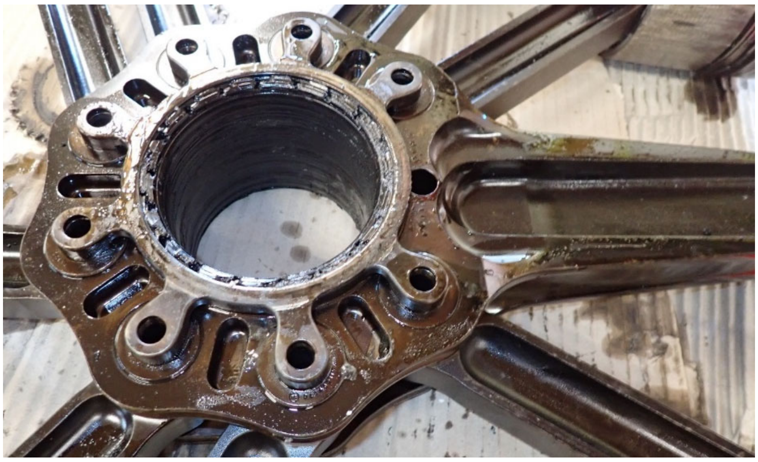


Figure 28

Rear master rod showing bearing damage

Thermostatic valve

The thermostatic valve was found in the hot oil position despite being at ambient temperature when examined. When the valve was disassembled it was found that metallic particles had jammed the valve, preventing it from returning to the bypass position. The valve was cleaned and was found to operate correctly. The particles that had jammed the valve were identified as iron, silver, aluminium and lead.

Temperature sensors

The two temperature sensors were examined and subjected to an electrical continuity test. No defects were found with the sensor removed from the rear accessory case (rear cockpit) but the sensor providing indications in the front cockpit was damaged. The electrical connector was disconnected from the sensor and it was found that the pins had become twisted together (Figure 29).

Figure 29

Oil temperature sensor electrical connection pins

Oil cooler

The oil cooler was scanned using computerised tomography (CT), which showed many metallic particles within the cooler. Several large bright particles were visible in the hot oil inlet which were determined to be silver (Figure 30). Multiple bright particles were identified throughout the core of the cooler, with a higher concentration towards the inlet end (examples circled in Figure 31). Other particles, probably of aluminium, were also identified throughout the inlet and the core. It was not possible to perform a detailed analysis of the inlet pathway, from the inlet pipe to the first core pack, because the X-rays did not penetrate the multiple layers of brass and steel.

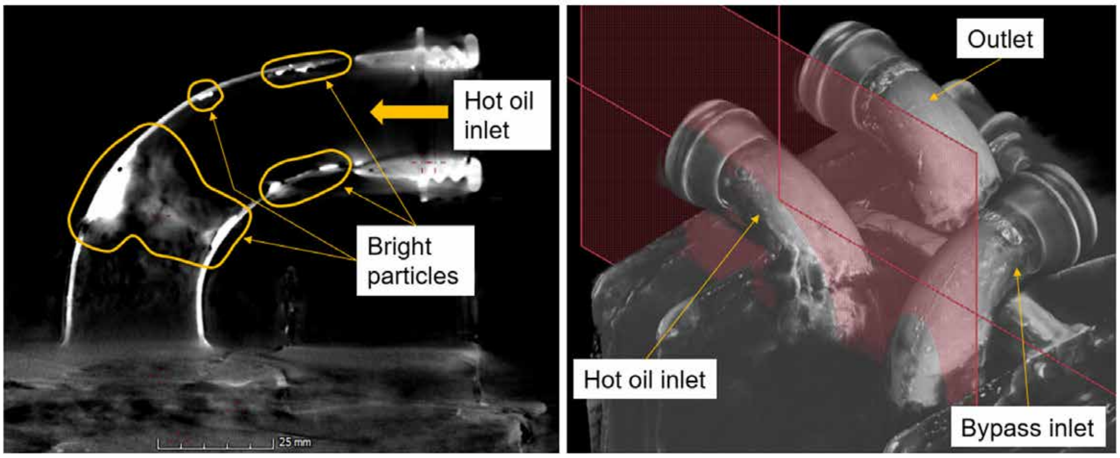


Figure 30

Section view through the oil cooler - hot oil inlet

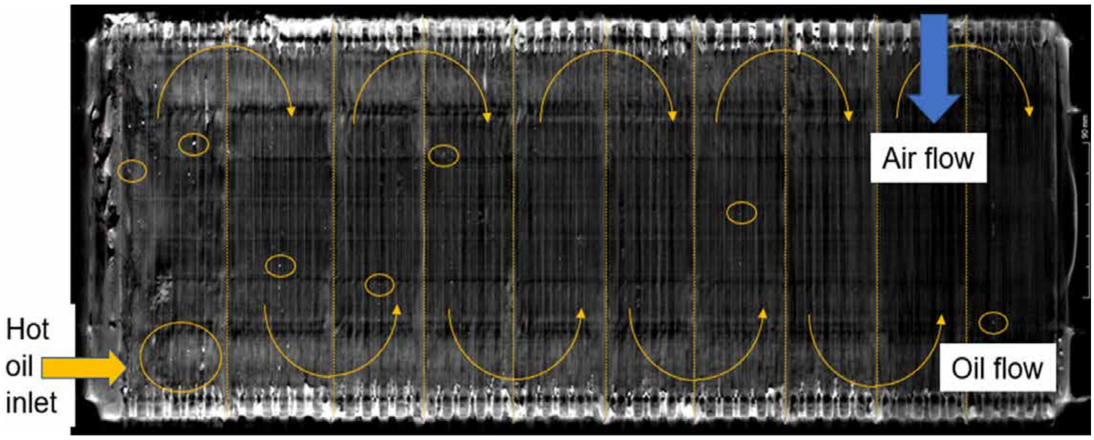


Figure 31

Oil cooler core. Some particles highlighted

Survivability

Whilst the fuselage had split across the front cockpit, the space the pilot occupied had remained largely intact. The rear cockpit was not disrupted. This left a survivable space for both occupants. The aircraft did not catch fire, despite having approximately 700 litres of fuel onboard, which allowed time for them to escape.

Both occupants were wearing kevlar flying helmets. It is likely these protected them from more serious head injuries.

Meteorology

At 1520 hrs, Cambridge Airport (5 nm north-east of the accident site) reported surface wind from 240° at 11 kt, visibility greater than 10 km, few clouds at 4,800 ft, temperature 22°C, dewpoint 6°C and QNH 1013 hPa.

At 1520 hrs, Stansted Airport (16 nm south south-east of the accident site) reported surface wind from 230° at 12 kt and visibility greater than 10 km. There was no discernible cloud, the temperature was 22°C, dewpoint 7°C and the QNH 1014 hPa.

The weather did not change significantly during the three flights the pilot conducted on the day of the accident.

Pilot background

The pilot held an EASA Air Transport Pilot's Licence and was a qualified Test Pilot. He was flying the Sea Fury on a valid Single Engine Piston rating. He also held a Flight Instructor rating and an Aerobatic rating. He held a valid Class 1 medical certificate.

He had a total flight experience of 3,508 hours including 31 hours flying G-INVN.

After the accident the pilot reflected on the aspects of his previous experience which he felt had helped him manage the engine failure. He had previously practiced 10 – 15 forced landings in a Spitfire simulator. Although the simulator was not representative of a Sea Fury, he felt it helped to reduce the startle and stress of the real thing. He reported that it enabled him to focus on flying the aircraft and maintaining airspeed.

Just prior to the accident flight he had flown a display in a North American P51D Mustang to renew his Display Authorisation. Prior to the renewal flight he had discussed with the examiner how to manage engine failures during a display. They considered the priority was maintaining airspeed and that an off-airfield landing may be the safest option even when close to the airfield. They agreed that the key was to arrive at the ground with the wings level and a low rate of descent.

The pilot had also previously experienced engine failures in a Boeing Stearman biplane and in a Saab Safir single engine training aircraft, although these had both occurred over airfields and he had been able to land successfully.

He described how he always took time to think about the aircraft type he was due to fly, to review the operating handbook and to visualise his actions. He also felt that his currency helped: although he had not flown the Sea Fury recently, he had flown a Chance Vought Corsair which has the same engine type.

He commented that he had attended the annual Warbird Symposium at Shuttleworth House in February 2020 which included lectures on engineering, operations, human factors and lessons learnt from display flying. He felt this refreshed his knowledge and helped him think clearly as the emergency unfolded.

Organisational information

The accident flight was a private flight. The operator provided a copy of the Organisational Control Manual (OCM) under which the aircraft was being operated (in accordance with CAP 632[4]) and a copy of the Pilot's Notes for G-INVN.

The only guidance relating to engine failure in the pilots notes stated:

> *'A power off landing should NOT normally be made with full flap as the flight path with gear down and full flaps is very steep and the rate of descent is very high. The recommended technique is to lower the flaps to the* TAKEOFF *position whilst maintaining 130 kt. When landing is assured the flaps should be lowered to the* MAX LIFT *position and a gradual round-out should be performed to change the attitude and flight path angle, and to arrive at the threshold at 115 kt. There is little increase in the landing roll between* MAX LIFT *and* DOWN *flaps. A flapless glide-speed of 150 kt is recommended until landing is assured.'*

Footnote

[4] CAP632 – *'Operation of "Permit-to-Fly" ex-military aircraft on the UK register'*. This document specifies the operational requirements that an applicant for the issue of a Permit-to-Fly for an ex-military aircraft is required to meet.

Other information

Propeller driving the engine – manifold pressure insufficient for selected engine speed

In a radial engine, as the crankshaft rotates in normal operation, the resultant force from the power stroke of each piston and the centrifugal load, is directed at the same spot on the crankpin via the master rod assembly. The location of the oil supply hole in the crankpin is optimised to ensure an effective oil film lubricates the master rod bearing in normal operation.

The oil flow is turbulent as it enters the clearance between the crankpin and the bearing, and therefore is not an effective lubricating film. Consequently, the oil hole is positioned such that the oil has become a uniform laminar film as it reaches the highly loaded bearing faces (the precise location having been established empirically by the manufacturer as it developed the engine).

If, because of insufficient gas load (manifold pressure), the propeller is allowed to drive the engine, the resultant force on the crankshaft is applied to the opposite side of the crankpin, where the oil supply is not optimised, and may quickly damage the bearing. This damage worsens over time and eventually the bearing will fail. Failure may occur several hours after the initiating event, and therefore a pilot may inadvertently damage the bearing without seeing any immediate symptoms requiring maintenance intervention. The engine is designed to cope with some reverse loading for brief periods, for example when the propeller is driven at lower airspeed when landing, but critical damage may occur quickly at higher speeds.

An *Engine Operating Information Letter* published by Pratt & Whitney in January 1952[5], describes how low manifold pressure with high rpm can lead to the propeller driving the engine and cause bearing damage. The letter recommends ensuring at least one inch of manifold pressure be used for each 100 rpm (so that for example at 2,200 rpm, 22 inches is the minimum manifold pressure).

This feature of radial engines was discussed with the accident pilot. He was familiar with the issue and reported that he always operated the engine to avoid low manifold pressure with high rpm. Whilst it was necessary to close the throttle to land, at this stage the airspeed was relatively low, and at high speed he would ensure the manifold pressure was greater than the rpm/100. When flying the stall manoeuvres, he reported that he flew a gentle climb to avoid needing to select idle power.

After speaking to the accident pilot, the AAIB interviewed all the pilots who had flown G-INVN for the previous 20 flights (back to 26 August 2019). All reported they were familiar with the hazards of operating at insufficient manifold pressure and reported that they operated the engine to keep manifold pressure above rpm.

Footnote

[5] Pratt & Whitney Manual of Engine Operation – Engine Operation Information Letter Number 25, 22 January 1952.

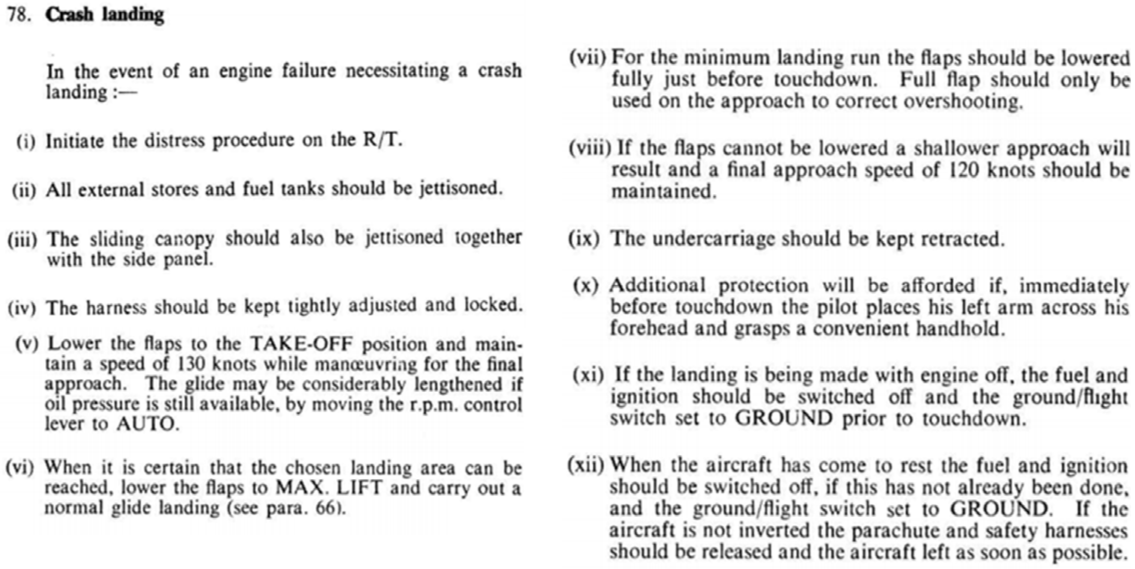
Other pilot's reports

The only problem reported by these other pilots was the oil leaks from the oil cooler. They reported that the oil temperature was never a problem in flight. Once the engine had warmed up, the oil temperature remained constant. They all reported that they left the oil cooler switch in AUTO in flight. A few pilots selected the switch to OPEN after landing if they had a long taxi and the weather was warm.

Off-airfield landing

The pilot reported that when the engine failed, he did not consider abandoning the aircraft. He had briefed the passenger that if the engine failed whilst away from the aerodrome he would attempt to land in a suitable field. When the engine did fail, he still considered this to be the safest option. Reflecting after the accident he was confident that this was the correct decision. He felt that, given the low altitude and the high rate of descent required to maintain airspeed, there was not enough time for them both to abandon the aircraft safely.

There was no procedure for an off-airfield landing in the pilot notes provided by the operator. However, based on his experience the pilot considered a gear-up landing was the safest option. He believed this would minimise drag in the descent, reduce the risk of the aircraft tipping over on landing and remove the risk of only one gear extending with limited hydraulic pressure. Figure 32 is an extract from the pilot notes published by the Royal Navy for the Sea Fury Mk 10 & 11[6].



78. **Crash landing**

In the event of an engine failure necessitating a crash landing :—

(i) Initiate the distress procedure on the R/T.

(ii) All external stores and fuel tanks should be jettisoned.

(iii) The sliding canopy should also be jettisoned together with the side panel.

(iv) The harness should be kept tightly adjusted and locked.

(v) Lower the flaps to the TAKE-OFF position and maintain a speed of 130 knots while manœuvring for the final approach. The glide may be considerably lengthened if oil pressure is still available, by moving the r.p.m. control lever to AUTO.

(vi) When it is certain that the chosen landing area can be reached, lower the flaps to MAX. LIFT and carry out a normal glide landing (see para. 66).

(vii) For the minimum landing run the flaps should be lowered fully just before touchdown. Full flap should only be used on the approach to correct overshooting.

(viii) If the flaps cannot be lowered a shallower approach will result and a final approach speed of 120 knots should be maintained.

(ix) The undercarriage should be kept retracted.

(x) Additional protection will be afforded if, immediately before touchdown the pilot places his left arm across his forehead and grasps a convenient handhold.

(xi) If the landing is being made with engine off, the fuel and ignition should be switched off and the ground/flight switch set to GROUND prior to touchdown.

(xii) When the aircraft has come to rest the fuel and ignition should be switched off, if this has not already been done, and the ground/flight switch set to GROUND. If the aircraft is not inverted the parachute and safety harnesses should be released and the aircraft left as soon as possible.

Figure 32

Extract from the Sea Fury Mk 10 & 11 pilot notes

---

[6] A.P. 4018A & B -P.N. Sea Fury Mk 10 & 11 Pilot Notes, 2nd Edition, May 1950.

Passenger briefing

The OCM required passengers to be briefed on seatbelt operation, canopy hood operation, communication equipment, forced landing procedure, in-flight emergencies, bail out procedure and aircraft hazard areas. The passenger reported that he received a thorough briefing in all these areas before the flight. He recalled that he and the pilot discussed the procedures for making an off-airfield landing and for abandoning the aircraft. They briefed that they would make an off-airfield landing if the engine failed and it was not possible to reach an airfield, and that they might need to abandon the aircraft in the event of a fire or after a mid-air collision if the aircraft was uncontrollable.

Chip detectors

To assist in the early detection of failures some engine and gearbox systems are equipped with magnetic chip detectors, in which magnetic plugs are installed at strategic locations within the oil system to attract ferrous material. In systems that provide an indication in the cockpit, when enough metal has built up on the plug it forms a bridge across an electrical connector and illuminates a warning light to alert the pilot. In other systems it is necessary to remove the plug to inspect for any build-up of particles on the magnet.

A major operator of R2800 engines has used such a system successfully to provide early warning of significant damage, enabling remedial action before catastrophic failure.

Corrosion in inactive engines

Corrosion is a possibility in engines during any extended period of inactivity, and inhibiting procedures are intended to address this. UK operator experience indicates that large radial engines that are inactive for several months without inhibiting do not necessarily suffer catastrophic failure.[7]

Analysis

Accident flight indications

The first abnormal indication reported by the pilot was the increase in oil temperature. The oil temperature continued to rise and, soon after, the oil pressure was seen to fluctuate. The increase in oil temperature was caused by the oil encountering increased heat energy from multiple sources and a reduction in the effectivity of the oil cooler.

Video footage of the engine run-up before the accident flight showed smoke emerging from the rear bank master cylinder (No 9) but not from any other exhaust. As the engine had been run for several minutes it is likely that any residual oil in the cylinders would have been burnt off or blown from the exhausts by that time. The No 9 piston exhibited substantial wear on the leading face of the piston (relative to engine rotation) and some of the piston rings were entrained into the piston ring grooves. This would have allowed oil to pass into the combustion chamber, generating the observed smoke, and would have allowed

---

Footnote

[7] UK operator of up to eight R2800-CB3 engines in low utilisation between 2004 and 2008, involving inactive winters of approximately seven months, following which there were no reported operating issues.

combustion gases into the crankcase. These gases would have elevated the temperature inside the crankcase and some of this additional heat energy would have been absorbed by the engine oil.

The abnormal wear of the master piston was a result of the change in geometry between the master rod, crankshaft and master piston. The relationship between the crankshaft and the master rod is determined by the master rod bearing, so this change in geometry would indicate bearing wear.

The metal particles liberated from the rear bank master rod bearing passed around the engine oil system and contaminated the entire engine, increasing friction and generating more heat in all moving components. All the oil filters were heavily contaminated with metal particles and from the CT scan it was evident that some material had also been captured within the oil cooler core. The multiple path arrangement of the cooler enabled oil to continue following through it but as the pathways became blocked, reducing the surface area available to transfer heat from the oil to the cooling air, its ability to remove heat from the oil system would have diminished. As the heat energy in the system continued to increase, the breakdown of the highly loaded main engine bearings accelerated, further contaminating the oil system.

Eventually the contamination was sufficient to block the oil filters, the filter bypass valves opened, and heavily contaminated oil entered the branches of the oil system. Some of the smaller oil passages (for example to the rear crankshaft journal bearing) were found completely blocked and it is likely that the fluctuations in indicated oil pressure were due to the gauge pressure line being intermittently blocked with metal particles.

The pilot reported that, shortly after he saw the abnormal oil indications, the engine began to run roughly with a significant amount of smoke, and oil covered the cockpit canopy. No damage, such as holes in the crankcase, was found that would have resulted in oil being lost from the engine. There was evidence on the side of the fuselage (Figure 6) that oil was passing out through crankcase breathers. This indicates an increase in crankcase internal pressure, probably caused by pressurised cylinder gases escaping via piston erosion. It is also likely that oil was escaping past the piston rings, in sufficient quantity not to be fully burnt, and then through the exhausts. Both mechanisms would have resulted in smoke and oil being seen by the occupants.

The pilot reported that the engine over sped just before it seized. It is likely that the contamination of the oil system reduced oil pressure to the propeller governor, making it unable to maintain the appropriate blade pitch. The aerodynamic loads on the blades drove them to fine pitch, resulting in an increase in engine speed.

Engine observations

To reduce the engine speed the pilot retarded the throttle and rpm levers, resulting in reduced load on the engine bearings. By this time, it is likely that the silver bearing metal in the front and rear crankshaft bearings was molten, and when the load was reduced this was sufficient for the bearings to solidify and seize the engine. This was evident in rotation of the journal bearings in the crankcase. The lack of damage exhibited by the centre bearing is probably due to its lower loading.

The silver bearing metal of the rear bank master rod bearing was eroded and the steel bearing shell was running against the crankpin. Load, and therefore wear, is distributed over the full surface of the bearing shell due to the rotation of the master rod relative to the crankpin. However, the same segment of the crankpin always reacts the power stroke and therefore the wear was concentrated on this part of the crankpin. The nitriding slowed this wear but once the case-hardened layer had been worn away, the damage increased rapidly. This was evident in the shape of the rear crankpin when it was inspected after the accident, with approximately 5 mm being lost from the diameter of the crankpin. This material was liberated into the oil system and caused further damage.

As the diameter of the crankpin reduced, the gap into which the oil exited increased from 0.13 mm (0.005 inch) to approximately 5.1 mm (0.200 inch) and would have allowed more oil into the bearing area. This would have disrupted the oil flow to the rest of the engine because the release of oil into the bearing cavities is carefully balanced throughout the engine. This might also have contributed to the oil pressure fluctuations reported by the pilot.

The deterioration of the master rod bearing resulted in a reduction in the clearance between the piston bottom dead centre position and the crankshaft counterweight. As the crankshaft rotated the counterweight struck the lower edge of the piston skirt, removing pieces of it, and broke the oil scraper rings. These pieces of aluminium piston and steel scraper ring were then unrestrained within the crankcase and caused impact damage to the casing. The irregular shape and inconsistent position of the damage to the cylinder flanges inside the crankcase was probably caused by these pieces being caught between the rotating counterweight and the flange. There was no evidence of the counterweight striking the cylinder flange directly. The broken pieces of piston and ring were transported throughout the engine by the oil system and contributed further to the blocking of the oil system passageways.

There was evidence, on the crowns of the rear bank pistons, of impact with the top of the cylinder and the inlet valve. The valve stems were not bent and the depth of the indentation indicated low impact forces, suggesting the impact occurred as the inlet valve opened and the piston was descending into the cylinder, thereby applying insufficient force to the stem to bend it. Wear to the master rod bearing probably allowed the pistons to overtravel at TDC and strike the top of the cylinder, as indicated by the ring around the periphery of the piston crown. There was a fine powder residue on some of the piston crowns, which was made up of carbon, lead, aluminium and bromine. The aluminium was probably carried into the combustion chamber in the oil and left behind as the oil was burnt off. The other components were typical residues from the combustion of aviation fuel.

Other observations

When the thermostatic valve was inspected it was found seized in the fully hot position. This indicates that, at the time the engine seized, oil would have been passing through the oil cooler core, but the valve was jammed with metal particles and so had not closed to the bypass position as the thermostruts returned to ambient temperature. The distribution of metallic particles throughout the oil cooler indicated that contaminated oil had been flowing through the core. The concentration of particles was greatest towards the inlet, indicating that particle-laden oil was flowing into the cooler, with some being entrained within the core, but that some particles were still suspended in the oil all the way to the outlet. This indicates that the oil cooler was contaminated by large amounts of material released from damage elsewhere in the engine. There was no evidence the oil cooler was itself a source of foreign material that could have caused damage to the master rod bearing. It was not possible to determine the amount of metal particles in the oil outlet flow from the cooler because the oil tank, to which the oil passed next, was destroyed during the accident.

The OIL TMP and OIL CLR CBs were found open. The pilot reported he had opened the oil cooler flap to reduce the oil temperature. Inspection at the accident site showed that the oil cooler flap had been open but was forced closed by the ground slide. The investigation could not determine why the OIL CLR CB had opened.

It is likely both oil temperature gauges were working because the pilot and passenger both reported seeing the same rise in temperature as the engine started to fail. Each cockpit gauge is connected to a separate sensor; one in the oil outlet and one in the rear accessory case. The electrical connector to the oil outlet sensor had rotated, twisting the pins together and causing an electrical short circuit. This would have opened the OIL TMP CB.

In the video footage of G-INVN departing for the first flight, no smoke was visible from the exhausts once the initial start-up had cleared the cylinders. When the aircraft returned from the flight there was an oil streak along the left side of the aircraft and smoke could be seen from the right bank of exhausts (due to the camera angle it was not possible to determine which exhaust). The investigation did not determine the cause of the oil streak, which may have come from either the left side crankcase breather or a left side exhaust. Video of the accident flight departure showed the rear bank master cylinder (No 9) exhaust smoking after all the cylinders had cleared following engine start. When the master rod bearing is worn the geometry of the master rod / link rod assembly results in a side load on the master rod, which causes the master piston to become eroded, and it is possible that this smoke indicated the master rod bearing had started to wear and oil was entering the combustion chamber.

Master rod bearing failure

It is likely that the initial mechanical failure was breakdown of the rear bank master rod bearing. Due to the extent of the damage and the amount of debris in the engine it was not possible to determine precisely what initiated the bearing failure. In the following section various possible mechanisms are discussed along with their probability and counter evidence.

Manifold pressure

Radial engines are particularly susceptible to master rod bearing damage during prolonged flight with manifold pressure insufficient to compensate for the reciprocating loads. The pilots who had flown G-INVN since the installation of the R2800 engine reported they were aware of this issue and stated that they operated the aircraft in a manner intended to avoid it.

Air lock in the oil system

G-INVN was in maintenance for approximately nine months during which there were no engine runs. Engine oil would have settled in the lowest parts of the engine and in some cases oil passageways would have emptied. It is possible for an air lock to have formed during the hot oil priming procedure prior to restart, resulting in a loss of lubrication when the engine was started. However, the oil path from the pressure pump to the rear bank master rod bearing is straight through the crank shaft and it is unlikely it would have been starved of oil long enough to cause significant damage. The hot oil priming process that the maintenance organisation reported it had completed was consistent with the manufacturer’s process and with industry practice. Air locks in the oil system are not considered typical of the R2800.

Hydraulic damage

Oil will drain into the lowest, inverted cylinders of a radial engine when it is stationary and must be purged before engine start to avoid damage. Oil can leak past the valve guides and piston rings into the combustion chambers. If there is enough to create a hydraulic lock, it will result in bending of the link or master rods. This damage will change the way the loads are applied to the master rod bearing and in time may cause bearing failure.

The maintenance organisation reported that during the oil priming process one spark plug was removed from each cylinder and the engine was rotated by hand-turning the propeller. Oil that had collected was either drained from the spark plug hole, or it was pushed into the exhaust system.

One operator of Sea Furys with Pratt and Whitney radial engines described to the AAIB the use of ‘burp plugs’ during oil priming to mitigate the risk of hydraulic lock. The burp plug is a one-way valve which replaces one spark plug per cylinder during the oil priming process. The burp plug allows oil to be ejected from the cylinder but ensures that air is drawn in through the inlet manifold rather than through the open spark plug hole. This results in any residual oil in the inlet manifold being drawn into the cylinder and removed, reducing the opportunity for residual oil to be drawn into the cylinder during engine starting.

During normal operation the engine is rotated until all cylinders have passed through TDC, before switching on the magnetos, to ensure that none of the cylinders is hydraulically locked when the engine starts. This can be achieved by hand rotating the propeller or by using the starter motor. It is usually preferable to turn the engine using the starter motor if it is fitted with a clutch because, should there be a hydraulic lock, the drive will slip before link or master rod damage can occur. In some engine installations, the leverage of a propeller blade, and the multiplying effect of any reduction gearbox, may provide sufficient mechanical advantage to cause damage if the engine is turned by hand.

There was no evidence of damage caused by hydraulic lock, excluding this as a likely cause of master rod bearing failure.

Contamination of the oil system

During the engine's overhaul before installation into G-INVN, all critical components were inspected and either repaired or replaced with serviceable items. Organisations familiar with the R2800 indicated that significant defects usually become apparent within 5 -10 hours of operation after overhaul. Should an engine pass this threshold without issue it will usually, with appropriate maintenance and correct operation, continue for many hundreds of hours.

The engine in G-INVN failed after 86 flying hours and some unrecorded ground running, past the point where overhaul-related issues might usually be identified. During maintenance prior to the accident flight, the engine was serviced and repairs made to the oil system. The engine oil was replaced and the filters cleaned as part of routine maintenance, and it was recorded that the oil cooler was leaking again. Several entries in the maintenance logbook indicated previous oil cooler repairs had been attempted, but ultimately it was decided to rebuild the cooler. The manufacture of a new cooler took approximately nine months and during this time the aircraft was dormant in the hangar.

The new oil cooler, utilising the original frame and new cores, was flushed and pressure tested upon completion. It is possible that debris remained in the multiple pathways within the cooler and became dislodged in flight on 4 August; or that foreign material entered the oil system during the oil replacement, filter cleaning, oil priming, or oil top-up after the first flight. It is also possible that some corrosion may have formed inside the engine because it was not inhibited during the oil cooler maintenance, and that this corrosion could have detached from the parent material and reached the bearing, causing damage. However, relevant operator experience indicates that this is not necessarily a factor in engines that are inactive for a few months. Likewise, the engine from G-INVN has not exhibited any corrosion during the investigation. The available evidence was not sufficient to determine which, if any of these, was a factor.

The first highly loaded bearing in the oil system is the rear bank master rod bearing, which therefore makes it the most likely to be affected by contamination entering the engine from the cooler or tank. Analysis of the oil and the material found in the filter elements revealed aluminium, silver, lead, indium and iron, all of which are materials used in the engine. The engine damage found would have resulted in all those materials being in the oil.

Given the amount of debris present it was not possible to isolate any foreign material that could be confirmed as initiating the damage to the rear bank master rod bearing. The oil tank was damaged by the starter motor during the accident, which resulted in most of the oil being lost, and some oil was lost through the crankcase breathers or burnt during the flight.

The organisation most familiar with the overhaul of R2800 engines considered that the damage found was consistent with contamination of the oil system.

Possible cause summary

Table 2 summarises the six possible causes of bearing damage identified by the investigation, and the counter evidence if any.

Based on this information the investigation found that oil contamination of some sort was the most likely cause of the initial damage to the rear master rod bearing. It was not possible to determine when this might have occurred.

Chip detectors and oil analysis

A magnetic chip detector might have detected the ferrous material produced by wear to the bearing and crankshaft and found in oil recovered from G-INVN. It is possible that a suitable system would have alerted the pilot during the first flight that maintenance intervention was required, thereby avoiding the accident flight.

Periodic analysis of oil samples can also provide an early indication of damage or excessive wear. This is most effective when conducted over many hundreds of hours and on several engines to establish trends, because it is not unusual for engine oil to contain some metallic particles in normal operation. The engine in G-INVN had run for only 86 hours since overhaul, which may have been insufficient to establish a significant trend.

Possible cause	Counter evidence
Insufficient manifold pressure for engine rpm.	All pilots reported that they operated the engine to avoid insufficient manifold pressure for engine rpm.
Air lock in the oil system.	Not typical for an R2800. Can affect other large radial engine types.
Hydraulic damage.	No damage to the connecting rods. All the cylinders were drained of oil during oil priming procedure and before engine starting.
Inadequate oil priming.	Procedure applied in accordance with normal practice.
Bearing quality issue related to engine overhaul.	Damage normally occurs sooner after overhaul. Engine had operated for 86 hours since overhaul.
Contamination of the oil system.	None.

Table 2

Summary of possible causes of rear master rod bearing damage

Pilot's actions

The first cockpit indication of an engine problem was an increase in oil temperature, which the pilot reported was normally very stable. The pilot's notes did not contain a procedure for high oil temperature. Based on his experience, the pilot opened the oil cooler manually and increased airspeed to increase cooling airflow, but the temperature continued to rise and the pressure started to fluctuate.

When the engine seized the pilot had the option to abandon the aircraft or to make an off-airfield landing. He reported that he had planned and briefed that, if the engine failed, he intended to make an off-airfield landing. When the engine did fail, he did not consider abandoning the aircraft and focused on landing as planned. With time to reflect after the accident he remained of the opinion that, given the low altitude and high rate of descent, attempting a landing was the safest option.

The pilot reported that, after the engine stopped, he focused on maintaining airspeed and keeping the aircraft flying. Although the pilot's notes used by the operator did not contain specific guidance on off-airfield landings, based on his experience he kept the landing gear retracted. This was consistent with the guidance in the Royal Navy Sea Fury Mk 10 & 11 pilot's notes. The high rate of descent limited the choice of fields. He tried to extend the flaps but with little hydraulic pressure they only moved slightly from the UP position.

The pilot was able to transmit a mayday call which enabled the emergency services, with the assistance of other aircraft in the area, to locate the aircraft quickly. He did not have time to jettison the canopy or switch off the fuel or ignition before landing.

The AAIB has investigated several single engine aircraft accidents in which the engine failed and the pilot lost control of the aircraft before reaching the ground, often resulting in serious or fatal injury. In this accident the pilot was able to maintain control until reaching the ground, preventing more serious injuries to the occupants. The pilot reported that, before flying, he always took time to mentally rehearse his actions in the event of an emergency. He believed this was of considerable assistance when the engine failed, and that his recent simulator training, general flying recency and past experience all helped him manage the situation successfully.

Conclusion

The engine failure was caused by breakdown of the rear master rod bearing. The release of material and increased friction overwhelmed the oil cooling system and exceeded its capacity to maintain normal operating temperatures, resulting in catastrophic damage to the reciprocating components and eventually engine seizure.

Symptoms of the bearing failure were visible before the accident flight, in the form of abnormal oil smoke, and might have been shown by a chip detector had one been fitted. However, from the moment excessive oil temperature was indicated, total engine failure could not be prevented.

The investigation did not discover precisely what initiated the bearing damage but determined that oil contamination was the most likely cause.

The pilot's experience, including practice engine failures in a relevant simulator, assisted him in conducting a safe forced landing. Maintaining sufficient airspeed, whilst avoiding built-up areas and the temptation to reach an aerodrome, contributed to this outcome. The accident demonstrates the importance of an effective emergency briefing before flight, and the value of wearing appropriate head protection.

AAIB comment

The investigation has not identified the need for new safety recommendations, but highlights three areas for additional consideration by operators of similar aircraft:

1. An engine oil chip detector may provide sufficient early warning of engine damage to indicate the need for remedial maintenance before further flight.
2. Forced landing or abandonment involves significant risk of injury in high performance aircraft. Operators and pilots can promote safe outcomes by providing clear safety briefings and ensuring all occupants wear effective head protection, as in this case.
3. Training in a relevant simulator can help familiarise pilots with prioritising the tasks necessary to conduct a safe forced landing, including the importance of maintaining sufficient airspeed, field selection, and the passenger and other emergency procedures that must be completed. The AAIB recognises that there are few such simulators for high performance piston driven aircraft, and alternative means of achieving the same training aims may also be beneficial.

Published: 16 September 2021.

AAIB Correspondence Reports

These are reports on accidents and incidents which were not subject to a Field Investigation.

They are wholly, or largely, based on information provided by the aircraft commander in an Aircraft Accident Report Form (AARF) and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A321-251NX, G-UZMI	
No & Type of Engines:	2 CFM International SA LEAP-1A32 turbofan engines	
Year of Manufacture:	2020 (Serial no: 9422)	
Date & Time (UTC):	3 January 2021 at 1450 hrs	
Location:	Bristol Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 7	Passengers - 58
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	40 years	
Commander's Flying Experience:	9,271 hours (of which 9,082 were on type) Last 90 days - 50 hours Last 28 days - 33 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and information from the operator	

Synopsis

During the boarding process, the crew recognised that the passenger distribution was incorrect for their aircraft type. The commander subsequently filed a safety report that initiated an investigation by the operator. It was found that the previous sector might have been flown with the aircraft CG out of operating limits, and issues were identified with data transfer between the aircraft management and departure control systems.

Although it was subsequently found that the aircraft had not flown outside certified limits, the operator implemented safety actions to strengthen its procedures and prevent recurrence.

History of the flight

Bristol to Edinburgh sector

At approximately 1450 hrs on 3 January 2021, the aircraft was on stand at Bristol Airport being prepared for a sector to Edinburgh. The aircraft originally allocated, an Airbus A320, had been replaced with an A321-NEO due to a technical issue. The aircraft commander and co-pilot originally rostered to fly were not qualified on the A321-NEO, so a crew qualified on type was called from standby and assumed responsibility for the operation.

The commander started the boarding process and prepared the aircraft for departure. The Turnaround Coordinator (TCO) handed the Loading Form and Certificate (LFC)[1], which included Last Minute Changes (LMCs), to the Cabin Manager (CM) who passed it to the flight crew. The co-pilot entered the load figures into the Electronic Flight Bag (EFB) load sheet application and noted that the load computation indicated that the CG was towards the forward limit of the operating envelope, but within computed operational limits. The flight to Edinburgh continued as normal.

Edinburgh to Bristol sector

At approximately 1650 hrs, during the boarding process at Edinburgh, the aircraft CM received the LFC from the TCO and passed it to the flight crew. The CM commented to the commander that the passengers were not seated as indicated by the LFC, so the commander requested a manual zone count of the passengers. It was found that the passenger distribution on the LFC was not correct and appeared to be based on row boundaries for seating zones on the A320 and not the A321-NEO. The flight crew entered the figures from the manual count into the EFB and found that the CG was forward of the permitted operating envelope. The commander instructed the CM to move passengers to the correct seating positions to resolve the issue, ensuring the aircraft operated within the allowable CG envelope for departure. The LFC was annotated with the new data. The commander left the flight deck and spoke with the TCO to discuss the issue. They agreed there appeared to be an IT system issue following the aircraft change such that the original LFC did not reflect the correct seating zone adjustments for the A321-NEO. With the issue identified and apparently resolved, the sector to Bristol, and subsequent two sectors, were flown without incident. On return to base, the commander filed an air safety report on the loading issue experienced at Edinburgh.

Investigation by operator

Initial analysis

Following receipt of the commander's air safety report the operator conducted an investigation and found that, unknown to the crew, the sector from Bristol to Edinburgh had been flown outside of the operational CG envelope[2] (Figure 1). It was concluded that following the change of aircraft type on the day of operation, the aircraft type and registration had been updated on the aircraft management system, but that change had not been identified by the departure control system responsible for generating the information recorded on the LFCs. When the TCO arrived for duty, he was advised by the operations centre that the flight had been changed from an A320 to an A321-NEO. He prepared the LFC with the correct type and registration details. On arrival at the gate, he extracted the load details from the departure control system to complete the

---

Footnote

[1] The Loading Form and Certificate shows the breakdown and distribution of the passengers, baggage, and freight on the aircraft. This allows the flight crew to calculate accurate performance figures and to ensure the aircraft is operating within centre of gravity limitations.

[2] The 'certified flight envelope' is mandated in the Original Equipment Manufacturer's Aircraft Flight Manual. However, this is further restricted by the operator to account for operational variations and errors such as fuel density, moving aircraft parts, dry operating weight, cabin movement, cabin distribution and baggage distribution. The result is the 'operational envelope'.

LFC but, unknown to him, the type change had not registered. Consequently, the flight was closed with the passenger distribution reflecting the seating configuration for an A320 and not an A321-NEO.

CONFIG 235Y (STD)
ENTRY MODE DETAILED (STD)
CREW 2+5 (STD)
CATERING A321 EU (STD)
MISC NONE (STD)
LIMITING WEIGHTS
PAX 58
CARGO kg 389
FOB T 5
TRIP FUEL T 1.9
TAXI FUEL T 0.2 (STD)

UNDERLOAD (kg): 18273 LIMITED BY ZFW

OUT OF LIMITS

	Weight T	CG %
DOW / DOCG	49.7	18.9
PAYLOAD	5.3	
ZFW / ZFWCG	55.0	15.3
T.O. FUEL	4.8	
TOW / TOCG	59.8	14.2
TRIP FUEL	1.9	
LW / LCG	57.9	14.5

Figure 1

EFB CG data produced in the operator's investigation using correct A321-NEO seating configuration for the Bristol to Edinburgh sector (reproduced with permission)

For the sector from Edinburgh, it was found that the ground handling agent had noted that an aircraft type change had been recorded in the aircraft management system. However, the TCO was directed to deal with an aircraft returning to another stand with a technical issue so did not review the departure control system. Rather, at the point of close-out of the flight, the load details were passed over the radio by the gate staff to the TCO to complete the LFC. While this was in accordance with procedures, the opportunity to detect the information in the system being in error was reduced. The investigation commented that:

> *'This clearly contributed to why the issue was not already noticed. Trust was put in the fact that there was no reason to think the departure control system would not update the bays in line with the type change'.*

Comments from aircraft manufacturer

The operator reviewed the Flight Data Monitoring information for the relevant sector and found that no certified aircraft limitations had been exceeded and that there was no impact on the controllability of the aircraft. However, as the investigation continued, the aircraft was grounded pending a review of the incident by the manufacturer. Following their analysis of the Flight Data Recorder, Post-Flight Report and load sheets, the manufacturer concluded that the flight was conducted within certified limits and that the aircraft could be returned to service.

Further investigation by the operator

Further investigation by the operator revealed that the discrepancy in information displayed between the aircraft management system and the departure control system was due to code errors in the Batch Interaction Layer (BIL) operating outside of the original design specification. The BIL provides the channel for data transfer between elements that make up the system. An internal validation process runs in the background, comparing the aircraft management system to the departure control system to identify and update any changes. This process runs every five minutes. However, due to the Covid-19 environment, there had been a high number of changes to the operator's schedule and the validation process was taking longer than normal to run. Therefore, changes made outside the five-minute window were not detected automatically by the system.

The operator's procedures allowed manual updates to the departure control system to be made after the change of aircraft type had registered in the aircraft management system. Investigation revealed that in this case the aircraft type had been changed manually, but this change occurred after passengers had started the boarding process at Bristol. It was determined that the process did not consider this scenario and consequently the system had no mechanism to prevent the change of type being manually updated when boarding of the aircraft had started. Additionally, the system did not provide an alert to either the gate staff or the TCO. The aircraft registration data in the departure control system is not directly linked to the aircraft type data such that they can be changed separately. A type change registered in the system would prompt the seating algorithm to alter the bay figures, but the registration could match the previous aircraft causing confusion. The various elements of the IT system architecture do not 'talk' directly to each other but operate through a variety of interfaces such as the BIL, which makes errors and inaccuracies more likely.

The investigation concluded that:

> *'The manual update within the* [departure control system] *from an A320 to an A321 triggered a seating algorithm to run which changed some seat allocations and in turn adjusted the passenger bay split information to match the new seating allocation and the bay split for an A321. There were no gate alerts for seating changes as those with seat changes had already been processed and so the passengers sat in their original seats. The dispatcher then unknowingly obtains these inaccurate figures from the system to populate the loading form which is passed to the pilots to complete their calculations'.*

Operator's Covid-19 aircraft biosecurity measures

The operator's Covid-19 biosecurity measures required the TCO to pass the LFC to the CM and not directly to the flight crew as had been the procedure before the measures were implemented.

Discussion

This serious incident was caused by a combination of operating factors in a complex system interacting in a manner which had neither been designed nor predicted. If passenger and cargo distribution on an aircraft leads to an undetected out of trim condition, the potential outcome could be unexpected handling qualities or control limitations.

The final weight and balance calculation is completed by the operating crew based on the loading data presented to them by ground personnel. If that information is incorrect, unless further evidence is available to indicate an anomaly, this final safety barrier is compromised as was the case at Bristol Airport.

Prior to the Covid-19 pandemic, the TCO would hand the LFC to the flight crew, providing an opportunity for them to query any LMCs directly. However, the operator's biosecurity measures required interactions with the flight deck to be minimised, so the LFC was delivered to the CM in the cabin. As the TCO was not on the flight deck, the crew were more likely to accept changes presented to them without discussion and complete their tasks as defined in their SOPs. However, as the CM checked the LFC before handing it to the commander at Edinburgh, the error was identified and trapped. This resulted in the commander filing the safety report which triggered the operator's investigation, which ultimately led to the cause of the error being detected.

Safety action

In response to this serious incident, the following safety action was taken:

The operator:

- Introduced a procedure where an aircraft is changed, requiring the Network Control team in the Integrated Control Centre (ICC) to conduct a manual check between the IT systems used for planning and loading to ensure the correct aircraft type and registration are displayed in all systems.
- Introduced a requirement for the Chief Pilot, in coordination with the ICC, to notify the duty pilot of any aircraft type changes. The duty pilot will discuss the potential risk with the operating crew.
- Requires a manual bay count to be completed before departure for every flight to ensure the weight and balance calculations are accurate.
- Published a poster to all stations to highlight the requirements for data checks following an aircraft change to ensure that information extracted from the system is correct.
- Initiated a further investigation into their IT systems to determine how operational changes are managed and communicated between the relevant parts of the system in order for a permanent solution to be established.

SERIOUS INCIDENT

Aircraft Type and Registration:	Hawker Hunter F6.A, G-KAXF	
No & Type of Engines:	1 Rolls-Royce Avon Mk 207 turbojet engine	
Year of Manufacture:	1956 (Serial no: S4/U/3361)	
Date & Time (UTC):	14 May 2021 at 1030 hrs	
Location:	St Athan Airport, Glamorgan	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Canopy damaged	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	57 years	
Commander's Flying Experience:	7,000+ hours (of which 95 were on type) Last 90 days - 32 hours Last 28 days - 32 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

During the takeoff roll, the canopy transparency detached from its frame and slid rearwards. The pilot rejected the takeoff and returned to the apron without further incident.

The CAA reported that the failure was due to an abnormal weakness or fault which was not possible to see during normal servicing inspections. As no similar events were identified, no formal action will be taken. However, the event will be briefed at relevant industry forums and by surveyors during visits to ex-military Continuing Airworthiness Maintenance Organisations (CAMO).

The CAMO responsible for this aircraft, intends to introduce additional inspections and pressurisation checks to canopy assemblies within their fleet.

ACCIDENT

Aircraft Type and Registration:	Aeroprakt A32 Vixxen, G-CLEH	
No & Type of Engines:	1 Rotax 912ULS piston engine	
Year of Manufacture:	2019 (Serial no: LAA 411-15590)	
Date & Time (UTC):	28 June 2021 at 1530 hrs	
Location:	Rossall Airfield, Lancashire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Nosewheel collapsed and damage to the propeller	
Commander's Licence:	Light Aircraft Pilot's Licence	
Commander's Age:	71 years	
Commander's Flying Experience:	481 hours (of which 144 were on type) Last 90 days - 16 hours Last 28 days - 7 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The aircraft has a fuel tank in each wing with a valve for each tank situated behind the seats, at shoulder level, on either side of the cockpit. During the flight the pilot closed the left valve to balance the fuel as more had been used from this tank. After landing the pilot decided to do a few circuits and so immediately taxied back to the runway whilst configuring the aircraft. Just before commencing the takeoff he remembered he had closed a fuel valve and reached behind the seat and moved a fuel valve handle.

Shortly after takeoff, at about 100 ft agl, the engine stopped and the pilot landed the aircraft in a field during which the nosewheel collapsed and the propeller was damaged. The pilot secured the aircraft and found that both fuel tank valves were in the closed position.

ACCIDENT

Aircraft Type and Registration:	CAP 232, G-IITC	
No & Type of Engines:	1 Lycoming AEIO-580-B1A piston engine	
Year of Manufacture:	1998 (Serial no: 15)	
Date & Time (UTC):	12 June 2021 at 1220 hrs	
Location:	Wombleton Airfield, North Yorkshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Propeller, landing gear and aileron damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	36 years	
Commander's Flying Experience:	324 hours (of which 50 were on type) Last 90 days - 18 hours Last 28 days - 7 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

As the aircraft touched down its right wing caught crops at the edge of the runway. This caused the aircraft to veer off the runway into a field, where it was brought to a stop by the crop. The pilot was uninjured, but the aircraft sustained damage during the accident. The pilot considers the causal factors to be late identification of aircraft drift on a narrow runway and not initiating an immediate go-around.

History of the flight

The pilot had flown the aircraft to Wombleton to carry out aerobatic training in preparation for a competition. The weather was CAVOK with the wind from 270° at 10 kt. The pilot took off from Runway 28 and carried out the aerobatic sequence twice whilst overhead the airfield. After 10 minutes flying, the pilot re-joined the left-base leg to land on Runway 28. The pilot lined up the aircraft for final approach and settled into a descent. As he flared the aircraft, it started to drift to the right side of the runway and although the pilot attempted to correct the drift, as the wheels touched down, the right wing caught the dense crops growing at the edge of the runway.

The aircraft veered off the runway into the crop and came to a stop. The pilot was uninjured but the propeller blades, landing gear and an aileron were damaged during the accident.

Pilot's comments

The pilot identified several contributary causes of this accident. The runway is narrow, 15 m wide, and has crops growing at its edges. Figure 1 shows the proximity of the crops. He normally configures the aircraft with a slipstream to improve forward visibility during landing but on this occasion, slipstream was not used. He described how he failed to observe the extent of the drift and when he realised and attempted to correct it, it was too late. He believed that, had he initiated an immediate go-around, it is likely the accident would have been averted.

Figure 1

Proximity of the crop to runway
(the object on the runway is a detached aileron spade)

ACCIDENT

Aircraft Type and Registration:	GY201 Amateur Built, G-BEBR	
No & Type of Engines:	1 Continental Motors Corp O-200-A piston engine	
Year of Manufacture:	2007 (Serial no: PFA 1824)	
Date & Time (UTC):	26 May 2021 at 1753 hrs	
Location:	Lower Durston, Somerset	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Serious)	Passengers - N/A
Nature of Damage:	Landing gear and wing damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	76 years	
Commander's Flying Experience:	5,000 hours (of which 2 hours were on type) Last 90 days - 15 hours Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot had recently acquired the aircraft and planned to carry out two circuits from a farm strip using various flap settings. While on the downwind leg, at about 400 ft agl, the engine started to misfire and did not produce sufficient power to enable him to land back on the strip. He therefore initiated a field landing and as he approached the field from the east his vision was impaired by the setting sun. He reported that he attempted to select full flap but found the flap handle jammed. He then "inadvertently" pulled back on the control column which resulted in the aircraft stalling near to the ground and landing heavily. The wing and landing gear were damaged during the impact and the pilot sustained injuries. Although he was able to exit the aircraft himself, his injuries required hospitalisation.

The pilot confirmed that there was sufficient fuel on the aircraft but did not know what caused the misfire and loss of power. He also reported that during his examination of the aircraft after the accident, a plastic torch was found within the port wing "jammed in the flap and aileron mechanism".

ACCIDENT

Aircraft Type and Registration:	Jodel D120, G-BKAE	
No & Type of Engines:	1 Continental Motors Corp C90-14F piston engine	
Year of Manufacture:	1961 (Serial no: 200)	
Date & Time (UTC):	23 June 2021 at 1055 hrs	
Location:	Shacklewell Airfield, Stamford, Lincolnshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damaged beyond economical repair	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	79 years	
Commander's Flying Experience:	894 hours (of which 20 were on type) Last 90 days - 5 hours Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot was planning to fly some visual circuits, with the intention of doing full stop landings before taking off again on each circuit. Grass Runway 24 was in use and the wind was light and variable.

After touching down on the second circuit, the aircraft didn't slow as expected. Believing there was not enough runway left in which to stop, the pilot elected to change to a touch-and-go. When the power was applied the aircraft yawed to the left. It then went off the edge of the runway into some very rough ground, coming to rest on its nose (Figure 1). The pilot was uninjured and vacated the aircraft without assistance. The aircraft sustained damage to its propeller and right landing gear; it was subsequently assessed as being damaged beyond economical repair.

The pilot attributed the accident to a late decision to go around and not being sufficiently quick in counteracting the yaw when the power was applied. While the wind was variable, the pilot also believed there might have been a small tailwind component.

Figure 1
G-BKAE after the accident

Bulletin correction

After publication it was noted that the location stated was incorrect. The original report stated the location of the accident was Shacklewell Airfied, Kent. The actual location of the accident was **Shacklewell Airfield, Stamford, Lincolnshire**.

The online version of the report was corrected on 9 December 2021. A full correction will be published in the February Bulletin 2022.

ACCIDENT

Aircraft Type and Registration:	Comco Ikarus C42 FB100 C, G-CLYP	
No & Type of Engines:	1 Rotax 912 UL 52-1 piston engine	
Year of Manufacture:	2020 (Serial no: 2012-7633)	
Date & Time (UTC):	23 June 2021 at 1545 hrs	
Location:	Perranporth Airfield, Cornwall	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Collapsed nose leg and damaged propeller	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	72 years	
Commander's Flying Experience:	507 hours (of which 15 were on type) Last 90 days - 14 hours Last 28 days - 6 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft touched down, bounced and landed hard causing the nose leg to collapse before the aircraft came to a stop. The pilot believes that lack of hydration may have affected his judgement during the landing. The BMAA has agreed to publish an article in their October edition of Microlight Flying to highlight the impact of seasonal weather changes on flying and using this accident as an example.

History of the flight

Following a flight from Little Snoring Airfield and a 55 minute stop at Cotswold Airport to refuel his aircraft, the pilot took off for his home airfield at Perranporth at 1320 hrs. It was a bright sunny day with an 8 kt northerly wind reported at his destination. The journey was uneventful, although the pilot commented that sunlight through the aircraft's overhead transparency had made him uncomfortable throughout. His approach to Runway 01 was stable at 60 kt with a good glidepath. As the aircraft flared the pilot realised he was too high, but he decided to continue with the landing. The aircraft touched down, it bounced and landed hard causing the nose leg to collapse before the aircraft came to a stop. The pilot reported that he had suffered a severe headache that evening which he attributed to dehydration, or possibly mild heat stroke, which may have affected his judgement during the landing. He had not considered the effect of sunlight through the aircraft's overhead transparency before his journey and had not taken a hat or rehydrated since leaving Little Snoring at 1020 hrs.

Discussion

The safety section of the July 2021 edition of Microlight Flying[1] briefly warns of the effects of summer climatic conditions and dehydration. The BMAA has agreed to publish an article in their October edition to highlight the impact of seasonal weather changes on flying and using this accident as an example.

Footnote

[1] Mott, R. (2021), *Safety; Wing Tipz; Sun protection and hydration*, BMAA, page 20.

Accident

Aircraft Type and Registration:	Quik GTR, G-CHWO	
No & Type of Engines:	1 Rotax 912ULS piston engine	
Year of Manufacture:	2013 (Serial no: 8654)	
Date & Time (UTC):	10 June 2021 at 1235 hrs	
Location:	North of Cooling, Kent	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - 2 (Minor)	Passengers - N/A
Nature of Damage:	Aircraft damaged beyond economic repair	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	57 years	
Commander's Flying Experience:	5,461 hours (of which 4,326 were on type) Last 90 days - 126 hours Last 28 days - 57 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft struck the ground during a simulated engine failure after takeoff due to the commander delaying taking control in sufficient time to prevent the accident.

History of the flight

The commander was carrying out a general skills test with a student, which included performing a practice forced landing (PFL) in an area of open fields 0.6 nm north of Cooling, Kent. The student successfully flew a constant-aspect[1] PFL from 1,400 ft agl into Field A (Figure 1). At a height of approximately 250 ft during the climb-out the commander told the student "Close the throttle, the engine has stopped", simulating an engine failure after takeoff. The commander expected the student to promptly lower the nose and make an approach to Field B, which was directly ahead, however the student did not lower the nose decisively and entered a right turn towards Field C.

Footnote

[1] A constant-aspect approach is an approach flown to a touchdown point in which the angle between the aircraft and the touchdown point remains constant as the aircraft descends, resulting in a curved approach path.

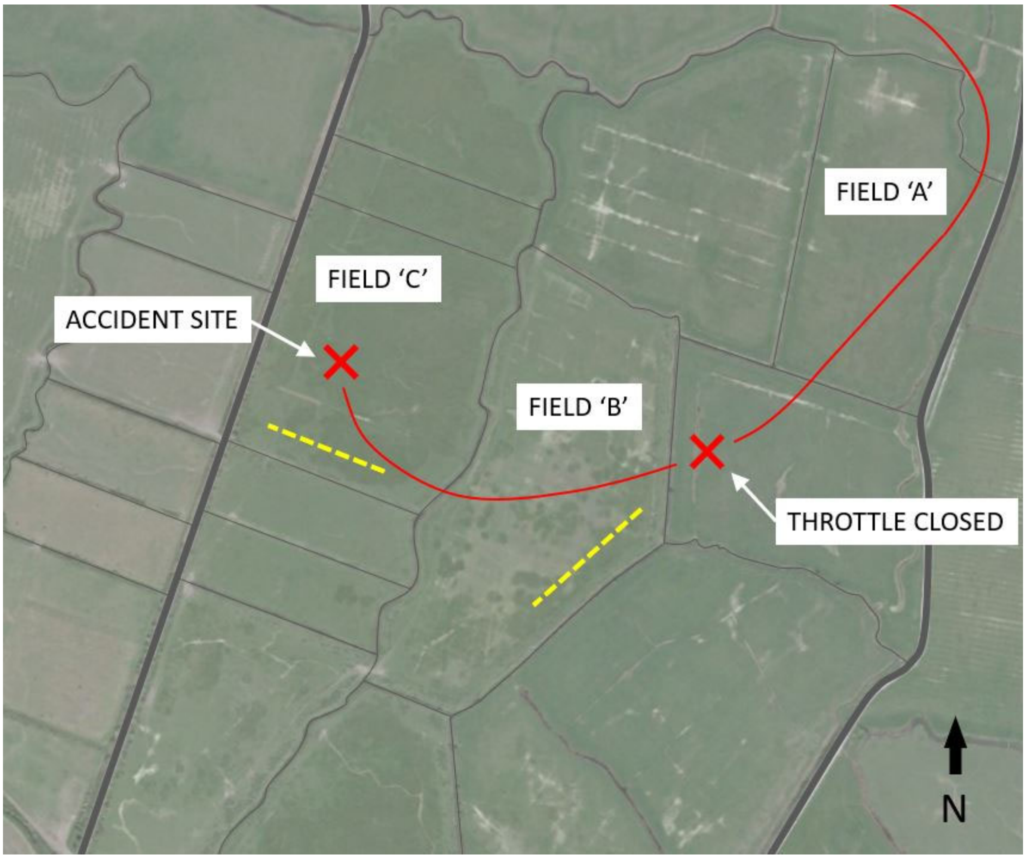


Figure 1

Reported accident flight path, with the commander's expectation of the student's approach paths to Fields B and C marked in yellow (image © 2021 Google)

The commander expected the student to roll out of the turn to approach Field C, parallel to the boundary fence, but the student continued to turn right and descend. The commander opened the throttle but there was insufficient time to prevent the right mainwheel contacting tall grass and the aircraft ground-looped in the field. The commander and student received minor injuries and the aircraft was damaged beyond economic repair.

Discussion

Following the accident the commander stated that the cause of the accident was his delay in taking control from the student whilst there was sufficient time available to prevent the ground contact. He also identified the student's unexpected field selection following the simulated engine failure after takeoff to be a contributory factor.

AAIB Record-Only Investigations

This section provides details of accidents and incidents which were not subject to a Field or full Correspondence Investigation.

They are wholly, or largely, based on information provided by the aircraft commander at the time of reporting and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

Record-only investigations reviewed July - August 2021

20-Apr-21 **Yak-3UA** **G-OLEG** Sywell Aerodrome, Northamptonshire

While completing the checks prior to engine start, the pilot misidentified the throttle and propeller controls, which were arranged differently to the aircraft he flew normally. He mistakenly applied full throttle instead of fine pitch. On starting the aircraft, the engine produced high power, causing the aircraft to pitch forward despite full tail-down elevator. The propeller was damaged and no injuries were reported.

26-Apr-21 **Cirrus 22** **N222SW** Wycombe Air Park, Buckinghamshire

Following a bounced landing the pilot applied power to go around. The aircraft did not achieve adequate performance to climb safely and was significantly damaged when it collided with a hedge beyond the runway. The pilot, who was the sole occupant, was uninjured and vacated the aircraft without assistance. He considered the final approach may have been too fast.

7-May-21 **Streak Shadow** **G-BYOO** Old Park Farm Airfield, Port Talbot, Glamorgan

The aircraft was landing on a farm strip with a significant upslope. A small tailwind, together with insufficient control input by the pilot to account for the increasing slope component, contributed to a long flare during touchdown. This resulted in a hard landing, the nose gear collapsing, and the aircraft rapidly coming to a stop.

7-May-21 **Diamond DA42M** **G-ZATG** Leeds Bradford Airport, West Yorkshire

The crew had briefed to conduct a practice EFATO followed by two asymmetric circuits as part of refresher training, with the first circuit being an overshoot and the second to land; the first circuit was completed successfully. However, because the airport was shortly to close, the crew elected to fly a tighter second circuit and omitted to lower the landing gear. Upon touching down, the aircraft slid along the runway before coming to a stop. The fuselage, nacelles and propellers sustained damage.

27-May-21 **Eurofox 912(S)** **G-CIML** Newtownards Airport, County Down

During the flare to land a gust of wind lifted the right wing causing the left wing to contact the ground. The aircraft swung to the left and departed the runway heading towards a steel fence. As the pilot attempted to avoid the fence the right wheel entered soft ground, the aircraft swung through 180° and it came to an abrupt stop on its nose.

Record-only investigations reviewed July - August 2021 cont

27-May-21 **Mainair Blade 912** **G-CBOM** Graveley, Hertfordshire

After flying for 75 minutes in turbulent conditions, described by the pilot as “a heavy workload in a flex-wing”, the pilot flew a normal approach and positioned the aircraft to land. However, after the initial flare, he reported encountering “unexpected significant sink” and, despite taking corrective action, the aircraft landed heavily and sustained substantial damage, including a fractured keel tube.

28-May-21 **Cessna 340** **N63EN** North Weald Airfield, Essex

The pilot landed having seen cockpit indications that the landing gear was down, but on touchdown the left landing gear collapsed and the aircraft subsequently left the runway surface. A bolt in the retraction system had failed allowing the landing gear to collapse.

30-May-21 **Renegade Spirit UK** **G-RNGD** Roughay Farm, Lower Upham, Hampshire

The pilot reported that during the take-off run, the aircraft veered to the left shortly after the tailwheel lifted off the ground. He was unable to regain the runway centreline and the aircraft entered a crop field where it came to rest inverted. The pilot was uninjured and reported that aircraft checks found nothing to explain the accident. He stated that the wind was around 5 to 6 kt and suggested that a crosswind gust could have been a factor.

31-May-21 **RotorSport UK Cavalon** **G-IDYL** Wendover, Buckinghamshire

The pilot conducted a forced landing in a field, after the engine bay fire warning light illuminated and he could smell burning. The aircraft collided with a hedge and was seriously damaged. A joint in the exhaust system had become disconnected, which had allowed hot gases to leak into the engine bay.

1-Jun-21 **Scintex CP1310-C3** **G-BCHP** New Farm Airstrip, Bristol

On landing, the pilot inadvertently did not fully retard the throttle. This resulted in the aircraft reducing speed at a slower rate than normal during braking and it subsequently departing the runway. The aircraft came to rest in a hedge.

Record-only investigations reviewed July - August 2021 cont

6-Jun-21 **American AA-1** **G-BFOJ** Sherburn Aero Club,
Sherburn in Elmet, North Yorkshire

The aircraft took off with the towbar still attached. The pilot was alerted to this over the radio and he returned to land. The tow bar came off on the runway and the propeller suffered slight damage to one propeller blade tip. The pilot reported that prior to the flight he had pulled the aircraft to the fuel pump but parked it further away than normal. This meant that he didn't need to push the aircraft backwards before starting up. He had also been distracted from his routine by walking away to talk to another pilot before entering the aircraft.

14-Jun-21 **Gulfstream AA-5B** **G-BIPV** Sandown Airport, Isle of Wight,
Hampshire

Following an uneventful approach to land in very little wind, with full flap deployed, the aircraft floated over the grass strip for an "unusually long" time before touching down. The brakes were applied but the pilot was unable to bring the aircraft to a safe stop. It overran the end of the runway into rough terrain and gravel, during which the nose gear collapsed.

1-Jul-21 **Quik GT450** **G-FRGT** Enstone Airfield, Oxfordshire

Whilst landing, the aircraft bounced and became airborne again. As it did so the trike skewed to the right. When it touched down again the wing contacted the ground and the aircraft flipped over, coming to rest inverted. The pilot was uninjured, but the wing and propeller were damaged in the accident.

9-Jul-21 **Acrosport 1** **G-TSOL** Fishburn Airfield, Durham

The pilot reported that the right landing gear collapsed following an uneventful landing. Examination found a broken bolt on the right landing gear. The corresponding bolt on the left landing gear was significantly distorted.

16-Jul-21 **Vans RV-14** **G-ORWS** Batch End Farm, Somerset

The pilot was flying to a grass farm strip, which he had not previously visited prior to the accident. He made a short field approach to the runway and touched down on all three wheels at the same time. He reported that the aircraft then bounced and on landing again, rapidly yawed to the left and tipped over.

Record-only investigations reviewed July - August 2021 cont

16-Jul-21 **PA-32R-301T** **N551TT** Compton Abbas Airfield, Dorset

Despite what appeared to be a normal landing with an 11 kt crosswind, the nose leg collapsed shortly after touchdown. The pilot reported that the likely cause was a mechanical failure.

16-Jul-21 **Robinson R44** **G-WHGA** Wolverhampton Halfpenny Green Airport, West Midlands

The student pilot, on his first solo, lost control in the hover and the helicopter struck the ground on its left side. The pilot suffered minor injuries. There was damage to the main and tail rotor blades, damage to the tail and minor damage to the fuselage. The main rotor blades of a nearby stationary R22 were struck by debris.

17-Jul-21 **Cessna 152** **G-GFIG** Denham Aerodrome, Buckinghamshire

Following three circuits with an instructor, the pilot took off for his second solo flight. He decided to land after the second solo circuit because he was aware of a faint engine related smell. On touchdown the aircraft bounced so he applied some power to go around but then realised that he hadn't applied full power and so elected to continue the landing and bring the aircraft to a stop. As the brakes were applied, the aircraft pitched down such that a propeller blade struck, and became stuck, in the ground.

18-Jul-21 **EV-97 Eurostar SL** **G-JBAV** Causeway Airfield, Coleraine, County Londonderry

During landing the aircraft bounced and drifted left. The pilot tried to go-around but the left wing hit a fence post to the left of the runway causing the aircraft to swing further left. The undercarriage collapsed and the right wing struck the fence. Lack of recency and dehydration may have contributed to the accident.

19-Jul-21 **Rans S6-ESA** **G-MZOZ** Perranporth Airfield, Cornwall

The aircraft bounced during landing causing the nosewheel to detach.

19-Jul-21 **Cessna 150G** **G-BRLR** Crossland Moor Airfield, Huddersfield, West Yorkshire

The pilot reported losing directional control while backtracking. The aircraft's wings were slightly damaged when they hit nearby bushes.

Record-only investigations reviewed July - August 2021 cont

22-Jul-21 **Ikarus C42 FB100 Bravo** **G-MEGZ** Cotswold Airport, Kemble, Gloucestershire

The aircraft landed hard resulting in damage to the landing gear.

23-Jul-21 **Piper PA-28R-200-2** **G-FULL** London Southend Airport, Essex

During the downwind checks the student confirmed the three green landing gear lights were illuminated. They were checked again on final approach and the instructor made another check just prior to touchdown. During the touchdown, which was described as smooth, the left main landing gear collapsed, the wingtip contacted the ground and the nose landing gear subsequently collapsed. The right main landing gear remained locked down and the aircraft came to rest at the side of the runway. The mechanical and electrical systems were tested but no fault could be found and the cause of the failure was not determined.

26-Jul-21 **Cessna 172S** **G-HLOB** Goodwood Aerodrome, West Sussex

The student pilot applied forward control column following a bounced landing. The aircraft touched down heavily on the nose gear which then collapsed, allowing the propeller to strike the ground.

26-Jul-21 **Aerotechnik EV-97 EuroStar** **G-CCUT** Defford Croft Farm, Worcestershire

The pilot had not flown for over six months due to the restrictions from the Covid-19 pandemic, so he undertook a flight with an instructor as part of his return to flying. After carrying out some handling exercises they returned to the airstrip to fly a number of circuits. On the first approach, with a slight crosswind, the aircraft landed heavily resulting in the nose leg bending, the right main landing leg breaking off and one blade on the propeller striking the ground.

28-Jul-21 **Shadow Series CD** **G-MWDB** Dairy House Farm, Crewe, Cheshire

Following an aborted takeoff the aircraft overshot the end of the runway and crashed into a hedge and farm machinery. The fuselage, nosewheel and a wing strut were damaged. The pilot reported that he suffered a minor foot injury.

1-Aug-21 **Piper PA-28-161** **G-BFDK** London Elstree Aerodrome, Hertfordshire

After completing two successful circuits the instructor noticed after the third climb out that the aircraft was handling differently, and the right wheel was trailing behind the flap. The instructor took control and successfully landed left-wheel-first on the grass to the side of the runway. When the right wheel touched the aircraft rotated approximately 180°.

Record-only investigations reviewed July - August 2021 cont

2-Aug-21	**Skyranger 912(1)**	**G-CCDG**	Oban Airport, Argyll and Bute	The aircraft landed heavily damaging the nose gear leg and propeller.
4-Aug-21	**Eurofox 912(1)**	**G-UFOX**	Westonzoyland Airfield, Somerset	On approach to land the pilot applied extra power to reduce the rate of descent. The aircraft drifted right of the runway and into an adjacent field of crop, where it sustained damage to the landing gear and right wing.
4-Aug-21	**Cadet III Motor Glider**	**G-BNPF**	Audley End Airfield, Essex	The right main landing gear collapsed following a firm touchdown.
4-Aug-21	**Team Mini-Max**	**G-MWHH**	London Colney Aerodrome, St. Albans, Hertfordshire	While cruising at 1,200 ft the engine stopped and could not be restarted. The pilot headed towards Colney aerodrome but had insufficient height to reach the runway and the pilot carried out a forced landing in a wheat field. As the landing gear passed through the crop the aircraft decelerated rapidly and pitched onto its nose coming to rest inverted.
10-Aug-21	**RotorSport UK MTOsport**	**G-PALT**	Beccles Airfield, Suffolk	The pilot reported that on takeoff the gyroplane suffered a retreating blade stall causing it to tip over onto its left side. It was extensively damaged and he suffered rib and lower leg injuries.

Miscellaneous

This section contains Addenda, Corrections and a list of the ten most recent Aircraft Accident ('Formal') Reports published by the AAIB.

The complete reports can be downloaded from the AAIB website (www.aaib.gov.uk).

TEN MOST RECENTLY PUBLISHED FORMAL REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

1/2015 Airbus A319-131, G-EUOE
London Heathrow Airport
on 24 May 2013.

Published July 2015.

2/2015 Boeing B787-8, ET-AOP
London Heathrow Airport
on 12 July 2013.

Published August 2015.

3/2015 Eurocopter (Deutschland)
EC135 T2+, G-SPAO
Glasgow City Centre, Scotland
on 29 November 2013.

Published October 2015.

1/2016 AS332 L2 Super Puma, G-WNSB
on approach to Sumburgh Airport
on 23 August 2013.

Published March 2016.

2/2016 Saab 2000, G-LGNO
approximately 7 nm east of
Sumburgh Airport, Shetland
on 15 December 2014.

Published September 2016.

1/2017 Hawker Hunter T7, G-BXFI
near Shoreham Airport
on 22 August 2015.

Published March 2017.

1/2018 Sikorsky S-92A, G-WNSR
West Franklin wellhead platform,
North Sea
on 28 December 2016.

Published March 2018.

2/2018 Boeing 737-86J, C-FWGH
Belfast International Airport
on 21 July 2017.

Published November 2018.

1/2020 Piper PA-46-310P Malibu, N264DB
22 nm north-north-west of Guernsey
on 21 January 2019.

Published March 2020.

1/2021 Airbus A321-211, G-POWN
London Gatwick Airport
on 26 February 2020.

Published May 2021.

Unabridged versions of all AAIB Formal Reports, published back to and including 1971, are available in full on the AAIB Website

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

aal	above airfield level
ACAS	Airborne Collision Avoidance System
ACARS	Automatic Communications And Reporting System
ADF	Automatic Direction Finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
AOM	Aerodrome Operating Minima
APU	Auxiliary Power Unit
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European Union Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EGPWS	Enhanced GPWS
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FAA	Federal Aviation Administration (USA)
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth's gravity
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
mb	millibar(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
PM	Pilot Monitoring
POH	Pilot's Operating Handbook
PPL	Private Pilot's Licence
psi	pounds per square inch
QFE	altimeter pressure setting to indicate height above aerodrome
QNH	altimeter pressure setting to indicate elevation amsl
RA	Resolution Advisory
RFFS	Rescue and Fire Fighting Service
rpm	revolutions per minute
RTF	radiotelephony
RVR	Runway Visual Range
SAR	Search and Rescue
SB	Service Bulletin
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TAF	Terminal Aerodrome Forecast
TAS	true airspeed
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TODA	Takeoff Distance Available
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
USG	US gallons
UTC	Co-ordinated Universal Time (GMT)
V	Volt(s)
V_1	Takeoff decision speed
V_2	Takeoff safety speed
V_R	Rotation speed
V_{REF}	Reference airspeed (approach)
V_{NE}	Never Exceed airspeed
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional radio Range

AAIB Bulletin 10/2021

AAIB
Air Accidents Investigation Branch