AAIB Bulletin 5/2019

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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:	British Aerospace (BAe) ATP, SE-MHF
No & Type of Engines:	2 Pratt & Whitney Canada PW126 turboprop engines
Year of Manufacture:	1989 (s/n 2013)
Date & Time (UTC):	3 May 2018 at 2210 hrs
Location:	8 nm west of Milton Keynes
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	4,277 hours (of which 2,169 were on type) Last 90 days - 54 hours Last 28 days - 19 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft experienced a loss of DC electrical power during the cruise whilst operating a cargo flight from East Midlands Airport to Stansted Airport, resulting in the loss of a significant number of flight deck instruments and systems. The crew decided to return to East Midlands Airport where they made a normal landing, following which DC electrical power was restored without crew action. The loss of electrical power was consistent with a failure of the No 1 Transformer Rectifier Unit (TRU) or its contactor, followed by a subsequent failure of the DC essential busbar COUPLE function. Subsequent testing of the aircraft's electrical system did not identify the cause of either failure.

The investigation identified that the aircraft's FDR was recording intermittently due to corrosion caused by moisture ingress. Two Safety Recommendations are made, relating to the prevention of moisture entering the FDR on BAe ATP aircraft with the Large Freight Door (LFD) modification and for the replacement of flight recorders using magnetic tape.

History of the flight

The aircraft was operating a cargo flight from East Midlands Airport to Stansted Airport and was established in the cruise at FL110 with the No 2 autopilot engaged. The co-pilot was the pilot flying and the commander was the pilot monitoring. As the aircraft was approximately 8 nm west of Milton Keynes and, shortly before commencing the descent towards Stansted Airport, the master caution aural alert sounded and the TRU 1 and DC LO VOLTS central warning panel (CWP) lights illuminated. This indicated that the No 1 TRU was no longer supplying 28 VDC voltage to the No 1 essential DC busbar (Figure 2).

The crew carried out Emergency and Abnormal Checklist (EAC) Card 49 *'TRU failure or single DC busbar low voltage'* (Figure 1). The commander initially attempted to reset TRU 1, but this was not successful. He then switched the No 1 non-essential DC busbar OFF and selected the DC essential busbar couple to connect the No 1 and No 2 essential DC busbars together. Following these selections, the DC LO VOLTS warning message extinguished, and the crew observed that the No 1 battery voltage indicator was in the green arc, indicating that the battery voltage was between 23 and 29 V. During this period, the commander was recorded on the CVR stating that he considered it was a busbar relay fault, rather than a TRU fault.

The crew conducted a DODAR[1] decision-making exercise and decided to return to East Midlands Airport. Shortly after, the commander tried to reset the TRU 1 again but this was unsuccessful. En-route the crew confirmed that the load on the No 2 TRU was below 180 amperes (A) and that no circuit breakers in the cockpit had tripped.

Approximately 15 minutes after the initial loss of electrical power, the commander noticed that his flight director had failed. The crew confirmed that the DC essential busbars were coupled and the DC LO VOLTS CWP caption had re-illuminated. The commander subsequently recalled that the No 1 inverter had failed and the No 1 battery voltage had reduced to 12V.

Seven minutes later, a master caution alert sounded and the GPWS CWP caption illuminated. This was shortly followed by the commander's electronic flight instrumentation system (EFIS) primary flight display (PFD) and navigation display screens becoming corrupted and unreadable and the autopilot disconnecting; the quick access recorder (QAR) recording also stopped. The commander then declared a PAN.

A few minutes later, as the aircraft was descending to 5,000 ft amsl, the No 1 engine control FROZEN indication and standby controls FAIL CWP caption illuminated, the flight deck lights flickered and a pulsing was heard on the radio by both crew. As a precaution, the crew advised ATC that the radios might stop operating. The FDR stopped recording a few seconds later. The commander selected the emergency busbar for his radio (the co-pilot's was also supplied by the emergency busbar) but the pulsing sound continued.

The aircraft was on base leg for Runway 27 at East Midlands Airport when the flight management system (FMS) failed, along with the No 1 DME and the autopilot flight mode annunciator panel. When the aircraft was about 7 nm from the runway, the pulsing sound on the radios stopped. The aircraft was vectored to a visual approach to Runway 27, which was followed by an uneventful landing, flown by the co-pilot whose

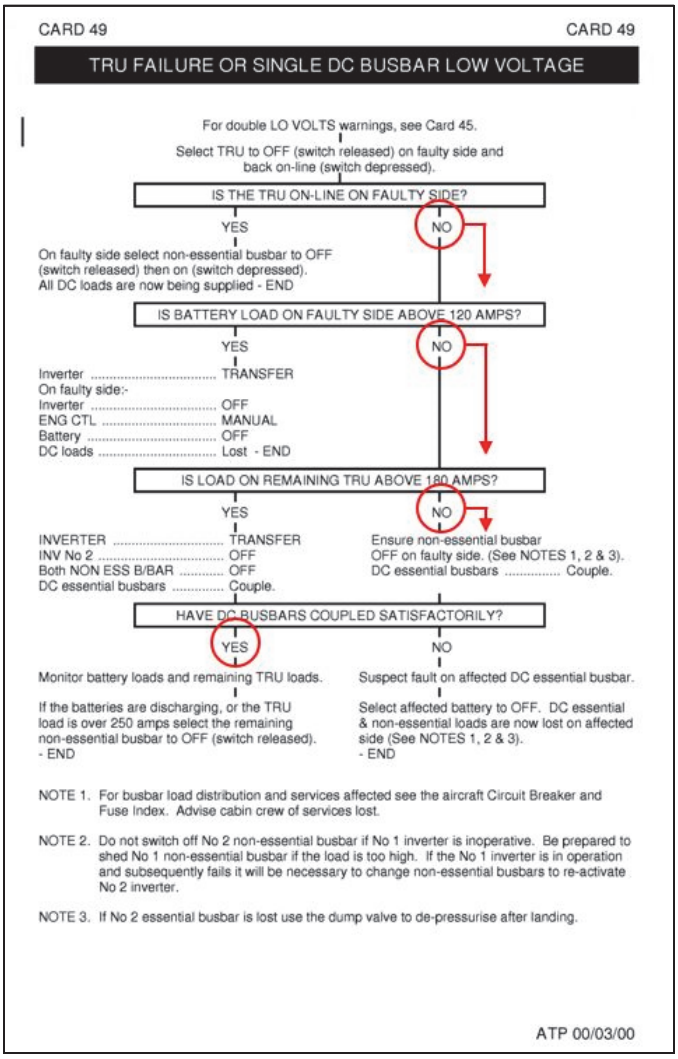
Footnote

1 Diagnose, Options, Decide, Act or Assign, Review.

EFIS screens were operating normally. As the aircraft touched down, the pulsing sound on the radios briefly returned before stopping again.

As the aircraft vacated the runway, the DC LO VOLTS and TRU 1 CWP warning messages extinguished and power was restored to the flight deck lights, the commander's EFIS screens and flight director. The crew checked the electrical load on TRU 2 and noted that it was more than 180 A, so they followed QRH Card 49 again. The crew selected the inverter transfer ON and selected inverter No 2 and both non-essential DC busbars OFF, to reduce the electrical load, and the DC essential busbars were confirmed as being coupled.

After the aircraft was parked, the crew and two engineers from the operator's maintenance organisation discussed the event and began fault-finding. As the No 1 battery busbar was connected to DC power, the No 1 battery overheat CWP caption briefly illuminated and one engineer noted that the No 1 battery was drawing over 300 A. Both batteries were switched OFF prior to further functional testing of the electrical power system.


CARD 49 CARD 49

TRU FAILURE OR SINGLE DC BUSBAR LOW VOLTAGE

For double LO VOLTS warnings, see Card 45.

Select TRU to OFF (switch released) on faulty side and back on-line (switch depressed).

IS THE TRU ON-LINE ON FAULTY SIDE?

YES: On faulty side select non-essential busbar to OFF (switch released) then on (switch depressed). All DC loads are now being supplied - END

NO

IS BATTERY LOAD ON FAULTY SIDE ABOVE 120 AMPS?

YES:
Inverter .... TRANSFER
On faulty side:-
Inverter .... OFF
ENG CTL .... MANUAL
Battery .... OFF
DC loads .... Lost - END

NO

IS LOAD ON REMAINING TRU ABOVE 180 AMPS?

YES:
INVERTER .... TRANSFER
INV No 2 .... OFF
Both NON ESS B/BAR .... OFF
DC essential busbars .... Couple.

NO: Ensure non-essential busbar OFF on faulty side. (See NOTES 1, 2 & 3). DC essential busbars .... Couple.

HAVE DC BUSBARS COUPLED SATISFACTORILY?

YES: Monitor battery loads and remaining TRU loads.
If the batteries are discharging, or the TRU load is over 250 amps select the remaining non-essential busbar to OFF (switch released). - END

NO: Suspect fault on affected DC essential busbar.
Select affected battery to OFF. DC essential & non-essential loads are now lost on affected side (See NOTES 1, 2 & 3). - END

NOTE 1. For busbar load distribution and services affected see the aircraft Circuit Breaker and Fuse Index. Advise cabin crew of services lost.

NOTE 2. Do not switch off No 2 non-essential busbar if No 1 inverter is inoperative. Be prepared to shed No 1 non-essential busbar if the load is too high. If the No 1 inverter is in operation and subsequently fails it will be necessary to change non-essential busbars to re-activate No 2 inverter.

NOTE 3. If No 2 essential busbar is lost use the dump valve to de-pressurise after landing.

ATP 00/03/00

Figure 1

EAC Card 49, with actions followed by crew annotated

Aircraft information – electrical system

The electrical power system of the ATP aircraft, Figure 2, is supplied by two 200/115 volt 45 Kva AC frequency-wild engine-driven generators. TRUs convert the AC power supplies to 28 VDC. The internal battery supply consists of two 24 V 37 Ah nickel-cadmium batteries capable of providing emergency power. Two solid-state inverters provide 200/115 VAC 400 Hz supplies.

The two AC generators and their respective control units are connected to separate frequency-wild busbars and via TRUs to the essential busbars. The battery supplies also connect to the essential busbars and separately to the emergency busbar. Each battery also has its own busbar that remains permanently 'live' when the battery power cables are connected to the installed batteries. Non-essential busbars are supplied from the essential busbars. The DC supply to the No 1 inverter is from the No 1 essential busbar and the No 2 inverter DC supply is from the No 2 non-essential busbar. The inverters supply two separate 400 Hz AC essential busbars.

The control and indication panels for the electrical system are located on the left roof panel (Figure 3) and a failure caution and warning system is provided for the management of fault conditions. The DC LO VOLTS CWP caption is illuminated when the power on either DC essential busbar falls below 24.5 V, after a five-second delay. If this occurs the non-essential DC busbar on the affected side is automatically disconnected.

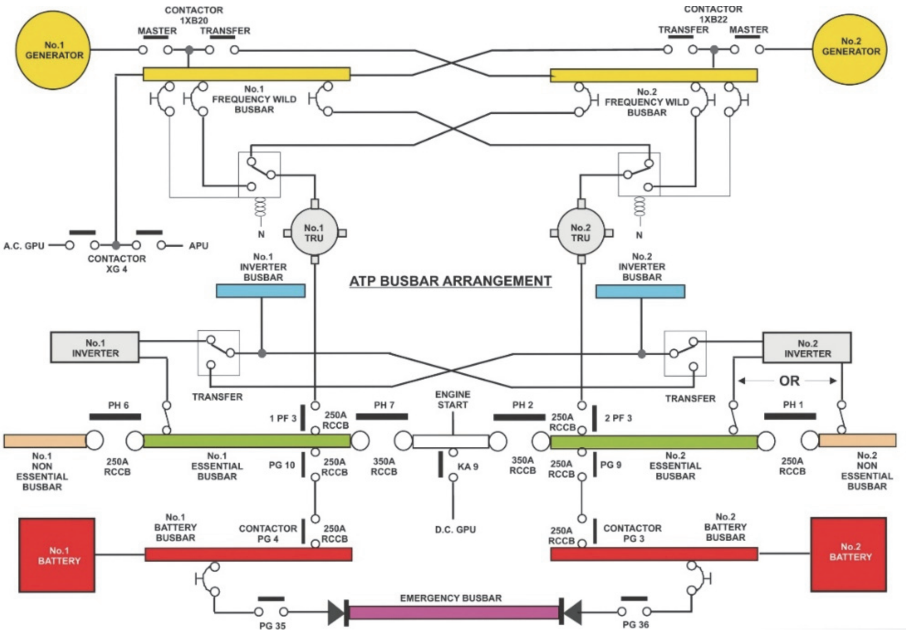


Figure 2

BAe ATP electrical power system (courtesy BAE SYSTEMS)

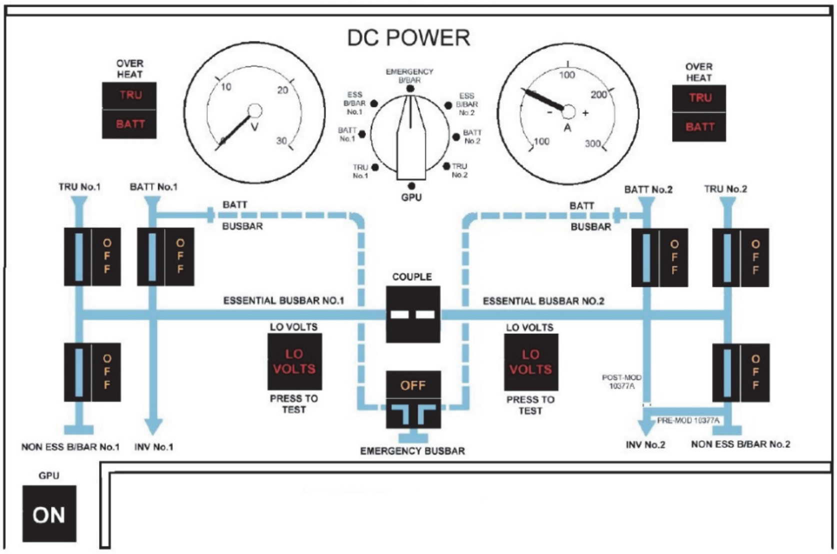


Figure 3

BAe ATP DC electrical power control panel (courtesy BAE SYSTEMS)

Aircraft examination – electrical system

Following the incident to SE-MHF, the operator's maintenance organisation conducted a visual inspection and electrical continuity tests of the aircraft's No 1 and No 2 TRUs, DC essential busbars and associated wiring harnesses, without detecting any abnormalities. The DC electrical system was then tested at high electrical loads of up to 230 A supplied from a single TRU, again without producing any abnormalities or failures.

The aircraft's No 1 and No 2 batteries, No 1 TRU and the No 1 and No 2 TRU contactors were removed from the aircraft for examination and functional testing, and no defects were identified. The aircraft was returned to service and no further failures were experienced with the DC electrical power system.

Recorded information – CVR, FDR and QAR

The aircraft was equipped with a two-hour CVR, a 25-hour FDR and a QAR. The QAR was routinely downloaded by the operator to support its Flight Data Monitoring (FDM) programme.

The CVR recorded the incident flight, which was 49 minutes duration. Both FDR and QAR recordings ended prior to the aircraft landing and an intermittent recording fault was identified with the FDR.

CVR, FDR and QAR system description

In SE-MHF, the QAR and FDR were installed in the rear equipment bay, located below the cabin floor within the pressurised area of the aircraft. The bay was accessed by a hatch on the underside of the fuselage (Figure 4). The aircraft was fitted with a LFD, which slides aft to its open position. The FDR and QAR were located below the LFD opening.

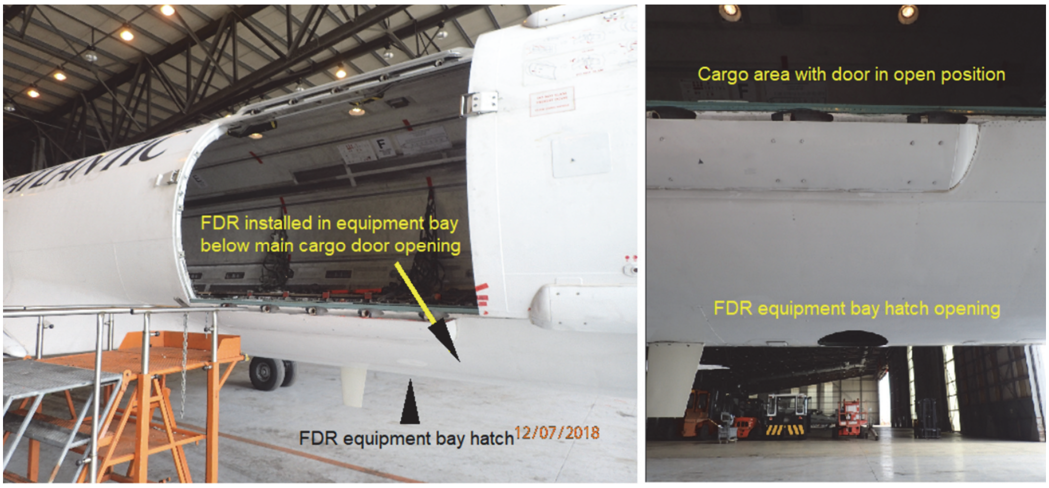


Figure 4

Location of FDR relative to LFD opening

The FDR and QAR were electrically powered from the No1 inverter 115 VAC 400 Hz busbar with the FDR starting to record as soon as electrical power was available. The CVR was electrically powered from the DC emergency busbar. The FDR provides the QAR with digital flight data[2], which the QAR records onto a removeable solid-state memory card, and the delay between receiving the data and it being recorded by the QAR is no more than 0.5 second. The QAR stops recording when electrical power is removed or the digital flight data signal from the FDR stops.

The FDR[3] (model PV1584) fitted to SE-MHF and other BAe ATP aircraft, was developed in the 1980s. It is a single-box design that incorporates both parameter acquisition and recording function, with digital flight data recorded onto magnetic tape. The FDR's electronics module contains 19 circuit boards, of which 17 connect to a main circuit board using push-fit connectors. The circuit boards are held in position by a metal panel that also forms part of the external cover of the FDR. The PV1584 is no longer manufactured.

The circuit boards and associated electrical components are covered with a conformal-coating that provides protection against moisture. However, the coating was not applied to the circuit board connectors or their solder connections as the FDR manufacturer[4] stated that it could cause reliability problems if the coating entered the connectors.

During certification, the PV1584 FDR was tested for the effects of moisture. However, it was not required to be tested for waterproofness and the effects of dripping water; this requirement was introduced for later generation FDRs that use solid-state memory. Solid-state memory recorders also undergo more extensive testing for crash survivability. The PV1584 FDR is not hermetically sealed and therefore moisture and liquids can enter the unit.

Footnote

2 The data is from electronic circuits prior to the signal being recorded onto the FDR magnetic tape.
3 Part number 650/1/14040/005, model PV1584F. Several variants of the PV1584 were manufactured, but each retained the basic design.
4 Meggitt Avionics purchased the original type design.

The PV1584 FDR incorporates a built-in test equipment (BITE) function that detects if the electrical signal at the tape-recording heads is lost, or a recorded signal is not present on the magnetic tape. This latter function does not perform a 'read-after-write' check so there is no validation that data has been correctly recorded. A fault must remain present for a period of at least 12 seconds before the BITE indicates a fault and if the fault clears, the BITE turns the fault signal off.

On the BAe ATP, an FDR fault is presented to the crew by illuminating a light on the Flight Data Entry Panel (FDEP), installed behind the co-pilot's seat. The crew are required to test the FDR fault light prior to the first flight of each day and check that the fault light is not illuminated as part of the pre-flight checks. The FDEP is not positioned in the direct line of site of either crew, so there is a possibility that an intermittent fault could go unnoticed. However, the operator of SE-MHF predominantly operated its fleet of BAe ATP aircraft at night and stated that the brightness of the fault light was sufficient to attract the crew's attention.

Comparison of SE-MHF FDR and QAR data

The FDR was removed from SE-MHF shortly after the incident and downloaded by the AAIB. QAR data for the incident flight, and approximately 40 hours of previous flight data, was provided by the operator.

Analysis of the flight data indicated that an intermittent fault within the FDR had resulted in a combination of partial recording of several flights and just over nine hours of historical data that should have been overwritten. Figure 5 provides an example of the partial flight recording and Figure 6 a time sequence of the FDR and QAR data. The time sequence coloured green in Figure 6 represents data that was correct, and the area coloured red (six flights) that should have been overwritten by more recent data coloured yellow (nine flights).

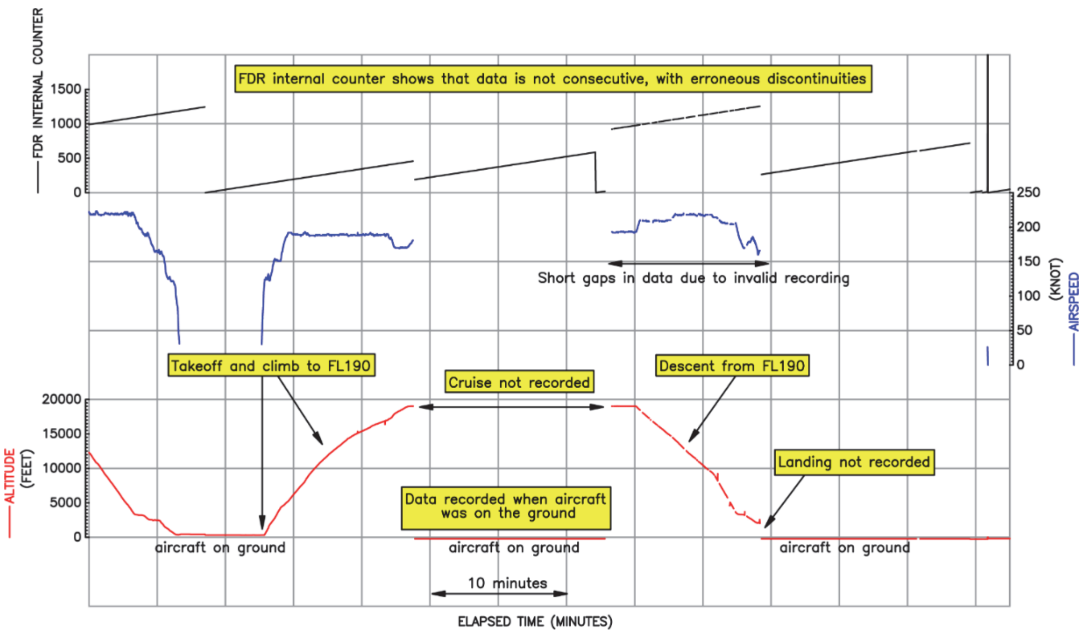


Figure 5

Example of SE-MHF erroneous FDR recording

This data showed that the electronics in the FDR that provide the QAR with data had continued to operate correctly, but an intermittent fault had prevented data from being written to the FDR's magnetic tape.

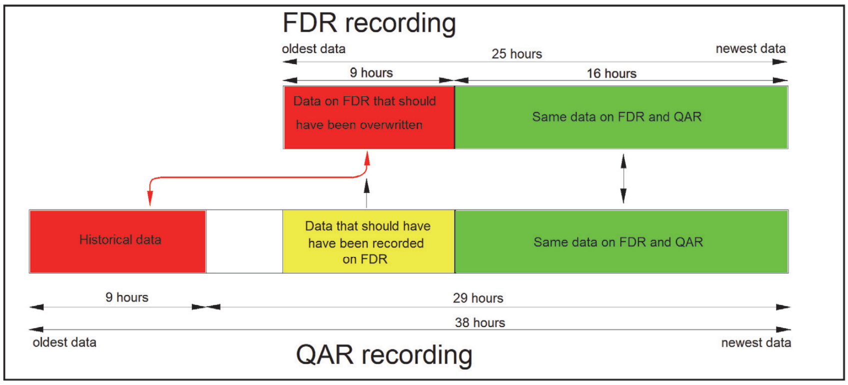


Figure 6

Pictorial time sequence of FDR recording

History of FDR serial number 10031

The FDR in this incident, serial number 10031, was fitted to SE-MHF on 11 January 2018 and removed shortly after the incident. The operator stated that between this period no defects with the FDR system were raised.

The operator purchased FDR serial number 10031 in March 2016. Records indicate that it was unserviceable but in November 2016 it was briefly fitted to one the operator's BAe ATP aircraft, SE-LGZ. During ground test the unit failed and was sent for repair to a Maintenance Repair Overhaul (MRO) facility. During repair, evidence of moisture ingress and damage was found that required replacement of a circuit board connector. A recording head had also failed, which had most likely caused the unit to fail. Serial number 10031 was returned to the operator in May 2017, where it was stored[5] prior to its fitment to SE-MHF.

Testing

During the AAIB investigation the FDR was tested for several days by the MRO facility that had previously serviced it. However, the intermittent recording fault could not be replicated. It was then disassembled and inspected. This identified:

- The inner face of the metal panel that secured the circuit boards was stained with moisture residue (Figure 7).
- An analogue to digital (A/D) converter circuit board (Figure 8) had an area of several cm^2 of staining that was attributed to moisture.
- Moisture residue and small areas of corrosion was apparent on the solder connections of two power-supply circuit board connectors (PSU1 and

Footnote

5 The FDR was stored in area that was monitored for temperature and humidity.

PSU2, Figure 8 and 9) and corresponding connectors on the main chassis interconnect.

- Corrosion was present on the chassis where the tape transport attached to the electronics module (Figure 10).

The MRO considered the intermittent recording fault had most likely been caused by moisture ingress. The MRO also added that other PV1584 FDRs received from the same operator's fleet of BAe ATP aircraft had been found with evidence of moisture ingress and damage. On occasion, staining from moisture residue has also been observed on the outside of the unit, indicating that water might have been dripping onto the unit. The FDR removed from SE-MHF did not show evidence of this.

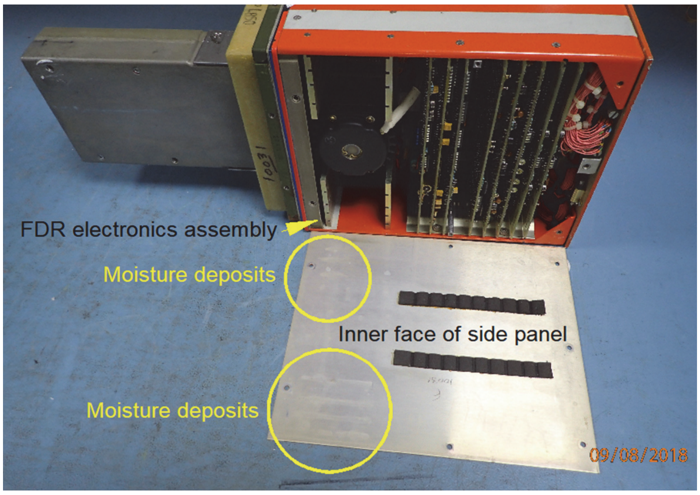


Figure 7

Inside of FDR electronics assembly side panel showing areas of moisture residue

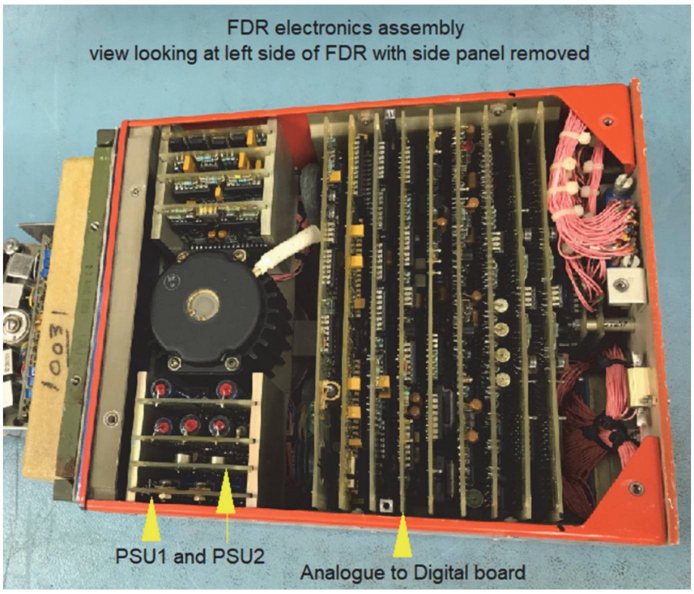


Figure 8

Position of PSU1, PSU2 and A/D circuits boards damaged by moisture

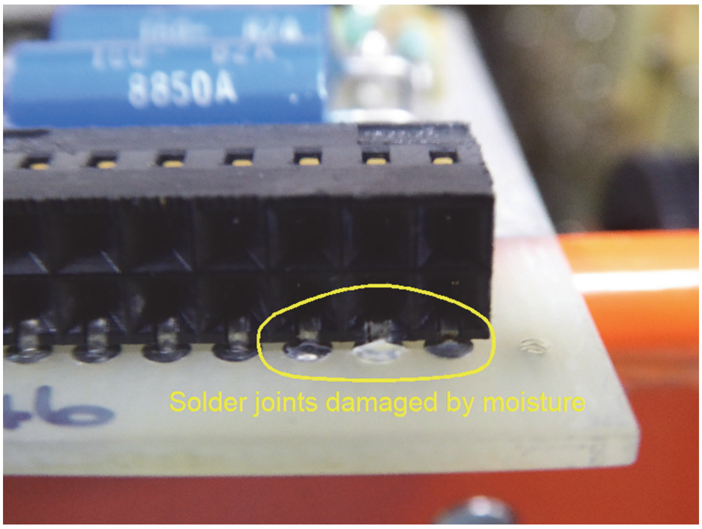


Figure 9

PSU1 connector solder joints damaged by moisture

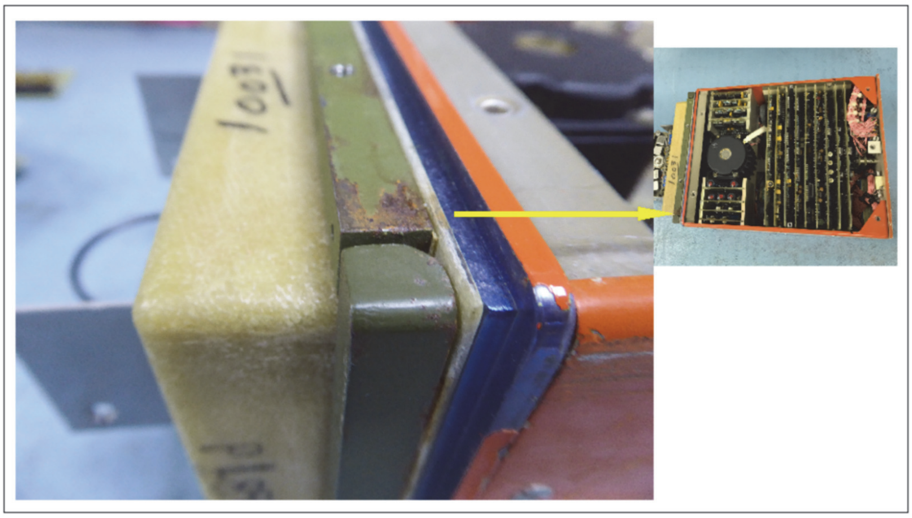


Figure 10

Corrosion on FDR chassis adjacent to electronics assembly

Effects of moisture on electronic devices

Moisture from rainwater contains dissolved electrolytes that can conduct electricity. Moisture entering electrical systems can cause equipment failures, intermittent operation and corrosion of solder joints and connectors that can affect long-term reliability.

BAe ATP LFD cargo door modification.

A total of 20 BAe ATP aircraft had been modified to cargo transport with the installation of the LFD that replaced the rear passenger door. Of these LFD aircraft, the operator of SE-MHF had operated 16. It had also operated a further 13 BAe ATP aircraft that used the rear passenger door for cargo loading (Figure 11), referred to as Small Freight Door (SFD) aircraft in this report.

At the time of this report, 12 LFD aircraft were in operation with the operator of SE-MHF, one operating in Indonesia, three in storage and four scrapped.

Figure 11
LFD and SFD cargo doors

Aircraft inspection – moisture ingress

The operator stated that during loading and unloading activities of LFD aircraft, rainwater and snow could easily enter the cargo area. Similar ingress on SFD aircraft was much less of a problem due to the smaller door aperture.

An inspection of the rear equipment bay of SE-MHF found that seals between the floor and supporting structure had degraded and there was evidence of light surface corrosion on several components. Discussions with the operator's engineering staff indicated that water had occasionally been found on the inside of the rear equipment bay hatch, but they could not recall whether this was more common on some aircraft in the fleet than others.

History of moisture ingress within FDRs fitted to the BAe ATP

The MRO facility provided 102 repair records for 37 PV1584 FDRs that had been fitted to a combination of LFD and SFD equipped BAe ATP aircraft between December 2010 and May 2018.

Analysis of these records indicated:

- Evidence of moisture ingress was found within 35% of the units serviced. Of these, the majority required replacement of damaged circuit board connectors.
- 22% of the units had failed due to moisture related damage; of these, 16% were removed because the FDR BITE had detected a fault, 4% were for readout and 2% for overhaul.
- 31 of 35 units with moisture ingress were fitted to LFD aircraft at the time of their removal.

- 3 of the 35 units found with moisture ingress were removed from SFD aircraft. All these units had been previously fitted to LFD aircraft.

Obsolete recording technologies

In 2010, the International Civil Aviation Organisation (ICAO) recommended[6] that the use of obsolete recording technologies for CVR and FDR, which included magnetic tape, should be discontinued by 1 January 2016. In response, EASA carried out a review in 2013 and their resulting '*Notice of Proposed Amendment (NPA) 2013-26*' contained the following statements:

> *'The unreliability of magnetic tape, magnetic wire and frequency modulation translate into causal factors of accidents and serious incidents being missed or not timely identified. As flight recorders using these technologies are not produced anymore, their average age is increasing, so that their failure rate is expected to increase as well.*
>
> *There is no easy way to check regularly the quality of the recorded data: a reliable self-monitoring of the recording medium condition is not in place with these kinds of recording technologies.*
>
> *Around one third of magnetic tape FDRs are found to have an insufficient recording quality.'*

EASA subsequently required that all magnetic-tape CVRs should be replaced by a two-hour solid-state memory CVR, with a compliance date of 1 January 2019. For FDRs, however, EASA conducted a rulemaking impact assessment, reflected in the EASA NPA 2013-26. This assessment indicated that, based on an aircraft service life of 30 years, by 2019 there would be only a very few magnetic-tape FDRs still in service ('*close to 0%'*). EASA did not, therefore, set a requirement for replacement of magnetic-tape FDRs.

In 2018, the AAIB contacted UK operators to establish CVR and FDR aircraft fitment. This showed that there were still a small number (fewer than 20) of aircraft operating with magnetic-tape FDRs. The operator of SE-MHF has also indicated that it intends to operate its fleet of BAe ATP aircraft beyond 2019.

The type design holder no longer provides a repair facility for the PV1584 FDR, but two MRO facilities in the UK do. One of these MROs advised that it was shortly to cease offering a repair service and the second MRO estimated that it might run out of spare parts to service the PV1584 model by approximately mid-2020. The two MROs also indicated that they were considering ceasing to offer a repair service for other models of FDRs using magnetic tape.

Footnote

[6] ICAO Annex 6 Part 1 (Aeroplanes) and Part III (Helicopters).

Analysis

Electrical system failure

The initial loss of DC electrical power was caused by a failure of either the No 1 TRU or its contactor providing connection of the TRU's output to the No 1 DC essential busbar. This fault condition persisted until the aircraft landed, when the dc lo volts and TRU1 warning captions extinguished.

The crew correctly followed EAC Card 49 resulting in the successful coupling of the No 1 and No 2 DC essential busbars. The further attempt to reset the No 1 TRU, following the busbar couple, deviated from the procedure contained in Card 49 although it did not affect the configuration of the DC electrical system at this stage as the No 1 TRU or its contactor remained in a failed condition.

The subsequent recurrence of the DC LO VOLTS CWP caption and resulting loss of electrical services is consistent with a reduction in voltage of the No 1 essential DC busbar, caused by the failure of the couple between the No 1 and No 2 DC essential busbars. The busbar couple failure was consistent with one of the busbar tie contactors (PH7 or PH2) failing open. The No 1 battery continued to provide DC electrical power to the No 1 essential busbar until it was sufficiently discharged for electrical services to be lost.

The COUPLE push button selector-indicator (PBSI) on the DC electrical control panel is unusual in that it has a two-part 'mimic' line[7], with the left and right halves illuminated by power from auxiliary connections to the PH7 and PH2 busbar tie contactors respectively. Therefore, should one contactor fail open, the busbar couple function will fail yet one half of the COUPLE PBSI mimic line will remain lit. This may have led the crew to believe that the No 1 and No 2 DC essential busbars remained coupled, when they were not.

The TRU1 CWP message extinguished after landing, coincident with the restoration of electrical power to those services that had been lost during the flight. It is possible that the airframe vibration from the landing was sufficient to clear the electrical fault that had caused the No 1 TRU to fail, and also to allow the DC busbars to couple once again, as confirmed by the crew after landing. Inspection of the aircraft's DC electrical system following the event did not reveal any component defects that would have caused the electrical failures experienced during the flight.

The transient No 1 battery overheat CWP caption noticed by ground staff during post-flight fault-finding was caused by the discharged No 1 battery receiving a charging current in excess of 300 A for a sufficient period of time to allow it to reach the 60°C temperature threshold required to trigger the CWP warning.

Footnote

[7] A mimic line is an illuminated segment of the switch denoting a connection between parts of a system that the switch controls when pressed.

Intermittent fault within the FDR system

The PV1584 FDR fitted to SE-MHF had an intermittent fault that caused nine hours of data not to be overwritten and the loss of data during several other flights. Inspection of the FDR found evidence of moisture within the electronics module. This most likely caused the intermittent operation of the magnetic-tape recording function. The moisture may have also prevented the correct operation of the BITE as no fault was noticed during the period of incorrect operation.

Records showed that between 2010 and 2018, 35% of the PV1584 FDRs removed from BAe ATP aircraft contained evidence of moisture within the unit's electronic module. The majority of these units required replacement of damaged connectors, with 22 FDRs confirmed as having failed due to moisture damage.

The majority of FDRs found with moisture ingress were those that had been fitted to BAe ATP aircraft with the LFD. Discussions with engineers, and inspection of SE-MHF, indicate that rainwater can enter the cargo bay area during loading, which may then find its way into the rear equipment bay and the FDR. There was also some evidence that rainwater had dripped onto the FDR. Over time this will increase the probability of moisture entering the FDR and cause it to fail as corrosive products develop. Although tested for resistance to moisture ingress at certification, the PV1584 is not hermetically sealed and therefore moisture and liquids can easily enter the unit. Unlike later generation solid-state recorders, the unit was not required to be tested for its waterproofness or the potential effects of dripping water.

Therefore, to minimise the effects of moisture ingress on the performance of the FDR fitted to the ATP, the following Safety Recommendation is made:

Safety Recommendation 2019-001

It is recommended that the European Union Aviation Safety Agency (EASA) require BAE SYSTEMS to protect the flight data recorder fitted to those ATP aircraft equipped with large freight doors from the effects of rainwater and other liquids.

In response to an ICAO recommendation to discontinue the use of magnetic-tape FDR and CVR technology, EASA required the replacement of all magnetic-tape CVRs with a solid-state CVR by 1 January 2019. However, although EASA acknowledged that magnetic tape is unreliable, obsolete and '*have an insufficient recording quality',* they did not require the replacement of magnetic tape FDRs.

In addition to the operator of SE-MHF, which has indicated that it intends operating their BAe ATP fleet for several more years, there are also a small number of UK-operated aircraft that are equipped with a magnetic-tape FDR. Discussions with UK based MROs indicate that long-term support for this obsolete technology is declining. However, it may still be several years before aircraft operating in Europe with magnetic-tape FDRs are finally retired from service, or a lack of spares require an operator to install an alternative solid-state FDR.

It is important that FDR systems are reliable and ensure high quality data is available to accident investigation authorities. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2019-002

It is recommended that the European Union Aviation Safety Agency (EASA) set an end date to prohibit the use of flight data recorders that use magnetic tape as a recording medium, to ensure compliance with ICAO Annex 6 from that date.

Conclusion

The aircraft experienced two separate, independent failures within the DC electrical power system during a cargo flight from East Midlands Airport to Stansted Airport, resulting in the loss of multiple flight deck instruments, lighting, left engine control and standby flying controls. The crew were able to return to East Midlands Airport where a normal landing was made, following which the DC electrical power was restored. The loss of electrical power experienced during the flight was consistent with a failure of the No 1 TRU or its contactor, followed by a subsequent failure of the DC essential busbar COUPLE function. The cause of both failures, which could not be repeated during subsequent testing, was probably intermittent and transitory so could not determined.

ACCIDENT

Aircraft Type and Registration:	Czech Sport Aircraft Sportcruiser, G-CGEO
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2009 (Serial no: 09SC303)
Date & Time (UTC):	7 October 2018 at 1445 hrs
Location:	Fowlmere Aerodrome, Cambridgeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Right main landing gear leg damaged
Commander's Licence:	Light Aircraft Pilot's Licence
Commander's Age:	75 years
Commander's Flying Experience:	1,048 hours (of which 350 were on type) Last 90 days - 8 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The aircraft's right main landing gear (MLG) leg was damaged following a normal landing at Fowlmere Aerodrome. Investigation of the failed MLG leg revealed a manufacturing defect that caused the progressive delamination of the leg during service. The aircraft manufacturer is currently certifying a strengthened MLG leg design and has incorporated improvements to the manufacturing process of the MLG intended to prevent recurrence.

History of the flight

The pilot, accompanied by one passenger, flew the aircraft on a 20-minute flight from Graveley Airstrip, Hertfordshire, to Fowlmere Aerodrome. The pilot stated that the landing at Fowlmere was smooth and that the taxi to the parking area was uneventful. After vacating the aircraft, the pilot noticed that a large crack was present in the rear face of the right MLG leg (Figure 1). The leg retained sufficient residual strength to support the aircraft when parked.

The calculated landing weight for the landing at Fowlmere was 592 kg, below the MTOM of 600 kg. The pilot stated that no cracks were visible in either MLG leg during the pre-flight inspection of the aircraft. A second member of the aircraft's owner group stated that the aircraft, when parked in a hangar, had been sitting 10 cm right wing low during the month preceding the accident with the tyres correctly inflated.

Figure 1
Damage to right MLG leg

Aircraft information

The Sportcruiser is a low-wing monoplane aircraft powered by a Rotax 912S or 912ULS piston engine. It has two seats and a fixed tricycle landing gear. The aircraft was available in the UK as a kit through the LAA Permit to Fly system and remains available as a factory-built aircraft with an EASA Restricted Certificate of Airworthiness (CofA)[1]. A small number of aircraft were factory-built prior to EASA Type Certification, including G-CGEO; these aircraft operate on an EASA Permit to Fly.

MLG leg structure and manufacturing process

The MLG legs are formed from composite materials, predominantly glass fibre fabric layers, impregnated with epoxy resin and cured in a two-part closed mould. As part of the manufacturing process two inflatable rubber tubes are laid longitudinally in the mould before the mould halves are closed. Each rubber tube is covered with a plastic stretch film layer and then glass fibre fabric layers are wrapped around the tube. When the mould halves are closed the rubber tubes are inflated, creating two oval holes within the landing gear leg section and providing a compressive load on the composite material around the tubes to increase fibre compaction within the finished laminate.

The plastic stretch film layer is made from linear low-density polyethylene (LLDPE) and its purpose is to prevent the rubber tubes from bonding to the landing gear leg laminate while the epoxy resin cures in the mould. The rubber tubes and stretch film are removed from the leg once the epoxy resin has cured.

Footnote

[1] These EASA certified aircraft are named PS-28 Cruiser. The Restricted CofA is due to the engine and propeller being approved as part of the aircraft's EASA Type Certificate in accordance with Part-21 (EU 748/2012) 21.A.23 regulations.

The part number of the failed MLG leg installed on G-CGEO was NK-03A-C[2], serial number 68/16 which was produced in May 2016. This landing gear leg had accumulated 332 flight cycles from new, whilst installed on G-CGEO.

Previous MLG events on Sportcruiser/PS-28 aircraft

The aircraft manufacturer provided a list of previous MLG damage to Sportcruiser/PS-28 aircraft (Table 1).

Date of occurrence	Aircraft type	Hours/ Cycles	Details
31/7/2015	PS-28 Cruiser s/n C0479	930/ 3,455	Small crack observed in right MLG. Damage attributed to rough field operation.
19/9/2016	PS-28 Cruiser s/n C0521	1,352/ 2,018	Cracks observed in lower rear side of left MLG. Damage attributed to exceeding torque of wheel attachment bolts.
18/11/2016	PS-28 Cruiser s/n C0507	1,592/ 3,107	Longitudinal cracking of both left and right MLG.
17/10/2017	PS-28 Cruiser s/n C0590	193/ cycles not known	Longitudinal delamination of left MLG at rear face. Aircraft frequently operated from grass runways. Both MLG legs cut open by the manufacturer, no foreign objects identified. Failure considered to be due to overload.
19/10/2017	PS-28 Cruiser s/n C0589	156/ cycles not known	Longitudinal delamination of left MLG. Aircraft frequently operated from grass runways.

Table 1

Previous MLG leg damage to Sportcruiser/PS-28 aircraft

The aircraft manufacturer stated that a possible contributory factor to cases of MLG delamination could be operation of the aircraft beyond its approved maximum takeoff and landing weight limits.

Footnote

[2] Part number NK-03A-C is directly equivalent to p/n SG0030L/P as used on other Sportcruiser and PS-28 Cruiser aircraft.

Aircraft examination

The damaged right MLG leg was examined by the AAIB to determine the cause of the failure. The visible crack in the rear face of the leg was 239 mm long. The leg was cut into three sections (Figure 2).

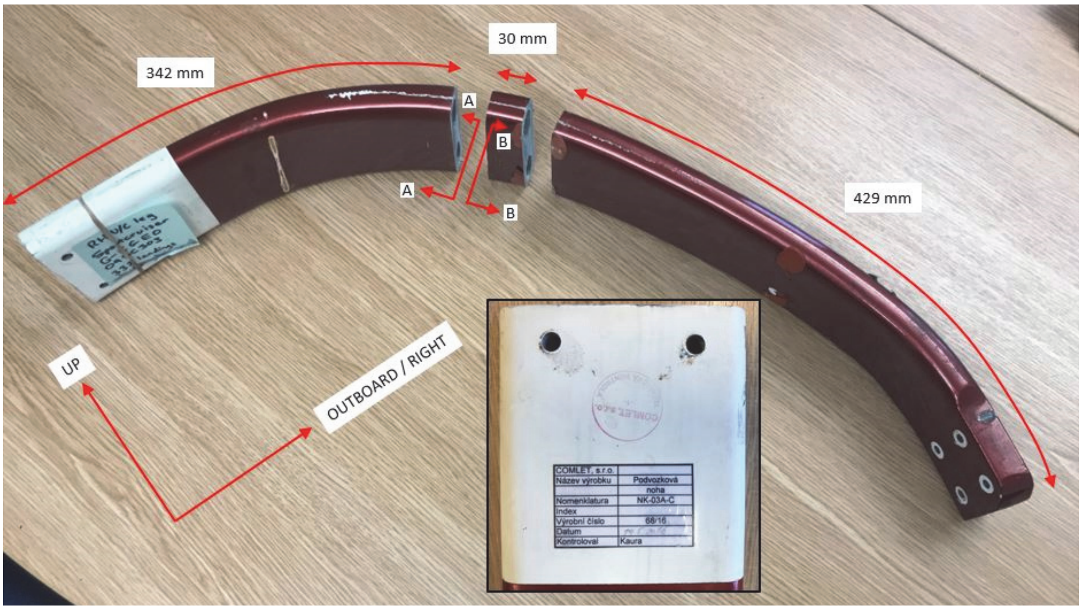


Figure 2

Sectioning of right MLG leg (leg dataplate image inset)

When the leg was cut open, plastic film was visible within the rear hole (Figure 3). Approximately 6 mm of the plastic film was trapped within the laminate between the rear and forward holes at section A-A.

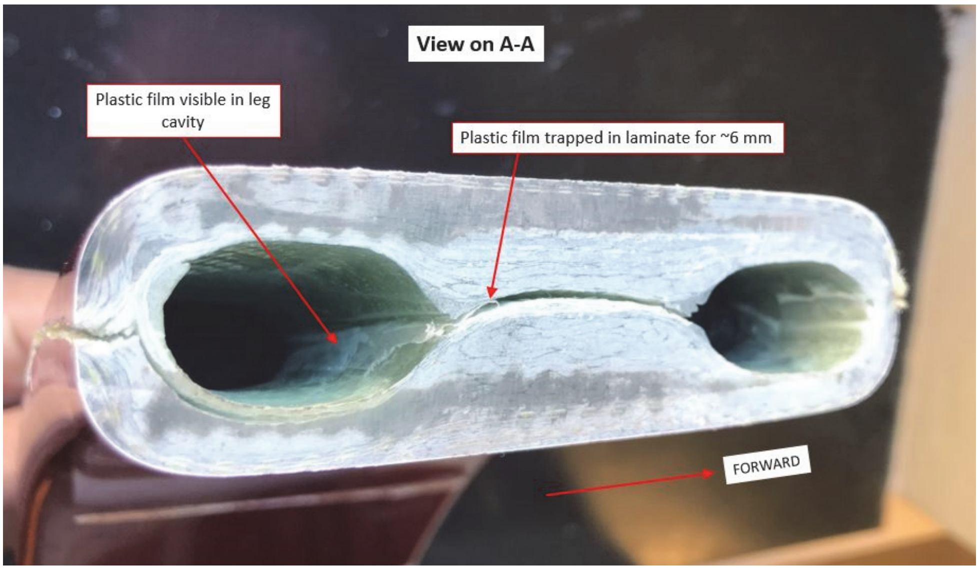


Figure 3

View on section A-A

The leg's composite structure had delaminated between the forward and rear holes (Figure 4). Additional delaminations were observed around the rear half of the rear hole, and between the rear hole and the aft face of the leg section. A small area of fibre pinching was also present at the rear of the leg section.

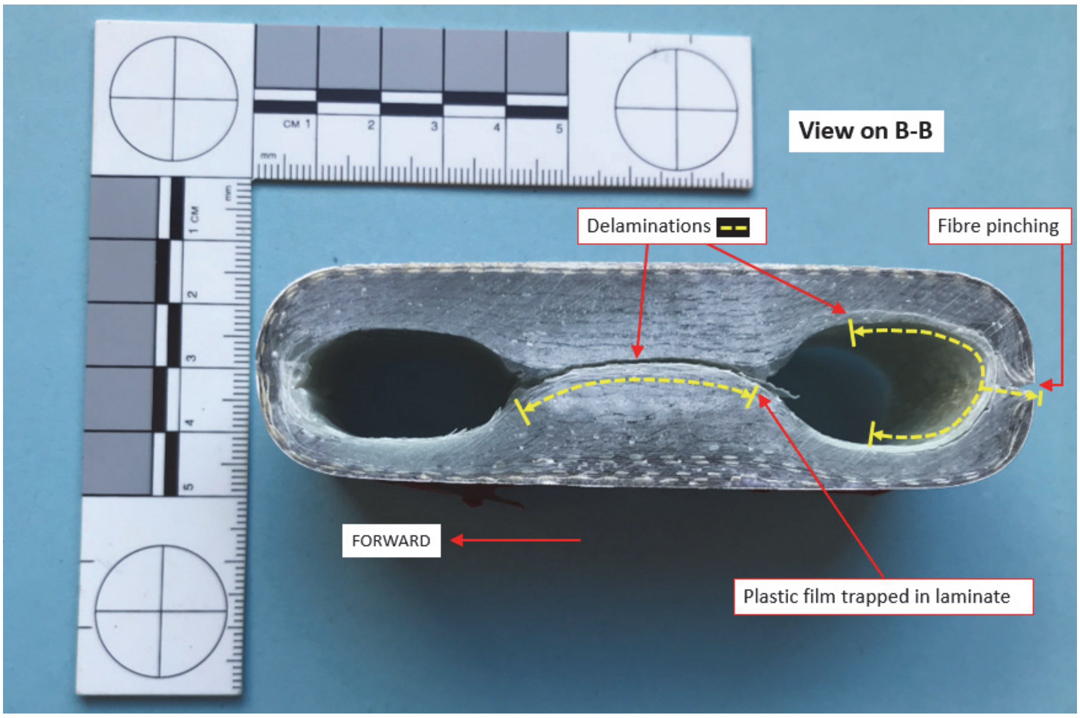


Figure 4

View on section B-B

A sample of the plastic film, measuring approximately 29 mm long by 8 mm wide, was recovered from the leg for laboratory analysis (Figure 5). Additional internal inspection of the leg revealed that the trapped plastic film was present within the rear leg hole over a length of approximately 260 mm, aligned with the external crack in the leg's aft face.

Tests and research

The plastic film sample recovered from the leg, shown in Figures 4 and 5, was analysed using FTIR[3] spectroscopy along with a sample of the stretch film used in the production process of the leg, supplied by the aircraft manufacturer. This analysis showed that the sample was the same material as that used in production of the leg.

Footnote

[3] Fourier Transform Infra-Red (FTIR) spectroscopy involves illuminating a sample with infrared radiation and measuring the spectrum of absorbed radiation in order to characterise the molecular composition of the sample.

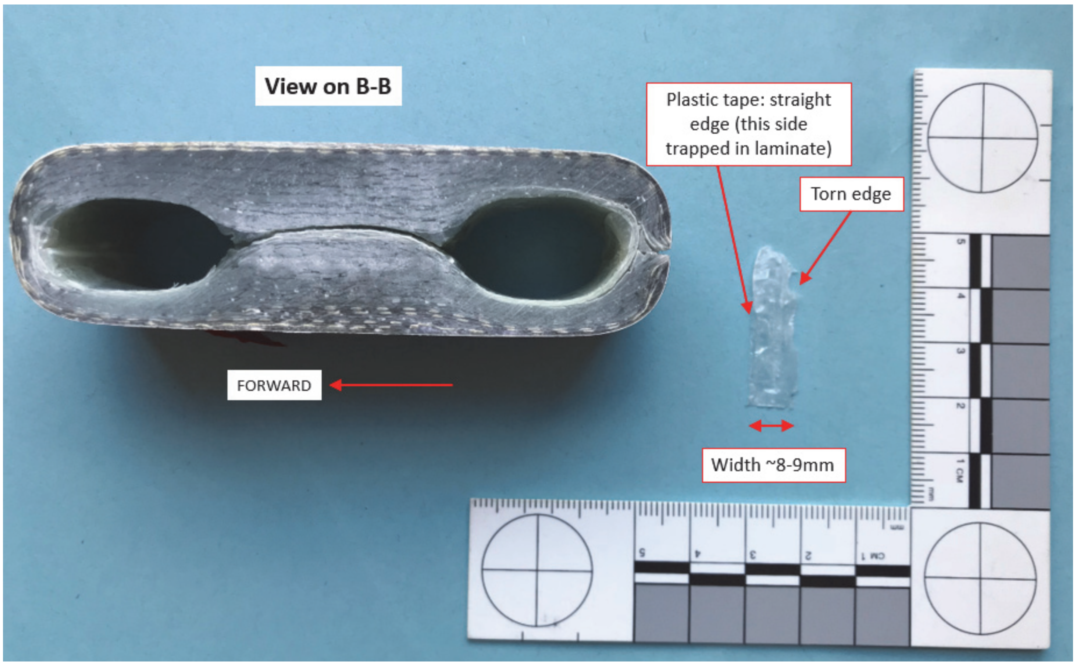


Figure 5

Plastic film sample recovered at section B-B

Analysis

The trapped stretch film within the right MLG laminate created a crack initiation site from which a crack initially propagated forwards, through the central portion of the leg's composite structure. This delamination reduced the stiffness of the leg, commensurate with the observation by the aircraft's owners that the aircraft was sitting 10 cm right wing low in the month preceding the accident flight. A small area of fibre pinching at the rear of the leg section created an additional weak point which eventually failed during the landing at Fowlmere Aerodrome.

The stretch film material was used during the manufacturing process of the leg and it did not form part of the leg's intended structural design. Pressure loads applied to the rear inflatable tube during the lamination process pushed the stretch film into the forward corner void of the rear section hole and the film became permanently trapped once the epoxy resin had cured. The torn edge of the rear length of the trapped stretch film material was created when the bulk of the stretch film was pulled from the rear section hole after the epoxy resin had cured, leaving the trapped portion behind.

Analysis of previously reported PS-28 Cruiser MLG failures showed that at least three of the events exhibited similar longitudinal cracking to that observed on G-CGEO. Investigation by the aircraft manufacturer of the MLG legs from PS-28 Cruiser s/n C0590 concluded that the failure was due to overload and that no foreign objects, including stretch release film, were present within the legs. The damaged MLG legs from s/n C0507 and C0589 were not sectioned to determine the root cause of these failures.

Conclusion

The aircraft's right MLG leg was found to be damaged following a normal landing at Fowlmere Aerodrome. Investigation of the failed MLG leg revealed a small quantity of LLDPE stretch film material within the leg's composite laminate structure that had been unintentionally trapped during the manufacturing process. The trapped stretch film formed a crack initiation site from which a crack initially propagated forward, through the central portion of the leg's composite structure, before the leg eventually cracked externally at the rear face of the leg section.

Safety action

The aircraft manufacturer is currently certifying a reinforced MLG leg, part number SG0160L/P, intended to increase the durability of the legs in service. This new MLG will be available for retrofit to all models of Sportcruiser and PS-28 Cruiser aircraft. In addition to slightly enlarging the MLG leg cross-section, the inflatable tubes and stretch film material used during leg manufacture are now surrounded by a woven glass fibre 'sock', to prevent radial migration of the stretch film into the leg's composite structure.

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:	Agusta AW139, G-MCSD
No & Type of Engines:	2 Pratt & Whitney Canada PT6C-67C turboshaft engines
Year of Manufacture:	2014 (Serial no: 41375)
Date & Time (UTC):	6 May 2018 at 1634 hrs (UTC)
Location:	Offshore from Aberdeen
Type of Flight:	Commercial Air Transport (Non-Revenue)
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Tail rotor blades damaged and tail rotor gearbox required replacement
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	8,000 hours (of which 854 were on type) Last 90 days - 48 hours Last 28 days - 23 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional information from the helicopter manufacturer

Synopsis

As the helicopter climbed after departure, the crew noticed an unusual vibration. They returned to Aberdeen and it was found that a cable fairing and lightning protection bonding strip was missing from one of the tail rotor blades.

Investigation by the helicopter manufacturer established that the bonding strip had failed due to fatigue and loss of the fairing was a secondary effect.

The manufacturer concluded that the occurrence was not safety related and EASA classified the event as 'Not-Unsafe'. The requirement for a Detailed Visual Inspection of the bonding strip will be added to extant maintenance tasks and the manufacturer is reviewing the manufacturing process.

History of the flight

During the climb out of Aberdeen Airport, at approximately 2,500 feet and 135 kt, the crew felt an unusual vibration which remained after levelling off at 3,000 ft and reducing speed. With all other indications showing normal, the crew decided to return to Aberdeen and transmitted a PAN call. The vibration decreased as the speed was reduced through

60 kt for a run-on landing, but then increased markedly once the helicopter was on the ground.

Examination of the helicopter

Visual examination of the helicopter found that a bonding strip and cable fairing had detached from one of the tail rotor blades (Figure 1). The missing parts were not recovered.

Examination of the other three tail rotor blades found that two more bonding strips were cracked.

Figure 1

Tail rotor blade fairing and lightning protection bonding strip installation
(left image shows an undamaged blade;
right image shows the damaged blade on G-MCSD)

Analysis of the HUMS data showed no exceedances, but one of the tail rotor gearbox acceleration parameters had recorded unusually high values during the incident flight. Metallic debris was found on the tail rotor gearbox magnetic chip detector, but this was insufficient to generate a TGB CHIP caution in the cockpit.

The tail rotor blades and the tail rotor gearbox were returned to the manufacturer for detailed examination.

Tail rotor blades

The cable fairing and part of the lightning protection bonding strip were missing from one tail rotor blade. Examination of the other three blades confirmed that two of the bonding strips were cracked.

Microscopic examination established that all three bonding strips had cracked because of fatigue. The fatigue originated in the same location on all three items (Figure 2).

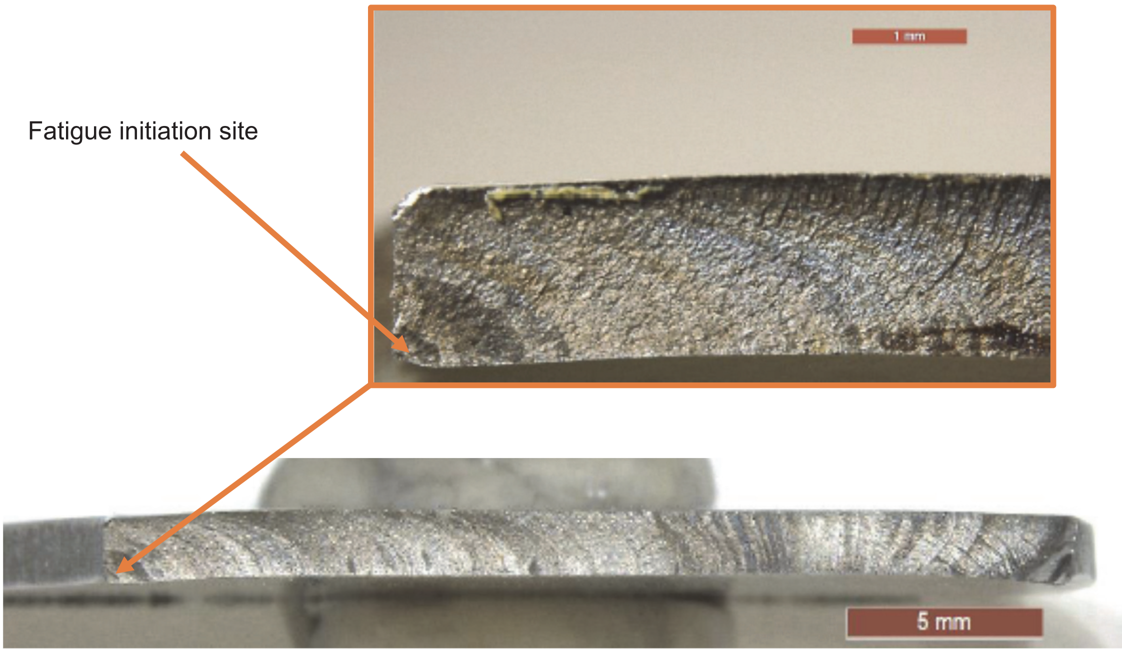


Figure 2

Fracture surface (fatigue originated from the lower left corner)

The manufacturer concluded that the loss of the root fairing was secondary to, and a direct consequence of the loss of the broken bonding strip.

Tail rotor gearbox

As part of the investigation, the gearbox underwent a 30-minute HUMS test prior to disassembly. No anomalies were reported, and no metallic debris was found on the magnetic chip detector after the test. The findings indicated that the increased acceleration recorded during the incident flight was probably induced by the loss of the rotor blade components.

Disassembly of the gearbox revealed early evidence of spalling on the output bearing, but the debris in the gearbox was insufficient to activate the TGB CHIP caution in the cockpit. Repair and overhaul records indicate that spalling has occasionally been observed, but the manufacturer does not consider it to be common. The spalling was not associated with the loss of the tail rotor blade bonding strip and fairing.

Previous occurrence

The manufacturer was aware of one previous similar event, which occurred in June 2017.

Conclusion

Investigation established that the bonding strips had cracked due to fatigue and loss of the root fairing was secondary to the loss of the bonding strip.

The helicopter manufacturer concluded that the occurrence was not safety related and EASA classified the event as ‘Not-Unsafe’. However, a requirement for a Detailed Visual

Inspection of the bonding strip will be added to Maintenance Task 64-01, to be performed every 300 flying hours/1 year. The manufacturer is also reviewing the bonding strip manufacturing process.

ACCIDENT

Aircraft Type and Registration:	Beech 58 Baron, G-BYDY
No & Type of Engines:	2 Continental Motors Corp IO-550-C piston engines
Year of Manufacture:	1998 (Serial no: TH-1852)
Date & Time (UTC):	8 September 2018 at 1130 hrs
Location:	Haydock Park Airfield, Newton-Le-Willows
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 4
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to left flap and left side of fuselage
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	4,950 hours (of which 2,500 were on type) Last 90 days - 80 hours Last 28 days - 25 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Due to a wet grass runway, the pilot was unable to stop the aircraft after landing and deliberately 'ground-looped' the aircraft to prevent overrunning. During this manoeuvre the aircraft collided with a parked aircraft. The damage sustained by the landing aircraft was minor, however the parked aircraft was extensively damaged. No persons were injured.

History of the flight

Prior to departure from Thruxton aerodrome, the pilot spoke to the Clerk of the Course at Haydock Park race course (Newton-Le-Willows Airfield) to understand the condition of the runway. The Clerk stated that the Head Groundsman had walked the course several times that morning and, in his opinion, the ground was wet but "firm enough for aircraft to land". A Piper PA-32 Saratoga and an AS355 Écureuil 2 Helicopter had both landed that day with no incident and were parked as instructed, at the far western end of the airfield.

On arriving at Haydock Park, the pilot overflew the airfield to confirm visually the wind conditions from the windsock. He noted that it was raining but felt confident there was sufficient runway, providing the touchdown was at the threshold.

The wind was 230° at 8 kt as the aircraft touched down on the threshold of the westerly runway (290°). The pilot allowed the aircraft to roll initially and then gently applied the brakes, but the wet conditions resulted in the aircraft maintaining speed over the last third of the runway. The pilot realised there was insufficient runway remaining to come to a stop and decided to deliberately 'ground-loop' the aircraft, as a go-around was not possible at this stage of the landing roll. The intended manoeuvre was to steer the aircraft to the left and then apply left engine power and right rudder to swing the aircraft. Right engine power would then be applied to straighten the aircraft and finally braking to bring the aircraft to a stop. But whilst steering to the left, the aft fuselage and left flap contacted the right wing of the parked PA-32 Saratoga. The aircraft continued with the manoeuvre and came to rest as intended. All the passengers and the pilot exited the aircraft unaided and without injury. There were no occupants in the parked aircraft.

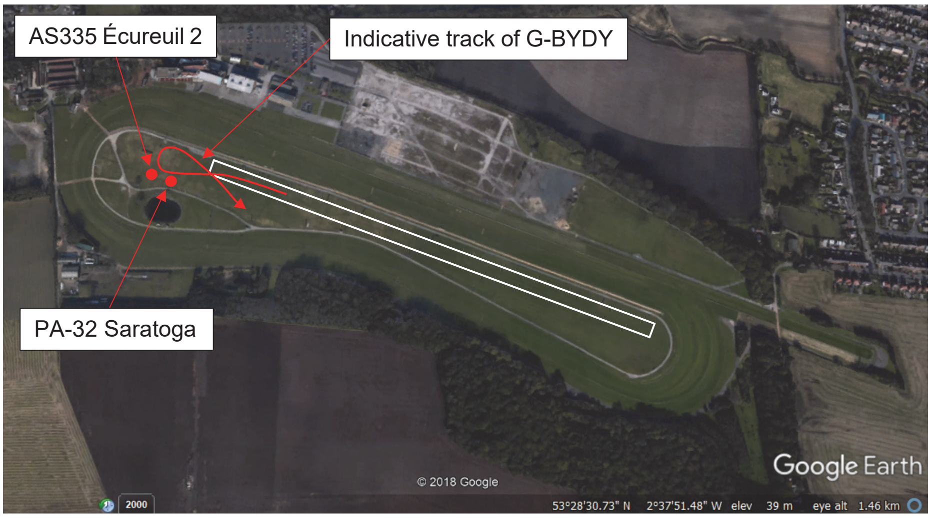


Figure 1
Haydock Park – Indicative track of ground loop

Aircraft examination

The damage to the Beech Baron was limited to the aft fuselage skin panel and several fuselage frames. The outer end of the flap on the left wing was also damaged but could still be retracted (Figure 2).

Figure 2
Damage to the Beech Baron – Fuselage and flap

The PA-32 Saratoga was extensively damaged with evidence of impact on the right wingtip and aileron. As a result of the impact, the airframe was significantly distorted (Figure 3).

Figure 3
Damage to the PA-32 Saratoga

Analysis

The pilot was aware that the runway length was just enough in the wet conditions, as he stated the touchdown needed to be firm and at the threshold. He considered that he executed the touchdown as planned but the wet conditions affected the braking over the last third of the runway. The pilot recognised that there was insufficient runway remaining to come to a stop and that he had passed the point where a go-around could be successfully commenced. He therefore decided to come to halt by deliberately ground-looping the aircraft. The pilot performed the manoeuvre as intended except the initial move was too wide and the aircraft collided with a parked aircraft. Both the parked aircraft and helicopter were clear of the runway and would not have impeded a normal landing. The pilot later commented that, in his opinion, "it is inadvisable to park aircraft in an area where overshooting the runway is a possibility. Any obstructions in this area should be minimised to reduce the possibility of damage and injury to personnel".

The CAA have published document CAP 793: '*Safe Operating Practices at Unlicensed Aerodromes*' which includes recommended safety factors to be applied when calculating landing distances on wet grass runways.

Conclusion

The pilot attempted an abnormal manoeuvre to stop the aircraft after it became apparent that braking performance had been affected by the wet condition of the runway. The manoeuvre would have been successful had contact not been made with a parked aircraft. No persons on the landing aircraft were injured and the parked aircraft was unoccupied.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 747-443, G-VROY
No & Type of Engines:	4 General Electric CF6-80C2B1F turbofan engines
Year of Manufacture:	2001 (Serial no: 32340)
Date & Time (UTC):	20 November 2018 at 1850 hrs
Location:	London Gatwick Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 18 Passengers - 398
Injuries:	Crew - None Passengers - None
Nature of Damage:	Heat damage to flap track fairing, various access panels and inboard flaps
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	13,238 hours (of which 7,255 were on type) Last 90 days - 156 hours Last 28 days - 53 hours
Information Source:	Aircraft Accident Report Forms submitted by the flight crew

Synopsis

During engine start there was a fire in the No 2 engine tailpipe. The ground crew alerted the flight crew who extinguished the fire using the relevant checklist. The aircraft returned to the stand and all the passengers were disembarked. Despite examination and testing of various engine control units and valves by their manufacturers, no faults could be found and all the equipment operated within normal parameters.

History of the flight

G-VROY had recently undergone heavy maintenance overseas and its first revenue flight was London Gatwick (LGW) to Orlando (MCO). The aircraft was pushed back from the North Terminal, Stand 566 and the engines were started. All flight deck indications were normal until part way through the start sequence for engine No 2, when the groundcrew engineer alerted the crew to flames coming from the engine tailpipe. The fuel control switch was selected to CUT OFF, the QRH (quick-reference handbook) drill FIRE ENGINE TAILPIPE was completed and no temperature exceedances were reported. The airfield fire crews arrived on site shortly after the fire had been extinguished. The remaining engines were shut down and the aircraft was towed back onto the stand for the passengers to disembark.

Aircraft examination

There was evidence of heat damage on the adjacent flap track fairing, several access panels and the inboard flaps. Structural inspections were performed, with no significant findings. Cosmetic repairs and replacements were completed as required.

The quick-access recorder (QAR) data was analysed and prior to engine No 2 compressor rotation there was a large fuel demand (119% compared to 11% for the other engines) through the fuel metering valve (FMV). The hydro-mechanical unit (HMU) was removed from the aircraft and sent to the manufacturer for analysis. The unit was found to perform within expected limits. Various other valves and controllers were removed and returned to their manufacturers for analysis, also with no faults found. All work undertaken during the preceding heavy maintenance period was checked and no faults were found.

Discussion

Despite the strip, examination and testing of various valves and controllers for the incident engine, no faults could be found to explain the increased fuel flow recorded in the QAR data. The high fuel flow rate into the combustion chamber during engine start would almost certainly lead to an engine tailpipe fire. The ground crew quickly identified that the fire was in the tailpipe and alerted the aircrew who actioned the correct checklist. A fuel tank biocidal treatment had been carried out during the heavy maintenance period and although the additive treatments have been verified correct, it is suspected by the operator that some residual debris may have remained. This residue may have affected the operation of the HMU valves.

ACCIDENT

Aircraft Type and Registration:	Aero AT-3 R100, G-SACW
No & Type of Engines:	1 Rotax 912-S2 piston engine
Year of Manufacture:	2010 (Serial no: AT3-058)
Date & Time (UTC):	17 February 2019 at 1250 hrs
Location:	Sherburn-in-Elmet Aerodrome, North Yorkshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nosewheel, nose landing gear, propeller, fuselage skin below engine damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	17,566 hours (of which 25 were on type) Last 90 days - 109 hours Last 28 days - 44 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

During the takeoff roll on grass Runway 19, the aircraft went over a "hump" in the runway at an airspeed of about 40 kt and became airborne. The pilot reported that, as the aircraft was "below flying speed", he reduced the pitch attitude slightly, but the aircraft's nose continued to drop and, upon contact with the runway, the nosewheel detached. The aircraft came to a stop shortly after (Figure 1) and the pilot shut down the engine. Both occupants were uninjured.

Figure 1

G-SACW nosewheel detached

ACCIDENT

Aircraft Type and Registration:	Aerospatiale SA341G Gazelle, YU-HMC
No & Type of Engines:	1 Turbomeca (Safran) Astazou 3A turboshaft engine
Year of Manufacture:	1974
Date & Time (UTC):	14 July 2018 at 1540 hrs
Location:	Private landing field, Enfield, Greater London
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Helicopter destroyed by fire
Commander's Licence:	Private Pilot's Licence (Helicopters)
Commander's Age:	65 years
Commander's Flying Experience:	266 hours (of which 266 were on type) Last 90 days - 17 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

While trying to reposition his helicopter from one part of his garden to another, the pilot perceived that the engine had lost power. He tried to return to the takeoff site but the helicopter came down about 20 metres short and rolled onto its side. The helicopter was destroyed by a post-crash fire. The cause of the reported loss of power could not be determined.

History of the flight

The helicopter was parked at the bottom of the pilot's garden while some building works were being carried out. The pilot intended to take off and position the helicopter nearer his house so he could clean and polish it, and then depart to Elstree for fuel. The takeoff weight with the pilot and 325 kg of fuel onboard was 1,524 kg (MTOW 1,800 kg). The wind was calm and the air temperature was 30°C.

After carrying out his usual daily inspection and pre-flight checks the pilot lifted off into a 5 to 10 ft hover. All checks were normal. He then moved forward and initiated a right turn. During the right turn he perceived that the engine had lost power. He tried to return to the takeoff site but came down about 20 metres short. The ground there was uneven with some large wooden pallets and other building materials. The pilot thought the helicopter probably struck one of the pallets and then rolled onto its side, with the rotor blades striking the ground.

The pilot instinctively climbed out and moved rapidly away from the helicopter. He had omitted to operate the emergency fuel shutoff lever and he could hear the engine running, at low power, as he left the helicopter. He could see steam or smoke so he fetched a fire extinguisher. When he returned the helicopter was on fire with large amounts of smoke.

The fire service had been notified of the fire by a passer-by and arrived on scene 8 minutes after the call, at 1551 hrs. The fire service applied water around the fire to stop it spreading. It then took them about 5 to 6 minutes to set up a new foam machine before they started applying foam to the fire, by which time most of the helicopter had already burnt out.

The pilot stated that the incident happened very quickly and he did not recall seeing or hearing any cockpit warnings.

Accident site and aircraft examination

After the fire had subsided, there was very little remaining of the helicopter (Figure 1). The maintenance organisation recovered the helicopter wreckage to their facility and conducted an investigation but were unable to establish a cause of a loss of power. There was no evidence that the engine had suffered an uncontained failure and the turbine was intact and could be rotated through about 30°, but no further due to impact damage to the combustion chamber. There was very little remaining of the fuel system that could be examined. The engineer at the maintenance organisation thought that the fuel tank had probably been punctured by a pallet or metallic materials on the ground where the helicopter came down, resulting in the post-crash fire.

Figure 1

Remains of YU-HMC at the accident site
(image used with permission)

Engine examination

The engine had accumulated 4,914 hours since new and 1,424 hours and 2,279 cycles since last overhaul (maximum time between overhauls is 1,750 hours and 5,600 cycles).

The engine manufacturer examined the remains of the engine and performed a borescope examination. Their findings included the following:

- The engine air intake was found to be dirty with aggregated soot deposits.
- The axial and centrifugal compressors did not have any mechanical damage, with no evidence of foreign object impacts.
- Some soft material with the appearance of fibreglass cloth was found in the air path between the axial and centrifugal compressors, indicating continued engine rotation after impact.
- There was small unknown debris like sand or dust at the centrifugal compressor's trailing edge.
- The stator vanes between the axial and centrifugal compressors were coated in black deposits which the engine manufacturer considered may have existed prior to the post-crash fire.
- The diffuser outlet between the axial and centrifugal compressors was coated in deposits that appeared like thin soil, sand powder or dust, which the engine manufacturer considered may have existed prior to the post-crash fire.
- There was some dust in the combustion chamber inlet but no anomalies inside the combustion chamber.
- The 1st stage turbine wheel had damaged blade tips which were consistent with a T4[1] overtemperature condition at some point.
- The blade tips of the 3rd stage turbine were discoloured due to heat which was also consistent with a T4 overtemperature condition at some point.

The engine manufacturer stated that thin soil or sand powder deposits in the engine are commonly encountered during engine usage which is why routine chemical washing of the compressor is required. If these deposits build sufficiently it will result in a lower compression rate of the air entering the combustion chamber and therefore less power with the same fuel flow. The fuel control unit will attempt to maintain a constant engine speed so it will increase fuel flow, which will result in a higher temperature. This can lead to a T4 overtemperature and consequential turbine blade tip damage. The system does not have an automatic T4 limiting system and is reliant on the pilot noticing the T4 exceedance and reducing power.

Footnote

[1] The T4 temperature is the temperature measured at the 3rd stage turbine exhaust. It is a temperature indicated to the pilot and has an exceedance limit.

The engine manufacturer stated that the 'dirty airpath' could have led to a T4 exceedance in-flight at some point, resulting in 1st stage turbine blade damage and consequential loss of power. However, because the engine was still running after impact, it was also possible that the T4 exceedance and turbine damage were the result of the heat from the post-crash fire.

Maintenance involving compressor wash

The maintenance organisation stated that compressor chemical washes and water rinses were carried out on YU-HMC every 30 flying hours or 6 months, whichever came first, in accordance with the helicopter manufacturer's maintenance requirements. The last compressor wash was carried out on 27 February 2018 during the helicopter's last annual inspection and it had accumulated about 30 hours since then. The helicopter had been booked in for its 30-hour maintenance inspection on 16 July 2018, two days after the accident.

The maintenance engineer, who had 34 years' experience maintaining Gazelles, stated that he thought the deposits found in the engine were the result of post-impact ingestion.

The pilot stated that he had not flown YU-HMC anywhere dusty but that there was soil at the accident site.

Analysis

Although it was a hot day with calm wind, the helicopter was 276 kg below its maximum takeoff weight so it should have had sufficient performance for the taxiing manoeuvre the pilot undertook. It is possible that the airpath to the centrifugal compressor had accumulated deposits during operation which led to a lower compression rate and a higher temperature operation. This, combined with the hot outside air temperature, could have led to a T4 exceedance, turbine damage and a consequential loss of power, leading to the accident. However, it is also possible that the T4 exceedance occurred during the post-impact fire and that some deposits were ingested while the engine continued to run on the ground, with the helicopter on its side.

ACCIDENT

Aircraft Type and Registration:	Cessna 152, G-CLAP	
No & Type of Engines:	1 Lycoming O-235-L2C piston engine	
Year of Manufacture:	1978 (Serial no: 15281555)	
Date & Time (UTC):	18 November 2018 at 1510 hrs	
Location:	North Weald Airfield, Essex	
Type of Flight:	Private	
Injuries:	Crew - 1	Passengers - None
	Crew - None	Passengers - N/A
Nature of Damage:	Minor damage to the wing tip of G-CLAP (taxiing), damage to rudder of G-PLAR (static)	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	38 years	
Commander's Flying Experience:	157 hours (of which 157 were on type) Last 90 days - 12 hours Last 28 days - 2 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

During taxiing after a flight from Elstree, the right wing of G-CLAP collided with the rudder of G-PLAR, a parked RV-9.

History of the flight

The pilot of G-CLAP had landed at North Weald after a flight from Elstree and was taxiing along a stretch of Taxiway A past 'The Squadron' building, looking for a place to park. The pilot states that he had, incorrectly, thought that this was the stretch to find a parking space as North Weald Radio had advised him to park near other Cessnas and he had seen aircraft that seemed to be in the process of parking in this stretch.

As the pilot taxied close to G-PLAR, an RV-9 which was parked with its tail towards the taxiway, he saw two people in front of it. The pilot of G-CLAP did not know whether G-PLAR was fully in the parking slot and did not realise how close the right wing of his Cessna was to the tail of G-PLAR. The pilot saw one man signal but misinterpreted this as an indication to go forward and, as he taxied closer to G-PLAR, the man quickly changed his signal to indicate to stop. However, it was too late and the wing of G-CLAP hit the rudder of G-PLAR. The pilot stopped the engine of G-CLAP and got out.

Comment

The pilot of G-CLAP commented that, in hindsight, he should have consciously taxied away from the centre of the taxiway to give a wide berth to the parked aircraft, as there were only aircraft parked to one side.

ACCIDENT

Aircraft Type and Registration:	Cessna U206C Super Skywagon, G-BPGE
No & Type of Engines:	1 Continental Motors Corp IO-520-F piston engine
Year of Manufacture:	1968 (Serial no: U206-1013)
Date & Time (UTC):	24 November 2018 at 1415 hrs
Location:	Strathallan Aerodrome, Auchterarder, Tayside
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 4
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to cowling, propeller and horizontal stabliser
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	8,210 hours (of which 349 were on type) Last 90 days - 196 hours Last 28 days - 61 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The aircraft touched down long and then struck a fence during a go-around. Despite some damage to the aircraft the pilot was able to land safely on the second attempt.

History of the flight

The pilot was transporting four skydivers in a Cessna U206C for a jump from Strathallan airfield. He had conducted about 1,000 landings at this airfield in this aircraft type. The grass runway was 620 m long with a fence at either end, and a road passing near the Runway 10 threshold. Due to cloud cover the skydive jump was cancelled, and the pilot was returning to land on Runway 10 with the skydivers onboard. The wind was calm.

The pilot reported that, on reflection, his approach to Runway 10 was too high and too fast. He touched down just over halfway down the runway and hit hard, causing the aircraft to bounce. The pilot initiated a go-around but the aircraft struck a frangible wooden fence at the end of the runway causing some damage to the cowling, propeller and horizontal stabiliser. Despite this the aircraft climbed away and the pilot was able to land on the second attempt.

Pilot comments

The pilot commented that he had got in the habit of consistently approaching high to Runway 10 because there were often people walking along the road near the threshold. He considered that he had probably been consistently landing a "bit too deep" each time on this runway. On this occasion he was heavier than normal with four skydivers onboard, the wind was calm, and he probably touched down further along the runway than normal. He had not appreciated how far along the runway he had touched down until he saw the ground marks afterwards. He realised with hindsight that he should have initiated a go-around sooner.

ACCIDENT

Aircraft Type and Registration:	CZAW Sportcruiser, G-CGJS
No & Type of Engines:	1 Jabiru 3300A piston engine
Year of Manufacture:	2011 (Serial no: LAA 338-14962)
Date & Time (UTC):	18 August 2018 at 1314 hrs
Location:	Near Clacton-on-Sea, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Landing gear, engine cowling and minor damage to firewall
Commander's Licence:	Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	715 hours (of which 550 were on type) Last 90 days - 27 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft suffered an engine failure while climbing through 1,400 ft after takeoff, and a forced landing was carried out into a ploughed field. The aircraft was damaged but the occupants were not injured. The flywheel had detached due to failure of its attachment bolts which were found to have broken; fatigue was evident on at least one bolt. There was a discrepancy in the time intervals for replacement of the bolts in the engine manufacturer's documentation.

History of the flight

The pilot/owner had built the aircraft and it was first registered in 2010. He was carrying out a training flight with a class rating instructor to revalidate his licence. The weather conditions in south-east England were fine with a westerly wind of around 15 kt.

The flight started from Maypole Airfield, north-east Kent, where a few circuits were flown. It then continued to Clacton Airfield, where Runway 18 was in use, so that a crosswind landing and takeoff could be practised. The aircraft landed uneventfully at Clacton and was parked on the grass for a short while.

The aircraft took off from Runway 18 at 1310 hrs. The pilot reported leaving the circuit to the west and changed frequency to Southend Radar. While he was making his initial call to Southend Radar there was a “loud clank” from the engine and power was lost. The instructor took over the radio communications while the pilot continued to fly the aircraft.

A restart attempt was unsuccessful and the pilot, recognising that he could not return to Clacton, picked a series of three fields he thought would be suitable for landing. He decided to aim for the third field as it appeared to have the best surface and to be clear of a crop, but as he got nearer he realised the field contained a crop of potatoes and the surface was deeply furrowed.

While the pilot focussed on flying, the instructor communicated with Southend Radar and advised they would be landing in a field. Southend Radar confirmed they had radar contact. The instructor monitored the pilot, reminding him of the wind and pointing out a field. However, it became apparent the pilot had selected a different field. The instructor pointed out that the chosen field was rough and suggested another, but the pilot was fully engaged with carrying out the landing and so, as he judged the landing would be safely made, the instructor decided not to interfere further.

The landing was completed into wind with full flap, and the pilot estimated the touchdown was at around 30 kt (20 kt groundspeed). On touchdown the aircraft decelerated rapidly, and the nose wheel snapped off as the aircraft slid to a halt. Both occupants were wearing full four-point harnesses and neither was injured. The pilot secured the aircraft before both occupants exited in the normal way through the hinged canopy. They walked a safe distance away and telephoned Southend ATC to advise they had landed safely.

In the meantime Southend Radar had contacted a nearby aircraft and advised its pilot of the situation. He flew over to assist and reported that he could see the aircraft in a field, together with vehicles and people.

Engine examination

A post-accident examination of the engine found that the flywheel had detached due to fatigue failure of at least one of its mounting bolts (Figure 1). Jabiru 2200 engines, which have the same flywheel mounting arrangement, have experienced similar failures.

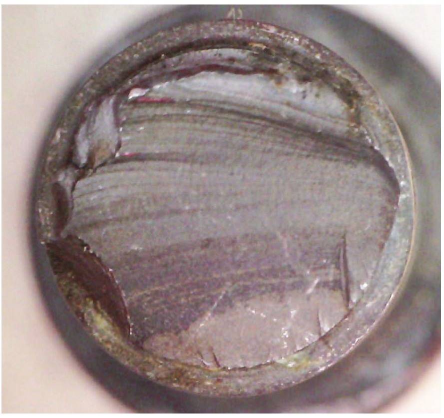


Figure 1

Fatigue striations on flywheel attachment bolt

Aircraft information

The aircraft was home-built from a kit by the owner and first flown in 2011. At the time of the accident it had flown 447 hours. The aircraft was fitted with a Jabiru 3300A engine and a Sensenich, ground adjustable, carbon fibre, two-bladed, 64-inch diameter propeller. The engine manufacturer advised that this propeller was not an 'approved propeller' for the engine, although this aircraft / engine / propeller combination was approved by the Light Aircraft Association (LAA). Therefore, special engine maintenance procedures were specified by the engine manufacturer, which required replacement of the flywheel bolts at 100 hourly intervals. These procedures were provided in '*The Maintenance Manual for Jabiru 2200 aircraft engine Jabiru 3300 aircraft engine Document no. JEM0002-7 Dated: 30th June 2016'.* The engine manufacturer advised this 100-hour requirement was introduced in October 2014.

'Service Bulletin JSB 014-2: Propeller Installation Maintenance', dated 9 June 2011 and available on the engine manufacturer's website at the time of the accident, provided in Section 6, '*Special Maintenance Schedule for Non-Approved Propellers*', a table of maintenance requirements which included the replacement of flywheel bolts every 500 hours.

'Service Bulletin JSB 012-4: Jabiru Engine Flywheel Attachment', dated 21 December 2017 and also available on the manufacturer's website at the time of the accident, introduced 10 possible causes that could lead to flywheel retaining screw failure. It states in section 3:

> *'…the following bulletin acts in concert with JSB 014 – failure to follow the recommendations of either bulletin will result in an incomplete approach which does not deliver the improvements to operating safety intended.'*

Section 4.1 states:

> *'Jabiru Service Bulletin JSB 014 provides information and recommendations for installing and maintaining all propeller types'*

and:

> *'Jabiru Aircraft consider compliance with JSB 014 mandatory for all aircraft being used for air work (such as training, hire and glider towing).'*

The owner stated he had been following the information contained in Service Bulletins and had checked the torque of the flywheel attachment bolts at every 100-hour inspection. He intended to replace the bolts at 500 hours as specified by Service Bulletin JSB 014-2, current at the time of the accident.

The engine Maintenance Manual notes:

> *'Due to the use of Loctite on the flywheel screws fitted with plain or Belleville washers this test is only intended to identify screws which are very near to or already have failed. The torque check will not identify screws which have begun to fail.'*

On 12 February 2019 the engine manufacturer issued Service Bulletin JSB 014-3 which aligned the maintenance requirement for '*non-approved propellers'* to that described in the Maintenance Manual.

Previous events

In 2014, when following up on a Jabiru 2200 engine failure, the Light Aircraft Association (LAA) identified high-cycle fatigue of the flywheel attachment bolts as the cause. Following this accident to G-CGJS, the LAA advised the AAIB they were aware of a number of events of flywheel attachment bolt failures on Jabiru 2200 series engines in the UK and elsewhere. However, this event was the first they were aware of affecting the larger, Jabiru 3300 engine.

The LAA published '*Safety Spot*' articles in June 2014, March 2015 and December 2018 related to failures of flywheel attachment bolts on Jabiru engines[1]. The LAA continued to work on the issue in consultation with the engine manufacturer, UK agents and other specialist organisations.

The engine manufacturer advised the AAIB of a case in 2014 where broken flywheel bolts were found on inspection on a 3300 series engine after a pilot had experienced some vibrations during flight. It was noted, and considered causative, that the aircraft had previously been flown with a damaged propeller and that the flywheel bolts had not been replaced afterwards.

The LAA commented that a failure of the flywheel attachment can cause an engine stoppage, even a partial failure such as an attaching cap screw head separating. The reason is that the flywheel on Jabiru engines forms an integral part of the aircraft's ignition and power supply systems.

Analysis

The engine failed suddenly when the aircraft was at 1,400 ft agl over an area of open fields. There were two qualified pilots on board, the pilot/owner who was flying the aircraft at the time, and the flying instructor who was the more experienced pilot. The instructor was able to assist the pilot by taking over the radio communications and monitoring the flying but did not feel he should intervene any further and risk making the situation worse. A safe landing was made.

The aircraft was fitted with a propeller type which was classified by the engine manufacturer as 'non-approved' although it was approved by the LAA. Due to its classification, the engine Maintenance Manual specified that flywheel bolts should be replaced every 100 hours. However, a current Service Bulletin on the engine manufacturer's website, which the owner had been following, specified replacement of the flywheel bolts every 500 hours, in contradiction to the engine Maintenance Manual.

Footnote

[1] Available at: http://www.lightaircraftassociation.co.uk/2014/Mag/June/safety%20spot%20June.pdf [Accessed 2 January 2019]
http://www.lightaircraftassociation.co.uk/2015/Magazine/Mar/safety_spot.pdf [Accessed 2 January 2019]
http://www.lightaircraftassociation.co.uk/2018/Magazine/Dec/SS.pdf [Accessed 2 January 2019]

The flywheel attachment bolts had been installed for 447 hours. Although there are a number of propeller installation risk factors described by the manufacturer in JSB 014, the failure is likely to have been as a result of the inadvertent exceedance of the intended life of these bolts.

Conclusion

The engine failed while the aircraft was climbing through 1,400 ft, and a successful forced landing was made. The engine flywheel had detached due to failure of its attachment bolts. The engine had completed 447 hours, which was within the service interval of 500 hours for replacement of the bolts, as published in a Service Bulletin on the engine manufacturer's website and as followed by the pilot/owner. The engine manufacturer's Maintenance Manual specified an interval of 100 hours for replacement of the bolts, but this was not reflected in the Service Bulletin. This discrepancy was resolved such that the documents only referred to the correct 100 hours replacement interval.

The LAA, in consultation with the engine manufacturer, identified proposed new safety actions which would be publicised to aircraft owners, in addition to those previously highlighted.

Safety action

The engine manufacturer made a series of improvements to the configuration of the flywheel attachment system on this engine type. The improvements included the introduction of Nordloc washers, which the manufacturer stated '*should be implemented on existing engines whenever flywheel bolts are replaced'.* The various configurations that have been used, and the installation process for Nordloc washers are detailed in Service Bulletin JSB 012.

The LAA was proactive in highlighting the failures of flywheel attachment bolts after first becoming aware of the problem.

On 12 February 2019, the engine manufacturer issued Service Bulletin JSB 014-3, which aligned the maintenance requirement for '*non-approved propellers'* to that described in the Maintenance Manual.

ACCIDENT

Aircraft Type and Registration:	Grumman AA-5 Traveller, G-BEZH
No & Type of Engines:	1 Lycoming O-320-E2G piston engine
Year of Manufacture:	1974 (Serial no: AA5-0566)
Date & Time (UTC):	30 January 2019 at 1018 hrs
Location:	Nottingham City Airport
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to both wings, left main gear and nose gear detached
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	4,706 hours (of which 18 were on type) Last 90 days - 92 hours Last 28 days - 29 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries made by the AAIB

Synopsis

Despite extensive use of carburettor heat prior to take off in conditions of high relative humidity, the engine stopped shortly after takeoff and a forced landing was made in an adjacent field. The landing gear sank into soft ground and the aircraft sustained extensive damage; the occupants were uninjured.

History of the flight

Prior to a training flight, as the conditions overnight had led to a ground frost, the instructor and student checked the surface conditions on the apron and an adjoining taxiway. The weather was good with a visibility of more than 10 km, no clouds and a light wind from 250° at 5 kt although the temperature of 0°C and dewpoint of -1°C indicated a high relative humidity. The pilots decided to proceed with their planned flight, whilst exercising caution, bearing in mind the ground conditions and the possibility of carburettor icing.

The aircraft was taxied for departure and the student carried out his power checks at the end of Runway 21. As part of this check, he selected carburettor heat and a drop in engine rpm was observed indicating the proper functioning of the carburettor heat system. A further check was then made on the airfield conditions with ATC and, during this period, carburettor heat was selected. The student then reselected carburettor heat at 2,000 rpm, whilst he checked the engine temperatures and pressures, before setting full power for takeoff. The takeoff progressed normally until passing 150 ft aal when the engine made two popping sounds and the engine rpm rapidly reduced to zero.

The instructor immediately took control, turned the aircraft away from an area of housing, and performed a forced landing into a field next to the airport. During the ground roll over soft ground the nose and left main landing gear detached from the aircraft; both wings also sustained damage. After the aircraft had stopped, both occupants were able to exit the aircraft in the normal manner and without injury.

Despite the extensive use of carburettor heat, the instructor considered that carburettor icing may have caused the engine to stop but he could not rule out other possible causes.

ACCIDENT

Aircraft Type and Registration:	Just SuperSTOL XL, G-SSXL
No & Type of Engines:	1 ULPower UL520iS piston engine
Year of Manufacture:	2016 (Serial no: LAA 397-15385)
Date & Time (UTC):	10 June 2018 at 1411 hrs (UTC)
Location:	Near Barton Aerodrome, Manchester
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Damaged beyond economical repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	76 years
Commander's Flying Experience:	9,000 hours (of which 100 were on type) Last 90 days - 100 hours Last 28 days - 65 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The aircraft was on a test flight prior to being issued with a Permit to Fly. Shortly after takeoff the engine failed. During the subsequent forced landing the aircraft landed firmly, sustaining severe damage. One of the two pilots suffered serious injuries.

It is believed that the engine failure was caused by fuel vaporisation as a result of high engine compartment temperatures.

History of the flight

The aircraft was conducting a series of test flights prior to its Permit to Fly being issued by the LAA, because it was newly built and the engine type was new to this aircraft type. Before the day of the accident, the aircraft had flown for approximately 7 hours with a different commander without event.

Before the first flight of the day, the aircraft was cleaned, and its underside was oil free. The engine's oil was checked and topped up to HALF full, as indicated on the dip stick[1]. The subsequent 20 minute flight was uneventful.

Footnote

[1] HALF on the dip stick equates to FULL (3 litres) when the aircraft is level.

The intent of the second flight was to do the required testing in the visual circuit at Barton Aerodrome. On board were a testing pilot[2], who was the commander, in the right seat and the aircraft's owner in the left. At the time, the weather was fine with a light and variable wind predominately from 200°, and the temperature was 24°C.

The aircraft took off from Runway 26 with about 8 US gal of Mogas (automotive gasoline) and the owner flying. When the aircraft was about 500 ft agl and 1 nm on the extended centreline, a warning indicated that the EGT indicated excessively hot. The engine's throttle was retarded, the aircraft turned right onto the cross-wind leg and levelled at about 800 ft agl. The engine then gradually lost power, failing shortly thereafter. The owner flew the aircraft in a right turn away from an area of woodland, with the aim of performing a forced landing in an adjacent ploughed field. The testing pilot then took control at about 200 ft agl to perform the landing.

The aircraft landed heavily, with right bank applied, and no flaps extended, resulting in the aircraft's landing gear collapsing and the aircraft coming to rest on its underside. The testing pilot suffered serious injuries and the owner minor injuries, but they were able to extract themselves from the aircraft without assistance. The testing pilot was taken to hospital in an ambulance.

When the aircraft was removed from the field, the length of the underside was very oily and had some soil stuck to it. However, there was no sign of any external oil leaks from the engine despite the oil cooler being damaged. With the engine level, the oil dip stick indicated just below minimum.

Aircraft information

The SuperSTOL XL is a high wing single engine light aircraft with side-by-side seating, designed to perform short takeoffs and landings.

Pilot Operating Handbook

The aircraft's pilot operating handbook states:

> *'**LANDING DISTANCE***
>
> *Landing distance from 50 ft. height, flaps down, throttle idle, approach speed = 60 KCAS. 450 feet.*
> …

Footnote

[2] The LAA assesses the suitability of test pilots for every flight test programme that it oversees. LAA Technical leaflet TL 1.19 provides more details and can be found here: http://www.lightaircraftassociation.co.uk/engineering/TechnicalLeaflets/Building,%20Buying%20or%20Importing/TL%201.19%20Initial%20Test%20Flying%20of%20LAA%20Aircraft.pdf [accessed April 2019]

Landing with the Engine Stopped

This airplane has no particular handling features during the landing with engine stopped and flaps up or down. Recommended speed at descent is 56 mph. Entry into flare and flare out at 1.5 feet with landing speed of 38 mph…
…

STALL SPEEDS AT MAX TAKEOFF WEIGHT

Flaps up: 37 mph IAS
Flaps down: 32 mph IAS'

Engine operating manual

The manufacturer's operating manual for the UL520 series of engines states that the UL520iS requires a minimum of 98 octane. The section '*General operating limits*' states:

'***Manifold air temperature***

We advise to bring fresh air from outside the cowling to the inlet air filter/manifold
Max. at start .... 60°C (150F)
Max. in flight .... 40°C (104F)'

The engine manufacturer commented that they advise '*bring fresh air from outside the cowling to the inlet air filter/manifold*' to try keep the inlet air temperature close to the ambient temperature.

Figure 1
Accident aircraft

Engine examination

The aircraft's air-cooled 6-cylinder engine was removed and sent to the manufacturer where its Engine Control Unit (ECU) data logger was first downloaded before the engine was examined.

Data available from the ECU was limited and did not include EGT, CHT or fuel pressure information. The data showed that the oil temperature was within limits. It also indicated that the inlet air temperature reached 76°C, though it is not known when this occurred. This high temperature indicated that the temperature inside the engine cowling was potentially high enough to affect the fuel delivery temperature and could cause a 'vapour lock'[3].

Following the accident to GJINX[4] in 2017, that had a ULPower UL 260i (4-cylinder) engine fitted, the LAA requested that fuel pressure information be recorded in the ECU. The engine manufacturer now supplies its engines with ECUs that monitor both fuel and oil pressure. The manufacturer stated that the accident engine will have this upgraded ECU fitted before it is returned to service.

The engine was then fitted to a test cell and was observed to operate normally. There were signs of an oil leak, but this was believed to be a result of the accident. It was then disassembled and no signs of overheating were observed.

The manufacturer believes that the engine failure was likely to have been caused by fuel vaporisation, due to high engine compartment temperatures resulting in a 'vapour lock'.

LAA's comments

In the absence of any other clear indications, the LAA "broadly agreed" with the engine manufacturer's diagnosis of the most likely cause of the engine failure. It has asked the engine manufacturer what the implications of an excessive inlet air temperature may be, so it can optimise its advice for future test programmes.

The LAA has received feedback from the engine manufacturer indicating that high engine inlet temperatures would not in themselves cause an engine shut down (for example by the ECU taking self-preservation action when sensing an over temperature) and the only direct consequence would be a slight loss in engine performance due to reduced inlet air density. However, a high inlet temperature would imply high engine compartment temperatures, which would tend to encourage vapour lock.

After the accident, the LAA conducted a test flight to check whether the flight manual's stated speed of 56 mph, for a landing with the engine stopped, is appropriate. Initial results suggest that that the minimum IAS to successfully flare the aircraft should be approximately 67 mph.

Footnote

[3] If fuel turns to vapour in the aircraft fuel system, large bubbles can form at high points within the fuel system, or in a constriction in the fuel pipe, which can prevent the passage of fuel to the engine. This phenomenon is known as 'vapour lock' and the effect can be a 'dead-cut' of the engine.

[4] The AAIB report on the accident involving G-JINX can be found here: https://assets.publishing.service.gov.uk/media/5ad7020fed915d32a3a70c72/Silence_Twister_G-JINX_05-18.pdf [accessed April 2019]

Pilot's comments

The owner believes that the aircraft landed firmly because it was too slow and stalled at about 20 ft.

Other events

Since 2003 the AAIB has identified vapour lock as a possible cause in nine accidents involving aircraft using Mogas. The most recent involved a Rutan Long-Ez (Modified), G-BPWP[5].

Discussion

Having had an excessive EGT warning, followed by an engine failure at about 800 ft agl, the pilots were left with little time in which to execute a forced landing in an area with limited landing options available. The testing pilot elected to take control at about 200 ft agl and perform a forced landing. Given he took control with little height available it is likely he did not stabilize the aircraft's IAS, became slow and, with no height in which to lower the nose to correct the IAS, the aircraft stalled, resulting in a firm landing.

The ECU recorded an air inlet temperature in excess of the maximum permitted in-flight temperature, and the ambient temperature was in excess of the LAA's maximum operating temperature for Mogas. The engine manufacturer and LAA concluded the most likely cause of the failure was a fuel vapour lock.

Safety actions

In consultation with the engine manufacturer, the owner stated he would have the engine cowlings redesigned to increase the intake airflow and modify the engine layout by relocating the fuel pumps and cooling fuel returning to the header tank. These changes are intended to reduce the possibility of a fuel vapour lock recurring.

LAA Technical Leaflet TL 2.26[6] highlights the procedures for using unleaded Mogas in piston engines. Due to the greater risk of vapour lock the LAA has stated that when using Mogas the temperature of fuel in the tank must not exceeding 20°C and the aircraft must fly below 6,000 ft.

The LAA plans further flight tests over a range of weights to gain more accurate approach speed data for this aircraft type.

Footnote

5 G-BPWP's accident report can be found here: https://assets.publishing.service.gov.uk/media/5c3e05b040f0b67c6c8d082e/Rutan_Long-Ez__Modified__G-BPWP_02-19.pdf [accessed April 2019]

6 LAA leaflet TL 2.26 can be found here: https://www.lightaircraftassociation.co.uk/engineering/TechnicalLeaflets/Operating%20An%20Aircraft/TL%202.26%20Procedure%20for%20using%20E5%20Unleaded%20Mogas.pdf [accessed April 2019]

The LAA has stated that it will review how it manages the testing of new engine types and engine installations. One option being considered is the download of the ECU's data as part of the engine's initial testing, so that all available measured parameters can be checked against the manufacturer's stated limitations.

ACCIDENT

Aircraft Type and Registration:	Nipper T.66 RA45 Series 3, G-AXLI
No & Type of Engines:	1 Ardem MK.10 piston engine
Year of Manufacture:	1969 (Serial no: S131)
Date & Time (UTC):	11 January 2019 at 1315 hrs
Location:	Approximately 3 miles east of Norton St Philip, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive
Commander's Licence:	Private Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	868 hours (of which 16 were on type) Last 90 days - 23 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft suffered a loss of engine power and overturned during a subsequent forced-landing attempt.

History of the flight

The pilot reported that he took off from Brown Shutters Farm and carried out general handling to the south of the field. Carburettor heat was applied a number of times. He then headed back towards the field from a location about 2 miles to the south. During the descent from just below 4,000 ft, with the engine running at about 1,500 rpm, the pilot began to open the throttle to keep the engine warm. Instead, it came to a rapid stop. Subsequently, whilst gliding at about 60 mph, the propeller started slowly rotating. The pilot then pitched down to increase airspeed, in the hope that the engine power would be restored. Although he reached approximately 120 mph, the engine did not respond. The pilot then reduced speed to continue a glide towards Brown Shutters Farm, making the second of two transmissions on the safety comm frequency. He again received no response but could see that the circuit was clear and continued to prepare for a straight-in approach on the into-wind Runway 33.

As he crossed some trees, a high sink rate developed, and the pilot realised he was in danger of striking some power lines. Consequently, he performed a quick S-turn and sideslip to land in a field immediately below. The softness of the ground caused the aircraft to flip over immediately and become completely inverted.

The pilot was able to exit through a restricted area between the canopy opening and the ground; the canopy having shattered during the ground impact.

Meteorology

The pilot reported the weather as: wind from the north-west at 8 mph, gusting 17 mph; cloud broken at 3,500 ft with 75% cover, sunny, visibility 9999, temperature 8°C, dewpoint 5°C. This information was obtained from the 'Dark Sky' weather App.

Discussion

The temperature and humidity figures quoted by the pilot are consistent with the conditions which, according to generally accepted carburettor icing probability charts, are likely to cause carburettor icing at cruise power. The charts assume the use of typical aeronautical carburettor designs with the normal (cold) air supply selected. There is no reason to suppose that the formation of icing in the types of carburettors used on the automotive-derived Ardem engine type in this aircraft would occur differently. Although the temperature figures quoted are presumed to be fairly local ground level observations, the small differences likely to be experienced during the flight would not have significantly changed the probability of carburettor icing occurring.

Conclusion

The pilot believes that carburettor icing led to the engine ceasing to produce power and his attempt to restore power sacrificed too much height to enable him to reach Brown Shutters Farm in the glide.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-181 Cherokee Archer II, G-OPET	
No & Type of Engines:	1 Lycoming O-360-A4M piston engine	
Year of Manufacture:	1975 (Serial no: 28-7690067)	
Date & Time (UTC):	4 December 2018 at 1133 hrs	
Location:	Cardiff Airport	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to nose landing gear	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	31 years	
Commander's Flying Experience:	90 hours (of which 85 were on type) Last 90 days - 7 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Whilst landing on Runway 12 at Cardiff Airport, the aircraft drifted left and departed the paved surface onto the grass, damaging the nose landing gear. The weather conditions were reported as good and the wind was variable at 3 kt.

The pilot was able to taxi the aircraft back onto the runway, but when he attempted to vacate it at Taxiway G, he found he could not turn the aircraft left. He shut the aircraft down and the airport fire service manually handled it to the apron.

The pilot reported that, as he closed the throttle and flared, the aircraft drifted left. He tried to correct the drift with rudder, but the aircraft had departed the runway before he managed to straighten it.

SERIOUS INCIDENT

Aircraft Type and Registration:	Piper PA-34-220T Seneca V, G-OXFF
No & Type of Engines:	2 Continental Motors Corp LTSIO-360-RB piston engines
Year of Manufacture:	2013 (Serial no: 3449485)
Date & Time (UTC):	2 November 2018 at 0830 hrs
Location:	Oxford Airport, Kidlington
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Melted and parted rudder cable; scorch witness mark on emergency battery wiring loom
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	3,800 hours (of which 1,515 were on type) Last 90 days - 137 hours Last 28 days - 85 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and inquiries made by the AAIB

Synopsis

The aircraft was about to enter the runway for takeoff when the instructor became concerned about the feel of the left rudder pedal. He aborted the flight and taxied the aircraft back to the hangar. The subsequent engineering inspection found the left rudder cable had parted, with evidence that it had melted through due to chafing against the standby battery cable. Safety actions have been taken by the Civil Aviation Authority and the manufacturer has issued a mandatory Service Bulletin (No 1337) to reroute the emergency power wiring to give more clearance from the rudder cables.

History of the flight

The aircraft had been collected from the hangar for an instrument rating examination flight by a student and instructor. The 'A' check, start up and subsequent preparatory checks proceeded normally. However, after engine start the emergency battery circuit breaker tripped. It was reset, the battery voltage was checked and found to be normal and it did not trip again. The taxi and power checks were carried out satisfactorily. ATC cleared the aircraft to enter the runway and backtrack to the holding point and this was carried out under the control of the instructor. However, during the taxi he noticed that the left rudder pedal felt soft and was "too easy to move" with no resistance. The right rudder pedal felt normal by comparison. He brought the aircraft to a halt and informed ATC. He asked the student to cross-check, who confirmed that the rudder pedals did not feel normal. They opened the cockpit door to observe the rudder movement. On pressing the right pedal, the rudder moved correctly to the right but when the left pedal was pressed, there was no movement. The instructor aborted the flight and taxied the aircraft back to the hangar for inspection.

Engineering investigation

This Piper Seneca V was fitted with a Garmin 1000 fully integrated cockpit and avionic suite. The system is reliant on electrical power and has a standby battery to keep the system running in the unlikely event of a twin-generator and main battery failure.

Inspection of the aircraft revealed the right rudder cable had chafed against the standby battery wiring and shorted to earth. The heat generated by the electrical short had melted through the steel-braided rudder cable. Figures 1 and 2 show the damage to the rudder control cable and standby battery wiring.

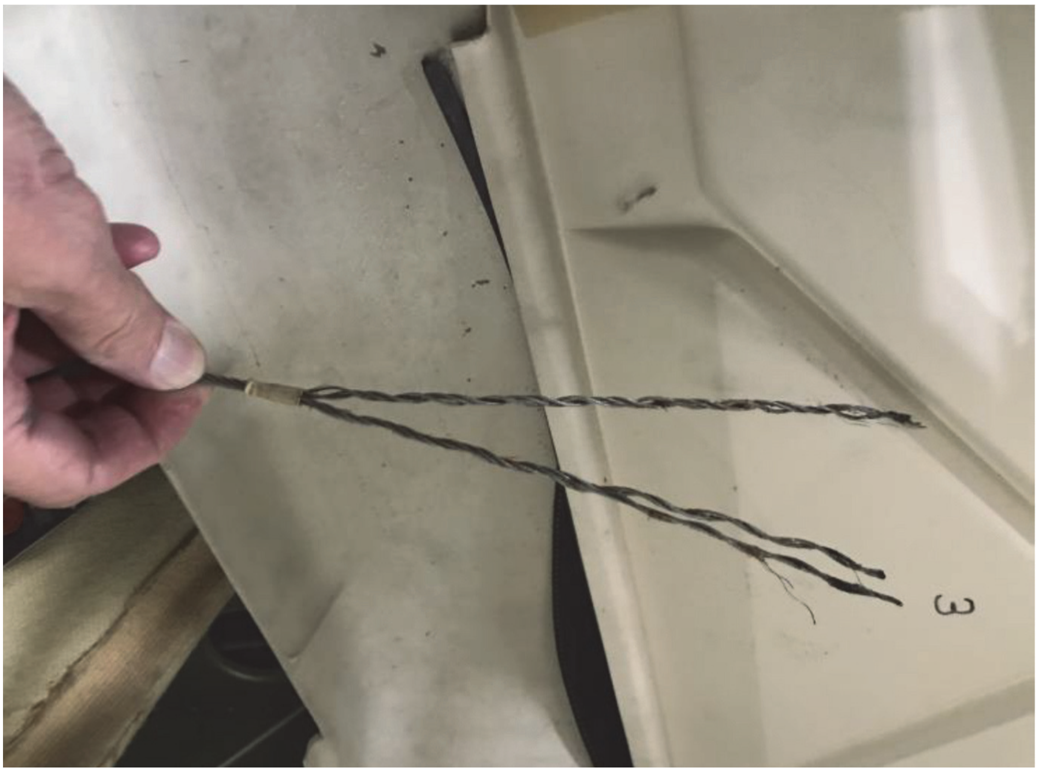


Figure 1
Damage to the rudder control cable

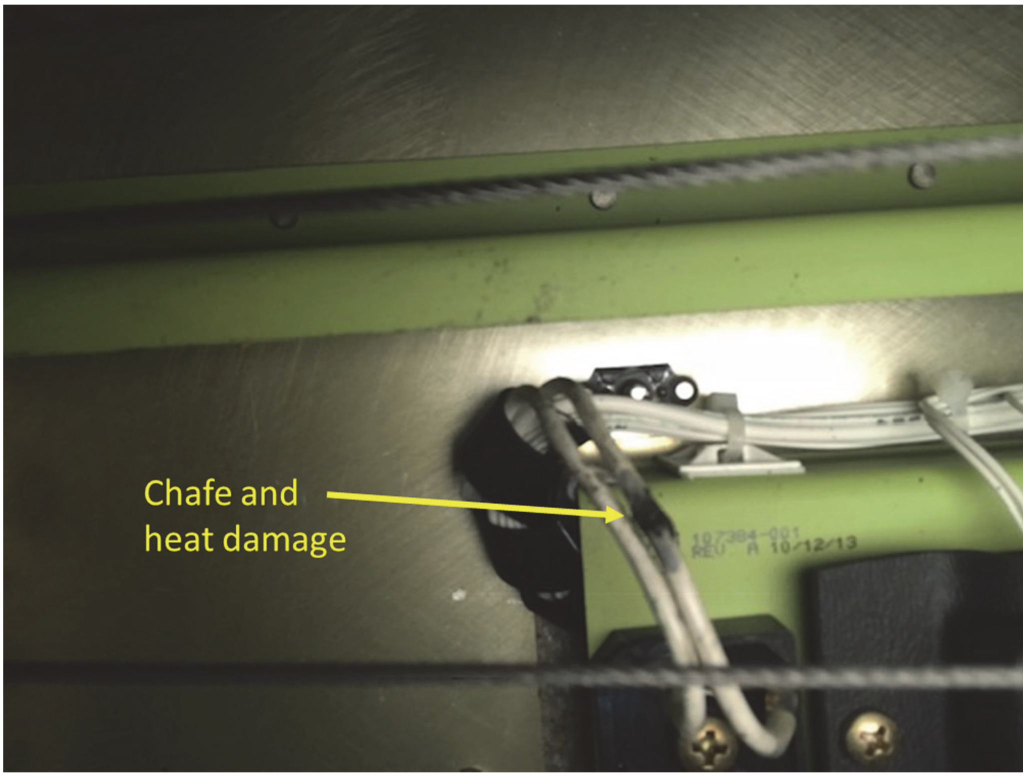


Figure 2
Chafe on the standby battery wiring

Safety action

> This potentially serious risk to airworthiness was brought to the attention of the manufacturer, the CAA, EASA and the FAA. The CAA took immediate steps to inform owners and operators of similarly configured Piper Seneca V aircraft.
>
> The manufacturer has subsequently issued a mandatory Service Bulletin (No 1337) which gives instructions to reroute a portion of the emergency power wiring to improve the clearance from the rudder control cables.

ACCIDENT

Aircraft Type and Registration:	Pitts S-1S Pitts Special, G-MAVK
No & Type of Engines:	1 Lycoming IO-360-A1A piston engine
Year of Manufacture:	1991 (Serial no: 4010)
Date & Time (UTC):	21 October 2018 at 1130 hrs
Location:	Near Towcester, Northamptonshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Wings damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	268 hours (of which 12 were on type) Last 90 days - 6 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During a flight from Turweston to Sywell, the engine stopped and the pilot made a forced landing in a field, north-west of Towcester. The field was too short to complete the landing and the aircraft came to rest in a hedge, damaging the wings. Following the recent installation of a new instrument panel, no markings had been applied to the sight-level fuel gauge which made fuel quantity management difficult. Although the pilot had received aerobatic training on the Pitts Special, it was not structured type-conversion training. The LAA has released a Technical Letter explaining the rules and giving guidance when transitioning to a new type.

History of the flight

Prior to departure, the pilot checked the quantity of fuel on-board using the sight gauge in the cockpit and judged that the tank was approximately half full. In his opinion this was sufficient for the short trip to Sywell and once the weather conditions became suitable he took off. The pilot flew the aircraft out of the Turweston circuit at full power and then throttled back ready to trim the aircraft for cruise at 140 mph. He felt the engine losing power and so advanced the throttle. When the engine did not respond, he applied full throttle but there was still no response. He confirmed the fuel pressure was normal (approximately 12 psi) and then cycled the mixture control, which produced a short burst of power after which the engine stopped. The pilot selected a field to land in but there was insufficient distance to complete the landing and the aircraft struck a hedge at the far end and came to a halt (Figure 1). The impact damaged the wings, but the pilot was able to exit the aircraft unharmed.

Figure 1

The final position of G-MAVK
(Photo used with permission)

Aircraft information

The pilot had purchased G-MAVK in October 2016 for aerobatic competition flying and had spent the intervening period preparing the aircraft. Although he was experienced on other types, he undertook several hours of aerobatic training with a qualified instructor in a similar Pitts Special, but did not receive structured type-conversion training.

The fuel tank capacity was 72 litres (20 gal US) and was fitted with a sight-level fuel gauge. The pilot had recently fitted a new instrument panel and at the time of the accident there were no quantity markings on the fuel gauge (Figure 2).

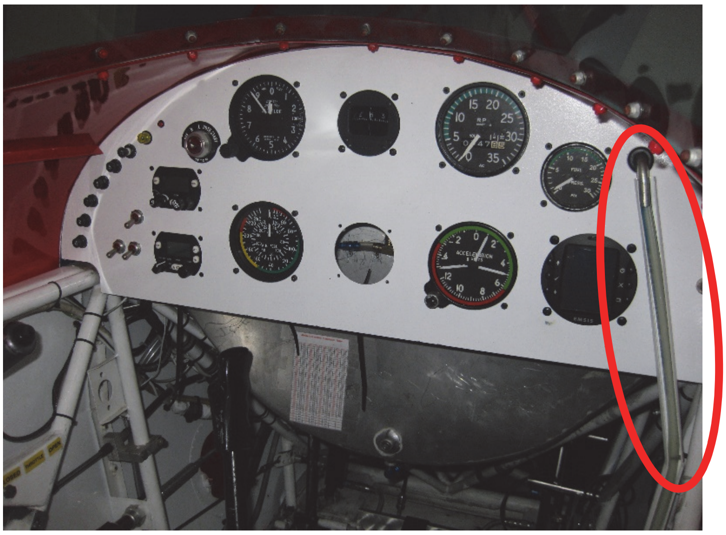


Figure 2

Cockpit of G-MAVK with the unmarked fuel gauge highlighted

Prior to takeoff the pilot used the fuel gauge to estimate the fuel quantity as approximately 35 litres (½ full). This would be enough for 30 minutes flying time and Turweston to Sywell takes about 10 minutes at nominal cruise speed. The engine stopped 8 minutes after takeoff which would indicate only 7 to 10 litres of fuel in the tank at departure or the fuel consumption was much higher than anticipated. During the post-accident examination, it was noted that there was no fuel remaining in the tank. The aircraft has subsequently been disassembled ready for repairs and the pilot has discovered some fuel pipe staining and a loose fuel pipe union on the carburettor.

Analysis

On a tailwheel aircraft such as the Pitts Special, the aircraft pitch attitude will affect the level of fuel shown in the sight gauge between level flight and the attitude on the ground. To mitigate this effect, sight gauges are usually dual-calibrated with on-ground and in-flight markings. At the time of the accident there were no markings to indicate the fuel quantity on G-MAVK and so the pilot could not accurately manage the onboard fuel quantity. This led to the engine stopping in flight due to fuel exhaustion. Although it has subsequently been discovered that a fuel union on the carburettor was loose, it is not possible to determine whether this was due to the accident or was a pre-existing defect.

It is opinion of the LAA that a lack of structured conversion training resulted in the pilot not performing an effective forced landing. The LAA has recently issued a Technical Leaflet '*Converting to a New Type*' as part of a mitigation to prevent similar accidents and has given advice in their magazine '*Light Aviation*' about the importance of proper fuel gauge markings.

Conclusion

Lack of fuel level markings on the fuel gauge made it difficult for the pilot to accurately manage the fuel quantity on-board, which resulted in the engine stopping due to fuel exhaustion. It has not been possible to determine whether there was a pre-existing fuel leak. The forced landing was only partially successful; although the pilot escaped with no injuries, both wings were damaged when the aircraft struck a hedge.

The LAA believes safety improvements can be made by ensuring pilots undergo structured conversion training before starting to fly a new type of aircraft. This would also assist pilots in taking effective actions in the event of emergencies, such as forced landings following an engine stoppage.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-PERE
No & Type of Engines:	1 Lycoming O-360-J2A piston engine
Year of Manufacture:	2003 (Serial no: 3382)
Date & Time (UTC):	19 February 2019 at 1138 hrs
Location:	East Lound, Doncaster
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive damage
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	24 years
Commander's Flying Experience:	650 hours (of which 117 were on type) Last 90 days - 59 hours Last 28 days - 29 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During a training flight, as the helicopter lifted into the hover, the student applied full left pedal in reaction to a right roll. This caused a dynamic rollover. The instructor was unable to react quickly enough to prevent the rollover.

History of the flight

The commander was conducting a circuit training flight for a student completing a Helicopter Private Pilot's License (PPL(H)). The weather was CAVOK with light winds. The circuit at Doncaster, where the training school is based, was busy so the commander elected to complete the training at a local grass airstrip near East Lound. The student had been progressing well through the PPL(H) syllabus and had recently completed his first solo flight.

They had completed five circuits and landings. On completion of the fifth circuit the student landed the helicopter, so they could debrief the last circuit and prepare for the next. The student was in control for the subsequent lift-off. As the helicopter became light on the skids, it started to roll slightly to the right. The student recognised this, stopped raising the collective and applied a small amount of left cyclic. This was insufficient to fully correct the right roll. The student then abruptly applied full left pedal. The helicopter yawed left, lifted from the ground and onto the back of the skids, then bumped forward and right, catching the front right portion of the skid on the ground. The helicopter rolled to the right and came to rest on its right side (Figure 1).

Figure 1
G-PERE After the accident

The commander and student exited the helicopter without injury.

The commander recalled that the event, from application of the left pedal to the helicopter rolling over, lasted approximately two seconds. He reported that he was not able to react quickly enough to the unexpected pedal input to prevent the rollover.

Dynamic rollover

Dynamic rollover occurs when a helicopter rolls about a fixed point, typically a wheel or skid. As the helicopter rolls the main rotor thrust is tilted in the same direction as the roll. This causes the helicopter to roll further. Beyond a certain angle, cyclic control is not sufficient to prevent the helicopter rolling onto its side. The effect is more pronounced with a right roll on this helicopter because the tail rotor thrust also causes it to roll to the right.

Analysis

As the helicopter became light on the skids the student pilot applied full left pedal in reaction to the right roll. This caused the helicopter to enter a dynamic rollover. The commander was unable to react quickly enough to prevent the accident.

The commander reflected that he may have been more relaxed because of the student's previous good performance and that he should have been closer to the controls during the lift to the hover. However, instructors need to balance the need to intervene promptly with the need to allow a student to "make and correct errors" to enable them to learn.

The student reported that he had recently started fixed wing flight training. He thought the combination of training on rotary and fixed wing may have contributed to the accident.

ACCIDENT

Aircraft Type and Registration:	Robinson R44 Raven, G-HWKS
No & Type of Engines:	1 Lycoming O-540-F1B5 piston engine
Year of Manufacture:	2007 (Serial no: 1747)
Date & Time (UTC):	26 February 2019 at 1635 hrs
Location:	Near Sketrick Island, County Down
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Blades damaged, minor damage to mast and tail cone
Commander's Licence:	Private Pilot's Licence
Commander's Age:	26 years
Commander's Flying Experience:	120 hours (of which 38 were on type) Last 90 days - 6 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was flying an approach to a private site on Sketrick Island. As he made his final approach over the water between the Island and the mainland, the helicopter struck electrical power lines which were strung from the mainland to the island. The pilot decided to land the helicopter immediately on the nearest road. Damage to the helicopter was to the main rotor blades as well as some limited damage to the mast and tail cone. There were no injuries to the pilot or passengers.

Wires and power lines can be very difficult to see from the air, with poles often providing the pilot with the only indication that they are there. Poles, especially wooden ones can be camouflaged by the landscape or hidden by trees. Wires and power lines can often be encountered in unexpected places especially in rural areas and they can present a significant danger to all types of aircraft. Careful preparation and reconnaissance can reduce the risks when landing at a site. Using freely available mapping tools such as Google Earth, it is possible to see wires and power lines which might affect the flight but which are not marked on aviation charts.

ACCIDENT

Aircraft Type and Registration:	Cameron Z-350 Hot Air Balloon, G-CERC
No & Type of Engines:	N/A
Year of Manufacture:	2007 (Serial no: 11028)
Date & Time (UTC):	15 September 2018 at 1855 hrs
Location:	near Wick, Bath
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 12
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor damage to the balloon envolope
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	2,033 hours (of which 620 were on type) Last 90 days - 23 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The hot air balloon struck a low-level powerline on the final approach to land. The commander had been unable to see the powerline until it was too late to avoid. All passengers were able to exit the basket without injury.

History of the flight

G-CERC was making an evening flight from Bath with 12 passengers. Variable winds made the planned landing site unachievable so, after finding several landing areas unsuitable, the commander chose a couple of grass fields on a downhill slope near Wick. The commander reported that he was aware of the approaching sunset and a large 'no landing' area beyond, which both confirmed his decision to land in these fields.

There were horses in the field beyond the chosen landing site, so the commander made a low approach using the quiet burner to avoid disturbance. The line of the approach was between two medium sized trees. The commander was aware of electrical cables to the right and left, but the approach appeared clear.

Passing approximately 3 m above the ground, the commander saw electrical wires and a supporting pole approximately 30 m ahead. He realised it was not possible to avoid the wires so pulled hard on the rapid deflation line. Before the basket touched down he briefed the passengers that a wire strike was imminent, that there may be a bang and to remain seated. When the basket was approximately 1 m from the ground, the envelope contacted the wires and a loud bang was heard. The basket turned and came to rest against a horse jump close to the pole. The commander briefed the passengers to remain in their landing positions whilst he assessed if it was safe to exit the basket.

Having done so, the commander gave instructions to the passengers to exit the basket and move away from the balloon. There were no injuries.

Once electrical engineers made the area safe, the balloon was recovered. There was minor damage to the balloon envelope, the electrical cables had snapped and there was damage to the supporting pole.

Analysis

The commander reported that the choice of landing site was dictated by the lack of previous landing opportunities, the large ‘no landing’ area ahead and the approaching sunset. He made a low approach due to horses in the field beyond. On this approach path the electrical wires were not visible to the commander until it was too late to avoid them.

Once the commander realised that a collision was unavoidable he used the rapid deflation system to get the basket on the ground as quickly as possible to reduce the chance of the wires contacting the basket. He explained to the passengers what was going to happen and instructed them to remain in their landing positions. He reported that this maintained calm and helped ensure everyone was able to exit the basket safely.

ACCIDENT

Aircraft Type and Registration:	Skyranger Swift 912S(1), G-UPHI
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2006 (Serial no: BMAA/HB/480)
Date & Time (UTC):	2 February 2019 at 1550 hrs
Location:	Private strip, Aughrim, County Down
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to the propeller, wings, engine and engine mounts, nosewheel
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	545 hours (of which 84 were on type) Last 90 days - 12 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot was landing to the left of the runway centreline to avoid rutted ground to the right but the aircraft veered off the runway during the landing due to wet, sloping ground. Despite applying corrective control inputs, he could not prevent the aircraft colliding with a boundary wall and coming to rest in a ditch. The pilot felt that had he requested a full briefing from the owner of the airfield, he would have landed further to the right of the centreline, to stay on the level ground.

History of the flight

The pilot was returning to a private airstrip at Aughrim, near Kilkeel, County Down, having flown two previous flights that day to Newtownards and Kernan Flying Club. The grass airstrip at Aughrim has a pronounced slope along the runway and departures are usually from Runway 17 (downslope) and landings on Runway 35 (upslope). When the pilot departed earlier in the day he noticed that the left side of Runway 17 was "badly rutted"; therefore as he approached Runway 35 to land he positioned to the left of the centreline (Figure 1).

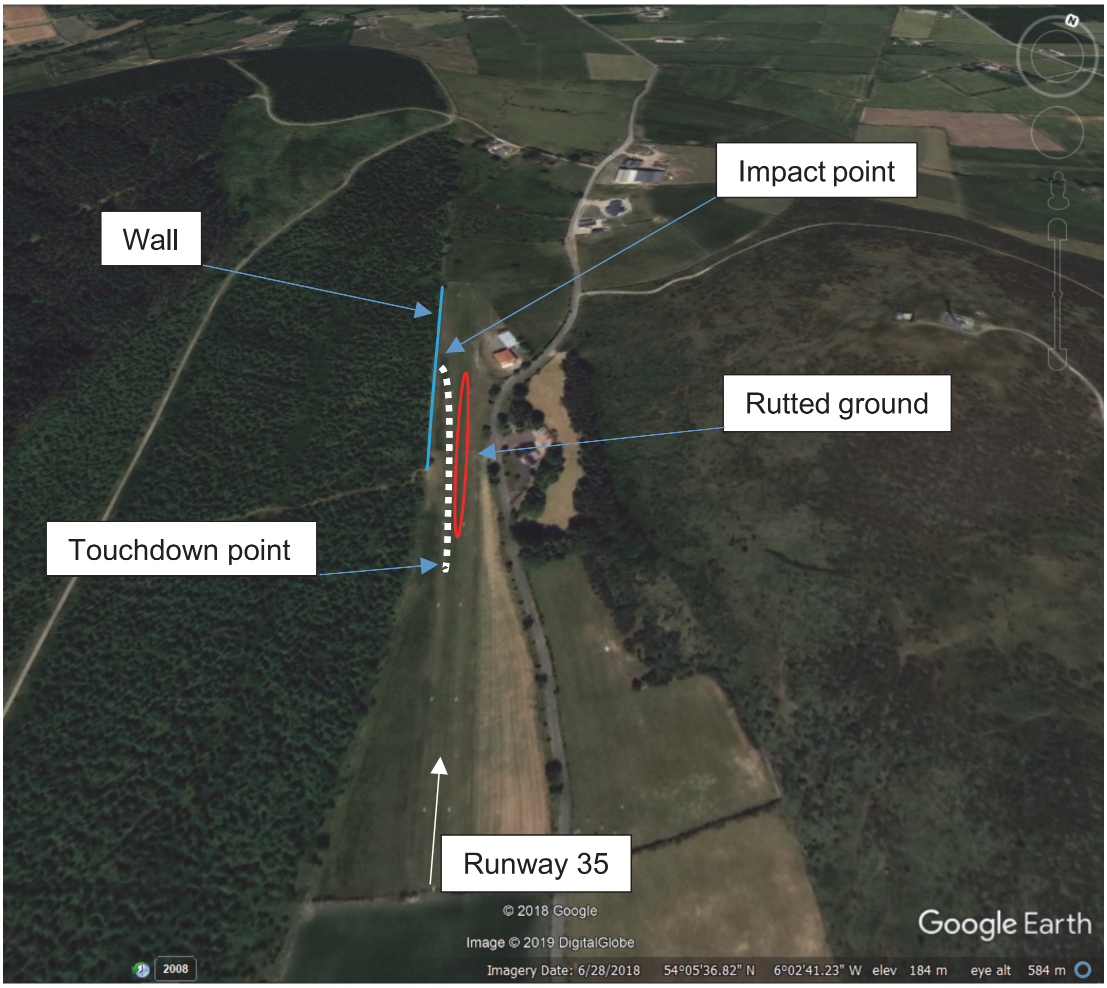


Figure 1
Aughrim airfield

The surface was soft and wet from melted overnight frost and as the aircraft touched down the pilot maintained some power to compensate for the upslope and to keep the nosewheel lightly loaded and prevent it from digging in. As the landing roll continued, the ground to the left side of the runway started to slope away. The pilot noticed the aircraft veering to the left and responded by lowering the nose to increase steering authority and applying full right rudder. It was at this point that the left main landing gear wheel may have caught a rut or depression, which caused the aircraft to swing rapidly to the left. This motion caused the pilot to inadvertently increase the engine power, increasing the rate of turn. By now the aircraft was fully off the runway where it struck a wall and sank into a ditch (Figure 2). The damage to the wing struts, propeller and other structural damage were all sustained from the impact with the wall. Both the pilot and passenger were able to exit the aircraft unaided and without injury.

Figure 2

G-UPHI after impacting the wall, showing sloping ground to the left.

Conclusion

It is the opinion of the pilot that he should have requested a thorough briefing from the airstrip owner and walked the strip to assess its topography and features as he was relatively new to the airstrip. He would then have been aware of the downslope to the side of the runway and not underestimated the soft ground conditions and that most landings take place to the right of the centreline, hence the rutted surface.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 100, (UAS, registration n/a)
No & Type of Engines:	4 DJI Electric motors
Year of Manufacture:	Unknown (Serial no: M02DC105020008)
Date & Time (UTC):	4 February 2019 at 1015 hrs
Location:	In a field near Clough Road, Hull
Type of Flight:	Aerial Work
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Rotors damaged and water ingress
Commander's Licence:	Other
Commander's Age:	53 years
Commander's Flying Experience:	15 hours Last 90 days - 5hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The drone operator was tasked to undertake a search of a drainage system in the Hull area for a missing person. After the setup and the pre-flight checks, the drone was flown to the search area over the water. As the drone approached the water, the Collision Avoidance System started to activate and climbed the drone away from the water. The operator did not correct the flightpath in time to prevent the drone contacting some branches overhanging the drainage system and the drone fell into the water.

The drone operator considered that he had agreed to fly too close to the water and trees in order to carry out the search. As a result, the organisation has changed the risk assessment for such searches to state that flight will not take place below 10 metres when over water.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 DJI Electric motors
Year of Manufacture:	Unknown (s/n 0GODF5Q0230142)
Date & Time (UTC):	18 February 2019 at 1200 hrs
Location:	Disused rail yard, Feltham, London
Type of Flight:	Emergency services operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Extensive damage
Commander's Licence:	Other
Commander's Age:	33 years
Commander's Flying Experience:	60 hours (of which 8 were on type) Last 90 days - 10 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries made by the AAIB

A few days before this accident, the aircraft had sustained light damage which included the area around motor No 1 and its associated electronic speed controller (ESC). Following some minor repairs being made by him, a test flight was being carried out by the operator's Chief Pilot at a disused rail yard in light rain. He assessed the current weather conditions as being suitable and checked the forecast which was for low winds and light rain. He carried out the pre-flight checks, including a check of the security of the batteries.

During the initial part of the test flight the aircraft performed as expected. However, towards the end of the test flight, when the aircraft was established in a low hover, a loud mechanical noise was heard, and it was seen to tumble to the ground.

The damaged aircraft was sent to the manufacturer for repair who reported that the motor No 1 ESC had failed during flight. It was not possible to establish whether the earlier light damage observed in the area around motor No 1 was a factor in this accident.

ACCIDENT

Aircraft Type and Registration:	DJI Phantom 3 Pro (UAS)	
No & Type of Engines:	4 Electric motors	
Year of Manufacture:	Unknown	
Date & Time (UTC):	22 May 2018 at 0830 hrs	
Location:	Railworld, Oundle Road, Peterborough	
Type of Flight:	Commercial activity	
Persons on Board:	Crew - None	Passengers - None
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Motor mounting damaged and aircraft destroyed	
Commander's Licence:	Other	
Commander's Age:	50 years	
Commander's Flying Experience:	10 hours (of which n/k were on type) Last 90 days - n/k hours Last 28 days - n/k hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The unmanned aircraft took off and reached an estimated height of 10-15 ft when an unusual noise was heard. Shortly afterwards one of the motors detached from the structure and the aircraft impacted the ground and was destroyed. The structure showed signs of multiple cracking around the motor attachment points and it is probable that these cracks joined together and resulted in the motor detaching from the structure.

History of the flight

The DJI Phantom 3 Pro is an unmanned aircraft (UA) with a maximum weight of 1.28 kg (Figure 1). With its flight controller, it forms an unmanned aircraft system (UAS). It was being flown to photograph a local tourist attraction using a camera mounted on a gimbal below the aircraft.

The pilot completed his pre-flight checks of inspecting the structure and propellers for signs of damage and proceeded with an uneventful takeoff. As the UA reached a height of approximately 10-15 ft the pilot heard an unusual sound which he took to be wind noise. Seconds later he heard the same noise and the UA descended rapidly before ground impact. During the impact the battery and camera separated from the UA and came to rest approximately two metres away. Upon inspection, one motor complete with mounting screws and propeller, was missing and despite a search of the area it was not found. The UA was extensively damaged but there were no injuries or third-party damage.

Figure 1

DJI Phantom 3 Pro with gimbal mounted camera

Aircraft examination

Examination of the structure around the motor attachment point indicated multiple cracks which had amalgamated and resulted in the attachment bosses detaching from the main structure (Figure 2).

Undamaged motor mount

Figure 2

Detail of damaged motor mounting with comparison to an undamaged mounting

(Photo used with permission)

Investigation of similar events

A poll[1] of over 1,000 users, taken in 2015 on the manufacturer's official forum, showed that 30% of respondents had an issue with structural cracking of their UA through normal flying and had not been the subject of an impact. It appears that these cracks are generally detected before the motor detaches and a variety of repairs and reinforcement methods are available in the on-line forums. One such reinforcement method is to fit aluminium strengthening plates to the exterior of the structure through the motor attachment screws (Figure 3). These are readily available from third party suppliers but are not an endorsed modification by the manufacturer. The manufacturer has a warranty and replacement scheme which covers any manufacturing defects.

Figure 3
Example of motor attachment reinforcement plate

In the published user manuals[2] for this UA, there are no specific structural inspections included in the pre-flight preparations. Inspections of every part are to be done '*after any crash or violent impact*'.

AAIB comment

Good airworthiness practice suggests that operators of UAs should consider inspecting the critical areas of the UA structure at regular intervals (including the use of a suitable magnifying glass) to identify cracks which may lead to a structural failure and subsequent loss of the control (Figure 4).

Footnote

1 https://forum.dji.com/thread-23532-1-1.html [accessed March 2019]
2 Phantom 3 Professional quick start manual version 1.2 – 19 April 2017
Phantom 3 Professional user manual version 1.8 – 06 June 2017

Figure 4
Example of motor attachment cracking

ACCIDENT

Aircraft Type and Registration:	DJI Phantom 4 Pro (UAS, registration n/a)
No & Type of Engines:	4 DJI Electric motors
Year of Manufacture:	2016
Date & Time (UTC):	17 June 2018 at 0545 hrs
Location:	Worcester, Worcestershire
Type of Flight:	Commercial Operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Extensive
Commander's Licence:	Other
Commander's Age:	61 years
Commander's Flying Experience:	25 hours (of which 16 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While on a surveying task the pilot was unexpectedly presented with a 'LANDING' warning, followed by several other warnings, before the aircraft entered a hover. Despite several attempts the pilot was unable to take control. The aircraft subsequently descended, colliding with a building as it did so, and was extensively damaged.

History of the flight

The aircraft was being flown on a surveying task in a built-up area, for which the pilot had approval. It took off on its third flight of the day with the battery indicating 51% charge and 13 minutes and 17 seconds of flight time remaining.

After an uneventful few minutes, the enunciated flight mode, on the aircraft's controller, changed from 'GPS' to 'LANDING' without any warning or input by the pilot. This was followed by the following messages also being displayed on the controller:

> *'Obstacle sensing will be disabled when aircraft is landing. Fly with caution*
>
> *Aircraft is close to home point. Initiate return to home will now trigger Auto Landing'*

The aircraft then entered a hover. Despite several attempts by the pilot to take control of the aircraft, including selecting A [Attitude] Mode and selecting RTH [Return to Home], the aircraft continued to hover. The pilot then rebooted the manufacturer's application on the monitor connected to the controller, but this had no effect. He then changed the monitor for a portable electronic device, but the aircraft continued to hover and not respond to any inputs. The pilot then reconnected the monitor and 'LANDING' continued to be displayed.

Shortly thereafter, having flown for about 6 minutes and 30 seconds, while it was in a hover, when the battery was indicting 11% and 2 minutes and 51 seconds of flight time remaining, the aircraft started to descend. As it did, it made contact with the side of a building and fell 30 ft. It came to rest on a flat roof, sustaining extensive damage to the aircraft.

Aircraft information

The *Phantom 4 Pro/Pro+ User Manual*, V1.4 states:

'***Intelligent Flight Battery**: The new 5870 mAh DJI Intelligent Flight Battery… provide up to 30 minutes of flight.*

Aircraft Status Indictor Description [1]

…

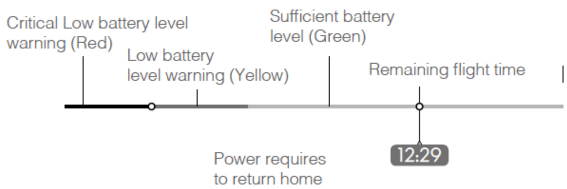
Warning	
Y ······ Fast yellow flashing	Remote Controller Signal Lost
R ······ Slow red flashing	Low Battery Warning
R ······ Fast red flashing	Critical Battery Warning

Low Battery RTH

The low battery level failsafe is triggered when the DJI Intelligent Flight Battery is depleted to a point that may affect the safe return of the aircraft. Users are advised to return home or land the aircraft immediately when prompted. The DJI GO 4 app will display a notice when a low battery warning is triggered. The aircraft will automatically return to the Home Point if no action is taken after a ten-second countdown. The user can cancel the RTH procedure by pressing the RTH button on the remote controller. The thresholds for these warnings are automatically determined based on the aircraft's current altitude and distance from the Home Point.

The aircraft will land automatically if the current battery level can only support the aircraft long enough to descend from its current altitude. The user can still use the remote controller to alter the aircraft's orientation during the landing process.

The Battery Level Indicator is displayed in the DJI GO 4 app, and is described below:



Battery level Indicator

Footnote

[1] The Aircraft Status Indicators communicate the system status of the aircraft's flight controller by way of different coloured LEDs on the rear of the aircraft. The Critical Battery Warning illuminates when the battery has about 10% of charge remaining.

Battery Level Warning	Remark	Aircraft Status Indicator	DJI GO 4 App	Flight Instructions
Low battery level warning	Battery power is low. Land the aircraft.	Aircraft status indicator blinks RED slowly.	Tap "Go-home" to have the aircraft return to the Home point and land automatically, or "Cancel" to resume normal flight. If no action is taken, the aircraft will automatically go home and land after 10 seconds. Remote controller will sound an alarm.	Fly the aircraft back and land it as soon as possible, then stop the motors and replace the battery.
Critical Low battery level warning	The aircraft must land immediately.	Aircraft status indicator blinks RED quickly.	The DJI GO 4 app display will flash red and the aircraft will start to descend. The remote controller will sound an alarm.	Allow the aircraft to descend and land automatically.

Aircraft examination

The aircraft was initially inspected by a UK repair agency, which concluded that it had experienced an "unknown behaviour".

The aircraft, without its battery, was then sent to the manufacturer for further analysis. They concluded the accident was due to a "critical low battery landing" but were unable to provide further information as to what may have caused the loss of control.

Other events

During 2018, there were several events to aircraft fitted with the manufacturer's TB50[2] and TB55[3] batteries where they indicated incorrect power levels. This was resolved by a firmware update[4]. The manufacturer commented that this accident was not related to this issue.

Pilot's comments

The pilot commented that he was not presented with any low battery warnings during the accident flight. He has subsequently recharged and used the accident battery several times, in a new aircraft, without event.

Discussion

The manufacturer concluded that the accident was the result of the aircraft commencing an automatic landing when its battery was nearly depleted. This may have been the case once the battery had reached 11% of charge remaining and started to descend. However, the pilot did not receive a low battery level warning, as stated in the aircraft's user manual.

Footnote

2 The TB50 batteries are fitted to the manufacturer's Matrice 200 series and Inspire 2 aircraft.
3 The TB55 batteries are fitted to the manufacturer's Matrice 200 series of aircraft.
4 Link to manufacturer's concluding statement on TB55 battery investigation: https://www.dji.com/uk/newsroom/news/dji-concludes-tb55-battery-investigation [accessed March 2019]

Also, the aircraft did not commence the automatic landing for several minutes after the message that it would do so was enunciated on the controller. No explanation for this, or the failure of the aircraft to respond to the pilot’s inputs, could be established.

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).

BULLETIN CORRECTION

Aircraft Type and Registration:	Auster AOP.9, G-BXON
Date & Time (UTC):	18 June 2017 at 1135 hrs
Location:	Spanhoe Airfield, Northamptonshire, Buckinghamshire
Information Source:	AAIB Field Investigation

AAIB Bulletin No 3/2019, page 36 refers

The information in the section titled *'Passenger'* has been amended to provide additional clarification. The text should read:

> The passenger on the accident flight was a friend of the pilot. He had automotive engine experience and had assisted with some aspects of the work on G-BXON's engine during its restoration. He was not a qualified pilot.

AAIB Bulletin No 3/2019, page 52 refers

The last two sentences in the first paragraph of the *'Engine maintenance'* section have been amended to provide additional clarification. The text should read:

> A friend with automotive engine experience had assisted the pilot in stripping the engine and cleaning engine inhibiting oil from 'top-end' components, which included honing the cylinders and cleaning and lapping the valves. Separately, it was reported that the magneto was also replaced.

The online version was amended prior to publication.

BULLETIN ADDENDUM

Aircraft Type and Registration:	Boeing 787-9 Dreamliner, G-TUIM
Date & Time (UTC):	6 July 2018 at 1711 hrs
Location:	London Gatwick Airport
Information Source:	Aircraft Accident Report Form

AAIB Bulletin No 2/2019, page 41 refers

The following Bulletin addendum was added to the online version of the report on 11 April 2019.

> The report identified the cause of the incorrect operation of the Nose Landing Gear Isolation Valve (NLGIV) as 'brinelling' (undesirable wear) of the internal pintle and 'coining' of the valve seat which, when combined, restricted the valve's operation. After further engineering investigation, however, the cause of the incorrect valve operation was determined to be a misaligned pintle hole in the housing of the valve. This misalignment restricted the valve's ability to open when commanded. Valves affected this way were returned to the manufacturer for 'review and mitigation'.

BULLETIN CORRECTION

Aircraft Type and Registration:	Cirrus SR22, G-SRTT
Date & Time (UTC):	9 June 2018 at 1039 hrs
Location:	Benington, Hertfordshire
Information Source:	Aircraft Accident Report Form submitted by the pilot, AAIB enquiries and examination of the engine

AAIB Bulletin No 3/2019, page 128 refers

Following further discussion with the pilot, the conclusion to this report now reads:

> **Conclusion**
>
> The pilot activated the CAPS following an engine failure in accordance with the POH and advice by the aircraft manufacturer. The engine failure was due to overheating of the connecting rod cap bolts as a result of insufficient cooling by the engine oil.

The online version of this report was amended prior to publication.

BULLETIN CORRECTION

Aircraft Type and Registration:	Grumman AA-5 Traveller, G-BEZF
Date & Time (UTC):	2 September 2018 at 1020 hrs
Location:	Turweston Aerodrome, Buckinghamshire
Information Source:	Aircraft Accident Report Form submitted by the pilot

AAIB Bulletin No 3/2019, page 134 refers

There was a typographical error in the aircraft registration in the penultimate sentence in the first paragraph. The text should read:

> Although the engine had stopped, the propeller was still rotating when G-BEZF struck the parked aircraft.

A new sentence was also added at the end of the report to provide additional information as follows:

> The syndicate member subsequently reported that the aircraft maintainer found no faults when he checked the brakes and assessed that the 'feel' of the brake pedals was within normal experience.

The online version of this report was amended prior to publication.

BULLETIN CORRECTION

Aircraft Type and Registration:	Slingsby T61F Venture T Mk 2, G-BUGT
Date & Time (UTC):	9 December 2018 at 1335 hrs
Location:	Field near Rufforth Airfield, York
Information Source:	Aircraft Accident Report Form submitted by the pilot and aircraft inspection report

AAIB Bulletin No 3/2019, page 169 refers

Rufforth Airfield was inadvertently referred to as RAF Rufforth when the March Bulletin was sent for printing. The location of the accident should have read:

Field near Rufforth Airfield, York

not

Field near RAF Rufforth, York

The online version of this report was amended prior to publication.

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

2/2014 Eurocopter EC225 LP Super Puma
G-REDW, 34 nm east of Aberdeen,
Scotland on 10 May 2012
and
G-CHCN, 32 nm south-west of
Sumburgh, Shetland Islands
on 22 October 2012.

Published June 2014.

3/2014 Agusta A109E, G-CRST
Near Vauxhall Bridge,
Central London
on 16 January 2013.

Published September 2014.

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.

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
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European 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)
FDR	Flight Data Recorder
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)
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
TGT	Turbine Gas Temperature
TODA	Takeoff Distance Available
UAS	Unmanned Aircraft System
UHF	Ultra High Frequency
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

Air Accidents Investigation Branch