AAIB Bulletin 1/2022

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AAIB Special Bulletins and Interim Reports

This section contains Special Bulletins and Interim Reports that have been published since the last AAIB monthly bulletin.

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AAIB Air Accidents Investigation Branch

AAIB Bulletin S2/2021 *SPECIAL*

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-8K5, G-FDZF
No & Type of Engines:	2 CFM56-7B27/3 turbofan engines
Year of Manufacture:	2008 (Serial no: 35138)
Date & Time (UTC):	11 September 2021 at 1240 hrs
Location:	Aberdeen Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 67
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	15,490 hours (of which 1,524 were on type) Last 90 days - 67 hours Last 28 days - 62 hours
Information Source:	AAIB Field Investigation

Introduction

At 1341 hrs on 13 September 2021, the AAIB was informed that a serious incident had occurred to Boeing 737-800, registration G-FDZF, during a go-around at Aberdeen Airport on 11 September 2021. The AAIB began an investigation assisted by the operator, the National Transportation Safety Board in the USA, and the aircraft manufacturer.

During the go-around, which was initiated at 2,250 ft amsl, the aircraft initially climbed, but just before it reached the cleared altitude of 3,000 ft amsl it began to descend. It descended to 1,780 ft amsl (1,565 ft agl) with a peak rate of descent of 3,100 ft/min, and it accelerated to an airspeed of 286 kt (the selected airspeed was 200 kt) before the crew corrected the flightpath.

The pilots of G-FDZF, like many other pilots, had not flown for significant periods during the 18 months before this incident. Although the investigation has not established a link between this incident and a lack of recent line flying, it is clearly a possibility. Therefore, this Special Bulletin is published to raise awareness of this event and to highlight that go-arounds from intermediate altitudes on an approach can provoke errors because they are not practiced frequently.

History of the flight

The crew of G-FDZF had operated a passenger flight from Newcastle International Airport to Palma de Majorca before operating the incident flight from Palma to Aberdeen Airport. The aircraft departed Palma at 1047 hrs with 67 passengers and 6 crew on board. At 1230 hrs the flight crew established contact with Aberdeen Radar for a radar vectored CAT I ILS approach to Runway 34 at Aberdeen. At 1235 hrs, as the aircraft was descending through 5,100 ft amsl, the crew were informed by ATC that there was a possibility that they may have to discontinue the approach, in which case they should expect a climb straight ahead to 3,000 ft amsl. This was because a search and rescue helicopter, which was currently on the ground at the airport, would take priority once airborne.

The crew established the aircraft on the localiser and glideslope at 3,000 ft amsl with the aircraft configured with the gear down and flap 15. A single autopilot was engaged, as was the autothrottle. At 2,600 ft amsl the aircraft was instructed by the radar controller to break off the approach, climb to 3,000 ft and turn left onto a heading of 270°. Eighteen seconds later, at 2,250 ft amsl, the aircraft began to climb towards the cleared altitude and began a left turn towards the heading. As the aircraft approached 3,000 ft amsl, the aircraft began to descend before the criteria were met for the flight director to transition from ALT ACQ[1] to ALT HOLD[2]. Further heading instructions were passed by ATC while the aircraft descended to a minimum altitude of 1,780 ft amsl, corresponding to 1,565 ft agl, after which a climb was re-established. The descent rate peaked at 3,100 ft/min as the aircraft passed 2,160 ft amsl. Figure 1 shows the aircraft's flightpath.

The tower controller noted on the radar repeater in the visual control room that the aircraft was descending unexpectedly and contacted the radar controller to advise him. This prompted the radar controller to contact the crew, instructing them to climb to 3,000 ft amsl. This call came just as the crew began to pitch the aircraft back into a climb. During the recovery the aircraft speed reached 286 KIAS[3], whereas the speed the crew had selected was 200 KIAS. As the aircraft passed through 3,000 ft amsl the crew re-engaged the autopilot and the flight path stabilised. The entire event occurred with the aircraft in IMC.

Footnote

1 ALT ACQ is a transition mode entered automatically from a climb or descent when nearing a selected altitude demand.

2 ALT HOLD commands pitch to hold the selected altitude. Successful engagement of ALT HOLD requires the altitude difference between the selected altitude and the aircraft's actual altitude to be less than 60 ft and the aircraft's rate of climb or descent to be less than 300 ft/min.

3 Aberdeen Control Zone/Area is Class D airspace, and the speed limit is therefore 250 KIAS below FL100 as described in the UK Aeronautical Publications (AIP) Part 2 – En-Route (ENR), Section 1.4, Paragraph 2.4.

The aircraft was then given a further climb, before being radar vectored for another approach to Runway 34. The subsequent approach and landing were completed without further incident.

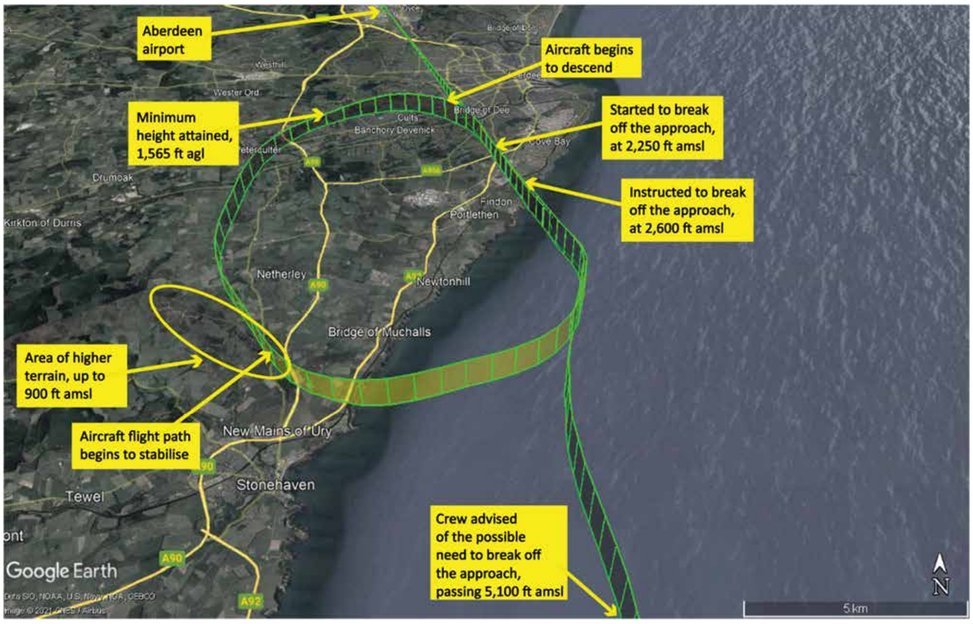


Figure 1

G-FDZF's flightpath into Aberdeen and the unintended descent

B737-800 Go Around Mode

The Boeing 737-800 is a dual autopilot, CAT III capable aircraft. Normal procedures, as outlined by the manufacturer, require the use of a single autopilot on an ILS approach unless the intention is to conduct a CAT II or III approach and landing. Automatic go-arounds are only available from a dual autopilot approach. The autopilot/flight director go-around mode is engaged by pressing the Takeoff/Go-around (TO/GA) switches. Pressing either of the switches when the engagement criteria are met will disconnect the single autopilot (if connected) and place the flight directors in go-around mode. The autothrottle (if engaged) will move to go-around thrust[1], and the flight directors will then command 15º nose-up pitch until the aircraft reaches a programmed rate of climb. Flight director pitch commands then target airspeed for each flap setting, based on a maximum takeoff weight calculation.

Recorded data

The aircraft's Cockpit Voice Recorder had been overwritten because the aircraft remained in service before the AAIB was notified of the event and the investigation began, but the data

Footnote

[1] Below 2,000 ft radio altitude, one press of a TO/GA switch will cause the autothrottle (if engaged) to advance to a power setting for a climb rate between 1,000 and 2,000 ft/min. With two presses of a switch, the autothrottle (if engaged) will advance to the full go-around N1 limit. Above 2,000 ft radio altitude, one press of a TO/GA switch commands thrust to the full go-around N1 limit (although this is not included in the Flight Crew Operating Manual and was unexpected by the crew).

from the operator's flight data monitoring (FDM) provider was available, as well as radar and R/T recordings from Aberdeen. Figure 2 shows a summary of the FDM data for the approach and the subsequent unintended descent. The four shaded areas are described below.

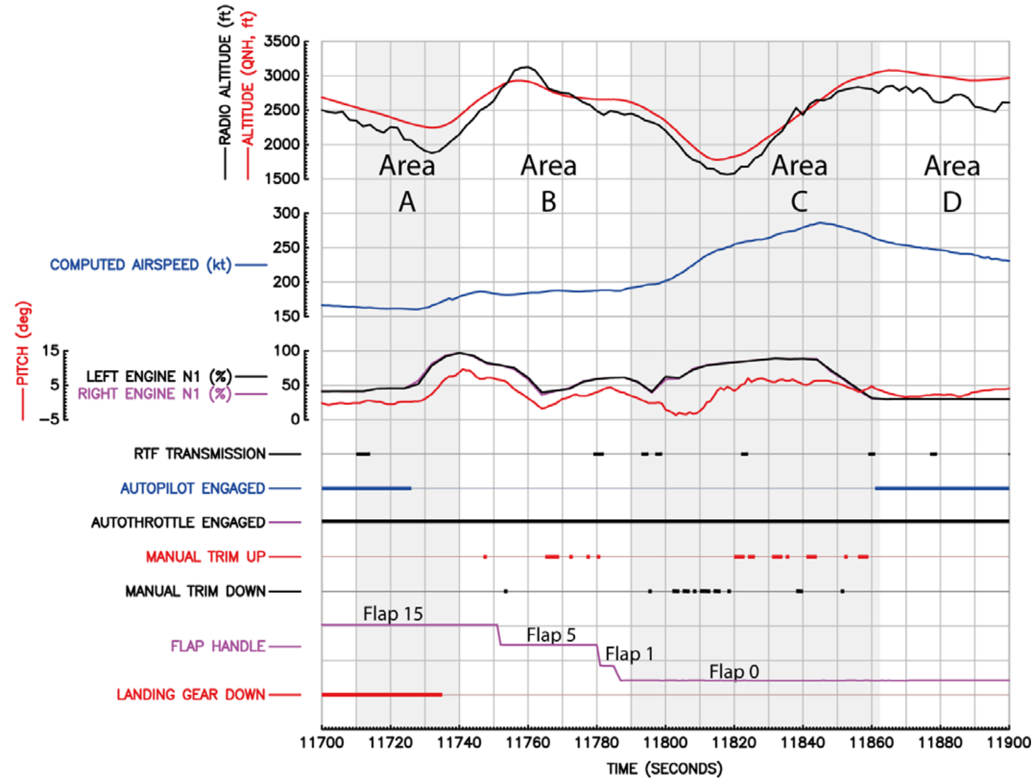


Figure 2

Flight data for the approach and subsequent unintended descent

Area A shows the flightpath from when the crew responded to the ATC instruction to break off the approach and shows the disconnection of the autopilot as the TO/GA mode was activated. It shows that the landing gear was retracted, the thrust increased towards the full go around N1 limit and the aircraft's pitch attitude increased as the aircraft climbed. Note the strong correlation between the changes in the pitch of the aircraft and engine power setting. No manual pitch trim inputs were observed in the data.

Area B shows that as the aircraft approached the selected altitude of 3,000 ft, the pitch of the aircraft decreased and the autothrottle reduced the engine power setting in anticipation of the level-off being commanded by the flight director. As the aircraft reached this point, the flaps were retracted from flap 15 to flap 5 and the aircraft then descended having failed to meet the criteria for the flight director to transition to ALT HOLD. The flaps were then further retracted from flap 5 to flap 1 and from flap 1 to flap 0 during the descent."

Area C shows the lowest altitude reached by the aircraft before it climbed again, and the peak airspeed. The climb occurred at about the same time as the crew replied to the ATC instruction to climb.

Area D shows the autopilot re-engagement and the flight path of the aircraft stabilising.

Crew recency

The crew of G-FDZF differed in their recency levels but both had experienced significant periods without flying in the preceding 18 months. The commander had flown 10 flights during the previous month. For the co-pilot, this was only his fourth flight in nearly 11 months having completed two flights with a trainer seven days before the day of this incident. Both pilots had completed numerous simulator sessions during the 18-month period to gain or retain recency or to complete their annual recurrent check.

Airlines have faced significant challenges in the last 18 months to keep crews current. Whilst there are legal requirements for crews to complete three takeoffs and landings within 90 days, there are no regulatory requirements laid out for crews to have actually operated the aircraft, especially on commercial flights. Operators have had to adapt and develop their own programmes to ensure that crews are prepared and competent to fly, often after significant periods away from the aircraft.

Simulators have been used not just for the takeoff and landing requirements but also to try and maintain crew skill levels when operating in both normal and emergency situations. The challenge has been, and is, to try and represent the real world of flying in a simulated environment. It can be difficult in the simulated environment to replicate moments of high crew workload caused by the effects of ATC instructions and background communications, the presence of other aircraft in the area, poor weather and other operational pressures. The safety benefits of simulator training are well established. However, the real-world environment creates different demands on crews, and it is possible that this event illustrates that lack of recent exposure to the real-world environment can erode crews' capacity to deal effectively with those challenges. Regulators have been concerned that pilots returning to the flight deck following extended periods without flying could be at risk of performing below their normal standard during their first few flights. Although this investigation has not established a link between this event and a lack of line flying, this Special Bulletin is published for awareness and because a link is clearly one possibility.

Other go-around incidents

Two-engine go-arounds can be difficult manoeuvres for crews to fly properly because they are often unexpected and are only encountered infrequently during line flying and simulator training. The AAIB has investigated other go-around incidents which have similarities to G-FDZF[1] and the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) recently published a report into a similar incident at Paris Orly Airport[2].

Footnote

1 Report into the serious incidents involving G-THOF, https://www.gov.uk/aaib-reports/aar-3-2009-boeing-737-3q8-g-thof-23-september-2007 (accessed November 2021), and I-NEOT, https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-737-86n-i-neot (accessed November 2021).

2 https://www.bea.aero/en/investigation-reports/notified-events/detail/serious-incident-to-the-boeing-737-registered-7t-vjm-operated-by-air-algerie-on-06-12-2019-at-paris-orly/ (accessed November 2021).

Aircraft deviation from the expected flightpath

The aircraft descended from close to 3,000 ft for 57 seconds before a climb was re-established, and this represented a significant deviation from the crew's expected flightpath. There was a high rate of descent, which was reducing the aircraft's separation from terrain, and an uncommanded and undesirable increase in airspeed that were not corrected in a timely manner.

Further work

The investigation continues to examine all pertinent operational, technical, organisational and human factors which might have contributed to this serious incident. In particular, work will be undertaken to:

- Assess the impact of the lack of recent flying on the actions of the crew.
- Assess the effectiveness of the barriers to crews recognising that there has been a significant deviation from the expected flight path.
- Ensure the flight director behaved as expected.
- Consider the effect of ATC instructions during the go-around and, subsequently, during periods of high crew workload.

Published: 2 December 2021.

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:	Airbus Helicopters AS355 F1, G-BOSN
No & Type of Engines:	2 Rolls-Royce 250-C20F turboshaft engines
Year of Manufacture:	1982 (Serial no: 5266)
Date & Time (UTC):	2 March 2021 at 1100 hrs
Location:	Bourne End, Buckinghamshire
Type of Flight:	Commercial Operations
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Fire damage to right engine cowling and to engine bay wiring
Commander's Licence:	Commercial Pilot's Licence (Helicopters)
Commander's Age:	54 years
Commander's Flying Experience:	5,150 hours (of which 835 were on type) Last 90 days – 39 hours Last 28 days – 20 hours
Information Source:	AAIB Field Investigation

Synopsis

Whilst hovering at 20 ft agl smoke was observed coming from the engine exhaust. A member of the operational team on the ground informed the pilot, who then landed immediately. A fire warning subsequently illuminated, and the pilot activated the fire extinguishing system. The fire was determined to have been caused by the loss of retention of the right engine inboard exhaust nozzle, which was released because of the failure of its securing clamp. The released nozzle had blocked the overboard exhaust outlet and allowed hot exhaust gases to impinge on the engine cowlings leading to local overheating.

The clamp failure was attributed to a combination of an incorrect locking washer being fitted during maintenance and elevated engine vibration which caused the clamp to loosen. A crack then propagated in low-load high-cycle fatigue until final rupture of the clamp.

The helicopter manufacturer is taking safety action to amend the Aircraft Maintenance Manual (AMM) highlighting the correct installation of the clamp.

History of the flight

The helicopter was operating on a film set at Hedsor House having been positioned on location the previous day. The pilot arrived at the site at 0650 hrs and carried out a pre-flight inspection of the helicopter. He then conducted a safety briefing with the Aerial

Coordinator[1] and staff from the production company, the Unmanned Aircraft System (UAS) operator and the company providing fire cover.

The first sequence of filming required the helicopter to be running on the ground while an actor approached and boarded through the right door. The pilot started only the left engine for this task, which lasted approximately 15 minutes and involved several 'takes'. Movement around the helicopter was under the control of the Aerial Coordinator and the pilot who were in radio contact with each other. On conclusion of these takes, the helicopter was shut down and the pilot and production staff prepared for a sequence of airborne filming.

The pilot gave a safety briefing to the stunt double who would occupy the left hand seat for the flight. At approximately 1035 hrs, the pilot started the aircraft and lifted into a 20 ft hover. After a short period of time, the Aerial Coordinator informed the pilot that smoke was coming from the rear of the helicopter. The pilot noted that there were no abnormal indications in the cockpit but decided to make a precautionary landing.

Just prior to the helicopter touching down, the Aerial Coordinator informed the pilot that the smoke appeared to be getting worse. The pilot continued with the landing and, noting that the cockpit indications remained normal, shut down both engines. The pilot instructed the stunt double to exit the helicopter.

Approximately 10 to 15 seconds later the Aerial Coordinator radioed that flames were now visible at the engine exhaust. As he heard the radio transmission, the pilot noticed the FIRE RH warning light illuminate. He pressed the engine fire button, and the fire bottle discharged its contents into the engine bay extinguishing the flames and the warning light cleared. The pilot completed the shutdown checks and exited the helicopter. There were no injuries.

Accident site

Prior to the AAIB arriving on site, the pilot and an engineer from a helicopter maintenance organisation examined the right engine bay and found that the inboard exhaust nozzle from the right engine had become detached, and that the clamp that secured the nozzle to the engine had failed. The detached exhaust nozzle had lodged in the aircraft-mounted exhaust tube, blocking it. The detached nozzle and the failed clamp were removed from the aircraft by the maintenance engineer.

The helicopter, having made a precautionary landing, was positioned on its skids in the grounds to the south of Hedsor House (Figure 1). Apart from paint blistering of some of the right engine cowls (Figure 2) and melting of the cowl latches, the external appearance of the helicopter was unremarkable.

Footnote

[1] The Aerial Coordinator provides safety oversight and liaison between the film production company and the pilot. In this case the Aerial Coordinator was based on the ground.

Figure 1

G-BOSN after landing

Figure 2

Paint blistering on engine cowling adjacent to right engine inboard exhaust tube

The right engine bay showed signs of elevated temperatures with melting of electrical connector back shells and harness clipping anti-fret material. The starter generator overboard duct had also deformed. The condition of the internal panel forward of the inboard exhaust outlet suggested that the panel had been on fire (Figure 3).

Figure 3

Evidence of fire damage on engine cowl viewed looking forward through right inboard airframe mounted exhaust duct

There was no evidence of fire in the left engine bay.

Recorded information

Video footage of the incident flight was made available to the investigation by the production company. Examination of the footage identified that 30 seconds prior to the helicopter lifting some smoke was emanating from around the engine exhaust; blistering of the paint on the upper engine cowl could also be seen. The smoke remained relatively light until the engine power was increased for takeoff. As it did so, the smoke became more pronounced. The helicopter was seen to enter a hover and then landed approximately 40 seconds later and 5 m forward from where it had lifted off.

The helicopter did not have either a flight data recorder or a cockpit voice recorder fitted, nor was it required to have them.

Aircraft information

The AS355F1, 'Twin Squirrel', is a twin-engine light utility helicopter developed by Airbus Helicopters (formerly Aérospatiale), France, in the late 1970s; the F1 variant first being certified in 1983.

The F1 variant is powered by two Rolls-Royce (formerly Allison) 250-C20F engines, each mounted to the rear of the main gearbox, side by side, on anti-vibration bases. The engines are mounted in separate fireproof compartments.

The engine is an assembly of four modules as follows: the compressor, gearbox, turbine and combustion modules (Figure 4). Air passes through the compressor and then rearward via external passageways to the rear of the combustion chamber. The air then enters the combustion chamber where fuel is introduced and burned. The combustion gases then move forward through a two-stage gas producer turbine, followed by a two-stage power turbine. The engine exhaust collector is located to the rear of the gearbox module and directs the exhaust gases through two exhaust outlets located at approximately 45° either side of the top of the engine.

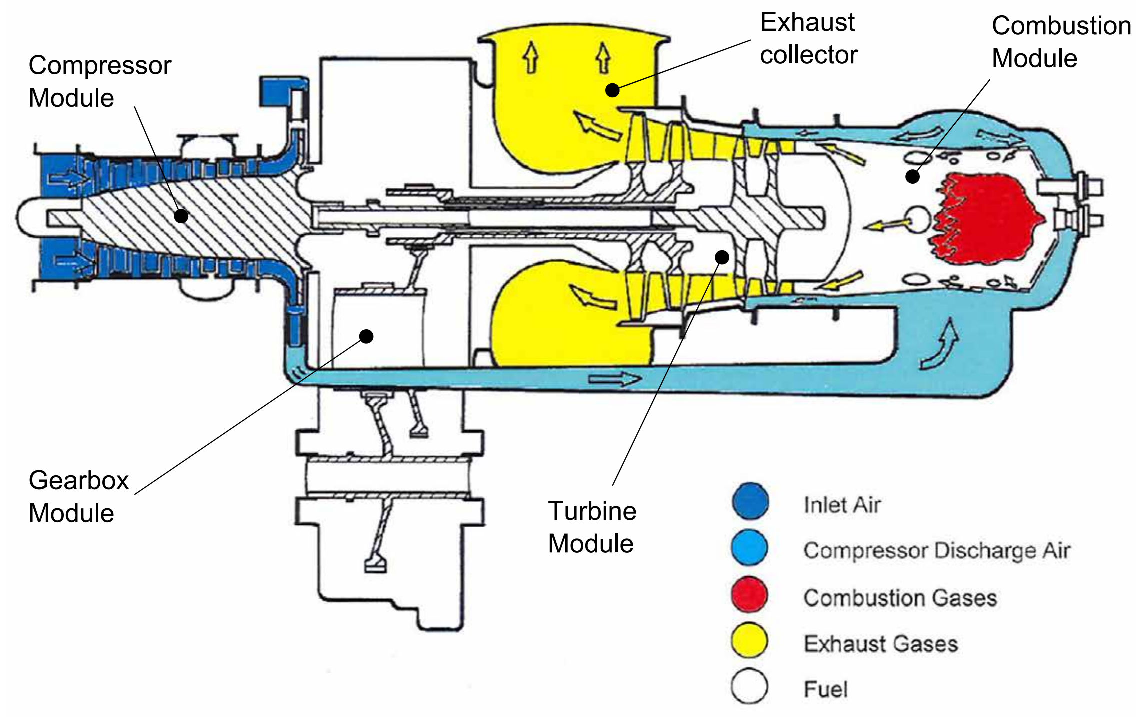


Figure 4

Rolls-Royce 250-C20F engine airflow schematic (reproduced with permission)

Two exhaust nozzles, supplied by the helicopter manufacturer, are clamped to the engine exhaust collector outlet flanges (Figure 5). These direct the exhaust gases rearwards. The inboard nozzle directs its exhaust gases through an airframe mounted exhaust tube, whereas the outboard nozzle exhausts directly to atmosphere (Figure 6).

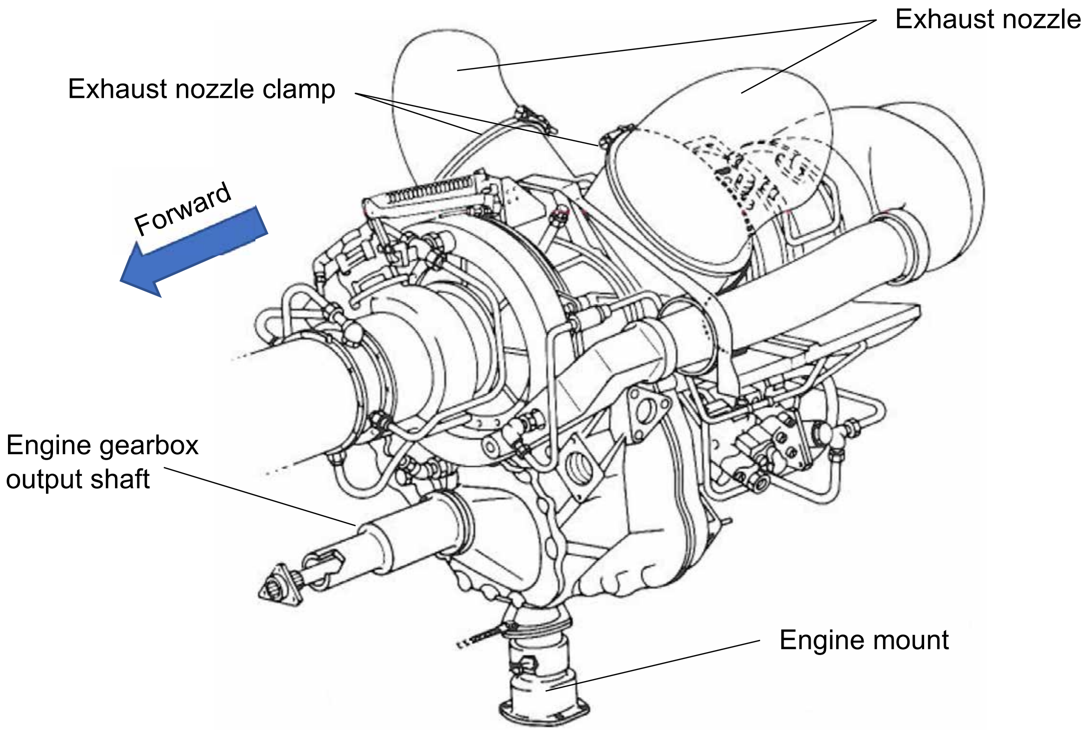


Figure 5

Rolls-Royce 250-C20F engine installation (reproduced with permission)

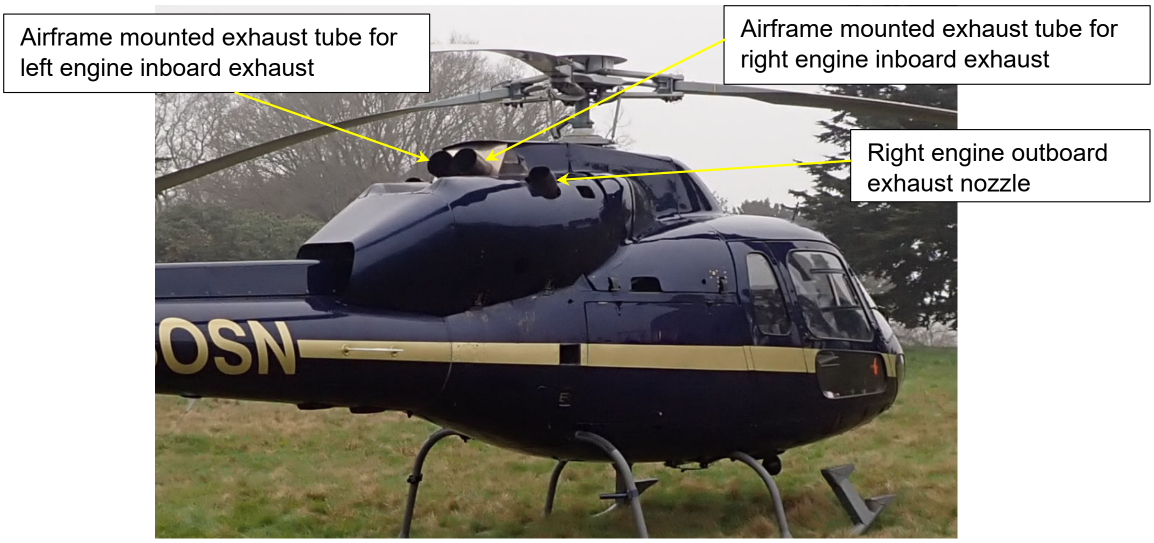


Figure 6

AS355F1 showing position of exhaust nozzles

Each exhaust nozzle is held in place with a 'V-band' clamp (Figure 7), which is also supplied by the helicopter manufacturer, incorporating a corrugated 'V' mounted on a tightening band. The band is secured in place with a screw tightened locking mechanism. The Illustrated Parts Catalogue (IPC) identifies the clamp with part number (p/n) F1N170V and a locking washer with p/n 350A57-1058-21. The clamp, which is released with a Certificate of Conformity, is supplied with a serrated locking washer that should be removed and replaced with the locking washer with p/n 350A57-1058-21. Locking washer p/n 350A57-1058-21 is not supplied with the clamp and must be ordered separately. Figure 8 shows an installed clamp with lock washer p/n 350A57-1058-21 fitted. The AMM MET 71-00-00-401 '*Removal – Installation – C20F Allision engine*' paragraph G.2. Installation, when referring to the installation of the exhaust nozzles, instructs:

'(4) Make sure that:

(a) the axis of the exhaust nozzle attachment clamp screw is positioned at the internal upper part of the engine and is parallel to the engine axis of symmetry,

(b) the locking washer is installed.'

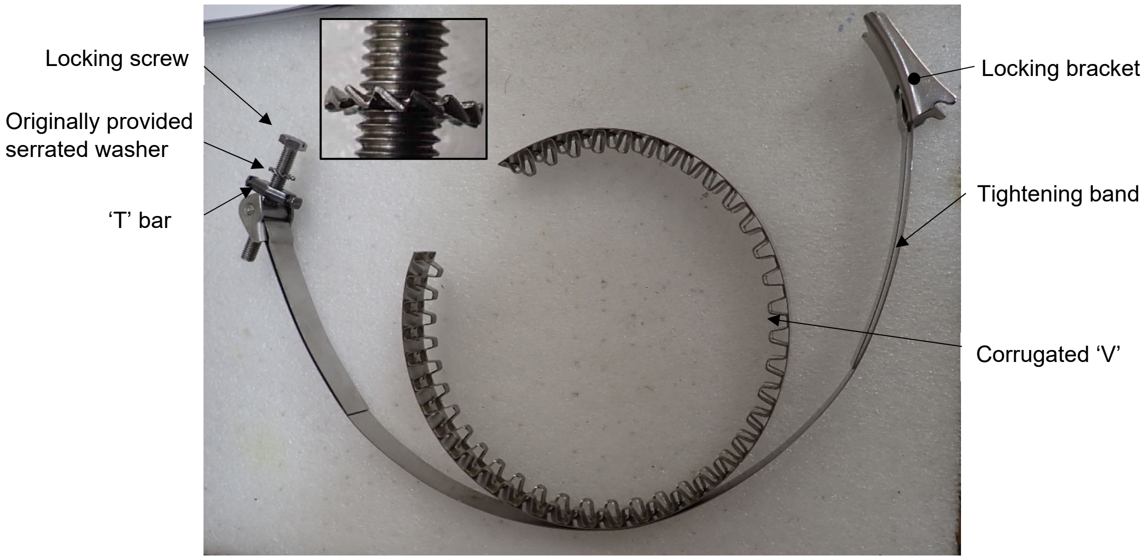


Figure 7

As supplied V-band clamp, inset showing serrated washer that must be removed prior to installation on the helicopter

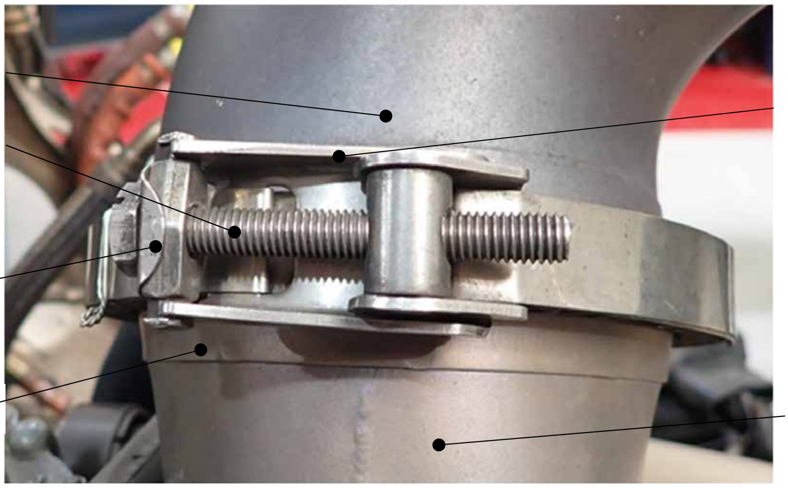


Figure 8

Exhaust nozzle clamp correctly installed

Aircraft maintenance

G-BOSN had recently been subject to a 6 month, 100 hour/12 month, 1,200 hour/28 month airframe inspection as well as the engines having their 100 hour inspections. At this time the right engine was removed from the aircraft due to a 'chip indication'[2]. The gearbox and turbine modules were returned to an engine overhaul facility where some gearbox components were found to have been worn and were determined to be the cause of the chip indication. The gearbox module was repaired accordingly. Both the turbine and gearbox modules were returned and refitted to the engine and the engine installed in the helicopter. When the engine was installed in the helicopter the exhaust nozzles were refitted. This involved refitting of the exhaust nozzle clamps.

After the right engine had been installed an installation ground run was completed and the aircraft returned to the operator. The maintenance organisation identified elevated magnetic chip detector readings, however associated them with the recent maintenance, with no further action required. This incident occurred 2.6 hours after the engine installation.

Previous clamp failure

Some 335 hours prior to the subject incident, the clamp securing the right engine inboard exhaust nozzle on G-BOSN failed. This event was not reported by the operator or maintenance organisation and was therefore not investigated. A replacement clamp was fitted to the engine on 22 December 2017 and was supplied to the maintenance organisation with two additional lock washers, p/n 350A57-1058-21. It is likely that the new clamp which was fitted at this time is the clamp that subsequently failed in this event; as the four clamps fitted to the aircraft are interchangeable and not traced, it was not possible to verify this.

Footnote

[2] This type of engine is fitted with an electronic chip detector. When debris is identified in the engine oil system a light comes on in the cockpit.

Aircraft examination

The helicopter was road transported to a helicopter maintenance facility where further assessment could be carried out. Closer examination of the engine cowling forward of the inboard exhaust confirmed that a fire had been present and melting of the engine harness sheathes was also evident. The exhaust clamp was recovered from the maintenance engineer who had removed it from the aircraft and passed to a metallurgical laboratory for detailed examination.

Metallurgical assessment of the clamp, p/n F1N170V

Laboratory examination of the clamp identified that the fracture occurred in the tightening band adjacent to the locking bracket (Figure 9). The fracture surface exhibited features consistent with low-load high-cycle fatigue crack propagation with the fatigue crack propagating across 97% of the width of the band. The remaining fracture surface, measuring approximately 0.5 x 0.5 mm, exhibited features associated with ductile overload (Figure 10) signifying very low load during the final rupture of the clamp.

Figure 9

Clamp bracket and tightening band showing location of crack initiation

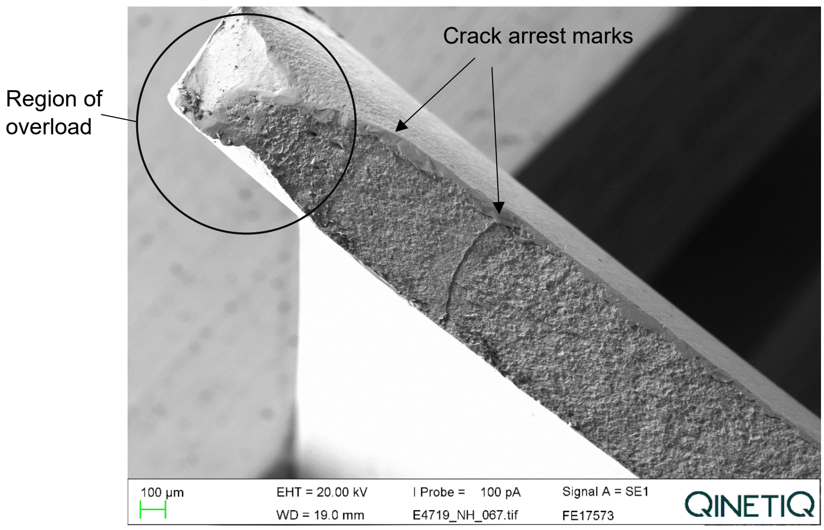


Figure 10

Tightening band showing area of ductile overload and crack arrest marks

Assessment of the fatigue surface found that the crack initiated on the edge of the outer surface of the tightening band, adjacent to the edge of the locking bracket. Mechanical damage on the outer surface of the band (Figure 11) adjacent to the crack initiation location, may have acted as a stress concentration for the initiation of the fatigue crack. The cut edge of the tightening band in this area exhibited features suggesting that it had been guillotined during manufacture (Figure 12). This unfinished surface may also have influenced the initiation of the fatigue crack. Significant staining (Figure 13) at the crack initiation location indicates that the crack may have been present prior to the incident flight. The remainder of the fracture surface showed consistent colouring with very few crack arrest marks, indicating that the crack growth was likely to have occurred during recent operation. The band material was assessed to be consistent with the grade and hardness for the stainless steel specified by the manufacturer.

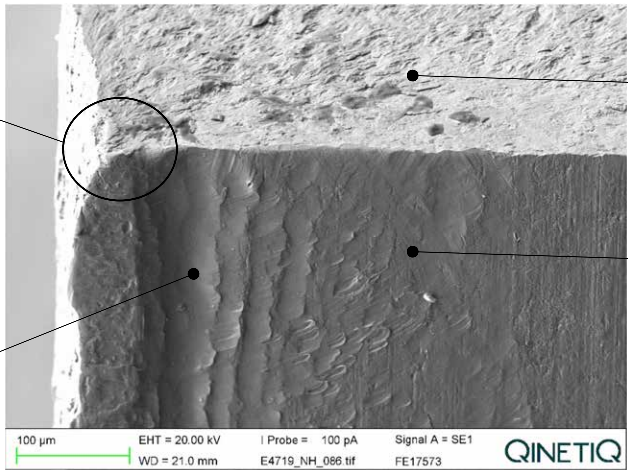


Figure 11

Edge of tightening band in the location of crack initiation

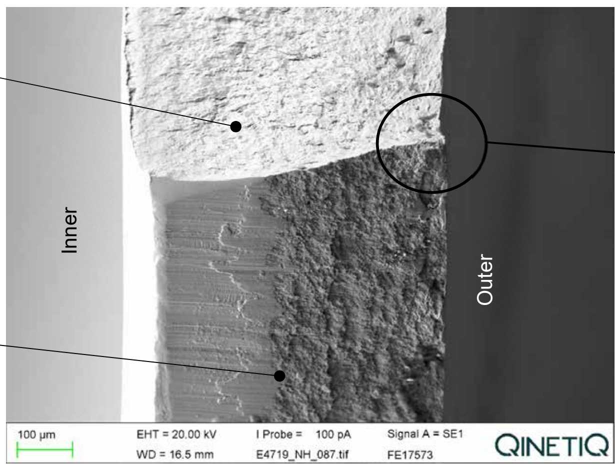


Figure 12

Edge of tightening band in the location of crack initiation

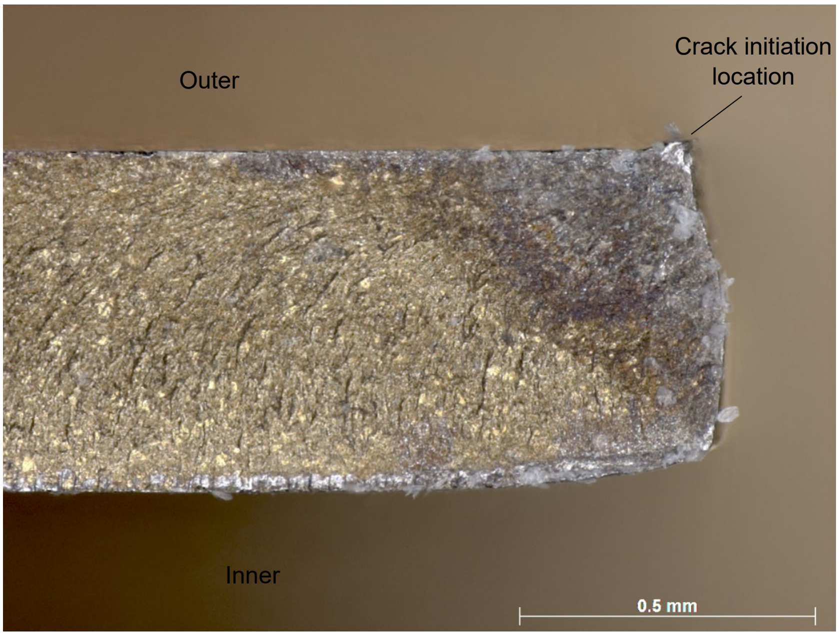


Figure 13

Tightening band fracture surface showing area of crack initiation staining

Examination of the clamp identified that it had been fitted with a serrated locking washer under the head of the locking screw. This washer was further examined and found to have evidence of gouging on all serrations and one of the serrated tabs had cracked (Figure 14). The lock washer, p/n 350A57-1058-21, was not fitted.

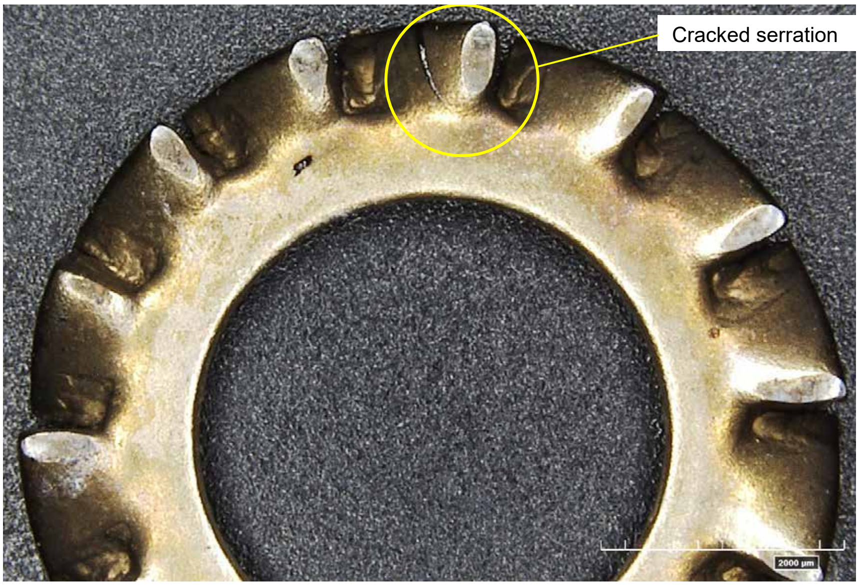


Figure 14

Serrated washer fitted to failed exhaust nozzle clamp

There were no markings on the clamp to confirm part number, batch number or manufacturing date.

Other information

Post-incident helicopter maintenance

A right engine chip caution illuminated during a post-incident maintenance ground run. Further ground running by the maintenance organisation also found an engine was operating close to vibration limits of 1.0 Inches Per Second (IPS) and was therefore rejected.

The engine's gearbox, turbine and compressor modules were returned to the engine overhaul facility for examination. This found that the compressor bearing was in poor condition and was likely to have contributed to the engine chip indication and increased vibration.

Observations from helicopter maintenance organisation

In comparison to other engine installations on similar helicopter types it was identified that the AMM for the AS355 F1 utilising the Rolls-Royce 250 engine only requires the exhaust nozzle clamp to be torque tightened when it is installed, whereas other installations required exhaust clamps to be re-torqued after the engine had been run.

Analysis

The investigation confirmed that a fire had occurred in the right engine bay. This was caused by heating of the engine cowling which was due to exhaust gases being directed onto the area. The right engine inboard exhaust nozzle was found to have been released due to the failure of its retaining clamp. It was found to have been blocking the airframe mounted exhaust tube, directing engine exhaust gases back into the engine bay and onto the engine cowling. Laboratory analysis of the retaining clamp found that a crack had propagated across its tightening band in low-load, high-cycle fatigue. It failed in overload when there was an approximate area of 0.25 mm^2 of material remaining.

The fatigue propagation mechanism and small region of overload fracture on the fracture surface suggests that the failure of the clamp was associated with the clamp becoming loose. The loosened clamp was then able to vibrate, exciting the clamp and allowing the crack to propagate. It is likely that mechanical damage, possibly associated with the clamp manufacture, acted as a stress concentrator, and served to initiate the fatigue crack.

The clamp loosening was likely to have been associated with the incorrect locking washer being fitted. The serrated locking washer which was originally supplied with the clamp should have been removed and replaced with a tab locking washer, p/n 350A57-1058-21, before fitting the clamp. The condition of the serrated washer indicates that it had been tightened multiple times as the serrations had flattened, and one of the serrations had cracked. This will have reduced its ability to maintain the locking screw in its position.

Some 2.6 hours before the incident, the helicopter was subject to routine maintenance inspections. At that time the right engine was removed because of a chip indication and the engine gearbox was repaired due to worn components. Subsequent engine ground running identified some metal on the magnetic chip detector, which was considered normal for a recently rebuilt engine, so the engine was released to service. Following rectification of the fire damage, the engine was reinstalled and generated metal debris during ground running. When a vibration survey was completed it was found that, whilst the engine vibration was close to the upper threshold, it remained within the engine manufacturer's in-service operating limits. The engine was rejected and investigation by the engine maintenance organisation found that the compressor module bearings were damaged and was probably the cause of the chip indications.

With the high engine vibration identified after the incident, it is likely that the engine would have been vibrating at a similar level during the 2.6 hours between the scheduled maintenance and the incident.

The combination of the reduced locking capability, due to the multiple re-tightening against the incorrect washer, and the elevated engine vibration are likely to have caused the locking screw to have backed off and allowed the clamp to vibrate resulting in its failure.

The IPC for the helicopter identifies the locking washer part number 350A57-1058-21 as part of the assembly; however, the maintenance manual only instructs to *'ensure the locking washer in fitted*'. With the clamp being supplied with a locking washer as part of the assembly, albeit the incorrect one, it is possible that a maintenance engineer could be satisfied that the correct washer was being used. It is likely that the incorrect washer was installed when the clamp was originally fitted in 2017 and not noticed to be incorrect when the clamp was refitted prior to the incident.

Additionally, there is a possibility that the clamp could become loose during the post-installation ground run. There was no requirement in the AMM to re-torque the locking screw after the ground run, but if there had been this may have provided an additional means to maintain the clamping load on the exhaust nozzle.

Conclusion

The engine bay fire was caused by the loss of retention of the right engine inboard exhaust nozzle which, when released, blocked the overboard exhaust outlet and allowed exhaust gases to impinge on the engine cowlings.

Elevated engine vibration, in combination with the fitment of an incorrect locking washer on the exhaust nozzle clamp screw, was sufficient to allow the screw to back off and allow the clamp to vibrate. The vibration was sufficient to cause a fatigue crack to propagate, ultimately causing the clamp to fail and allow the release of the exhaust nozzle.

Safety actions

As a result of this investigation the helicopter manufacturer is taking Safety Actions to ensure the correct washer is fitted when installing the exhaust nozzles to the engines as follows:

> The helicopter manufacturer is amending the AMM to clarify the engine exhaust nozzles installation working card to:
>
> - Check the condition of the exhaust clamp (absence of cracks, etc.)
> - Check if the serrated washer delivered with the clamp is replaced by the tab washer
> - Introduce an installation drawing depicting the correct installation of the clamp and its tab washer
> - Check if the tab washer is properly installed and bent according to the installation drawing
> - After installation, complete a ground run and then re-adjust the tightening torque to ensure correct tightness.

Published: 16 December 2021.

AAIB Correspondence Reports

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

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

The accuracy of the information provided cannot be assured.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A319-111, G-EZBD	
No & Type of Engines:	2 CFM CFM56-5B5/P turbofan engines	
Year of Manufacture:	2006 (Serial no: 2873)	
Date & Time (UTC):	13 July 2021 at 1048 hrs	
Location:	London Luton Airport	
Type of Flight:	Commercial Air Transport (Non-Revenue)	
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:	32 years	
Commander's Flying Experience:	4,412 hours (of which 4,272 were on type) Last 90 days - 16 hours Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft carried out a high speed rejected takeoff above V_1 speed due to a discrepancy between the commander and co-pilot's airspeed indications. The discrepancy occurred because of a blockage in a pitot tube following a long period on the ground.

History of the flight

The aircraft had last operated a commercial sector on 14 June 2021 when it had flown from Edinburgh Airport to Luton Airport. The aircraft was then parked at Luton until 13 July 2021, when it was scheduled for a non-revenue flight after a period of long-term parking.

The pilots were aware that the aircraft had been parked for a protracted period and had heard of aircraft suffering issues with blocked pitot tubes in similar circumstances. During their briefing they discussed crosschecking the airspeed indications at 80 kt and emphasised the need to make any discrepancy of more than 20 kt clear to each other.

The pushback, engine start and taxi out were uneventful and there were no indications of any instrument malfunctions. The aircraft positioned for a departure from intersection H on Runway 07 at Luton (Figure 1).

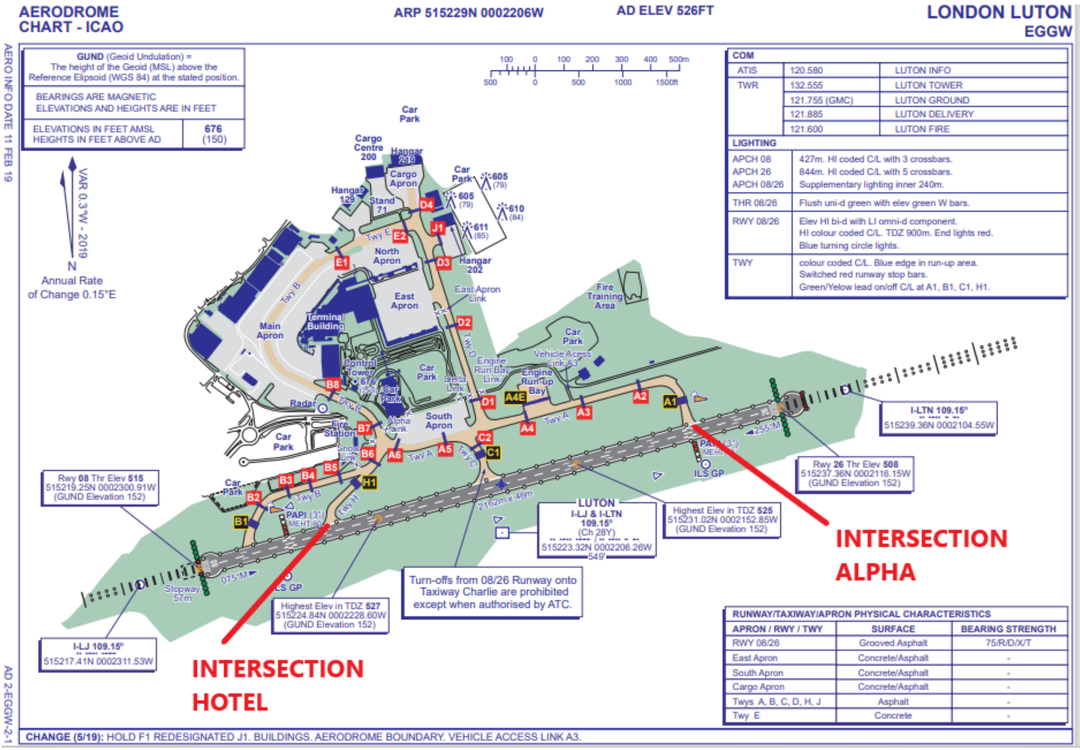


Figure 1

Luton Airport Diagram

Once lined up on the runway centreline abeam the H holding point, the commander set 50% thrust and stated that the engines took longer to spool up than normal, especially engine No 1. Once 50% thrust was set, the commander set takeoff thrust and read out the Flight Mode Annunciators. He noted the aircraft was already travelling at approximately 55 kt before the co-pilot had confirmed the thrust was set. During the acceleration the co-pilot cross checked his airspeed indications with the Integrated Standby Instrument system (ISIS), something which the crew had discussed during their briefing. When he first checked the ISIS it showed approximately 60 kt. He checked the Primary Flight Display (PFD) and noted it still indicated 40 kt. He immediately rechecked the ISIS and it had increased to approximately 80 kt. At 80 to 90 kt, the co-pilot told the commander that his airspeed indication was still reading 40 kt. The commander then checked the co-pilot's PFD to confirm that the speed was still at 40 kt and not increasing. The minimum airspeed indicated on the PFD is 40kt.

The commander glanced outside to check they were still on the centreline and how much runway remained before checking his own PFD, which was now above 100 kt and accelerating very quickly. V_1 had been calculated as 109 kt so the commander "made a very quick decision to reject and at V_1 called STOP and initiated the rejected take off procedure moments later". The RTO was carried out in accordance with SOP, except the co-pilot was unable to make a call at 70 kt due to his inoperative airspeed indication. The aircraft came to a stop abeam the A taxiway (Figure 1), approximately 350 m from the end of the runway. After confirming an evacuation was not required, the aircraft was taxied off the runway and back to stand.

Personnel information

Both pilots had done relatively little flying in the three months preceding the event. The commander had flown 12 hours 31 minutes in the preceding 90 days and only 37 minutes in the preceding 28 days. The co-pilot had flown 14 hours 45 minutes in the preceding 90 days and 12 hours 31 minutes in the preceding 28 days. The co-pilot stated in interview that he felt the lack of recency had been a factor in the event. The commander, however, felt that the lack of recency had not been a significant issue. Both pilots were aware of an Operational Engineering Bulletin which had been published concerning other blocked pitot events.

Recorded information

The operator provided the AAIB with a download of the FDR, CVR and Direct Access Recorder. The recorded data showed that after the thrust levers were advanced to the FLEX position, both engines accelerated symmetrically to the target thrust setting. As the aircraft accelerated, the CVR recorded the co-pilot stating that his airspeed was 40 kt. The takeoff was rejected at an indicated airspeed of 120 kt which was the same as the groundspeed. The aircraft decelerated and came to a halt approximately 350 m from the end of the runway.

Operator's examination of aircraft

The aircraft pitot systems were examined after the event and all appeared to be satisfactory. All three pitot systems were flushed in accordance with Aircraft Maintenance Manual (AMM) procedures. During the flush some debris was seen to be removed from the co-pilot's pitot system. The material was not recovered so the quantity and constituent of the debris could not be determined. Following the flush procedure, all the aircraft pitot systems were leak checked in accordance with AMM procedures and all were satisfactory.

The operator had maintenance procedures in place for placing aircraft into long term parking and recovering them from it. The procedures varied dependant on the length of the parking period but all the procedures required that pitot covers be fitted. The aircraft was parked on 14 June 2021 and the '*Parking Less Than One Month*' checks were carried out, recording the fitting of pitot covers. The aircraft was then subject to '*7 Day Checks*' on 21 June 2021, 27 June 2021, 3 July 2021 and 10 July 2021. Each of these required the removal of the pitot covers to allow the aircraft to be ground run and then for the covers to be installed at the end of the check.

Aircraft performance

The aircraft's takeoff weight was 41,000 kg, well below the maximum of 66,000 kg. Although the RTO was initiated 11 kt above V_1, due to the light weight the aircraft was within the field length limited performance and stopped with 350 m of runway remaining.

The flight data was reviewed by the engine manufacturer in light of the flight crew comments regarding engine acceleration. The manufacture concluded that the engine performance was within the expected parameters.

Meteorology

The Luton ATIS for the time of the event gave the following weather conditions:

> Wind 360º at 6 kt, visibility greater than 10 km, no significant weather, cloudbase 3,000 ft agl and temperature 14°C.

Analysis

The aircraft suffered a discrepancy between airspeed systems, which was identified during the takeoff roll through routine flight crew cross checks. Prior to the flight the crew had discussed company documentation relating to previous airspeed discrepancy events on other aircraft and so they were alert to the possibility. The co-pilot noticed a discrepancy between his PFD and the ISIS at approximately 60 kt. He rechecked the indications and confirmed that the PFD indications had remained at 40 kt and informed the commander by which point the ISIS was indicating between 80 and 90 kt. The aircraft was light and therefore accelerating very rapidly. The commander looked briefly across the cockpit to confirm the situation and then called "Stop." The aircraft airspeed was above 100 kt and increasing rapidly. As a result of the rapid acceleration, by the time the commander was able to articulate his order, the RTO was initiated at 120 kt, 11 kt above the calculated V_1. However, due to the light weight the aircraft was within the field length limited performance and stopped safely on the runway.

The debris from the pitot probe was not recovered, so it was not possible to determine the source of the material that obstructed the co-pilot's pitot probe. Recorded data showed that the calculated airspeed on the co-pilot's system remained at 0 kt throughout the event and so it is likely that the system was significantly blocked.

The engineering checks carried out on the aircraft before and during the parked period all recorded that pitot covers were fitted. It was not possible to determine when the pitot blockage occurred.

Conclusion

The aircraft suffered an airspeed discrepancy resulting from a blocked pitot probe. The crew recognised the fault and the takeoff was rejected.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-4Y0F, EC-MIE
No & Type of Engines:	2 CFM CFM-56-2CI turbofan engines
Year of Manufacture:	1992 (Serial no: 26069)
Date & Time (UTC):	16 June 2021 at 0104 hrs
Location:	East Midlands Airport
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to towbar and two landing gear tyres
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	11,750 hours (of which 9,570 were on type) Last 90 days - 120 hours Last 28 days - 11 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

After an uneventful pushback, the towbar was left on the taxiway in front of the aircraft. Soon after the aircraft commenced taxiing, its left landing gear went over the towbar. The missing towbar was noticed when the ground crew returned the tug to the towbar parking area. The aircraft was subsequently stopped from taking off to allow an inspection to take place. Damage was found to two landing gear tyres, which were replaced before the aircraft departed.

The investigation found that the ground crew did not complete some of their tasks or check the taxiway was clear before they left the area.

As a result of this incident the handing agent implemented several safety actions to make the ground crew's procedures more robust.

History of the flight

The aircraft was on a cargo flight from East Midlands Airport, Leicestershire, to Vitoria Airport, Spain. It was parked on Stand 99, on the West Apron. This is a 'nose-in' stand which requires a pushback prior to taxi. The ground crew in attendance for the pushback were a headset operative (HO) and a tug driver (TD). At the time, it was night.

The pushback and start up were uneventful. Once the pushback was completed the HO placed a chock in front of the nosewheel, to prevent the aircraft from moving, while the towbar and the HO's headset were disconnected. It is the HO's last task and responsibility to remove the chock and hand it to the TD, who places it in a basket on the tug, before walking off the taxiway. At this time the commander informed the HO that he was cleared to disconnect, and he would await the 'visual clearance', with the nosewheel steering bypass pin, on the right side of the aircraft.

Upon clearance from the HO, the TD reversed the tug slightly to allow the HO to disconnect the towbar from the tug. The HO then disconnected the towbar from the aircraft, removed the bypass pin and disconnected his headset. The TD turned the tug around and exited to re-connect the towbar to the rear of the tug, positioning the towbar on top of the rear attachment on the tug. However, before he secured it to the tug with a drop-in pin, he noticed that the HO was walking away from the aircraft with the chock still in front of the nosewheel. This was recorded on CCTV. The TD left the towbar on top of the attachment, went to the nosewheel, removed the chock and placed it in the basket on the tug. He then re-entered the tug and drove off the taxiway to collect the HO, without connecting the towbar to the tug. The towbar remained on the taxiway in front of the aircraft. Once the HO had given the crew the visual clearance, he entered the tug and the TD drove them to the towbar parking area, before the aircraft started to taxi, but without checking the taxiway was clear.

The crew received clearance from ATC to taxi towards Runway 27. Soon after the aircraft started to move, the co-pilot felt something similar to the toe brakes being applied momentarily. Upon asking the commander if he had checked the brakes, the commander said he had not. They did not see the towbar under the aircraft's nose prior to commencing the taxi, Figure 1.

Figure 1

EC-MIE and towbar just prior to taxiing

After the tug arrived at the towbar parking area, the HO got out to disconnect the towbar to discover it was not attached. Upon informing the TD he immediately drove back to Stand 99, without the HO, entering the taxiway without permission, and found the towbar in the taxiway with damage indicating that the aircraft had taxied over it, Figure 2. The TD immediately informed ATC and his supervisor, who informed airfield operations.

Figure 2
Towbar showing damage

Whilst the aircraft was waiting to depart at the holding point for Runway 27, ATC informed the crew that there had been an incident during the pushback and an inspection of the aircraft was required. Subsequently, they were informed by the handling agent that the aircraft had struck something and they should return to a stand for an inspection. The aircraft was subsequently taxied back towards the East Apron, stopped, shutdown and towed onto a stand, where it was inspected. Upon inspection, damage was discovered to the two tyres on the left landing gear, Figure 3. The damaged tyres were replaced before the aircraft departed after a delay of nearly four hours.

Figure 3
Damage to one of the landing gear tyres

TD comments

The TD, who was also a qualifed HO, stated that he did not connect the towbar when he was at the rear of the tug, before he retrieved the chock, as he was distracted by the HO walking away from the aircraft. While he knew it was not his resposnsibility to remove the chock, he felt he should do it as he had previously witnessed another incident where a HO had left the chock behind and the aircraft taxied over it.

He added that, as an HO, he had witnessed a TD remove the chock on the odd, very rare occasion.

Addtionally, he realised he had entered the manoeuving area without permission but he was in a state of panic at the time.

HO comments

The HO, who was also a qualified TD, stated that he did not know why he did not remove the chock because he normally does it. He commented that sometimes the TDs place the chock on the towbar, despite it not being their responsibility. He has also "occasionally" removed the chock when he has been a TD.

He added that he did not know why he gave the 'all clear' signal to the crew when the towbar was still there, but he felt that the signal was primarily to show the steering bypass pin had been removed rather than check the taxiway was clear. Also, there was no procedure in place to wait until an aircraft had commenced taxiing.

Analysis

The HO and TD have defined tasks and responsibilities during a pushback, with the HO being responsible for removing the chock from the nose wheel and passing it to the TD.

On this occasion it appears that the HO forgot to remove the chock, as he was seen on CCTV walking towards the edge of the taxiway before the TD went to remove it. This omission seems to have distracted the TD at a key point when he was in the process of connecting the towbar to the tug, and he seems to have prioritised the removal of the chock over ensuring the towbar was connected to the tug. This was likely a result of him previously witnessing an aircraft taxi over a chock.

While it is the HO's responsibility to remove the chock, it appears that, while it was not a regular occurrence, it was not unknown for a TD to remove it.

Had they positively checked the taxiway in front of the aircraft and waited at the edge of the taxiway until the aircraft had taxied away, they may have noticed the towbar and stopped the aircraft before it taxied over it.

Fortunately, the damaged towbar was found before the aircraft took off, thus avoiding the aircraft taking off or landing on damaged tyres, the result of which may have been more serious.

Conclusion

The aircraft taxied over a towbar soon after it had been pushed back. The towbar had been left in front of the aircraft through a combination of one member of the ground crew forgetting to remove a chock and another being distracted by this as he was in the process of connecting the towbar to the tug. Both members of the ground crew also seem to have not checked the area in front of the aircraft as they cleared the taxiway.

Safety actions

As a result of this incident, the following safety actions were taken:

The handling agent reviewed the headset operatives' and tug drivers' roles and responsibilities and added the following procedures:

- The chock is removed from the nosewheel by the headset operative.
- The chock is handed to the tug driver who stows it in a basket on the tug.
- The tug driver immediately vacates the taxiway with the tug and towbar.
- The tug driver parks in view of the aircraft and checks the area is clear in front of it.
- After the tug has departed, the headset operative checks that the area in front of the aircraft is clear of equipment and FOD [foreign object damage/debris], and that the pathway is clear.
- The tug driver waits for the aircraft to taxi to ensure they are no longer required.

The handling agent also reviewed and amended its training material, '*safe systems of work',* and auditing processes to reflect these changes and to try to prevent recurrence. It also publicised the event and these changes to its staff in its '*Internal Operations Briefing'*.

ACCIDENT

Aircraft Type and Registration:	Cessna 120, G-AJJT
No & Type of Engines:	1 Continental Motors Corp C85-12F piston engine
Year of Manufacture:	1947 (Serial no: 12881)
Date & Time (UTC):	15 July 2021 at 1035 hrs
Location:	Lower Withial Farm, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Severe damage to the left wing, propeller and landing gear
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	76 years
Commander's Flying Experience:	696 hours (of which 608 were on type) Last 90 days - 12 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB

Synopsis

Just after takeoff, at approximately 100 ft agl, the aircraft engine faltered, misfired and stopped. The pilot immediately configured the aircraft for a forced landing in a field. The aircraft landed heavily and sustained damage to its left wing, propeller, and landing gear. The pilot exited the aircraft uninjured. The cause of the engine stoppage is not known.

History of the flight

The pilot had prepared his aircraft for flight and had checked its fuel and oil levels during his walk-round. The start-up, power and pre-takeoff checks were normal. Just after takeoff, and whilst at approximately 100 ft agl, the engine faltered, misfired twice and stopped. The pilot immediately turned to avoid buildings, initiated a glide descent, and landed heavily in a nearby corn field. During the landing the left wing, propeller and landing gear were severely damaged. The pilot was uninjured and was able to exit the aircraft unaided.

Mitigating factors and potential cause

In the pilot's analysis of the accident, he considers the following factors prevented a more serious outcome. Firstly, he made an immediate decision to carry out a forced landing in a suitable field and focussed on maintaining airspeed and avoiding obstructions. Secondly, given the aircraft's low height above the airfield, he did not attempt to restart the engine.

The pilot has also considered either fuel starvation due to a blockage or an empty tank might have caused the engine stoppage. However, he had checked for fuel pre-flight and observed that the right tank, which was selected at the time, was showing between ¼ and ½ on the gauge after the accident. Other than these possibilities, and in the absence of other evidence, the cause is not known.

SERIOUS INCIDENT

Aircraft Type and Registration:	Europa, G-FLOR
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	1999 (Serial no: PFA 247-12793)
Date & Time (UTC):	23 June 2021 at 1415 hrs
Location:	Brinkworth, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left door, gas strut and hinges missing, minor damage to left tailplane
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	19,864 hours (of which 4 were on type) Last 90 days - 85 hours Last 28 days - 20 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent AAIB enquiries

Synopsis

The pilot was on a local flight from Cotswold Airport with a passenger. The aircraft was flying at approximately 100 kt and 2,500 ft amsl when, without warning, the left cockpit door detached. After checking that the aircraft's control responses appeared normal, the pilot returned to Cotswold where the aircraft landed without further incident. Subsequent inspection of the left tailplane identified minor damage to the leading edge and upper surface consistent with it having been struck by the door.

This was the eighth event involving the inadvertent opening of cockpit doors fitted to Europa aircraft operated in the UK. The LAA have developed and issued a modification to the Europa to prevent the door latch lever reaching the closed position when the door is not properly latched.

History of the flight

The pilot had purchased G-FLOR seven days before the accident, and it was the first Europa aircraft that he had flown. The passenger had not flown in a Europa before. The pilot advised that he had been briefed by the aircraft's previous owner of the need to "double check" the security of the cockpit doors.

Having completed external checks of the aircraft, the pilot and passenger seated themselves in the cockpit's left and right seats respectively and closed the cockpit doors.

The pilot checked the correct latching of the front of both doors by pushing on them. He then leaned across to check the rear of the right door was latched by pushing against it but noticed that it moved outwards slightly. The pilot then opened and reclosed the right door and, having moved the locking lever back to its closed position, confirmed that the door was correctly latched.

The pilot asked the passenger to similarly check that the rear of his left door was latched by pushing on it, but the passenger was unable to reach, and so the pilot pushed on the door area adjacent to his left shoulder. He advised that he did not feel or see the left door move outwards or notice a gap between the rear of the door and its frame. Prior to takeoff, the pilot rechecked the doors again and stated that they "appeared secure".

The takeoff and climb to 2,500 ft amsl appeared normal but, at a speed of about 100 kt, the left door suddenly detached from the aircraft without warning; the aircraft was 5 nm south-east of Cotswold Airport. The pilot maintained control of the aircraft and, having checked that the control response appeared normal, returned to Cotswold and landed without further incident.

The left tailplane was subsequently found to have been damaged (Figure 1), in a manner consistent with it having been struck by the door. The door was not recovered.

Figure 1
Damage to G-FLOR's left tailplane

Aircraft information

The doors are of a gull wing arrangement with each door hinged in two places along its top edge (Figure 2). Each hinge is attached to the fuselage using Araldite 420 adhesive mixed with flox[1], and two bolts that are secured using AN970-3 washers and nuts fitted from the inside of the fuselage (Figure 3). The large diameter 'penny' type washers assist in spreading the load and also prevent the nuts from embedding into the composite structure as they are tightened.

The door is held closed by two tapered shoot bolts which extend out longitudinally from the lower corners of the front and rear sides of the door, between 10 to 12 mm into guides in the door frame (Figure 4). The push rod for each tapered shoot bolt is attached to the door locking lever with a bolt, washers, and an anchor nut fitted to the push rod. The tapered shoot bolt tips are secured to the push rods using roll pins.

The door locking lever assemblies are protected by covers, which are intended to prevent inadvertent operation, such as snagging clothing that could inadvertently move the lever to its open position. The covers fit tightly around the mechanism, such that if the push rod bolts were to come loose, it would be unlikely for the bolt to be able to completely disengage from the push rod anchor nuts because of close contact with the inside of the covers.

A gas strut is fitted to the rear of each door to support them when in the open position. When closing the door from the cockpit, the pilot pulls on the door handle locking lever, which is positioned towards the front of the door. Due to resistance of the gas strut, combined with some flexing of the door and a need to also compress the door seal, the rear of the door may not always fully close.

If the door is not fully closed at the rear, it is possible to move the door locking lever to the closed position with only the front tapered shoot bolt engaged in its guide. This gives the false impression that the door is closed and fully latched but with the rear tapered shoot bolt resting against the outside of the fuselage skin adjacent to the door frame. If this occurs, a small gap may be evident near the lower rear area of the door.

The door design was discussed with the LAA and as to whether it could appear to be latched correctly, such that movement would not be apparent when pushing against the rear of the door even though the shoot bolt was not correctly engaged into its guide. It was considered that for this to occur, the end of the shoot bolt would need to press against the door frame next to the guide. This would require the rear push rod to either bend, or that the mechanism had not been correctly set up. However, the push rods were relatively short, and it was considered that they were unlikely to bend sufficiently. Had the mechanism also not been set correctly during the manufacture of the aircraft, it may have been expected that this would have been identified early in the operating life of the aircraft, but G-FLOR had been in service since 1999. There was no record of any maintenance work caried out on the left or right door since the aircraft was manufactured.

Footnote

1 A mixture of cotton fibre and epoxy.

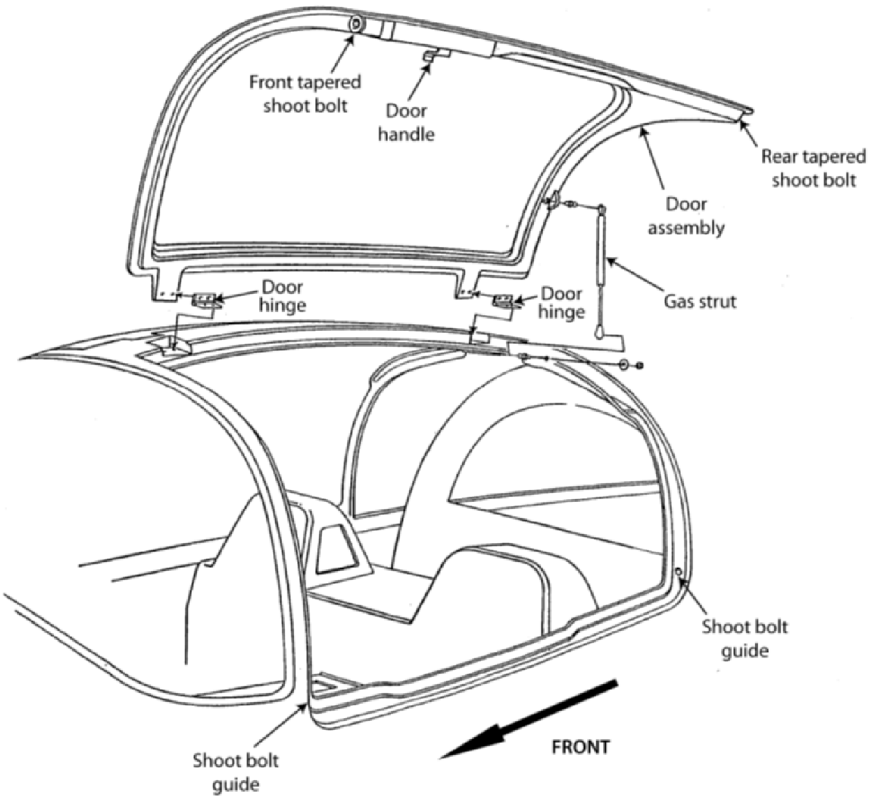


Figure 2

Door arrangement (image used with permission)

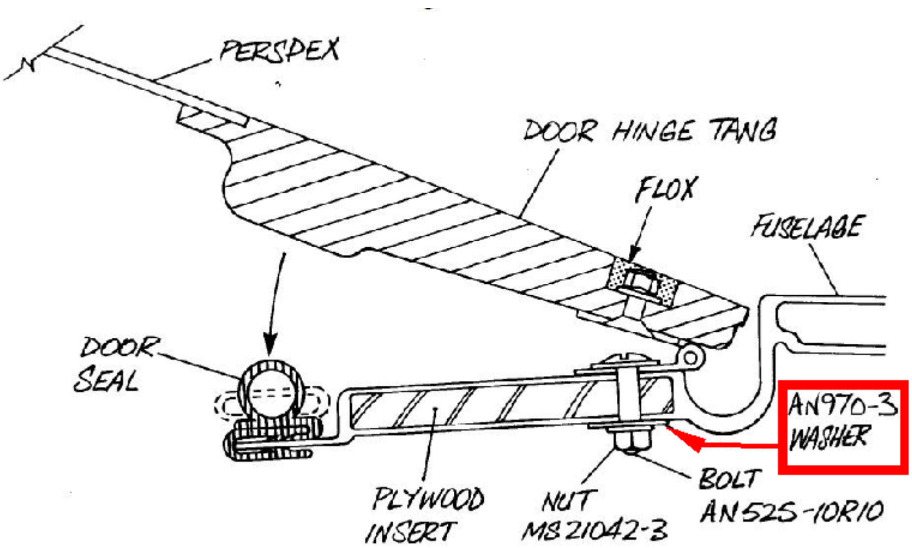


Figure 3

Door hinge fastening (image used with permission)

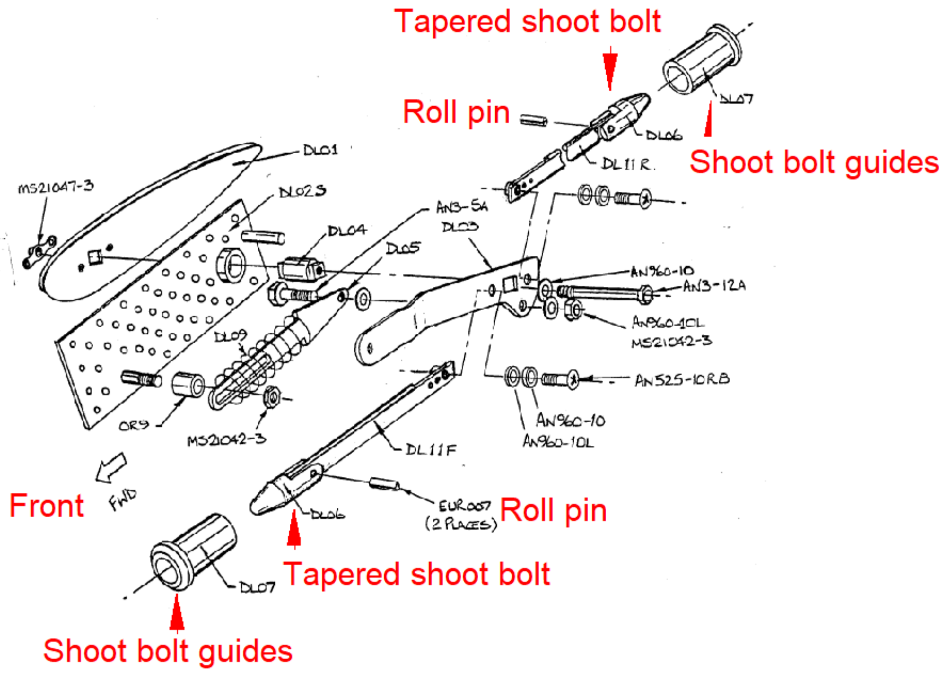


Figure 4

Door locking mechanism (image used with permission)

Aircraft examination

The rear tailplane sustained minor damage to its leading edge and upper surface.

The left door's forward hinge leaf had remained attached to the fuselage with the hinge knuckles having failed due to overload. The rear hinge was missing (Figure 5), with damage consistent with it having been pulled from the fuselage. The damage was consistent with loads exerted by the door when it had opened in flight.

Inspection of the remaining left door forward hinge and both the right door hinges, showed that the AN970-3 washers were not fitted.

There was no evidence of significant damage to either the left door's front or rear shoot bolt guides, the surrounding door frame or fuselage. However, there was superficial damage to the paintwork adjacent to both the left door's front and rear guides (Figure 6 and Figure 7). The damage was similar and was consistent with having been caused by the tapered shoot bolt coming into contact with the fuselage skin and the door frame. Possible causes for this included:

- The shoot bolt had rested against the fuselage skin because it had not engaged into its guide when the door was closed, and the locking lever moved to its closed position.
- The shoot bolt had rested against the fuselage skin because the door had been inadvertently closed with the locking lever in the closed position.

- The shoot bolt had rubbed against the inside of the door frame because the door had been opened and/or closed with the locking lever not in the fully open position.
- The shoot bolt had rested against the inside of the door frame when the locking lever was in the closed position.

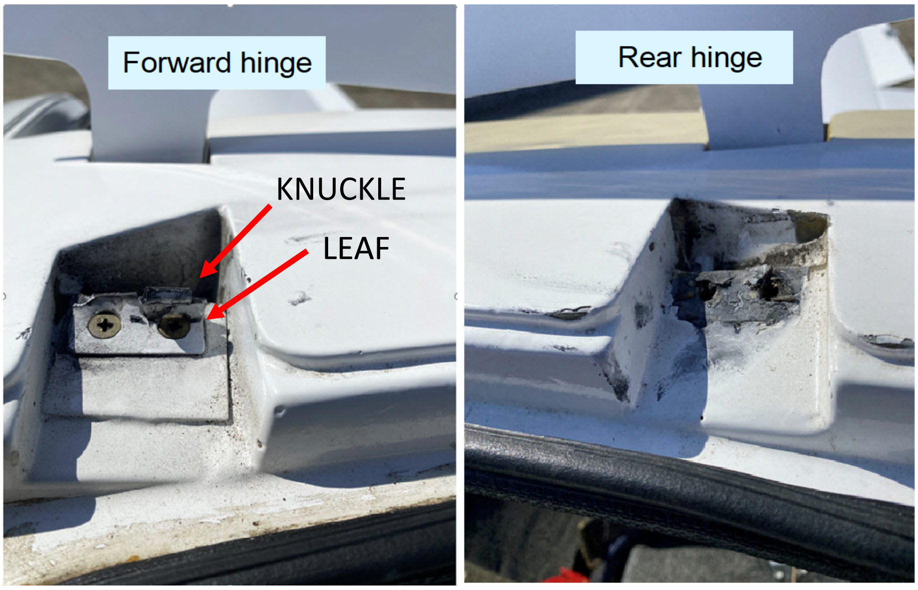


Figure 5

Left door forward and rear hinges

Figure 6

Front shoot bolt guide

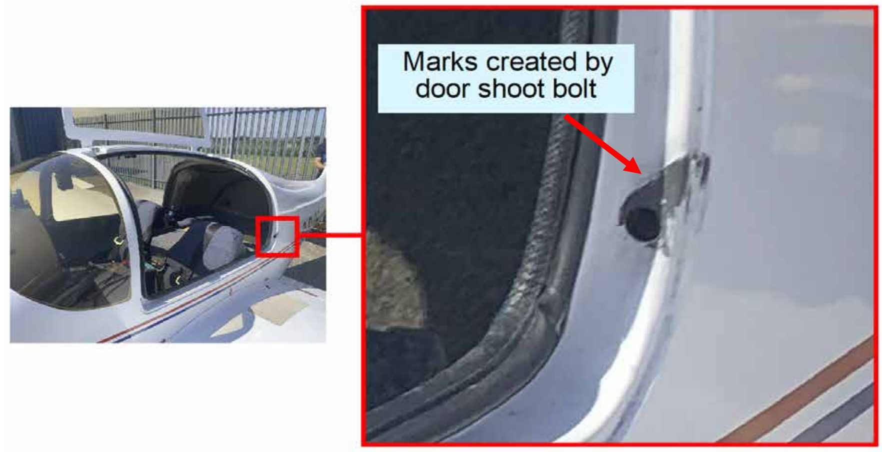


Figure 7
Rear shoot bolt guide

Previous events involving Europa doors

Since 2003, there have been eight occurrences in the UK involving inadvertent opening of cockpit doors fitted to Europa aircraft. Table 1 provides details for the seven previous cases that occurred between 2003 and 2020.

The investigation involving G-BYJI in 2012, concluded that the rear tapered shoot bolt had not been engaged into its guide prior to takeoff, and that the rear hinge had subsequently failed in overload when the door opened in flight (Figure 8).

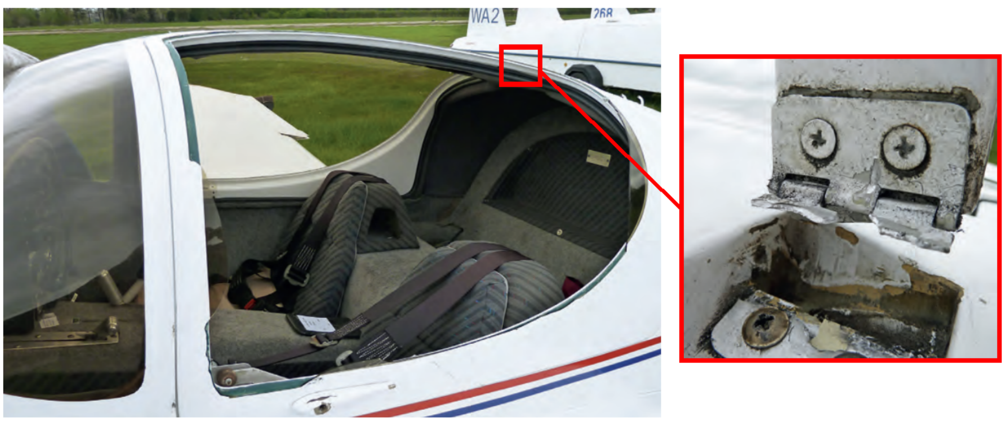


Figure 8
Damage to G-BYJI

The investigation involving G-FIZY in June 2014 also concluded that that the rear shoot bolt had had not been engaged into its guide prior to takeoff. The damage to the remaining section of the door hinges were 'fresh' and no significant damage was reported in the area of the guides but there was evidence of the rear shoot bolt rubbing on the outside of the door frame. During this accident, the door had also struck the tailplane, causing significant damage.

Date / aircraft registration	Description	Commanders flying experience
March 2003 / G-PEGY	Left door opened as aircraft was taking off. Aircraft departed runway with damage to wheel fairing, brake pipe and right wing. Pilot concluded that the door was not fully latched.	1,345 hours (of which 36 were on type).
August 2003 / G-IIGI	Left door opened at 3,000 ft amsl and perspex broke. Pilot closed door and landed safely. Evidence indicated that the rear shoot bolt was not engaged in guide.	3,500 hours (of which none were on type).
August 2008 / G-CCUL	Right door detached at 2,500 ft amsl. Landed safely.	Not available.
April 2012 / G-BYJI	Left door opened at 1,800 ft amsl and perspex broke. Door remained attached and aircraft landed safely.	270 hours (of which 10 were on type).
July 2013 / G-OURO	Left door opened on climb-out and subsequently detached at 300 ft. Door struck left wing trailing edge causing superficial damage. Landed safely.	261 hours (of which 17 were on type).
June 2014 / G-FIZY	Left door detached at 950 ft amsl. Door struck the left tailplane, causing significant damage. Evidence indicated that the rear shoot bolt was not engaged in guide.	17,670 hours (of which 5 were on type).
March 2020 / G-BLVL	Door opened during takeoff roll (report did not advise which door). Pilot pitched down and propeller struck runway.	Not available.

Table 1

Events between 2003 and 2020 involving Europa cockpit doors opening

Previous safety action

Following the accident to G-FIZY, the LAA advised the AAIB that they would work with the aircraft manufacturer to design a safety modification to prevent a recurrence of doors inadvertently opening on Europa aircraft[2].

Although the modification work was started, with trial fitment of parts to one aircraft, the trial aircraft had then been subject to unrelated repairs which led to it being out of service for a prolonged period.

On 1 November 2021, the LAA approved and issued a standard modification (mod number SM 15833) for fitment to Europa aircraft to prevent the door latch from closing when the door

Footnote

2 AAIB Bulletin 08-2021 (publishing.service.gov.uk) [accessed September 2021].

is not pulled home at the rear, and the rear pin properly engaged. The requirement for this modification has been promulgated by LAA Airworthiness Information Leaflet MOD/247/012, which has been allocated mandatory status for all Europa aircraft operating under an LAA Permit to Fly and is required to be fitted within five flying hours after that date, or next permit revalidation, whichever comes first.

The modification consists of an aerodynamically shaped stop secured to the fuselage outer surface. It is in such a position that it blocks the rear latch pin's movement if the occupant attempts to close the latch with the pin resting on the outside surface of the fuselage if the door hasn't been properly closed at the rear edge. The modification also introduces brightly coloured warning marks on the cabin door latch handles to help alert the pilot to the latch handle not being in the fully closed position.

Analysis

The evidence from this event is consistent with that of previous occurrences involving the inadvertent opening of cockpit doors fitted to Europa aircraft because the door was not correctly latched. This includes a lack of significant damage to the door guides and surrounding fuselage of G-FLOR, which would have been expected if a correctly latched door was to have detached from the aircraft. The damage to the forward hinge and airframe structure at the rear hinge location was consistent with overload failure as a result of the aerodynamic loads placed on the door as it had opened, rather than a fatigue-related failure of either hinge. The possibility that the rear hinge was also not fitted with washers, combined with higher loads that may have been placed on it as the door opened, may explain why this hinge detached from the fuselage.

A review of the events shows that although some pilots were relatively inexperienced on type, with five or less flying hours on the Europa (including the pilot of G-FLOR), several other pilots had more experience. Therefore, the cause of inadvertent opening of doors may not necessarily be attributed to a lack of familiarity on type. However, the data does indicate that at least six out of the eight events involved the opening of the pilot's left door. One possible explanation for this is that the aircraft is usually flown from the left seat, from which the pilot can check the security of the right door by leaning across and pushing on the door at both the front and rear immediately adjacent to the locking guides. However, due to the confines of the cockpit and relative position of the left door's rear shoot bolt guide, it is more difficult for the pilot to check that the rear of the left door is correctly latched. Equally a passenger may not be able to assist the pilot to check the left door or, if they can, may not have the necessary experience to correctly identify if the door is latched or not.

The pilot of G-FLOR had checked the left door twice before takeoff. Discussions with the LAA indicated that it was unlikely that the door could be incorrectly latched and still appear secure when pushed against. However, there were marks adjacent to the door guide that could have been caused by the shoot bolt pressing against it because the push rod had been bent at some point, and so the possibility remains that this could have presented a false indication to the pilot. The door has not been recovered and so a problem with the door mechanism could not be ruled out.

Conclusion

The evidence indicates that that the door opened in flight because the left door's rear tapered shoot bolt was not engaged in its guide. It was not possible to determine if this was because the door mechanism was at fault or if the pre-flight check had not identified that the door was correctly latched.

Safety action

> On 1 November 2021, the LAA approved and issued a standard modification (mod number SM 15833) for fitment to Europa aircraft to prevent the door latch from closing when the door is not pulled home at the rear, and the rear pin is properly engaged. The requirement for this modification has been promulgated by LAA Airworthiness Information Leaflet MOD/247/012, which has been allocated mandatory status for all Europa aircraft operating under an LAA Permit to Fly and is required to be fitted within five flying hours after that date, or next permit revalidation, whichever comes first.

SERIOUS INCIDENT

Aircraft Type and Registration:	Jabiru J400, G-CCPV
No & Type of Engines:	1 Jabiru 3300A piston engine
Year of Manufacture:	2006 (Serial no: PFA 325-14058)
Date & Time (UTC):	17 August 2021 at 1326 hrs
Location:	Tevioyhead, Northwest of Spadeadam danger area, Scottish Borders
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Light Aircraft Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	491 hours (of which 266 were on type) Last 90 days - 20 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, flight data and ATC recordings

Synopsis

During a planned VFR flight, the aircraft entered cloud over high ground. The pilot quickly became disoriented and lost control. The aircraft emerged from the cloud with enough height available to regain control and the flight continued safely. Forecasts were available prior to the flight that predicted low cloud on the planned route. CAP1535S, Skyway Code version 3 includes a chapter on meteorology with advice for GA pilots on weather decision making.

History of the flight

The pilot used an internet forecast to check the weather and noted a south-westerly wind of 20 kt, good visibility, and overcast cloud with a base of 3,500 ft. The pilot departed from a privately owned airstrip in the Scottish Borders area at 1302 hrs. The intended destination was Sleap (EGCV). The highest spot elevation in the vicinity of the planned route was 1,953 ft amsl.

The pilot requested and received a basic service from Scottish Control. At around 1320 hrs he was flying at 2,500 ft approaching high ground to the north-west of the Spadeadam danger area (D501A). He estimated that there was 800 ft between the cloud base and the high ground. The pilot reported that as he was approaching the highest point on his planned route the cloud suddenly descended and he entered it. He attempted to climb using full power and became disoriented. He felt that the aircraft stalled and that he had lost control. The aircraft completed three 360° right turns before it emerged from the cloud. The aircraft was in the cloud for between three and four minutes.

The pilot headed for the only area that he could see was clear of cloud and inadvertently entered the Spadeadam danger area. The controller noticed G-CCPV had entered the danger area and contacted the pilot. When informed that the pilot had lost control in IMC the controller offered help and coordinated with the Spadeadam controller. The Scottish controller proactively followed up with the pilot of G-CCPV later in the flight to check on his safety.

The pilot quickly left the danger area and intended to continue to Sleap. Later he felt that the weather was not suitable to continue and safely diverted to Kirkbride.

Recorded information

Flight data was obtained from the pilot's mobile navigation application.

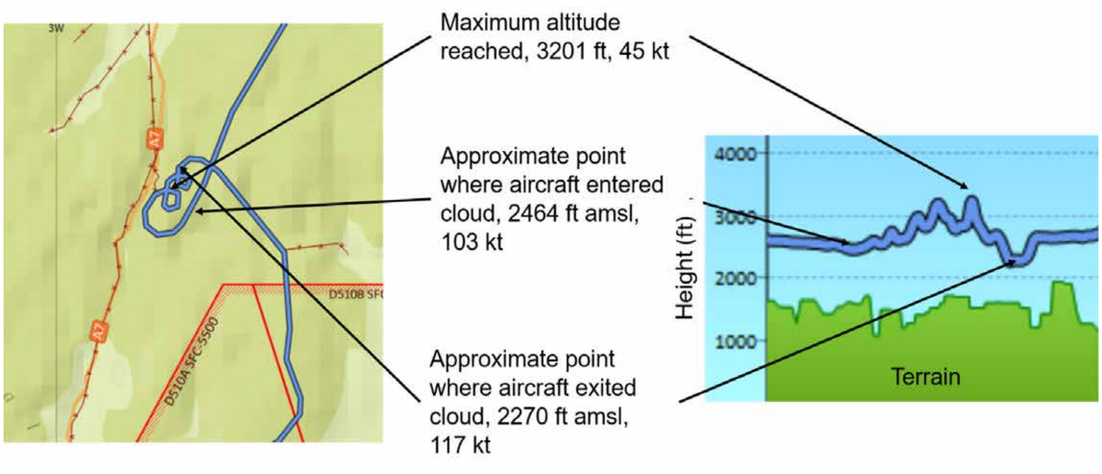


Figure 1

Aircraft track, altitude (ft amsl) and ground speeds (kt) during inadvertent entry to IMC

Aircraft information

The aircraft was equipped with an attitude indicator and a turn and slip indicator. Flight in IMC was not permitted in this permit to fly aircraft.

Meteorology

The pilot reported he used a web service to check the weather on the day. This service provided METARs and TAFs for aerodromes.

The Met Office aftercast stated there was an area of high pressure to the west of the UK bringing a north-westerly flow over the country with a complex frontal system over Scotland and northern England.

The Met Office form 215 showed a warm front lying in proximity to the departure airstrip and described weather conditions in the relevant area of generally 20 km visibility, with broken or overcast cloud with bases at 1,500-2,500 ft amsl and widespread scattered or broken cloud at 500-1,000 ft amsl, occasionally lowering to the surface near the warm front and in coastal areas.

The METARs at relevant stations were consistent with this forecast. At Spadeadam (station height of approximately 950 ft) the METARs showed the cloud base remained consistently broken or overcast at 1,500-1,700 ft agl throughout the period.

Personnel

The pilot reported he had completed IMC training approximately 20 years ago but had not completed any refresher training or instrument flying practice since then. It is not possible to add any instrument qualifications to a LAPL and only VFR flight is permitted with this type of licence.

The Skyway Code

CAP1535S, Skyway Code version 3[1] includes a chapter on meteorology with advice for GA pilots on weather decision making. It recommends use of Metform 215 and reminds pilots that TAFs and METARs give cloud levels in height above aerodrome elevation. It recommends '*VFR flight with a cloud ceiling of 1500ft or less (AGL) warrants special attention to terrain and obstacles.*'

Analysis

The pilot formed an impression that the cloud would be high enough to attempt his planned flight, which included flight in the vicinity of terrain with a spot elevation of 1,953 ft amsl. He entered cloud over high ground and quickly became disoriented and lost control of the aircraft. The aircraft was equipped with basic instruments to monitor attitude in IMC but the IMC training the pilot had completed in the past was little help as it had not been practiced on a regular basis. IFR flight was not permitted in this aircraft or on the pilot's LAPL. Instrument flying practice would require a safety pilot and simulated IMC conditions or an instructor in a different aircraft.

It was fortunate that the aircraft was still high enough when it exited the cloud that the pilot could regain control before striking terrain. The Met Office aftercast showed that forecasts were available prior to the flight that would have revealed that low cloud was likely on the planned route.

Conclusion

The pilot became disoriented in inadvertent IMC over high ground and lost control of the aircraft. The event shows that instrument flying skills degrade without practice. CAP1535S, Skyway Code version provides valuable safety advice for general aviation pilots on meteorology and weather decision making.

Footnote

1 CAA (2021), CAP1535S Skyway Code Version 3, https://publicapps.caa.co.uk/docs/33/CAP1535S%20Skyway%20Code%20Version%203.pdf [Accessed on 16/11/2021]

ACCIDENT

Aircraft Type and Registration:	DJI Inspire 2
No & Type of Engines:	4 Electric Motors
Year of Manufacture:	2017 (Serial no: 095XDAX00201KM)
Date & Time (UTC):	20 July 2021 at 0825 hrs
Location:	Brighton, East Sussex
Type of Flight:	Commercial Operations (UAS)
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Extensive damage to propellers, camera gimbal and arms
Commander's Licence:	Other
Commander's Age:	51 years
Commander's Flying Experience:	160 hours (of which 85 were on type) Last 90 days - not known Last 28 days - not known
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB

Synopsis

The UA was being flown under contract to carry out aerial camera work around a tall tower structure of a seaside tourist attraction in Brighton. The UA had flown several times around and over the top of the tower up to approximately 600 ft agl. It had completed a shot directly above the tower when contact with the controller was lost. It then descended and hit the top of the tower. Its descent appeared to be under control, but the UA failed to respond to any flight commands. The flight data recorded a loss of link, but the technical cause of the loss of control of the UA could not be determined.

History of the flight

The UA was being flown under contract to carry out aerial camera work around a tall tower structure of a seaside tourist attraction in Brighton. The UA operator was positioned on the ground several metres away from the base of the tower and had direct line of sight of the UA.

The UA had flown several times around and over the top of the tower up to approximately 600 ft agl. It had completed a top-down shot directly above the tower when contact with the operator was lost. It descended out of line of sight and did not respond or engage its fail safe 'return to home command'. It landed directly on top of the tower within a platform described as a "crow's nest" but did not descend to the ground. During its landing it sustained substantial damage to its airframe, propellers, and camera gimbal. The UA did not cause any damage to the tower structure and was recovered manually.

There was no indication of power loss or of a propulsion system failure of the UAS. Up until when contact with the operator was lost the UA was responding normally, and there were no indications of any technical issues. The apparent controlled descent and movement of the UA, and its failure to engage its return home feature before striking the tower, could not be explained and was only recorded as a loss of link in the flight data.

SERIOUS INCIDENT

Aircraft Type and Registration:	Evolve Dynamics Sky Mantis
No & Type of Engines:	4 Electric Motor Engines
Year of Manufacture:	2020 (Serial no: LINCS 2)
Date & Time (UTC):	1) 14 January 2021 at 1100 hrs 2) 17 February 2021 at 0930 hrs
Location:	1) Skegness, Lincolnshire 2) Skegness, Lincolnshire
Type of Flight:	Commercial Operations
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	1) Moderate damage to landing gear, fuselage and a motor. One blade missing 2) Moderate damage to landing gear and propellers. One blade missing
Commander's Licence:	1) Other 2) Other
Commander's Age:	1) 38 years 2) Unknown
Commander's Flying Experience:	1) 14 hours (of which 2 were on type) Last 90 days - 5 hours Last 28 days - 5 hours 2) 9 hours (of which 2 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

A screw which attached the propeller blade of a UA to the motor hub adaptor failed during a training flight. A second screw failure was experienced by the same operator after the UA had been repaired and had been fitted with a different design of hub adaptor and screws.

The first failure was caused by stress corrosion cracking possibly with the presence of hydrogen embrittlement. The second was a fatigue failure which may have been initiated and accelerated by hydrogen embrittlement. The hardness of both screws exceeded the specification which increased the susceptibility of the screws to hydrogen embrittlement.

The UAS manufacturer has introduced several design changes to prevent reoccurrence.

History of the flight

14 January 2021 Accident

The pilot was operating the UAS on a familiarisation flight with an instructor and observer present. During a decent to landing, an unusual noise was heard, and a part was seen to depart from the UA when it was at approximately 10 m agl. The UA yawed to the left and fell to the ground. An initial inspection of the UA by the operating team revealed that the screw attaching one of the blades to a motor hub adaptor had fractured. A piece of the threaded part of the screw remained in the motor hub adaptor plate, but the remainder of the screw was not recovered. The blade was recovered approximately 20 m from the UA.

Following the accident, the manufacturer repaired the UA and changed all the motor hub adaptors to a different design. The motor hub adaptor had been subjected to approximately 1.16 million motor revolutions when the failure of the screw had occurred.

17 February 2021 Accident

A different pilot was performing a training flight under supervision with the same UAS. The UA was held in 'loiter mode' at about 100 m agl and about 120 m from the pilot. Whilst observing through the onboard camera, he noticed a change in motor sound and saw the video image wobble. He looked up to see the UA wobble, drop a distance and then wobble again. The pilot operated the return to launch site function and then the ascend control, but there was no response from the UA, which continued to descend until it struck the ground.

The UA was recovered approximately 170 m from the launch point with one of the propeller blades from the rear left motor missing, along with part of the retaining screw. Neither item was recovered. The threaded part of the screw and a jam nut were still attached to the motor hub adaptor. The manufacturer estimated that 3.6 million motor revolutions had been completed since the repair.

Aircraft information

The Evolve Dynamics Sky Mantis is a remote operated UAS designed for the emergency services sector (Figure 1). Lift and propulsion are from four electric motors mounted at the end of fuselage arms which drive two-bladed propellers. The propeller blades and fuselage arms can be folded to facilitate storage. The maximum motor speed is 9,500 rpm, however 2,500 to 4,500 rpm is typical for most operations.

Figure 1
Evolve Dynamics Sky Mantis

Two different motor hub adaptor designs have been used; the adaptor fitted at the time of the January accident was designed by the UAS manufacturer (type 1) and this was subsequently changed to an adaptor designed and supplied by a third-party manufacturer (type 2).

Type 1 - UAS Manufacturer motor hub adaptor

Each propeller blade is attached to the hub adaptor by a single M3, zinc plated, class 12.9 steel, socket head, shouldered cap screw. The 12 mm long screw is fastened into the threaded lower plate and secured with a split pin which engages with the castellations in the upper plate. Two further screws with split pins attach the adaptor to the motor. Washers are used to protect the composite blade (Figure 2).

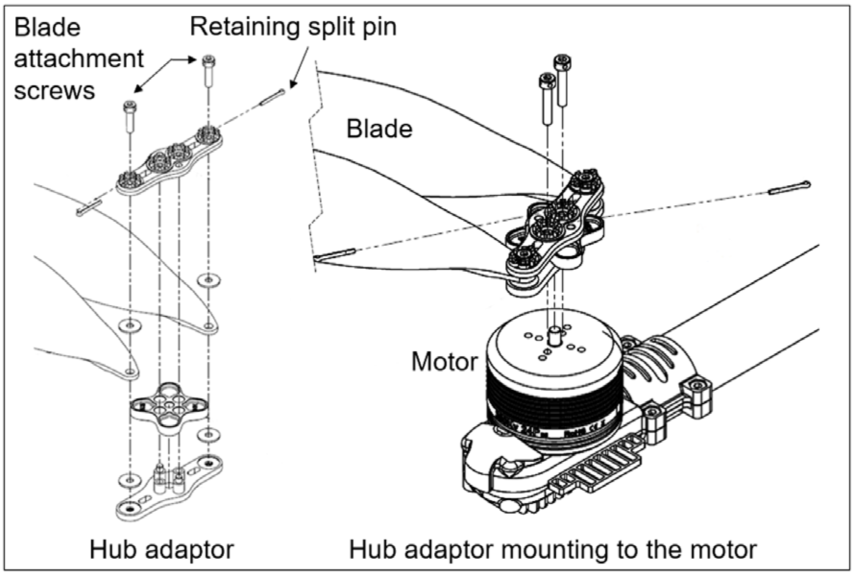


Figure 2
Type 1 Motor hub adaptor

Type 2 - Third party motor hub adaptor

The type 2 motor hub adaptor is similar in design except that it uses a jam nut underneath the lower plate, lock washers and thread lock compound to retain the propeller blade screw. The M3 screw is also made from class 12.9 steel however, it has a black oxide finish (Figure 3).

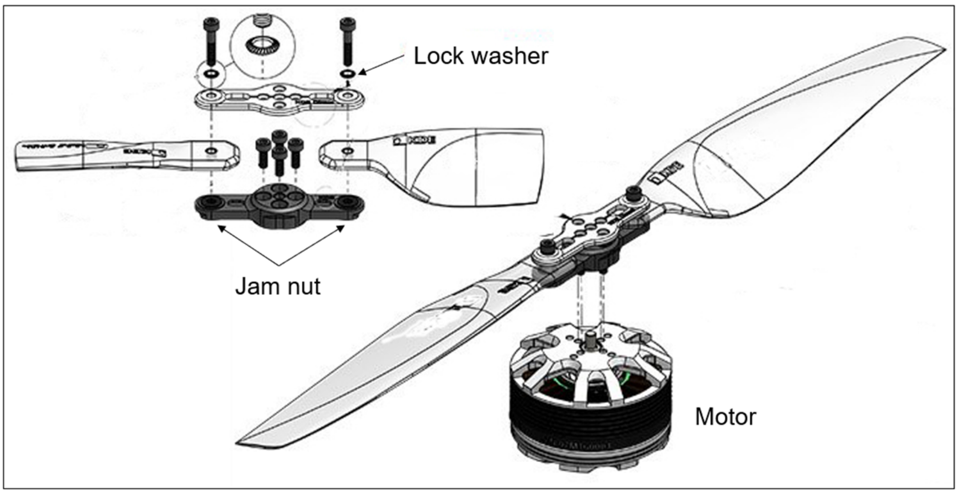


Figure 3
Type 2 Motor hub adaptor

Aircraft examination

The failed blade attachment screws were examined by a specialist metallurgist under an optical microscope up to x45 magnification and a scanning electron microscope up to x5,000 magnification, to determine the failure mechanism.

Type 1 - UAS Manufacturer motor hub adaptor

The screw had failed at the second thread from the plain diameter, (Figure 4) and the cut thread profile showed no material defects which would have initiated the failure. The fracture surface was intergranular, consistent with Stress Corrosion Cracking (SCC) with radial marks denoting the direction of crack propagation. There was light oxidation of the fracture surface, consistent with the relatively short period of service. The characteristics of the fracture face could not preclude the possibility that Hydrogen Embrittlement (HE) had also contributed to the failure mode.

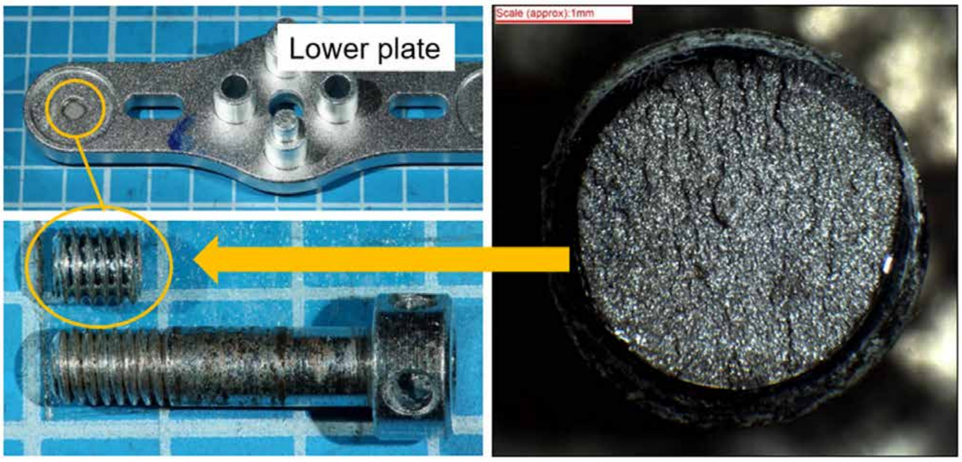


Figure 4
Type 1 Blade attachment screw, fracture face

Type 2 - Third party motor hub adaptor

The predominant failure mode of the type 2 screw was through fatigue, which initiated from the thread root and had propagated across 90% of the cross section before final separation occurred. No initiating defect could be identified however, approximately 20% of the stable crack growth cross-section exhibited evidence of intergranular fracture, consistent with hydrogen embrittlement. The remainder being trans-granular indicative of fatigue crack growth. The level of embrittlement was determined to be insufficient to have caused the failure however, it may have reduced the threshold for crack initiation and would have accelerated the crack growth.

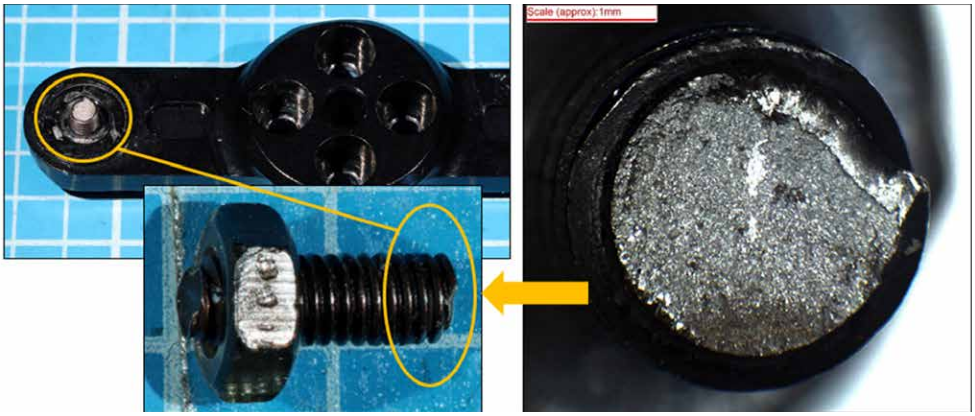


Figure 5
Type 2 Blade attachment screw, fracture face

Tests and research

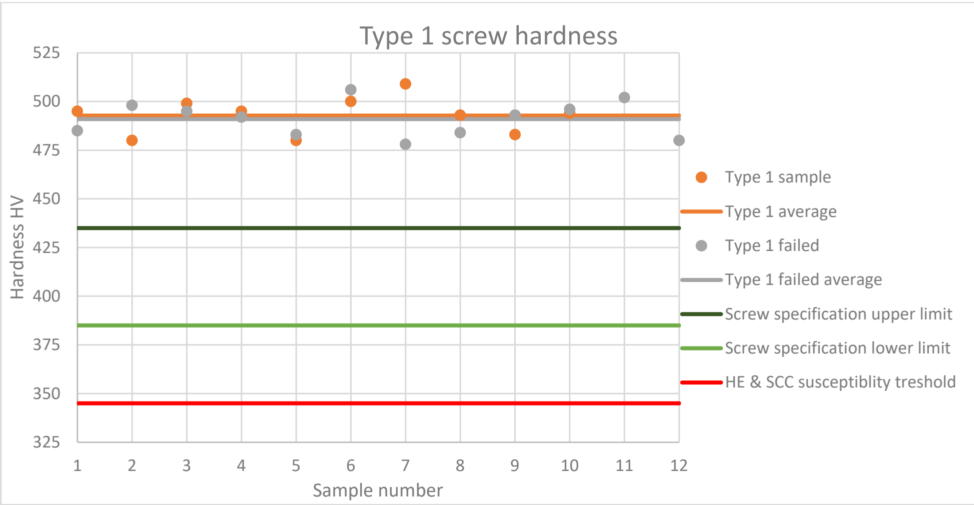
Hardness testing

Ten screws of each type were selected at random by the manufacturer and tested for hardness by an independent test facility to ASTM E92-17, Standard Test Methods for Vickers

Hardness of Metallic Materials. The remains of the two failed screws were also subjected to the same testing. The material specification is steel to BS EN ISO 898-1:2013 12.9 and the Vickers Hardness range for this steel is 385 HV to 435 HV, as shown by the two green bands in graphs 1 and 2. The red line in both graphs, denotes the hardness value (345 HV) above which steels become susceptible to both HE and SCC.

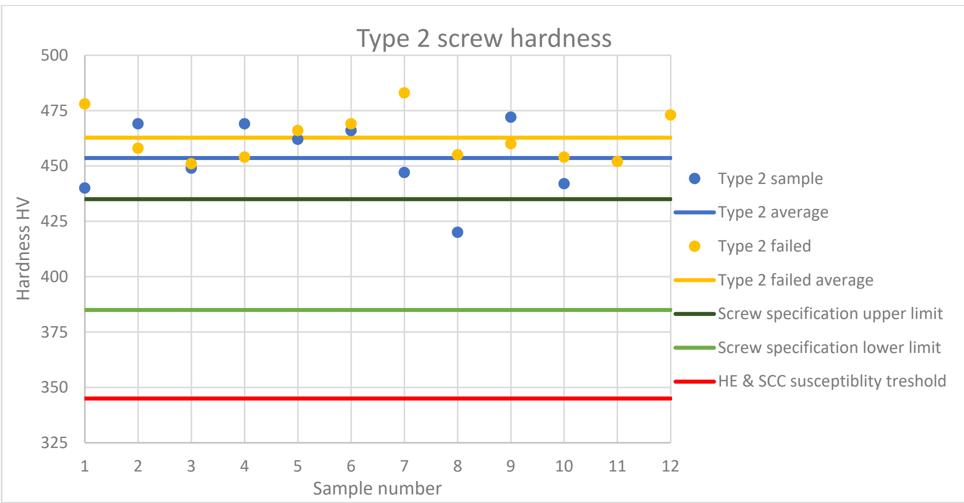
All the sample screws and the failed type 1 screw were very similar in hardness and exceeded the specification value. The difference between the average hardness of the sample screws and the failed screw was 2 HV.

Apart from one of the sample type 2 screws, all screws exceeded the hardness specification. The average hardness of the failed screw was almost 10 HV greater than that of the average hardness of the sample screws.



Graph 1

Hardness testing of type 1 screw samples



Graph 2

Hardness testing of type 2 screw samples

Manufacturer testing

Various pieces of video evidence taken by the UAS manufacturer were supplied to the AAIB showing several functional tests that had been undertaken to prove that the type 2 design could withstand operational loads under a variety of conditions. No test managed to replicate the failures seen during the accident flights.

Other information

Stress corrosion cracking

SCC is a stable crack growth mechanism that occurs when a suspectable alloy is subjected to a static stress in a corrosive environment. Heat treated low alloy (martensitic) steels are suspectable to SCC when the hardness exceeds 345 HV.

Hydrogen embrittlement

High strength steels susceptibility to HE increases with hardness, typically values exceeding 345 HV would invoke precautions to be taken during manufacturing. These might include de-embrittling the steel after a process step that may have introduced hydrogen, eg zinc plating. If hydrogen is present in the material, it is diffused within the crystalline lattice and it will concentrate at the points of highest residual or applied stress. This concentration changes the properties of the material and can result in failure at lower than the predicted strength. For HE to occur it must be a susceptible material with hydrogen present and sufficient stress, either applied or residual. HE failures may occur anything from a few hours to several years after the absorption of hydrogen.

The details of the manufacturing steps for either screw could not be obtained.

Design changes

In response to the two failures, the UA is now supplied with type 2 motor hub adaptors but with M4 screws. Single use locking nuts and shakeproof washers are used instead of the previously used thread locking compound. The assembly process is more detailed and controlled and a brass spacer bush has been fitted into the composite propeller blade root. Random sampling to test for hydrogen embrittlement has now been incorporated in the manufacturing process.

Further design changes are under consideration which include changing the screw material from class 12.9 steel to a corrosion resistant steel with a lower yield strength.

Analysis

Type 1 Accident

The primary failure mechanism for the type 1 screw was considered to be stress corrosion cracking but a contribution by hydrogen embrittlement could not be discounted.

The UAS was being operated near the coast and hence the saline content in the air may have provided an environment conducive for SCC. Radial markings indicated that a crack had initiated on the surface, in the root of a thread and propagated across the diameter and the entire fracture surface area was intergranular in nature. Hydrogen may have been present as a result from the zinc plating process due to ineffective de-embrittlement. The complete coating of the screws with zinc would have trapped the hydrogen in the part and therefore not allowed a path for it to escape. The screw was susceptible to both HE and SCC as it was significantly above the threshold of 345 HV and it also exceeded the hardness specification value.

The stress on the screw would have been a combination of flight loads on the blade and the axial preload as the screw was tightened. Testing done by the manufacturer has demonstrated that the screws can withstand all the operational loads in combination with the tightening torque.

Type 2 Accident

The failure of the type 2 screw was predominately fatigue crack growth but with areas of the fracture surface exhibiting hydrogen embrittlement. No initiating flaw could be identified but it is possible that stress concentration at the thread root in combination with HE was sufficient to initiate a crack which then grew during the 3.6 million motor revolutions before failure. It is possible that the application process for the surface finish was the source of hydrogen in the screw. The high hardness of the material would have reduced the fracture toughness and in combination with the HE further reduced the time to failure.

Design changes

The UAS manufacturer primarily changed the diameter of the screw from M3 to M4 as a solution to the failures. Whilst this gives an increase in cross sectional area and therefore extends the mean time to failure, no changes were made to the screw material or the manufacturing processes. The use of class 12.9 steel screws with the hardness values exceeding the specification was determined to be a causal factor in the failures. It was determined that if the screws had a greater fracture toughness and had hydrogen not been present then neither failure might have occurred.

Conclusion

The type 1 screw failure was probably driven by the operational environment and the presence of hydrogen within the very hard steel. This combination resulted in stress corrosion cracking possibly exacerbated by hydrogen embrittlement.
The type 2 screw failure by fatigue crack growth was probably initiated and then accelerated by hydrogen embrittlement.

The use of screws in both accidents with the hardness exceeding the specification value, was determined to be a causal factor in their failures.

Safety actions

As a result of these two events the manufacturer has made several design changes to the motor hub adaptor.

The UAS manufacturer has reviewed the design of the motor hub adaptor and made the following changes:

- Increased the screw diameter to M4
- Incorporated a stress test to ensure that bolts do not suffer from hydrogen embrittlement
- Used a serrated washer
- Used a single use lock nut
- Removed the thread locking compound
- Added a brass spacer to the blade root

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only UAS investigations reviewed: October - November 2021

19 Jul 21 **DJI Gryphon Dynamcis** Near Ballymena, County Antrim

As the UA was being flown over the sea, just off the coast, it inverted without warning and fell into the water. Subsequent investigation by the operator indicated that a loss of propulsion from one of the motors was the likely cause.

27 Aug 21 **MA Avro 405 autogyro** Old Warden, Bedfordshire

The model autogyro became uncontrollable after takeoff and struck a bystander, cutting their hand. The model aircraft was destroyed.

27 Aug 21 **DJI Mini 2** Oldmeldrum, Aberdeenshire

Whilst photographing a wedding, the UA struck a tree. The pilot was unable to locate the UA due to the height of the tree.

28 Aug 21 **DJI Phantom 4 Pro** Stowe, Buckinghamshire

Towards the end of a flight, when the UA was being positioned back to the takeoff point, the controller's screen went black and turned off. The UA dropped to the ground.

02 Sep 21 **MA Ripmax Acro Wot** Belper, Derbyshire

Whilst the aircraft was flying straight and level at about 150 ft agl, and 75 m from the pilot, it stopped responding to the transmitter's control inputs. The aircraft subsequently flew out of sight and was not recovered.

15 Sep 21 **DJI Mavic 2 Enterprise Dual** Newport, Gwent

During commercial operations to survey a building, the UA struck the building and fell to the ground.

16 Sep 21 **DJI M300 RTK** Oxshott Rail Station, Surrey

Whilst flying the UAS at night during a missing person search, the operator chose to descend to his selected landing site whilst simultaneously translating forwards, rather than flying a vertical descent. The UA struck a tree which the operator had not seen during the landing approach, resulting in extensive damage to the UA.

17 Sep 21 **DJI Mavic Zoom 2** Kingscote, Gloucestershire

After takeoff the UA reached a height of approximately 40 m when it suddenly went into a spiral descent and then struck the ground.

18 Sep 21 **DJI Mavic Pro 2** Fritton Lake, Great Yarmouth, Norfolk

The UA was filming for a television programme. The UA clipped a tree and the UA fell into a lake.

Record-only UAS investigations reviewed: October - November 2021 cont

23 Sep 21 **Mavic 2 Pro** Wimborne, Dorset
The UA hit a tree branch and suffered substantial damage.

23 Sep 21 **Parrot Anafi USA SE** Near Lee-on-the-Solent, Hampshire
On bringing the UA back to land, it suddenly tipped to its right and descended a couple of feet as if it had lost power. It then appeared to shake before flipping over and striking the ground. Subsequent examination identified a damaged motor housing and a loose battery.

25 Sep 21 **MA Ripmax Acro Wat** Near Faversham, Kent
On turning towards base leg before final approach the visibility reduced in mist adjacent to the flying area, obscuring the pilot's line of sight. The pilot reduced the throttle immediately, but the aircraft flew into trees.

29 Sep 21 **DJI M210 RTK** Hillingdon, Greater London
The UA fell to the ground from a hover at approximately 40 ft agl and was damaged beyond economic repair.

29 Sep 21 **DJI Phantom 4 RTK** Craignaw, Dumfries and Galloway
The UA collided with a hillside following a programming error whereby incorrect terrain elevation data was entered for the route.

03 Oct 21 **DJI Mavic 2 Enterprise Dual** Weldon, Northamptonshire
Five minutes into the flight the connection between the remote pilot and UA was lost. The pilot was unsuccessful in trying to reconnect. The UA flew out of sight and was not recovered.

05 Oct 21 **Yuneec H520E** Cromarty Firth, Ross and Cromarty
The UA had completed three survey flights without incident. The UA's batteries were replaced for the fourth flight; pre-flight checks identified no issues and the UA took off uneventfully. At a height of 15 to 20 m the motors were heard to "stutter" and then stop, and the UA fell to the ground within the controlled area. The UA was destroyed.

16 Oct 21 **Yuneec H520** Tidworth, Wiltshire
Whilst conducting a roof survey, the UA clipped a weather vane and struck the roof, before falling to the ground.

18 Oct 21 **DJI M300 RTK** Crawley, West Sussex
Part of a propeller blade detached in flight and the UA fell to the ground, suffering substantial damage.

Record-only UAS investigations reviewed: October - November 2021 cont

19 Oct 21 **Tarot Ironman 1000 Octocopter** Didcot, Oxfordshire

In flight, one of the UA motors detached from the mounting causing the aircraft to lose lift. It was unresponsive to pilot inputs and made an uncontrolled descent to the ground. One of the three landing gear legs sustained damage.

20 Oct 21 **DJI Mavic 2 Pro** Luton, Bedfordshire

After 12 minutes of flight and at a height of about 20 m the UA hit a tree. The aircraft was not recovered.

25 Oct 21 **Prion Mk3 D15** Newton Stewart, Dumfries and Galloway

The UA, which has a single-engine fixed-wing configuration with a tricycle landing gear, was attempting a cross-wind landing, parallel to and in the lee of a row of tress, when it collided with one of the trees. It is likely that the UA was affected by the wind curling around the row of trees.

31 Oct 21 **Yuneec Typhoon H Pro** Prestwich, Manchester

The pilot was concerned that the UA was flying too far away so decided to land it quickly. The UA was damaged in the subsequent hard landing.

08 Nov 21 **DJI M300** Rhes Y Cae, Flintshire

After about two minutes of flight, the UA fell, out of control, to the ground and suffered substantial damage. A subsequent inspection of the wreckage identified that the arm holding one of the motors had not been correctly secured, and the pilot stated that this had not been visually checked before flight.

09 Nov 21 **DJI Mavic Pro** Upper Vobster, Somerset

The pilot lost sight of the UA and it struck one of the trees over which it had been flying. The UA was not recovered.

22 Nov 21 **DJI Matrice 300** Keyworth, Nottingham

The UA hit cabling above the launch site while lifting off and fell to the ground, where it was extensively damaged.

22 Nov 21 **Mavic 2 Enterprise** Bradworthy, Devon

The UA was approaching to land when at approximately 3 m above the remote pilot's head it became unresponsive and drifted into nearby trees. The remote pilot remained in sight of the UA, which sustained propeller damage.

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:	DH82A Tiger Moth, G-AXBW
Date & Time (UTC):	13 August 2021 at 1059 hrs
Location:	Malshanger Estate Airstrip, Hampshire
Information Source:	Record Only investigation

AAIB Bulletin No 12/2021, page 53 refers

Prior to publication the AAIB was informed that, during this accident, G-AXBW collided with two other aircraft rather than the single aircraft originally reported.

As a consequence, the report has been amended to reflect the involvement of this additional aircraft. The amended report now reads:

> *After hand-swinging the propeller to start the engine, the engine rpm unexpectedly increased. As the pilot had omitted to chock the aircraft, it moved forwards and collided at low speed with two other Tiger Moths which were parked nearby. The pilot considered that the safety message is to ensure, in future, that the aircraft is chocked prior to start.*

The online version of this report was corrected prior to publication on 9 December 2021.

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

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

Published July 2015.

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

Published August 2015.

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

Published November 2018.

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

Published March 2020.

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

Published May 2021.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

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

Air Accidents Investigation Branch