AAIB
Air Accidents Investigation Branch

AAIB Bulletin 6/2021

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01252 512299

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

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

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

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Summaries of Aircraft Accident Reports

This section contains summaries of
Aircraft Accident ('Formal') Reports
published since the last AAIB monthly bulletin.

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

AIRCRAFT ACCIDENT REPORT 1/2021

This report was published on 4 May 2021 and is available in full
on the AAIB Website www.aaib.gov.uk

Report on the serious incident to Airbus A321-211, registration G-POWN at London Gatwick Airport on 26 February 2020

Registered Owner and Operator:	Hagondale Ltd, Titan Airways
Aircraft Type:	Airbus A321-211
Nationality:	UK
Registration:	G-POWN
Place of Serious incident:	London Gatwick Airport, UK
Date and Time:	26 February 2020 at 0009 hrs

Introduction

The Air Accidents Investigation Branch (AAIB) became aware of this serious incident on 26 February 2020. In exercise of his powers, the Chief Inspector of Air Accidents ordered an investigation to be carried out in accordance with the provisions of Regulation (EU) 996/2010 (as amended) and the UK Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018.

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

In accordance with established international arrangements, the following safety investigation authorities appointed Accredited Representatives to the investigation: the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) in France, representing the State of Design and Manufacture of the aircraft; the National Transportation Safety Board (NTSB) in the USA alongside the BEA, representing the State of Design and Manufacture of the engines; and the Aircraft Accident and Incident Investigation Board of Cyprus. The aircraft operator, various maintenance organisations, the European Union Aviation Safety Agency (EASA), and the UK Civil Aviation Authority (CAA) also assisted with the investigation.

Summary

As part of scheduled maintenance overseas, G-POWN underwent a biocide shock treatment on its fuel system, using Kathon biocide, to treat microbial contamination. The aircraft returned to the UK on 24 February 2020, once the maintenance was complete.

In the 24 hours preceding this serious incident, there were abnormalities with the operation of both engines across four flights. On the flight before the fourth (event) flight, the crew reported momentary indications of a No 2 (right) engine stall. After the aircraft landed, this was investigated using an inappropriate procedure obtained from an aircraft troubleshooting manual not applicable to G-POWN, but no fault was found.

The aircraft took off from London Gatwick Airport Runway 26L at 0009 hrs on 26 February 2020 but, at around 500 ft agl, the No 1 (left) engine began to surge. The commander declared a MAYDAY and turned right downwind for an immediate return to the airport but, shortly afterwards, the crew received indications that the No 2 engine had stalled. The crew established that the engines were more stable at low thrust settings and the thrust available at those settings was sufficient to maintain a safe flightpath. They continued the approach and the aircraft landed at 0020 hrs.

The investigation identified the following causal factors:

1. G-POWN's fuel tanks were treated with approximately 38 times the recommended concentration of Kathon.

2. The excessive Kathon level in the aircraft's fuel system caused contamination of the engine Hydro Mechanical Units (HMU) resulting in a loss of correct HMU regulation of the aircraft's engines.

3. A troubleshooting procedure was used for the engine No 2 stall that applied to LEAP-1A32 engines, but G-POWN was fitted with CFM565B3/3 engines. The procedure for CFM56-5B3/3 engines required additional steps that would have precluded G-POWN's departure on the incident flight.

The investigation identified the following contributory factors:

1. The Aircraft Maintenance Manual (AMM) procedure did not provide enough information to enable maintenance engineers to reliably calculate the quantity of Kathon required, and the specific gravity value of Kathon was not readily available.

2. There were no independent checking procedures in place at the base maintenance Approved Maintenance Organisation (Base AMO) to prevent, or reduce the likelihood of, calculating and administering an incorrect quantity of biocide.

3. There were organisational factors at the Base AMO that contributed to the incorrect Kathon quantity calculations. In particular, the workload was high for the available facilities and personnel, and there was no internal technical support function for engineers to consult when they were uncertain.

4. The manufacturer's recommended method of searching the troubleshooting manual was not used to find the applicable procedure relating to the engine No 2 stall.

Following this serious incident, Safety Action was taken by regulators, the International Air Transport Association, the manufacturers of the aircraft, engines and biocide, the AMOs involved, and the operator. The specific action taken is detailed in Section 4.2 of this report.

Redundancy in safety critical systems is one of the principles supporting the safety of commercial air transport but fuel contamination undermines that redundancy because it can affect all engines simultaneously. It is essential that maintenance systems are resilient to errors that can lead to fuel system contamination. Therefore, five Safety Recommendations have been made in this report to promote the classification of biocide treatment of aircraft fuel systems as a critical maintenance task, which would ensure that an error-capturing method is included as part of the task.

Conclusion

Findings

Operation of the aircraft

1. Engine No 1 exhibited starting abnormalities before flights one, three and four. The crews employed up to three starting cycles on those occasions resulting in the engine starting apparently normally.

2. All four flights departed with no persisting ECAM messages.

3. Engine No 2 exhibited symptoms of a stall during the approach to Gatwick on flight three, including a transient ECAM message, which Crew B reported to Technical Control on arrival.

4. Crew A were properly licenced and qualified, and sufficiently rested for the event flight.

5. Commander A engaged with relevant engineers regarding each engine abnormality affecting the flights he was operating, including a telephone call with Technical Control after both engines had started before the incident flight.

6. There was no clear information available to either crew for them to diagnose the engine abnormalities as being symptomatic of an underlying issue of fuel contamination.

7. Prior to taxiing on the incident flight, the engine abnormalities were associated with seemingly unconnected system faults.

8. During the incident, Crew A did not have time to consider shutting down engine No 1 after it began to surge and before engine No 2 exhibited indications of a stall.

9. After receiving indications of a stall on engine No 2, Crew A found a thrust setting using both engines that enabled the aircraft to maintain a safe flightpath.

10. Calm and clear weather conditions meant Crew A could perform an immediate visual return to Rwy 26L.

11. During the incident, effective workload management and crew cooperation amongst the whole crew resulted in a prompt and successful return to Rwy 26L.

The biocide overdose

1. Base Engineer 1 was correctly licensed and qualified to perform the tasks he was assigned on G-POWN.

2. Neither engineer at the Base AMO had performed biocide treatment before and neither knew what ‘ppm’ meant.

3. Each engineer attempted to use internet calculators to help with the calculation but did not have the background knowledge needed to do the calculation correctly.

4. G-POWN was treated with approximately 38 times the required concentration of Kathon biocide.

5. Other than the excessive Kathon biocide treatment, the aircraft had been adequately maintained and had a valid certification of airworthiness.

6. YL-LCQ was also treated with too much Kathon biocide at the Base AMO shortly after G-POWN’s treatment.

7. A critical maintenance task identified in accordance with EASA Part M.A.402(h) or Part-145.A.48(b) requires an error-capturing method to be implemented.

8. The Base AMO had not classified the biocide dosing task as a critical maintenance task.

9. The Base AMO had not introduced a means of error capture during the biocide dosing task.

10. All the AMOs surveyed after publication of AAIB Special Bulletin S1/2020 classified fuel biocide treatment as a critical maintenance task.

11. The AMM procedure lacked detail in terms of the method of mixing the Kathon with the fuel.

12. Facilities at the Base AMO did not provide any practical means of mixing the Kathon with fuel prior to uplifting the fuel to the aircraft.

13. Personnel at the Base AMO believed that the Kathon administration method they used on G-POWN and YL-LCQ would result in sufficient mixing to successfully and safely treat the aircraft.

14. The Kathon was administered via the overwing aperture, which meant it did not mix effectively with the fuel that was uplifted, resulting in local areas of high Kathon concentration in the wing fuel tanks and engine fuel systems.

15. Kathon concentration in the fuel was in excess of the AMM limit of 100 ppm/vol.

16. Excess Kathon caused contamination of the engine HMUs.

17. The HMU contamination led to starting problems on engine No 1.

18. The HMU contamination caused a loss of engine regulation resulting in the surge and stall events on engines No 1 and No 2 during the incident flight.

19. Further evidence of excessive Kathon content in the aircraft fuel was shown by the deposits observed in the engines' combustion chambers and turbine stages.

20. No engine damage was directly attributed to the presence of these deposits. The cause of the damage to the engine No 2 HPC blades was not identified and it is possible that this damage may have been present prior to the incident.

21. A survey of British and French AMOs that perform biocide treatments for commercial aircraft showed that the Base AMO was typical of other AMOs that perform this task infrequently, in terms of process and procedure.

Troubleshooting at Gatwick Airport

1. The line engineer was correctly licenced and qualified to perform the tasks he was assigned on G-POWN.

2. The TSM was accessed through AirN@v and was not searched using the manufacturer's recommended method.

3. During the search of the TSM for a suitable procedure, the data was not filtered to ensure that only procedures applicable to G-POWN were accessible.

4. A troubleshooting procedure was carried out on G-POWN that applied to LEAP-1A32 engines, but the aircraft was fitted with CFM565B3/3 engines.

5. The troubleshooting procedure used (for LEAP-1A engines) only required an external general visual inspection of the engine.

6. The correct TSM procedure (for CFM56 engines) required an additional internal borescope inspection which would have resulted in the engines being removed before further flight.

7. Several factors in combination led to the selection of the wrong procedure:

    a. The ATA fault code reference from the PFR was used as a chapter reference for the TSM.

    b. It was relatively easy to select the wrong TSM chapter (and therefore the wrong procedure) because the chapter labels were similar in appearance.

    c. There was an apparently appropriate procedure in the TSM chapter consulted even though it was the incorrect chapter.

    d. Procedures for LEAP-1A engines were not expected to be found within the operator's maintenance data.

    e. There were no attention-getting stimuli on the printed procedure to prompt an awareness that the incorrect procedure had been selected.

8. The line engineer was not aware of the importance of only using the manufacturer's recommended method of searching the TSM.

9. It was common for engineers at the Line AMO and other AMOs consulted by the AAIB to search the TSM in a similar way to the line engineer.

Training in the use of maintenance documentation

1. Engineer type training is the primary means for licensed engineers to learn to use the TSM and associated applications for accessing it.

2. Training needs analyses for engineer type training should be supported with input from the aircraft TC holder.

3. Engineer type training provided by the manufacturer includes the recommended method for searching for troubleshooting procedures.

4. The line engineer received all his most recent Airbus type training from an approved EASA Part-147 maintenance training organisation associated with the Line AMO, which did not explicitly emphasise the manufacturer's recommended way to search for troubleshooting procedures using AirN@v and airnav^{X}.

5. The regulatory approval and audit process is unlikely to identify whether a training course emphasises the manufacturer's recommended method of using maintenance data applications.

6. The competency assessment criteria for the line engineer did include how maintenance data was accessed and his most recent competency assessment in January 2020 did not document any issues with the way he used the maintenance data applications.

Online applications to access maintenance documentation

1. The Line AMO did not have access to the operator's maintenance data in airnav^X because access had not been delegated by the operator.

2. The operator believed that airnav^X access had been delegated to the Line AMO.

3. The line engineer would have been less likely to select the wrong procedure using airnav^X than AirN@v.

4. It was possible to select the wrong procedure in either AirN@v or airnav^X.

5. The graphical interface of the operator's delegation screen provided misleading cues that suggested access to airnav^X had been delegated.

6. The method of delegating access to airnav^X was difficult without specific instructions from the manufacturer.

Safety Recommendations and Action

Safety Recommendations

The following Safety Recommendations have been made:

Safety Recommendation 2020-018

It is recommended that the European Union Aviation Safety Agency amend the Acceptable Means of Compliance AMC2(a)(3) for regulation Part-145.A.48(b), *Performance of Maintenance,* to include the treatment of aircraft fuel systems with biocide additives as an example task that is to be considered as a critical maintenance task.

Safety Recommendation 2020-019

It is recommended that the European Union Aviation Safety Agency amend the Acceptable Means of Compliance AMC1(c) for regulation M.A.402(h), *Performance of Maintenance,* to include the treatment of aircraft fuel systems with biocide additives as an example task that is to be considered as a critical maintenance task.

Safety Recommendation 2020-020

It is recommended that the European Union Aviation Safety Agency (EASA) conduct safety promotion with the National Aviation Authorities (NAAs) of EASA Member States to promote the classification of biocide treatment of aircraft fuel systems as a critical maintenance task.

Safety Recommendation 2020-021

It is recommended that the European Union Aviation Safety Agency, during future audits of Continued Airworthiness Management Organisations and Approved Maintenance Organisations for which it is the Competent Authority, include a check that consideration has been given to the classification of biocide treatment of aircraft fuel systems as a critical maintenance task.

Safety Recommendation 2020-022

It is recommended that the Civil Aviation Authority (CAA), during future audits of CAA-approved Continued Airworthiness Management Organisations and Approved Maintenance Organisations, include a check that consideration has been given to the classification of biocide treatment of aircraft fuel systems as a critical maintenance task.

Safety Actions

As a result of this serious incident, Safety Action was taken by various organisations as set out below.

Action by regulators

The EASA issued Safety Information Bulletin SIB 2020-06 on 20 March 2020, to notify affected stakeholders of recent air safetyrelated events involving Kathon biocide and to remind aircraft owners and operators to ensure that the correct method and dosage is used for approved biocide treatment of aircraft fuel systems.

The FAA issued Special Airworthiness Information Bulletin SAIB NE20-0417 on 25 March 2020 that contained similar regulatory guidance.

Action by IATA

IATA's Technical Fuel Group established an informal Biocide Task Force with the following tasks:

1. Support the development of an equipment standard for biocide metered injection systems.
2. Support research into alternative biocide products.

3. Facilitate sharing of industry experience and best practices between airlines, AMOs and OEMs.
4. Informing European airlines of news and developments relating to fuel biocide treatments.
5. Lobbying the European Chemicals Agency in support of approval of Biobor JF and for unified REACH derogations in the interim period.

Action by the manufacturers of the biocide and the engines

The manufacturer of Kathon discontinued the use of its product for aviation fuel applications on 10 March 2020.

On 16 March 2020, CFM, the manufacturer of G-POWN's engines, issued Alert Service Bulletin 73-A0296 recommending that operators of CFM56-5B engines suspend the use of Kathon during aircraft fuel system biocide treatments. Similar instructions were issued for other variants of the CFM56 engine family, as well as all General Electric turbofan engines.

AMOs in the EU are continuing to use Biobor JF for biocide treatments, through the approval of temporary national derogations of the REACH regulations.

Action by the aircraft manufacturer

The aircraft manufacturer is revising the AMMs across their product range to replace 'ppm' with the term 'ml/1,000ltrs', and also plans to include a definition of ppm in the AMM glossary in cases where this term is used elsewhere.

The AMM biocide dosing procedures are being revised to simplify the task instructions and to provide a step-by-step methodology. Explanatory notes will be added so that an operative understands why each step is being carried out. It is also planned to include a table giving the biocide volumes required for each fuel tank. The revised AMM procedures will include a check on the biocide dosing calculation, prior to the calculated biocide quantity being added to the fuel tanks.

The aircraft manufacturer undertook to confirm the level of biocideto-fuel mixing achieved when biocide is added to fuel prior to refuelling the aircraft, using the 'pre-mixing' method as currently defined in the AMM. This work would ensure that this dosing method achieves the same degree of biocide mixing as is the case with a metered injection rig. The manufacturer stated that if the testing revealed a lower level of mixing, the pre-mixing method could be removed from the AMM. A joint approach with Boeing would be taken to ensure consistency and best practice, in line with IATA guidance.

Action by the Base AMO that performed the biocide treatment

The AMO that performed the biocide treatment on G-POWN introduced a new role of ‘technical engineer’. The technical engineer would be an EASA Part-66 B1 licensed engineer, outside of the management chain within the organisation, who would be available to assist other licensed engineers and mechanics with technical queries, such as calculations.

The AMO undertook to introduce usage limits in stores so that staff would not be able to withdraw chemicals in quantities that significantly exceed the maximum permitted.

The AMO increased the amount of office space available to the planning department and nominated a room dedicated to work pack compiling.

The EASA SIB 2020-06 was included in the recurrent training syllabus for all AMO staff.

The AMO undertook to write a procedure for biocide treatment, which would incorporate the following:

1. Two independent licensed engineers would make the calculation. Both calculations would be verified by the Technical Engineer against their own independent calculation.
2. A spreadsheet-based biocide calculator to allow the engineer to calculate the amount of biocide to be administered by entering the specific details of the fuel.
3. Biocide treatment would be considered as a “critical maintenance task” and would require duplicate/independent inspection of the calculations and the accomplishment of the task.

The AMO would provide additional training on the differences between Airn@v, and Airnav^{X}.

The AMO would provide additional training on using the TSM within each application.

Action by the Line AMO

The Line AMO liaised with the manufacturer and the operator for delegated access to airnav^{x}.

A safety and compliance notice was issued to all staff concerning the use of AirN@v and the importance of filtering for the correct Fleet Serial Number.

Station managers were reminded to perform competency assessments to an adequate standard.

An additional check of competence was introduced using maintenance data in the certification authorisation interview.

A safety and compliance notice was issued to disseminate the manufacturer's training material on using the AirN@v TSM. This was also added to their Airbus engineer type training courses and equivalent material for airnav^{x}.

The Part-147 maintenance training organisation included a signoff task in their practical logbooks for engineers regarding the use of effectivity and troubleshooting manual for Airbus and other manufacturers' types.

The G-POWN incident was included in continuation training and instructor awareness from September 2020 onwards.

Action by the operator

The operator undertook to maximise crew learning from the G-POWN serious incident, by incorporating it in its recurrent CRM training package for all aircrew, starting in September 2020.

The operator incorporated into its engineer continuation training an exercise on communication and information management, based on this event, to enable duty engineers to maximise their awareness of the ongoing serviceability of an aircraft. It also added related detail to its Safety Management System.

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.

ACCIDENT

Aircraft Type and Registration:	Replica Royal Aircraft Factory BE2c, G-AWYI
No & Type of Engines:	1 De Havilland Gipsy Major Mk 10-1 piston engine
Year of Manufacture:	1969 (Serial no:1)
Date & Time (UTC):	2 September 2020 at 1038 hrs
Location:	Sywell Aerodrome, Northamptonshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Severe damage to entire airframe
Commander's Licence:	Private Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	1,747 hours (of which 287 were on type) Last 90 days - 18 hours Last 28 days - 14 hours
Information Source:	Field Investigation

Synopsis

The aircraft was performing a flying display with several other vintage aircraft when the aircraft was seen to enter a descending right turn. The aircraft did not recover from the descent and struck the ground in a steep nose-down attitude.

It is likely that the aircraft entered a spin, although the possibility that the initial departure was a spiral dive could not be eliminated. The reason for the departure from controlled flight could not be determined. No pre-existing mechanical defects were found with the aircraft or engine.

History of the flight

The aircraft was taking part in a practice air display with five other vintage aircraft at Sywell Aerodrome in Northamptonshire. The display team had flown the same display sequence for a couple of years, but due to the Covid 19 pandemic, this was the first display practice of the 2020 season. During the display the six aircraft fly a series of choreographed manoeuvres and flypasts to simulate a first world war dogfight. To ensure safe separation between the aircraft during the display, the display area is divided into two halves by the B-axis[1] and into three height bands.

Footnote

[1] The B-axis is an imaginary line in the centre of the display area at 90° to the display line.

On the morning of the accident the six pilots met for a pre-flight briefing. This was followed by three walk-throughs of the display routine to ensure each pilot understood the planned display. One of the team then briefed the Flight Information Service Officer in the control tower on the planned display and agreed a display time.

The six aircraft took off at 1029 hrs and commenced the display. After the first few manoeuvres, G-AWYI and a Fokker DR1 were holding position flying orbits at 500 – 600 ft to the right of crowd centre. The plan was for the pair to position behind a Sopwith Tri-plane and another Fokker DR1 as they flew back down the display line. However, G-AWYI was seen to enter a descending right turn from 500 – 600 ft. The aircraft continued in the steep descending turn, completing two and half rotations, before it struck the ground. The accident occurred at 1038 hrs.

When the display leader realised an accident had occurred the display was stopped, and the five other aircraft landed safely.

During the display the airport fire service wait in their vehicles ready to react if an incident occurs. The fire crew saw the aircraft descending and started driving towards the area before the aircraft had struck the ground. They were on site quickly and were able to assist the pilot. The pilot was conscious and trying to get out of the aircraft. He was taken to hospital having sustained a fractured vertebra, broken ribs, severe face lacerations, a broken wrist and broken thumb.

Witnesses

Although many people were watching the practice display, G-AWYI was not the focus of the display when the accident occurred. So, whilst several people saw the aircraft descending to the ground, no one on the ground witnessed what happened before.

The pilot flying the Fokker DR1 which was orbiting behind G-AWYI at the time, saw the aircraft roll into the right turn. He recalled that they were orbiting at 600 ft waiting for the Sopwith Tri-plane and the other Fokker DR1 to fly down the display line so they could formate behind them as they turned. However, when he saw the two aircraft, he realised that G-AWYI and his aircraft were not in the ideal position and would need a large turn to formate behind them. When he saw G-AWYI roll into the right turn he recalled thinking that the roll was ”a bit harder than normal”, he commented that the pilot normally flew the aircraft very gently and this was just a bit more “spirited” than normal. He described seeing the wing drop and the aircraft entering what he thought was a spin. He recalled that the manoeuvre appeared to be very gentle and he expected to see the rotation stop and the aircraft recover. However, the rotation did not stop, and he saw the aircraft continue to descend to the ground.

Pilot’s recollection

The pilot had a good recollection of the events prior to the flight and of the first part of the display. He recalled the aircraft was flying well with no problems. He was flying orbits at 500 ft and remembered seeing the Sopwith and Fokker flying along the display line. He was not in an ideal position to formate behind them and needed to make a large turn to get in position. He remembered rolling into the turn and the aircraft "just departing into a spin". He applied full power and believes he applied out-of-turn rudder. He had a clear memory of pulling back on the control stick and the wing dropping again. His next memory was the "nose going straight down and the aircraft not responding" and feeling like "the aircraft wasn't flying anymore".

The pilot thought that the aircraft had entered a spin rather than a spiral dive as it did not feel like the aircraft was accelerating. However, he did not think that he had simply stalled the aircraft in the turn. He described how he flew the aircraft primarily on feel and had flown many hours on the aircraft. He did not think that he would have been too slow in the turn. He thought that the aircraft may have encountered some wake from his or another aircraft or that the aircraft could have been affected by a wind gust.

The pilot did not think there was any problem with the engine at any stage and did not think he had any control restrictions.

Recorded information

No radar recording was available for the aircraft. However, a spectator who was filming the display on a mobile phone captured the accident sequence.

In the first frame of the footage, G-AWYI is banked to the right with the fuselage in a roughly level attitude. The aircraft can then be seen descending in a right turn with the nose dropping into a steep nose-down attitude. After the aircraft turns through approximately 360°, the nose-down attitude appears to reduce slightly before the nose drops again, the rotation rate then appears to increase and the turn tightens. The aircraft continues to rotate until it struck the ground. The time from the first frame to the aircraft's contact with the ground is 9 seconds. The time from the completion of the first 360° turn to the ground is approximately 5 seconds.

A professional photographer, who was at the airfield, also managed to capture several high-resolution photographs of the aircraft as it descended to the ground. The photographs taken capture G-AWYI in the latter part of its descent (Figures 1 and 2).

The control surface positions can be seen in the sequence of images in Figure 1. The ailerons appear to be neutral. The elevators appear to be trailing edge up suggesting the pilot was applying some aft control input. The rudder trailing edge was to the right (of the aircraft's longitudinal axis) suggesting the pilot was applying some right rudder. It was not determined exactly how much elevator or rudder was applied but neither appeared to be at full deflection.

Figure 1

Four images of G-AWYI in the right descending turn showing control surface deflections (Used with permission and under copyright of the photographer)

Figure 2

Collage of images of the aircraft continuing to rotate to the right as it descended
(Used with permission and under copyright of the photographer)

Accident site

The wreckage of G-AWYI was located in a field inside the western boundary of the aerodrome (Figure 3). The ground was soft and contained several large mounds of waste earth and rubble from recent building work which restricted emergency vehicle access to the injured pilot and the aircraft.

Figure 3

Accident site at Sywell Aerodrome

There were no ground marks to indicate the aircraft had slid or bounced on impact. The front section of the aircraft and the engine were embedded in the ground at a steep nose-down attitude (Figure 4). One blade of the fixed pitch, wooden propeller had snapped off and fragmented. The remaining blade had cracked radially around the root but was still attached to the hub. The aircraft's wooden skids were embedded in the soft earth and the landing gear was severely disrupted and partially detached from the fuselage. Due to the steep angle of impact, the aircraft's rear fuselage and tail remained high in the air and leaning to the left. The airframe structure around the rear cockpit and aft of the cockpit floor was bent and deformed by the force of the impact (Figure 5).

Figure 4

G-AWYI at the accident site

To enable the rescue services to work around the aircraft safely, the aerodrome Rescue and Fire Fighting Service (RFFS) propped up the tail with a ladder to stabilise the aircraft structure.

Figure 5

G-AWYI showing deformed fuselage structure

Evidence from the impact marks on the wings indicated the leading edges of the left wings struck the ground as the aircraft rotated to the right. The lower right wing hit a large mound of earth which snapped the wing in half along the chord line approximately a third of the way along its length from the fuselage. The upper right wing had also struck the mound of earth but had remained in one piece. The forward interplane struts on both the left and right side had snapped, (Figure 6). Although the rear outboard strut had snapped at the connection to the upper wing, the inboard strut remained unbroken and connected. The left upper wing was removed by the RFFS to make it easier to provide medical treatment to the pilot and to extract him from the cockpit.

Figure 6

Damage to the lower right wing

With the exception of the centre wing section where the bracing wires had been pulled from their brackets by the impact, the wing bracing wires were intact and connected to their respective brackets. The bracing wires on the left upper wing were disconnected when the wing was removed by the RFFS.

During the impact sequence the front fuselage had compressed and the engine block had become embedded in the ground. The fuel tank, positioned behind the engine, had been crushed and punctured causing the fuel to leak out (Figure 7). The front cockpit structure was severely damaged but the rear cockpit, where the pilot had been seated, sustained significantly less damage.

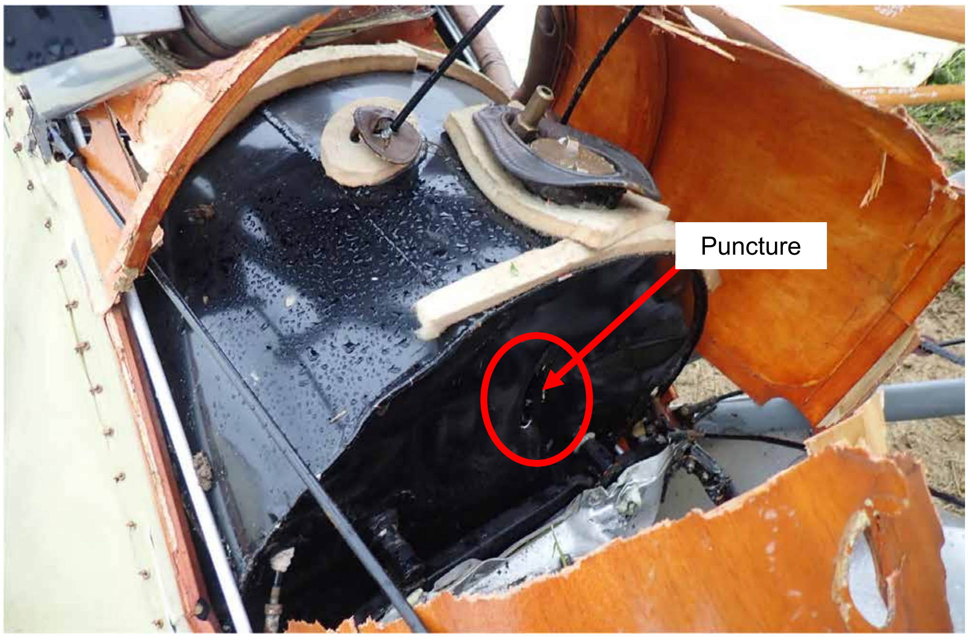

Figure 7

Fuel tank showing punctured surface

The rear cockpit instrument panel and support structure had broken away from the fuselage mounting and was hanging forwards into the front cockpit. The airspeed indicator on the left of the panel was dislodged, the glass face smashed, and the mechanism disrupted. The rest of the instruments were still in place and largely undamaged, although the panel was bent along a vertical axis to the left of centre (Figure 8). It is possible the pilot's head, face and mask had contacted the instrument panel as the aircraft hit the ground causing his facial injuries and the damage to the panel.

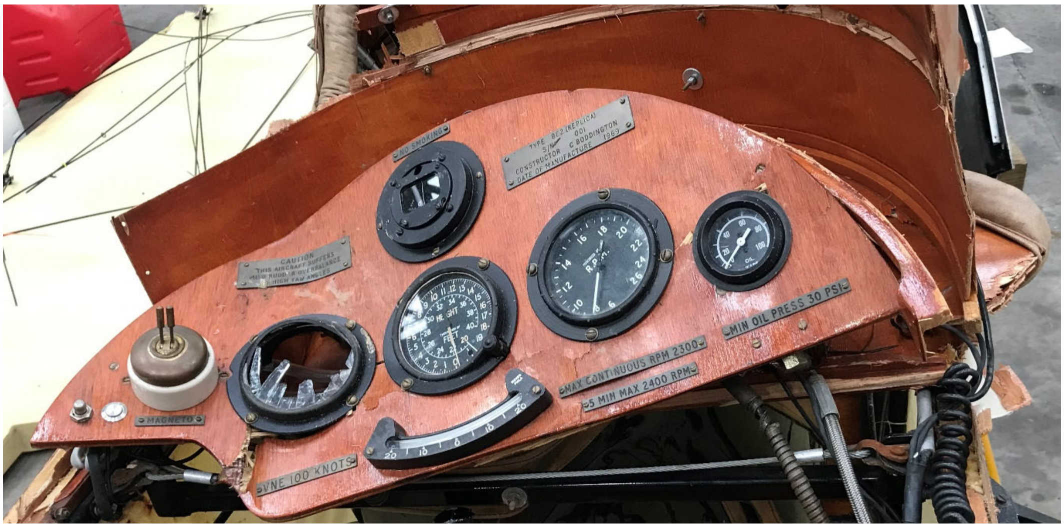

Figure 8

Rear cockpit instrument panel showing deformation

The base of the pilot's wooden seat cushion had cracked longitudinally but was still fitted over the metal bucket seat structure. A broken pen and a heavy black plastic solar charging panel were found on the cockpit floor, (Figure 9). The pilot later confirmed the solar panel had been placed in the canvass stowage compartment behind the pilot's head before the flight. Spare clothes and paper items were still contained in the canvass stowage bag.

Figure 9

Rear cockpit looking downwards showing solar panel case beside the seat

On site examination established that all the cables connecting the flight controls to the control surfaces remained intact and fitted to their respective attachment points.

When the engine's fuel gascolator was removed, it was found to be full of fuel, indicating that fuel was still being supplied to the engine prior to impact and had leaked out of the fuel tank when it was ruptured. The engine had broken away from its mounting frame and there was significant rupturing of the engine bay structure and pipework.

Aircraft information

Constructed as a replica Royal Aircraft Factory BE2c World War 1 observation biplane, the aircraft was designed and built in 1969 at Sywell Aerodrome for a feature film. It was one of several aircraft commissioned for the film, but funding ran out before the film could be made. After several years, the aircraft was sold to an American owner who flew it until 1977 when it crashed on takeoff. The wreckage remained in storage until it was purchased by the current owner and returned to Sywell for extensive restoration in 2005.

The aircraft was originally constructed using Tiger Moth components but was significantly modified to replicate a BE2c. The Tiger Moth wings, wing stagger and dihedral were retained but the wing sweep was removed. The single bay rigging of the Tiger Moth wing was modified to the double bay rigged biplane layout of the BE2c[2]. Interplane and cabane struts were lengthened to increase the gap between the upper and lower wings and new tail surfaces were constructed. A new undercarriage was manufactured and fitted, and forward wooden skids added. A new, directional tailskid was designed and rigged to the aircraft rudder system. No slats were installed on the wings, but the aircraft retained the Tiger Moth differential ailerons on the lower wings (with asymmetric down going aileron). The original BE2c design had ailerons fitted to both upper and lower wings.

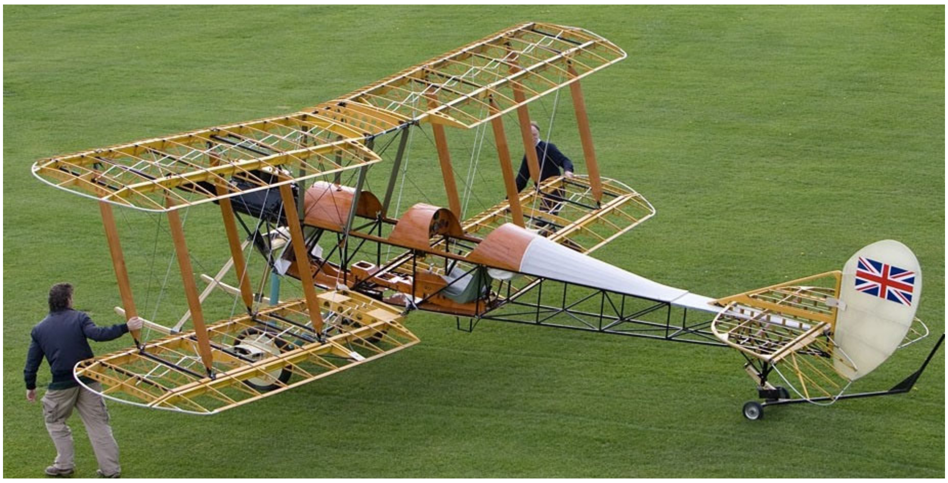

Figure 10

G-AWYI during its restoration

During the restoration, (Figure 10), the original design was modified to improve safety. Following structural load analysis, additional strengthening measures were taken. A four-point harness was added to the front and rear cockpit, additional control cables were added to the elevator control circuit, stronger bracing wires installed and structural strengthening to the tail section. The fin and rudder shapes and areas were altered to more closely replicate a BE2c, but no horn balance was fitted to the rudder. The original Tiger

---

Footnote

[2] The space enclosed by interplane struts fitted between upper and lower wings is called a bay, an aircraft with one pair of struts between each wing is called a single bay. Two pairs of struts between each wing is called a double bay.

Moth rudder control system was also retained which consisted of rudder actuating cables attached to extensions to the rudder pedals bar. This arrangement means that a small input at the rudder pedals results in a large defection of the rudder. A minicom radio and intercom were installed in a narrow wooden box on the right side of the rear cockpit to provide air and ground communications.

The aircraft was fitted with a De Havilland Gypsy Major 10-1 piston engine. This engine was designed as an inverted engine[3]. In order to better simulate the engine installation of a BE2C, the Gypsy Major engine was modified to operate with the cylinders uppermost and fitted with an additional, dummy, exhaust system. The engine drove a wooden, two bladed, fixed pitch Hercules propeller. The fuel tank was moved from the centre section and installed between the engine and the front cockpit. A smoke generator tank was installed in the engine bay to simulate battle damage during flying displays.

Figure 11

G-AWYI earlier during the accident flight
(Used with permission and under copyright of the photographer)

Aircraft examination

The right vertical side of the airframe was bent inwards aft of the rear cockpit and the left vertical side of the airframe was also buckled inwards level with the back of the rear cockpit seat. This buckling was sufficient to cause a restriction in the elevator trim mechanism, however, there were no witness marks on the inside of the airframe to indicate that the trim mechanism had been in contact with the fuselage before the accident.

In the rear cockpit, the control column was wedged forward under the horizontal metal frame of the instrument panel. The lower right seat harness anchor bracket bolts had been pulled out of the airframe structure, (Figure 12).

Footnote

[3] An inverted engine is designed to be installed and operated with the crankcase uppermost and the cylinders below the crankcase.

Figure 12

Rear seat lower right harness anchor bracket bolts pulled out of frame

The upper, horizontal metal cockpit frame aft of the rear pilot's seat had bent (Figure 13) and the seat's mounting points were deformed.

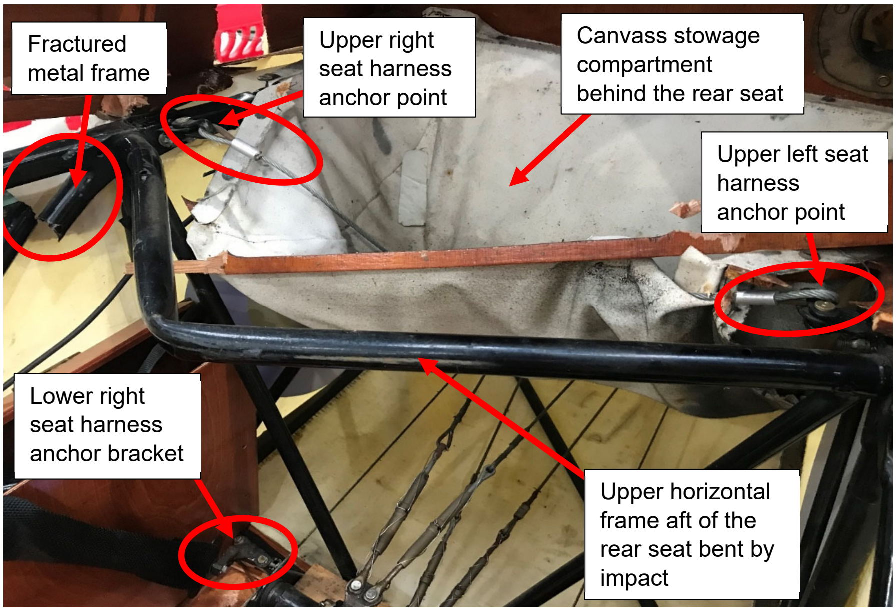

Figure 13

Airframe damage behind the rear cockpit seat – view looking aft and to the left

The position of the rear seat, after the accident, restricted rearward movement of the control column. A hole was found in the control column's leather gaiter where it had been worn away by contact between the control column and the seat (Figure 14).

Figure 14
Hole in the control column gaiter

The pilot later confirmed that, in order to prevent the tail from lifting in a prevailing wind during taxiing the pilot has to pull back hard on the control column, this results in contact between the control column and the seat, damaging the leather gaiter. Contact between the edge of the seat and the control column does not indicate an elevator control restriction because full elevator deflection is achieved before contact with the seat.

The engine's ignition harness was disconnected from its spark plugs and the spark plugs removed. The propeller rotated freely indicating that the engine crankshaft was still turning, and the engine had not seized during the incident. The piston combustion chambers, valve heads and piston crowns were examined by boroscope but no damage or anomalies were found. Oil was still present in the engine and the oil filter was free of debris.

All of the damage to the aircraft structure was consistent with the forces experienced during the impact and no evidence of pre-impact damage or defects was found during the examination.

Survival

The pilot was sat in the rear cockpit and although the aircraft struck the ground in a near vertical attitude distorting the fuselage structures, a survival space remained. There was no post-impact fire.

The rear instrument panel had fallen into the front cockpit reducing the survival space available, had the cockpit been occupied.

The pilot was wearing a kevlar flying helmet with a leather cover to make it look more authentic for a vintage aircraft.

Weight and balance

The aircraft's total weight was estimated to be 1,572 lbs (maximum AUW – 1880 lbs) and the centre of gravity was 7.67 inches aft of the datum[4]

Meteorology

At the time of the accident the flight information service officer recorded the observed weather conditions. He recorded the surface wind was 210° at 12 kt, cloud and visibility were CAVOK, the temperature was 17°C, the dew point was 8°C and the surface pressure was 1017 hPa.

Another pilot who took off approximately 5 minutes prior to the display team commented that wind conditions changed markedly over the next 45 minutes. He had to land at a farm strip approximately 8 nm north-east of Sywell due to the airfield closure after the accident. On takeoff he described the conditions as "perfect" but on landing there was "rough air", turbulence and windshear below 500 ft. He attributed the change in conditions to an approaching weather front.

Weather conditions at the airfield deteriorated in the afternoon with rain arriving at approximately 1430 hrs.

In 2013 the AAIB reported on a similar accident to a De Havilland DH53 Humming Bird which occurred at Old Warden Aerodrome, Bedfordshire[5]. The investigation found that it was likely that the wind conditions contributed to the accident.

Pilot information

The pilot held a private pilot's licence (both national and EASA) with a single engine piston (SEP) and aerobatic ratings. The pilot held a display authorisation for the replica BE2c. He also held a valid Class 2 medical.

The pilot initially learnt to fly in 1986 and had accumulated a total of 1,747 flying hours when the accident occurred. Most of that flight time was on vintage aircraft.

He had been flying G-AWYI since May 2011 when he completed the rebuild. He had accumulated 287 hours on the aircraft. He had last displayed the aircraft in early August at Old Warden Airfield and had flown 14 hours in the aircraft in the last 28 days. On the return flight from Old Warden to Sywell he had completed the test flight to renew the Certificate of Validity for the aircraft's Permit to Fly and reported there were no problems with the aircraft.

He had practiced spinning in various types, most recently in a Tiger Moth in June 2020.

Footnote

[4] Forward cg limit – 6.0 inches aft of datum, aft cg limit -8.5 inches aft of datum

[5] AAIB Report G-EBHX – https://www.gov.uk/aaib-reports/de-havilland-dh53-humming-bird-g-ebhx-1-july-2012

Other information

Spinning

A spinning aircraft is best described as an aircraft whose wings are experiencing an aggravated stall and whose resultant aerodynamic force causes the aircraft to 'autorotate', a condition where the aircraft is continuously rolling, yawing and pitching. In a fully developed spin, the aerodynamic forces on the aircraft are balanced by the inertia forces created by the rolling and yawing motion. The flight path will normally follow a helix whose axis is orientated vertically. For a spin to occur the wing must stall and the nose must yaw. This can occur in an uncoordinated turn if too much up elevator (pitch up) is applied with either too much or too little rudder[6].

Spin recovery techniques vary between aircraft and it is important for pilots to know the correct recovery technique for the aircraft they are flying. However, generically they involve applying; out-of-turn rudder to stop the yaw, control stick forward (or neutral) to reduce the wing's angle of attack. and ailerons neutral. Once the rotation stops, the rudder is centralised and the pilot can recover from the ensuing dive. Applying power during the initial recovery tends to flatten the spin and can delay or compromise recovery. If the pilot attempts to pitch up too early or too aggressively the aircraft can enter a secondary stall or spin.

Spiral dive

A spiral dive is a steep descending turn with the aircraft in a nose-down attitude and with the airspeed increasing. It can look very similar to a spin but the significant difference is the wing is not stalled and the airspeed will be increasing as the aircraft descends. If a pilot rolls rapidly into a steep banked turn and allows the aircraft's nose to drop, they would have initiated a spiral dive.

A spiral dive flight test conducted in October 1989 in a Tiger Moth described the aircraft entering '*a steady rotation around the horizon almost identical in rate and motion to that displayed by the aircraft in a stabilised spin*'. After about 360° of turn the aircraft stabilised with '*a deep nose attitude of approximately 45 – 50 degrees nose-down, with a gradual increase in airspeed*'.

Flight test report

After G-AWYI was rebuilt a flight test was conducted, by a test pilot, as part the process of obtaining the aircraft's permit to fly.

During the flight test straight, turning and accelerated stalls were completed. Spinning tests were not conducted. The report stated that:

> *'The aircraft was benign at the stall for all tests performed. The stall was characterised by a gentle g brake; full back stick was not reached. There was no obvious stall warning, other than a general 'mushing' sensation.'*

Footnote

[6] Wood, R. H., Sweginnis, R. W. *Aircraft Accident Investigation*.

The 1g stall speed at maximum takeoff weight was 40 kt.

The aircraft's longitudinal stability was satisfactory at all speeds, but the longitudinal stick force required to manoeuvre the aircraft was relatively low. The stick force required to generate a 1.5 g vertical acceleration from trimmed flights was 5 lbs and for 2 g was 8 lbs.

Due to the small fin and large rudder, the aircraft was not directionally stable and could easily generate large sideslip angles. The rudder tended to overbalance so the pilot needed to keep his feet on the rudder pedals to hold a particular rudder position and to maintain balanced flight. The aircraft also exhibited a '*reasonable amount of adverse aileron yaw*'[7] which needed to be balanced with the rudder. The report stated that;

> *'In the yaw axis, the aircraft exhibited negative directional stability, which was common for the era. With feet resting on the rudder bars, the aircraft was reasonably conventional directionally. However, when sideslip was generated, or if feet were removed from the pedals, there was a tendency for the rudder to overbalance. Being a large rudder surface, it could generate large sideslip angles during steady heading sideslip tests, which required large angle of bank to keep the aircraft straight in the cross-controlled condition.'*

Since the flight test was completed the owners had added flow disruptors to the fin to improve the rudder overbalance. The pilot reported that this had improved the rudder characteristics.

Analysis

Whilst flying orbits at approximately 500 ft the aircraft entered a descending right turn. The aircraft descended in a steep nose-down attitude and continued to rotate to the right.

The pilot believed the aircraft entered a spin. However, from the available evidence it is not clear if the initial departure was a spin or a spiral dive. Previous tests in a Tiger Moth showed that a spin and a spiral dive can look and feel very similar. The pilot did not recall the airspeed increasing during the descent which would suggest it was a spin rather than a spiral. It is possible that the initial departure was a spiral and this transitioned to a spin as the pilot tried to pitch up.

The pilot believes that he initially made the correct inputs to recover from a spin and recalled the aircraft starting to recover. He remembered pulling back on the stick to climb away from the ground. However, he recalled the wing dropping again and the aircraft continuing to descend and rotate. It is understandable that the pilot would instinctively want to pitch up as the aircraft was passing approximately 300 ft with a very low nose attitude. However, it is likely that the aircraft had not recovered enough airspeed when he pitched up, leading

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Footnote

[7] Adverse aileron yaw is the yawing moment that is caused by the differences in the lift and drag of the left and right wings when ailerons are deflected. The down-going aileron increases the local lift but also increases the local drag and this 'aileron drag' can result in a yawing motion in the opposite direction to the rolling motion commanded.

to a secondary stall. As the pilot felt the aircraft recovering, he would have centred the rudder. However, the rudder on this aircraft did not naturally self-centre and, due to the rigging between the pedals and the rudder, small movements of the pedals caused large deflections of the rudder. In this very dynamic situation, it is possible that he did not get the rudder accurately centred. If the pilot inadvertently moved the rudder past centre and slightly into the turn as the aircraft stalled again it would explain why the aircraft entered a secondary spin.

Photographs taken during the second part of the spin show the rudder was displaced into the turn and elevator was displaced up. These inputs are the opposite of those required to recover from the spin. However, at this stage the aircraft was very close to the ground. The time from the wing dropping again to the ground was approximately 5 seconds. It is unlikely that the pilot had time to process what was happening and to make the correct inputs. As the aircraft was approaching the ground it would be instinctive to pitch up. It is possible that the in-to-turn rudder was just where the rudder was after he initially tried to centre the rudder and he did not have time to make any further changes.

Once the aircraft entered a secondary spin it is unlikely there was enough altitude to recover.

There is not enough evidence to determine why the aircraft initially departed from controlled flight. The pilot was experienced at flying this aircraft and did not think that he simply stalled the aircraft in the turn. However, the aircraft requires quite low stick force to stall, the stick does not need to come fully aft and there is no marked stall warning. It is possible that whilst manoeuvring the aircraft slightly aggressively the pilot inadvertently stalled the aircraft. The adverse aileron yaw requires quite large rudder inputs to maintain balanced flight particularly if large aileron inputs are used. It is possible that this led to the aircraft being out of balance in the turn. The small fin and large rudder means that it is quite easy to generate large sideslip angles and yaw rates. This would lead to a spin if the aircraft was stalled. The aircraft was not fitted with leading edge slats which are fitted to the Tiger Moth to help reduce the aircraft's tendency to enter a spin when a wing drops at the stall.

It is also possible that the aircraft was affected by wake. The BE2c and the Fokker Tri-plane had been orbiting in the same airspace, so the BE2c may have flown back through its own wake or that of the Fokker. This could have contributed to the departure. It is also possible that the aircraft was affected by turbulence. Another pilot flying at the same time reported that the air was becoming more unstable around the time of the accident. It is possible that a lull caused the aircraft to lose airspeed and this may have contributed to the departure.

The pilot was experienced at flying this aircraft and had recently practiced spinning in a similar aircraft.

Engineering

All the damage found on the aircraft was consistent with the forces imparted during the accident. The impact marks and damage to the wings confirmed the aircraft was still rotating on contact with the ground. There was no evidence of any engine, structural or control problems that would have contributed to the accident.

Survivability

Whilst the aft seat harness remained secure, the harness mounting brackets partially separated from the airframe. Partial separation of the seat harness brackets and the distortion of the seat mounting structure allowed the pilots head to strike the instrument panel causing his head and facial injuries. The damage to the panel illustrated in Figure 8 is consistent with this possibility.

The heavy plastic solar charger was positioned in the storage bag behind the pilot's head prior to take off but was found on the floor of the cockpit after the accident. It is likely it was released by the force of the impact and may have struck the back of the pilot's helmet.

The rear cockpit instrument panel broke away from its mounting and was found in the front cockpit. Had the front seat been occupied it could have struck the front passenger and caused significant injuries.

It is likely the helmet prevented the pilot from suffering more severe head injuries when he made contact with the instrument panel or the solar charger struck his head. The addition of a four-point harness and the survival space created by the rigid cockpit framework also contributed significantly to the survivability of this accident.

Conclusion

Whilst orbiting at low-level it is likely that the aircraft entered a spin, although the possibility that the initial departure was a spiral dive could not be eliminated. It was not possible to determine the reason for the initial departure from controlled flight.

It is likely that the pilot started to recover but tried to pitch up before the aircraft had built sufficient airspeed leading to a secondary spin.

The pilot was wearing a kevlar flying helmet and it is likely this prevented him from suffering further serious injuries.

There was no evidence of any mechanical fault which could have contributed to the accident.

Published: 29 April 2021.

INCIDENT

Aircraft Type and Registration:	Airbus Helicopters EC175B, G-EMEB	
No & Type of Engines:	2 Pratt & Whitney Canada PT6C-67E turboshaft engines	
Year of Manufacture:	2017 (Serial no: 5030)	
Date & Time (UTC):	23 September 2020 at 1000 hrs	
Location:	Aberdeen Airport	
Type of Flight:	No intention of flight	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Bearing failure within the left accessory gearbox	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	37 years	
Commander's Flying Experience:	5,180 hours (of which 1,325 were on type) Last 90 days - 112 hours Last 28 days - 30 hours	
Information Source:	AAIB Field Investigation	

Synopsis

A failure of an alternator pinion roller bearing in the left accessory gearbox (LAGB) occurred during a post-maintenance ground run following a scheduled replacement of the main gearbox. The investigation identified that the roller bearing was subjected to an excessive axial load during operation, caused by compression of grease and air within the alternator shaft link during installation by the operator of a 10 kVA alternator to the LAGB. The cause of the incident was identified as the application of an excessive quantity of grease to the alternator pinion cavity, as required by the aircraft maintenance manual instructions. The method used by the operator to attach the alternator to the left accessory gearbox was identified as a contributory factor in the incident.

The manufacturer has amended the content of the aircraft maintenance manual to ensure that any excess grease is removed from the alternator shaft link cavity and has communicated this information by issuing a Safety Information Notice[1] to EC175 operators.

Introduction

The bearing failure occurred whilst the helicopter was on a maintenance ground run with no intention of flight. However, given the circumstances of the failure, and the possibility

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Footnote

[1] SIN 3599-S-63.

that it could have occurred in flight, the Chief Inspector of Air Accidents instigated a safety investigation to determine the cause.

Maintenance activity

Replacement of the main gear box

The helicopter was undergoing scheduled maintenance to replace the main gear box (MGB), which had reached its overhaul life of 800 flying hours. An overhauled MGB was supplied to the operator by the helicopter manufacturer[2]. Before this could be installed on G-EMEB, certain accessory equipment had to be removed from the old MGB for installation on the new MGB, including the LAGB 10 kVA alternator.

The exchange of the MGB accessory equipment took place in the operator's maintenance hangar with both MGBs mounted in transport stands, which provided good access for the work carried out. A Part-66 B1 licenced aircraft engineer (LAE), who was type-rated on the EC175, removed the alternator from the old LAGB, together with its V-band clamp and interface spacer as an assembly, by unfastening the four bolts that attach the interface spacer to the LAGB (Figure 1).

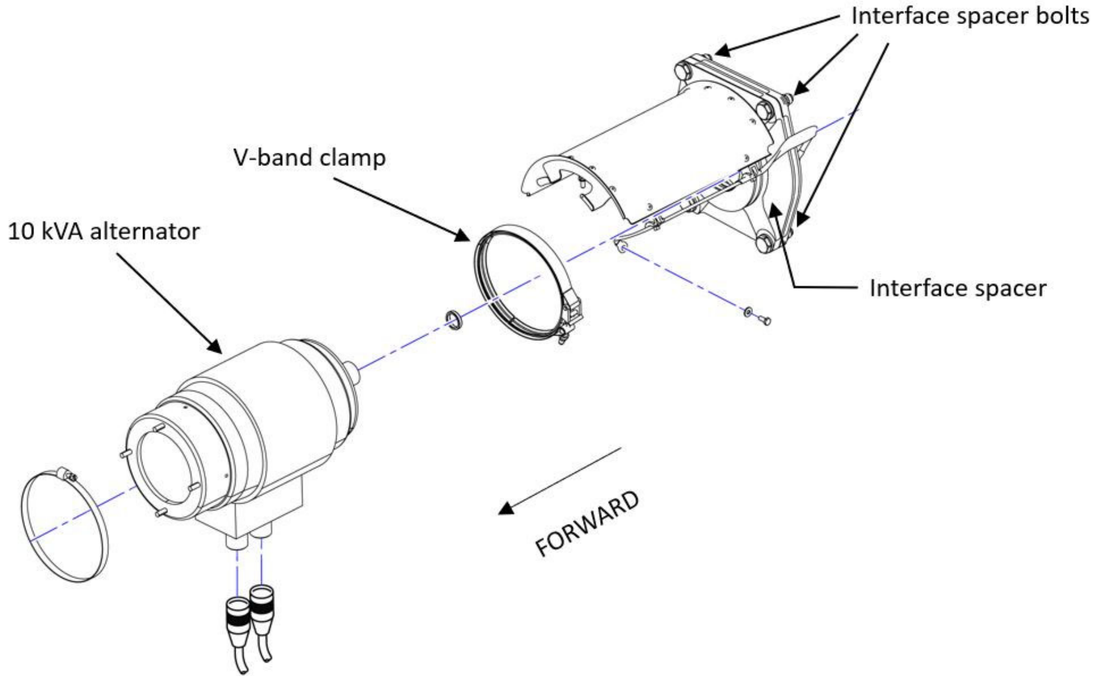


Figure 1

10 kVA alternator, V-band clamp and interface spacer (image used with permission of Airbus Helicopters)

Footnote

[2] As part of the manufacturer's MGB overhaul process, the MGB (with the left and right accessory gearboxes attached) had been run on a test cell with no faults identified. In addition, the overhauled left accessory gearbox had been run on a separate test cell for 12 hours with a power of 30 kW applied, which is higher than the maximum power of the 10 kVA alternator. The power applied on this test cell was cyclically varied (to introduce a cyclical torque loading to the gearbox), again with no faults identified.

The new LAGB had a cover plate fitted over the alternator mounting location, which required removal in accordance with aircraft maintenance manual (AMM) task 24-21-00, 4-2, prior to installation of the alternator. Step G.6.b of this AMM task required the alternator pinion cavity to be filled with grease[3] *'until it overflows'*, before an oil-lubricated O-ring was installed in the groove of the alternator shaft link (Figure 2). The alternator shaft link was then inserted into the alternator pinion and secured with a screw and washer. There was no AMM instruction to clean any excess grease from the alternator shaft link after it had been installed.

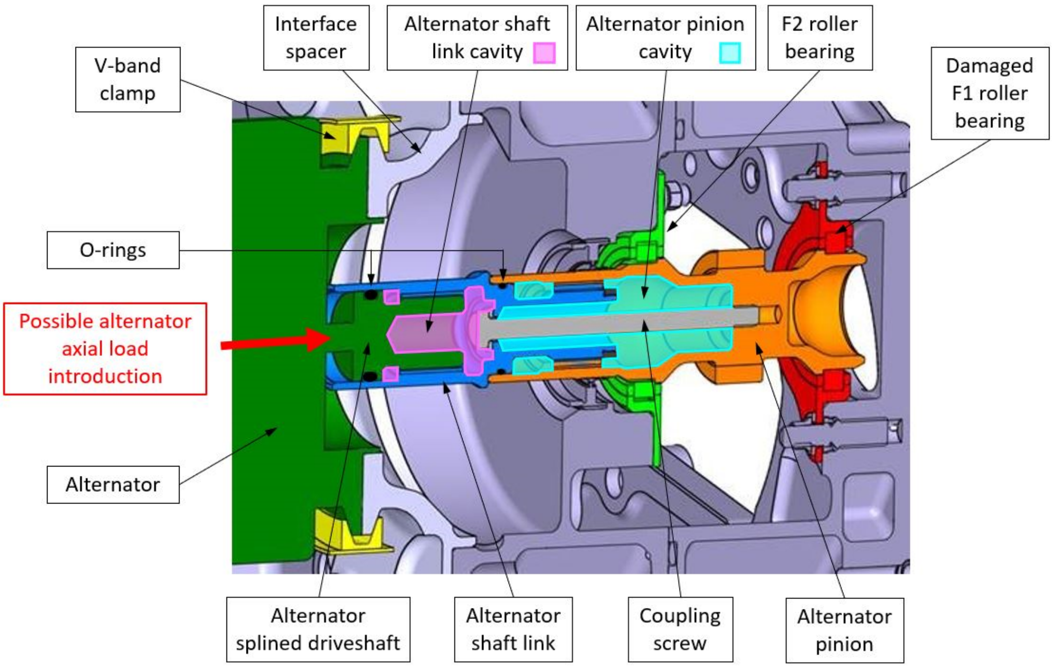


Figure 2

LAGB alternator drive (image used with permission of Airbus Helicopters)

The AMM instructions for the installation of the alternator to the LAGB require the interface spacer to be installed first[4], before the alternator is fitted to the interface spacer by attaching it with the V-band clamp[5]. The LAE, however, installed the alternator, V-band clamp and interface spacer as an assembly to the LAGB, by attaching it with four bolts that fasten the interface spacer to the LAGB. He applied a small quantity of grease to the splines of the alternator drive shaft, as required by the AMM, before the alternator was installed.

The LAE stated that whilst this was the first occasion that he had performed an alternator change on an EC175B, he was familiar with this type of task having performed numerous similar alternator changes on the operator's S-92A and EC225 helicopters. He stated that he felt well rested prior to the shift and that he was under no undue time pressure to complete the work.

Footnote

[3] Product code CM116, a graphite aircraft grease.

[4] AMM task 24-21-00, 4-2, Removal/Installation – Blank or Left Alternator 10 kVA Equipment on LAGB, step G.7.

[5] AMM task 24-21-00, 4-1, Removal/Installation – Left Alternator 10 kVA, step G.2.h.

Engine ground runs

Following completion of the MGB replacement, G-EMEB was moved to an apron for a ground run[6], with no intention of flight. The commander did not identify any abnormalities during his external walk-round inspection and stated that the MGB oil was at the correct level. The No 1 engine was started, and one minute later the MGB BACKUP OIL amber warning caption illuminated. The crew consulted the XMSN page on the multi-function display and noted that the MGB backup oil pressure was briefly 0.2 bar, before it then jumped to the normal value of 2.6 bar, where it remained. All other MGB parameters were in the normal range. The commander then started the No 2 engine.

The ground run proceeded uneventfully with the main rotors running in flat pitch until 18 minutes after the No 1 engine start, when the XMSN CHIP amber warning caption illuminated. The flight crew consulted the electronic checklist and identified that the warning had been triggered by the LAGB chip detector. The commander shut down both engines. Following the ground run, difficulty was experienced in attempting to turn the main rotors by hand in the driven direction, and a "crunching" sound could be heard from the left side of the MGB. The MGB oil was drained and was notably discoloured. The MGB assembly, including the LAGB and right accessory gearbox (RAGB), was sent to the manufacturer for examination.

Main gearbox

Overview

The EC175B MGB is a modular design with a main module that transmits the power from both engines to the main and tail rotors. The LAGB is located on the rear left side of the MGB and is driven by the main module via the left freewheel pinion. The LAGB consists of a train of spur gears within a casing, which rotate the backup oil pump, the No 1 main hydraulic pump, the No 1 air conditioning compressor, the MGB oil cooler fan and the 10 kVA alternator[7].

The drive for the DC generator on the RAGB is of a similar design to the LAGB alternator. The RAGB provides drive to the No 2 main hydraulic pump, No 2 air conditioning compressor and the emergency DC generator.

Alternator

The alternator is driven by an alternator pinion and an alternator shaft link (Figure 2) which has an internally-splined cavity that engages with the external splines on the alternator driveshaft. The alternator shaft link has a splined connection with the alternator pinion and is secured to it by a screw and washer. The alternator driveshaft has an oil-lubricated O-ring that is an interference fit within the end bore of the alternator shaft link. This O-ring seals the alternator shaft link internal cavity when the components are assembled.

Footnote

[6] AMM task 63-00-00, 6-1, Check after maintenance work

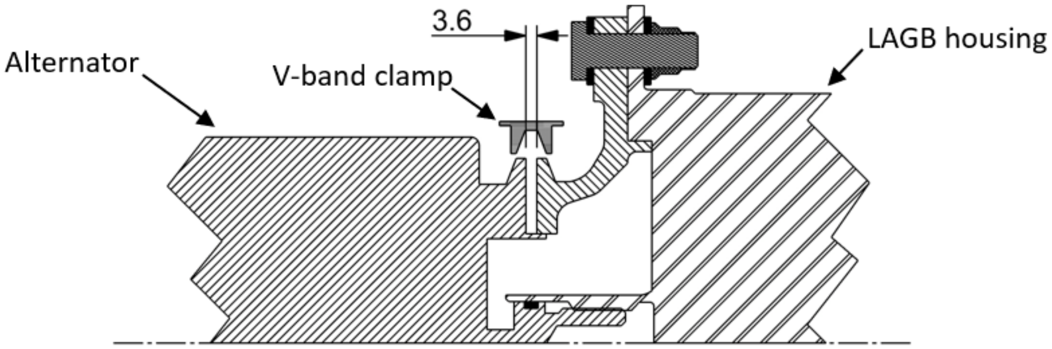
[7] The 10 kVA alternator is optional equipment for EC175s and is used to power the anti-ice system.

Bearing arrangement

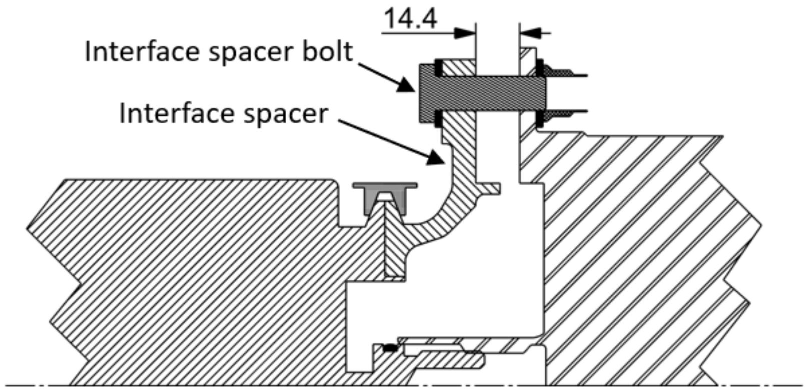
The alternator pinion is located and supported in the LAGB casing by two identical roller bearings: the F1 bearing at the rear end and the F2 bearing at the forward end of the pinion. The F1 and F2 roller bearings are designed to principally accommodate radial loads and are only rated at 10% of the radial load capacity when loaded in the axial direction. The F1 and F2 bearings were replaced with new parts when the LAGB was overhauled, prior to its installation on G-EMEB.

Alternator clamping distances

The manufacturer stated that the maximum possible clamping distance between the alternator and the interface spacer, when using the V-band clamp to attach them together, was 3.6 mm, (Figure 3(a)). The maximum clamping distance when attaching the alternator, V-band clamp and interface spacer to the LAGB as an assembly was 14.4 mm, four times greater than when using the V-band clamp (Figure 3(b)).



(a) Maximum clamping distance using V-band clamp, 3.6 mm



(b) Maximum clamping distance using interface spacer bolts, 14.4 mm

Figure 3

Maximum clamping distances using the V-band clamp and interface spacer bolts

Displacement of grease

The volume of grease displaced from the alternator pinion cavity, due to insertion of the alternator shaft link and screw, is approximately 70% greater than the volume available within the shaft link cavity once the alternator is mounted on the LAGB (shaded green in Figure 2).

The volume of grease remaining within the shaft link cavity once the alternator is mounted is influenced by the following factors:

- The degree to which the alternator pinion cavity was initially filled with grease, prior to insertion of the alternator shaft link.
- The amount of grease removed from the alternator shaft link cavity on the socket used to tighten the alternator shaft link screw.
- Any grease extruded outside the alternator shaft link, upon its insertion.
- Any excess grease cleaned away from the alternator shaft link cavity prior to installation of the alternator.

MGB examination

Magnetic chip detectors

Metallic particles were found on magnetic chip detector (MCD) No 4, in the LAGB sump, and MCD No 6, in the MGB oil sump. Metallurgical analysis of this debris determined that it was 100C6 steel alloy, the bearing material used in the F1 bearing. Excessive axial and radial play were noted in the alternator pinion shaft, due to loss of location of the alternator pinion at the failed F1 bearing.

Bearings

The LAGB outer casing was removed and visual examination confirmed that the F1 bearing had overheated and the bearing rollers were significantly deformed, with evidence of roller skidding (Figure 4). All the bearing rollers remained within the F1 bearing. The bearing cage, which is formed from a PEEK[8] material, was found in the LAGB sump. It had deformed due to excessive temperature and had migrated from the bearing.

The end of the alternator pinion that is supported by the F1 bearing was also heat-distressed and the pinion shoulder, at the point of engagement with the F1 bearing, showed evidence of creep and wear (Figure 5). The nature of this damage was consistent with the pinion running in the overheated F1 bearing whilst subject to a compressive axial load.

Footnote

[8] Polyether ether ketone, an organic thermoplastic polymer.

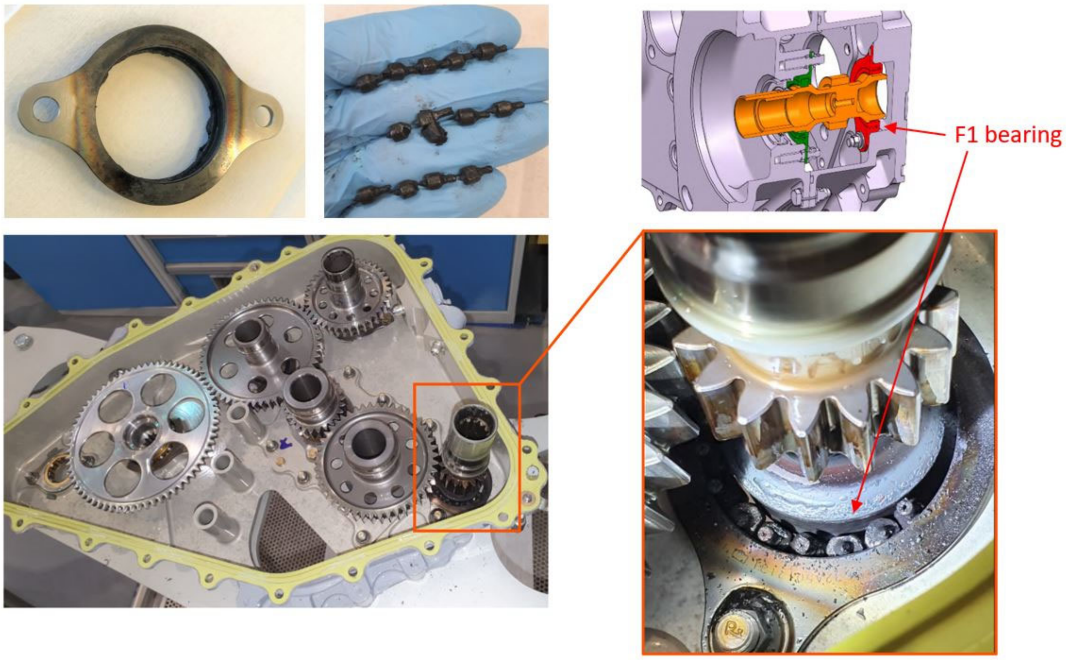


Figure 4

Failed F1 bearing in the LAGB (image used with permission of Airbus Helicopters)

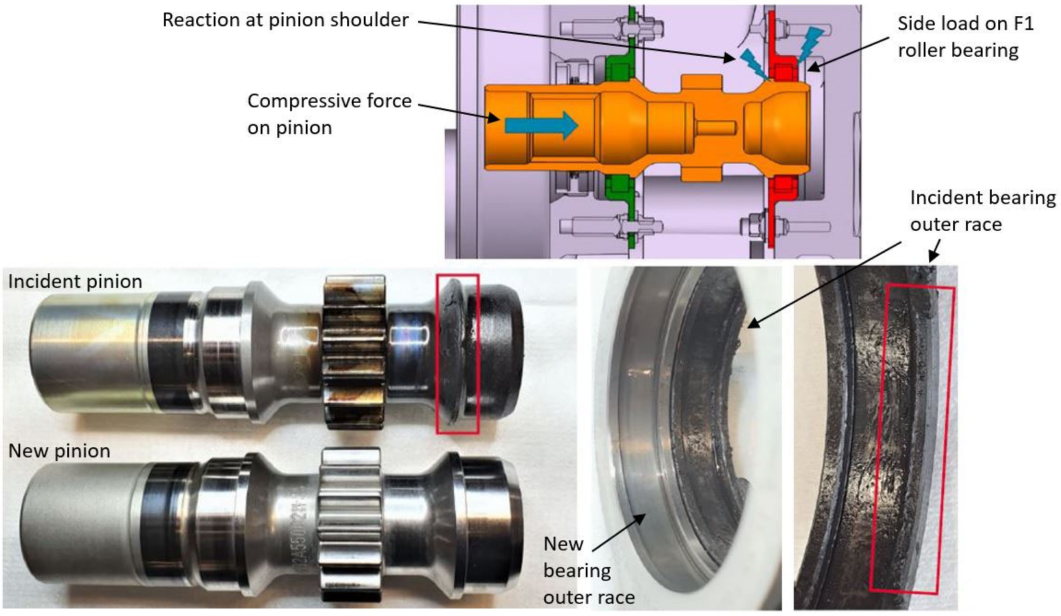


Figure 5

Damaged alternator pinion (image used with permission of Airbus Helicopters)

Alternator examination

The alternator was examined at the equipment manufacturer. The alternator conformed to all dimensional requirements apart from a minor variance between the mating flange and the rear cover, which had no influence on the F1 bearing failure. Visual examination of the alternator revealed that it was in good condition and the two ball bearings that support the alternator rotor were also in good condition, with no excessive or abnormal wear. The static electrical values measured were compliant with the requirements stated in the alternator component maintenance manual. It was determined that the alternator was serviceable and free from any defect that could result in an axial load being applied to the alternator pinion within the LAGB.

Testing by the manufacturer

The manufacturer conducted a test in which the installation of an alternator was attempted on an LAGB where the alternator shaft link cavity was completely filled with grease. In this condition the alternator could not be installed, as the gap between the alternator and the interface spacer was too large for the V-band clamp to engage.

After removing a small amount of grease from the alternator shaft link cavity, installation of the alternator was possible, with a small gap of 1-2 mm remaining between the alternator and the interface spacer due an excessive quantity of grease. Once the V-band clamp was installed and tightened to the AMM torque figure of 6.8 Nm, this gap had closed and it was observed that the LAGB drive had become notably difficult to turn by hand, which is an abnormal condition. The increased resistance in the LAGB drive was due to an excessive compressive axial load introduced in the alternator pinion, due to compression of the grease and air trapped within the sealed alternator shaft link as the alternator had been clamped to the LAGB.

Backup oil pressure warnings

The manufacturer stated that backup oil pressure warnings on the first runs of MGBs had been observed on other EC175s with other operators. The transient warning is due to gearbox oil displacing air within the gearbox oil distribution system when an MGB is first run. This air-purging effect had no influence on the failure of the F1 bearing.

Hazard assessment

The manufacturer performed a hazard assessment to consider the effect of a similar failure occurring in flight. The hazard assessment included a jam occurring in the LAGB leading to the loss of drive to the backup oil pump, No 1 hydraulic pump, cabin air conditioning compressor, MGB cooling fan and 10 kVA alternator. This scenario was considered to be conservative by the manufacturer in their assessment of the hazards, as its stress analysis showed that should the alternator pinion jam, the gear teeth on the pinion would fail, allowing drive to continue to the other LAGB accessories.

The loss of each of the LAGB accessories would be detected by the aircraft's caution and warning system, with each failure generating an amber warning caption. The hazard assessment concluded that the severity level of this failure scenario was *'MAJOR'*, resulting from a significant erosion of safety margins, and that the occurrence level was *'REASONABLY PROBABLE'* with a probability of occurrence between 10^{-5} and 10^{-3} per flight hour. The hazard assessment therefore concluded that no resulting unsafe condition[9] was identified.

The published flight manual procedure would require the flight crew to reduce engine power and fly at a minimum speed of 130 KIAS, to ensure sufficient cooling airflow through the MGB oil cooler, and to limit the flight duration. The operator's Emergency Checklist would require the crew to ***'land as soon as possible'*** at the nearest site where a safe landing could be carried out.

Analysis

Since the LAGB had successfully run on a test cell for 12 hours without any deterioration detected in the alternator pinion bearings, with a 10 kVA alternator installed, it is likely that the installation of the 10 kVA alternator by the operator directly influenced the F1 bearing failure that occurred after 18 minutes of the post-maintenance ground run.

Examination of the failed F1 bearing and alternator pinion revealed that they had been subjected to a compressive axial load during the ground run. This axial load was greater than the ability of the F1 roller bearing to withstand it, leading to the bearing overheating and causing the PEEK bearing cage to melt, which was then extruded from the bearing. The overheating also caused significant wear of the bearing rollers, releasing bearing debris into the MGB oil system and causing discolouration of the MGB oil.

Testing conducted by the manufacturer showed that an excessive quantity of grease within the alternator shaft link cavity can create a significant compressive axial load on the alternator pinion when the alternator is clamped to the LAGB. This is due to compression of the excess grease and air within the sealed shaft link cavity acting as a hydraulic piston. This loading case was unintended and had not been anticipated when the LAGB components and associated AMM maintenance procedures were developed.

The method of attaching the alternator to the LAGB used by the operator's LAE meant that the compression of the grease and air within the shaft link cavity was up to four times greater than would have been the case if the method specified in the AMM had been followed.

The manufacturer stated that the reason for filling the alternator pinion cavity with sufficient grease to cause it to overflow was to ensure that grease remained within the alternator pinion splined area during the in-service period between overhauls, to ensure lubrication of the splines.

This large quantity of grease, combined with the sealed design of the alternator shaft link cavity once the alternator driveshaft was inserted, created a latent condition in which an unwanted axial load could be introduced into the alternator pinion and F1 roller bearing.

Footnote

[9] As defined in EASA AMC 21.A.3B(b).

Safety action

In response to this incident the manufacturer released Safety Information Notice (SIN) 3599-S-63, alerting EC175 operators to the potential hazard of excessive grease within the alternator shaft link cavity. The manufacturer has also revised the content of AMM tasks 24-21-00, 4-1 (Removal/Installation – Left Alternator 10 kVA) and 24-21-00, 4-2 (Removal/Installation – Blank or Left Alternator 10 kVA Equipment on LAGB), requiring that any excess grease is removed from the shaft link cavity prior to installation of the alternator on the LAGB. The SIN also highlighted the need to follow the published AMM procedure when installing the alternator, by attaching it using the V-band clamp.

As the mounting of the DC generator on the RAGB has a similar design to the 10 kVA alternator, the manufacturer also revised the related AMM installation procedures for the DC generator.

Second event

The AAIB received a report of a second event involving an EC175B that took place on 9 March 2021, in which an LAGB alternator pinion bearing failure occurred during a ground run following the scheduled replacement of the MGB assembly. Investigation by the operator[10] revealed similar circumstances to the G-EMEB event, as excessive grease had been applied to the alternator pinion cavity and the alternator, V-band clamp and interface spacer had been mounted to the LAGB as an assembly, rather than by the method required in the AMM. This event occurred after the issue of Safety Information Notice 3599-S-63. The operator stated that it will issue a reminder to its maintenance personnel.

Conclusion

The failure of the F1 bearing was caused by an axial load applied to the roller bearing in excess of the bearing's rated capacity. The axial load occurred due to the compression of excess grease and air within the sealed alternator shaft link cavity when the alternator was mounted to the LAGB. The method used to mount the alternator to the LAGB was not in accordance with the instructions in the AMM. This contributed to the generation of the axial load, which was up to four times greater than would have been the case had the AMM instructions been followed.

The manufacturer has amended the content of the AMM to ensure that any excess grease is removed from the alternator shaft link cavity and has communicated this information by issuing a Safety Information Notice to EC175 operators.

Published: 22 April 2021.

Footnote

[10] The operator involved in this second event was different to the operator of G-EMEB.

ACCIDENT

Aircraft Type and Registration:	Schleicher ASH 25 E, G-CFST	
No & Type of Engines:	1 Rotax 275 two-stroke engine	
Year of Manufacture:	1989 (Serial no: 25073)	
Date & Time (UTC):	26 August 2020 at 1216 hrs	
Location:	Cheltenham, Gloucestershire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Fatal)	Passengers - 1 (Minor)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	BGA Glider Pilot's Licence	
Commander's Age:	91 years	
Commander's Flying Experience:	6,007 hours Last 90 days - 14 hours Last 28 days - 3 hours	
Information Source:	AAIB Field Investigation	

Synopsis

G-CFST launched behind an aerotow tug from Aston Down Airfield with the intention of soaring along the Cotswold Ridge between Dursley and Broadway. The soaring conditions proved challenging and the glider became too low as it followed the ridge to the east of Cheltenham, an area with few options for a successful field landing. The glider collided with the top of a line of trees while the pilot was attempting to start the glider's sustainer engine and trying to find a suitable place to land. After colliding with the trees, the glider struck the ground nose-first imparting fatal injuries to the pilot. The rear seat passenger received only minor injuries.

The investigation found that the accident occurred because the glider was flown over an area where the combination of the terrain and the glider's altitude meant a successful field landing could not be assured. While the pilot had been flying under an informal age-related 'dual-only' limitation imposed by his gliding club, the investigation was not able to determine to what degree age was a factor in the pilot's decision making on the accident flight.

Following this accident, the BGA began a consultation process with their member clubs to develop policy and guidance for the management of pilots who, for any reason, might benefit from flying with a safety pilot or relinquishing PIC status.

History of the flight

The accident pilot, hereinafter referred to as the pilot, was a member of the gliding club at Aston Down Airfield. On the day of the accident he was taking part in a time and distance challenge of soaring between Dursley and Broadway along the Cotswold Ridge. The ridge is approximately depicted by the dashed blue line on the map at Figure 1.

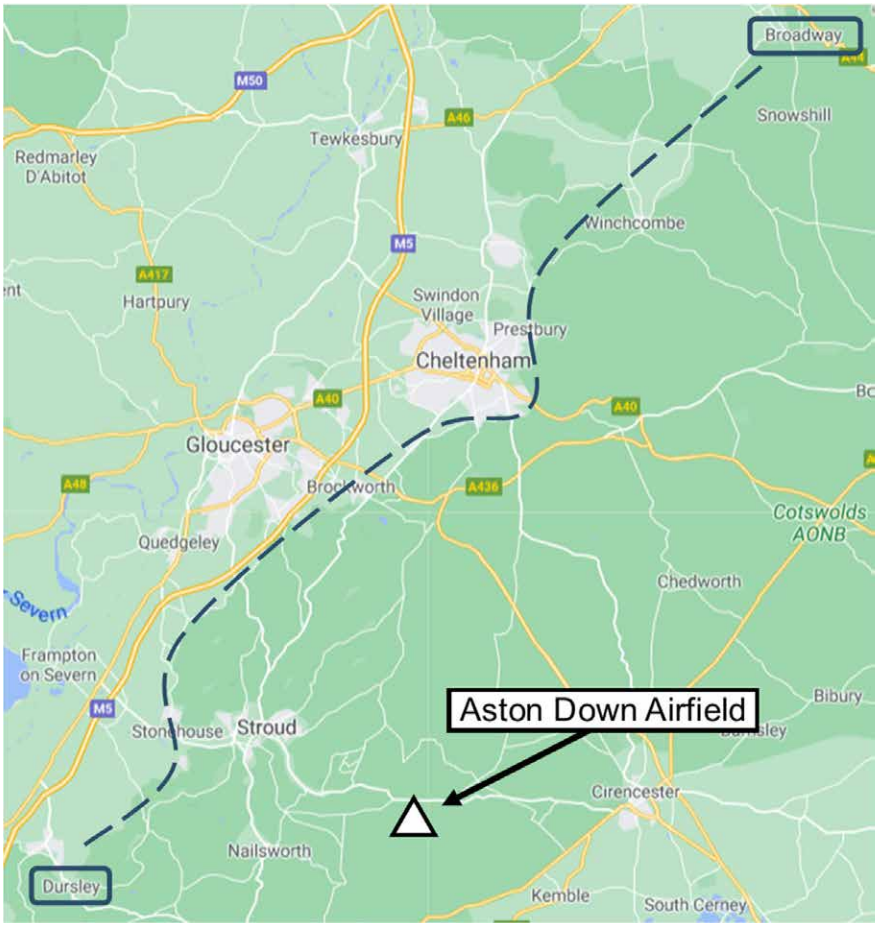


Figure 1

Challenge route between Dursley and Broadway
(©2020 Google)

The pilot was accompanied by a long-standing friend who he had asked to join him for the day's flying. The friend, hereinafter referred to as the passenger, was also an experienced glider pilot and the two had flown together many times previously.

The passenger reported that the pilot had attempted to test-start G-CFST's sustainer engine, using the in-cockpit impulse starter handle, when standing beside the glider at the launch queue. While the engine did not fully fire up, it "coughed" on the third or fourth attempt, which the pilot reportedly took as an indication of its serviceability. The passenger also confirmed that they both carried out a "harnesses and canopies secure check" during the pre-flight checks.

The glider launched behind an aerotow tug just before 1200 hrs and climbed out to the west, reaching approximately 1,500 ft aal (2,100 ft amsl) before releasing the tow in the vicinity of Woodchester (Figure 2). The passenger reported that the pilot maintained the correct position behind the tug throughout the aerotow.

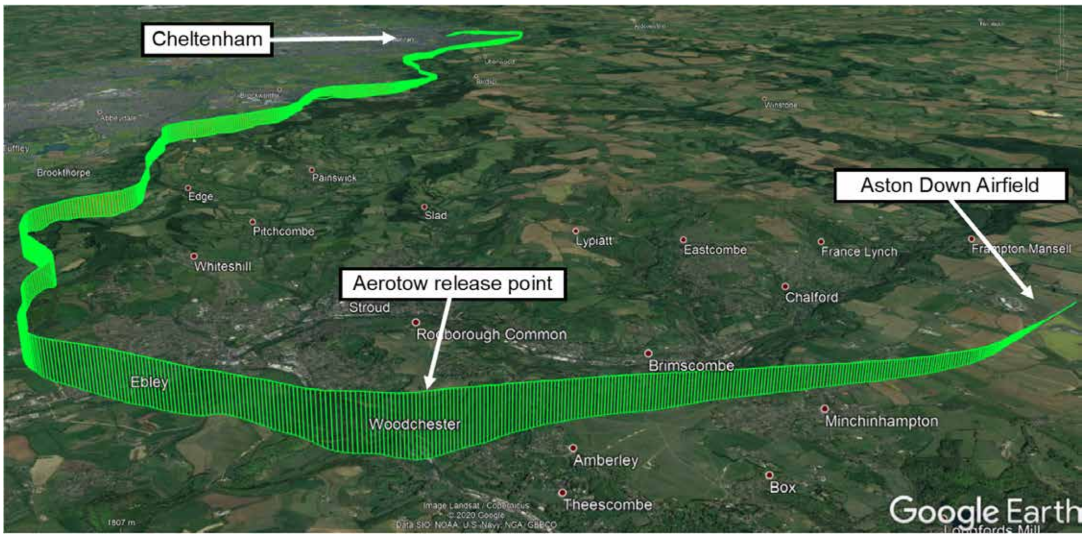


Figure 2

Flight elevation profile
(Image Landsat/Copernicus ©2020 Google)

He also reported that there was very little lift to be found as the glider tracked north-eastwards along the ridge. Crossing the 'Birdlip bowl[1]' to the east of Gloucester (Figure 3) they experienced significant "sink," losing over 350 ft in 1.8 nm.

The passenger judged that the ridge "was not working" and became increasingly concerned they were too low to continue following the route as intended. At that point he suggested to the pilot that they should "err on the side of caution" and divert to Gloucester Airport, approximately 3 nm to the north-west. Possibly because they had picked up lift while tracking northbound towards Shurdington, the pilot instead chose to continue following the ridge east of Cheltenham. While concerned that they were lower than he was comfortable with, the passenger judged that, given the shallow glide angle of the ASH 25 E, they still had just enough height to allow them to escape to the north and, potentially, land at the airstrip adjoining Cheltenham racecourse (Figure 3).

Footnote

[1] Colloquial name for the area where the ridge tracks east and then north in the vicinity of Birdlip.

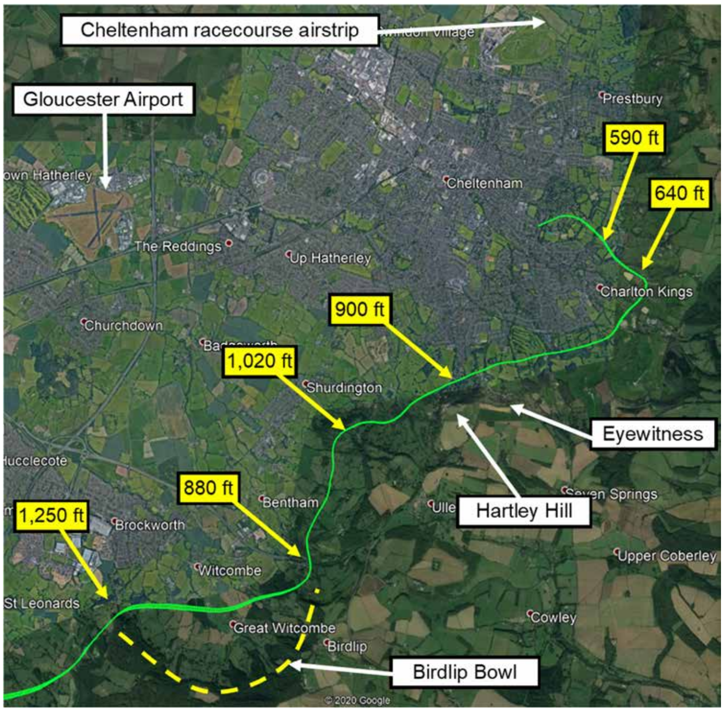


Figure 3

Overhead view of G-CFST's track and approximate navigation logger-derived altitudes (©2020 Google)

Once past Shurdington, the glider descended steadily as it tracked eastwards. An eyewitness reported being on Hartley Hill at 270 m (885 ft) amsl (Figure 3) and seeing the glider heading from west to east close to the ridge "just below" their level. The witness's estimate of the glider's altitude broadly correlated with data recovered from navigation logging devices in the aircraft.

The glider was below ridge level at approximately 4-500 ft agl as it passed east of Hartley Hill (Figure 4). As the ground rose to meet it beyond Charlton Kings, the glider's height reduced to below 250 ft agl at the point where the pilot turned to the north-west.

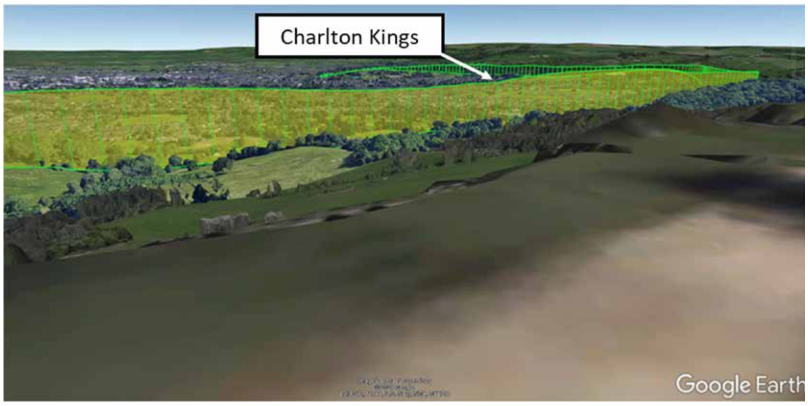


Figure 4

View of glider track looking north-east from the witness's location on Hartley Hill (Image Landsat/Copernicus ©2020 Google)

Shortly after turning away from the ridge near Charlton Kings and without informing the passenger, the pilot began an attempt to start the glider's engine and turned to the south-west. The additional drag with the engine deployed required the pilot to lower the glider's nose to maintain speed for a windmill start[2]. Despite the dive angle achieved, the passenger estimated that they were 5 kt slower than ideal for a start attempt. He could hear the engine turning over but it did not fire up and the glider was heading toward a row of trees short of a residential area. Just before the glider entered the trees, the passenger put one hand across his face to protect it and pulled back on the control column to try and stall the aircraft and drag the tail through the trees in an attempt to reduce the energy of the collision.

CCTV evidence showed the glider hitting the tops of the trees in a right-wing low attitude. It then pitched steeply upwards and yawed rapidly to the right before falling to the ground, nose-first, beyond the tree line.

The first person on scene was a witness who had been tending animals approximately 100 m from the accident site and heard the impact. He arrived at the glider within "two to three minutes" and found the pilot unconscious. The passenger was dazed but already talking to the emergency services by mobile phone. The witness then left the site to get help from his wife, a nurse, who was in their house 150 m from the glider. On arrival at the aircraft, the nurse saw that the pilot was still unconscious. She checked his pulse and found it to be present but weakening. While remaining with the pilot to comfort him, the nurse could hear a "motor" running in the fuselage. The passenger identified this as the electric fuel pump which was controlled by a switch in the front cockpit. Concerned about a potential fire risk, he asked the nurse to try and turn the pump off. Under his direction she operated a "silver-coloured flick switch" in the front cockpit but the fuel pump kept running. The passenger then reached over his shoulder and pulled at the connecting wires to both batteries to disconnect them, thereby removing the power supply from the fuel pump.

The ambulance paramedic who arrived on scene at 1236 hrs determined that the pilot had passed away. The passenger, having been initially trapped, was released from the cockpit by the emergency services and was able to walk, with assistance, to the waiting ambulance.

Recorded information

Loggers

Four flight logging devices had recorded GPS positions and other parameters during the flight. The horizontal paths differed by as much as 40 m but were usually more closely matched. The altitude profiles recorded similar vertical motion but were offset from each other by large amounts. These offsets could not be accounted for by using different commonly used datums[3]. The altitude profile of one of the loggers, a Naviter Oudie (referred to as logger A), was consistent with the departure airfield elevation and used for further flight path analysis. The flight path is shown in Figure 5.

Footnote

[2] Procedure and speeds for a windmill start are covered in the section on 'glider description' in this report.

[3] The datum defines zero elevation which may or may not coincide with local sea level.

Figure 5

Accident flight

One of the loggers, a Cambridge GPS NAV Model 25 (referred to as logger B) also recorded pressure altitude. Correcting this for terrain elevation at the start of the flight results in an altitude profile that broadly agrees with the GPS altitude profile of logger A. The correction does not account for any changes in the ambient conditions during the flight or the fact that the sensor measures the cockpit static pressure and not the external pressure via a static port.

Logger B also recorded an Environment Noise Level (ENL) parameter, also described as the Engine Noise Level. This is used to establish whether an engine is used during a competition flight. It has an internal microphone which captures the ambient noise and the logger processes the signal into a single value that is recorded whenever a geographic position is logged. This is not in specific units but can be compared to previous flights and documentation relating to acceptability as a competition logger.

Three loggers recorded ground speed and the equivalent data was derived from the flight path recorded by the fourth. The ground speed values were closely aligned. Pertinent data from the loggers is shown in Figure 6.

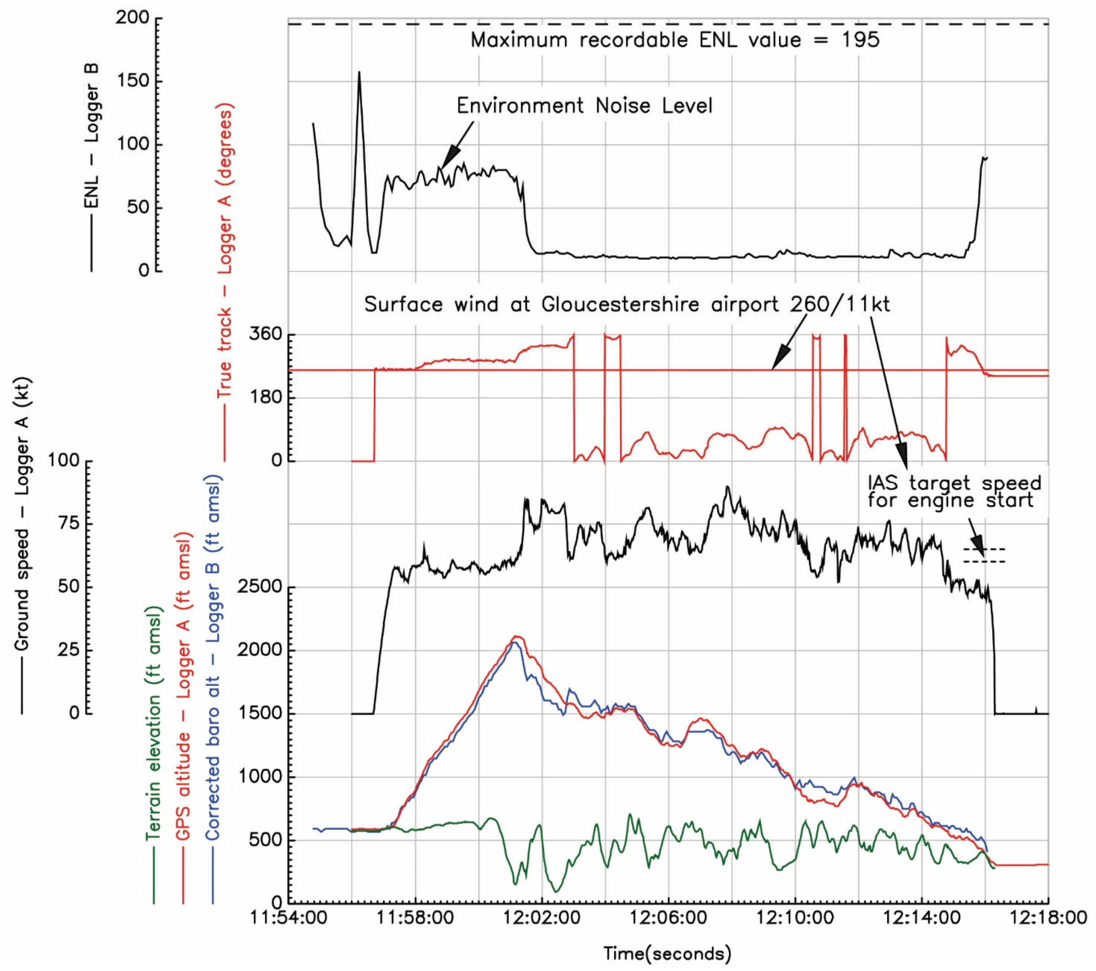


Figure 6

Accident flight recorded parameters

The glider takeoff run started at 1156 hrs, it climbed at approximately 388 ft/min and reached a peak recorded GPS altitude of 2,110 ft amsl. This was followed by a generally descending flight path with small further climbs.

Noise level

The ENL values recorded during the accident flight were compared to the previous flights downloaded from the logger and were found to be broadly similar for the majority of the accident flight. The ENL values of 90 recorded at the end of the accident flight are more than the normal noise generated by the glider in the final approach but less than that generated during the landing run. For the logger, the typical range of ENL values expected while running a two-stroke engine is over 150 and typically 180 or more, but this is not specific to G-CFST.

Figure 7 shows the ENL value increasing relative to the final flight path. It is likely that the increased values recorded at the end of the accident flight are associated with the deployment of the engine, but it is not known if it reflects an attempt to start the engine, or is just an increase in aerodynamic noise.

Figure 7

ENL values at the end of the flight

CCTV

The final part of the flight was recorded by two CCTV cameras. The final moments are partially obscured by trees but provide sufficient information to establish the fundamental final manoeuvre. The details are provided in the History of the Flight section of this report.

Glider description

General

The ASH 25 E is a two-seat, mid-wing, self-sustaining, powered glider, designed and manufactured by Alexander Schleicher GmbH & Co. It is of predominantly glass fibre construction and has a 25 m wing, T-tail and retractable landing gear. Each wing has an inner and outer section, with the structural and flight control joint at 3.8 m span.

Flying controls

With the exception of the rudder, the flight controls are actuated using a combination of pushrods and bell cranks. The rudder is operated by steel control cables. Three trailing edge flaps, which also function as ailerons, extend over the full span of each wing. Each wing has a double-panelled airbrake that extends from the upper surface.

Seat restraints

Both seats are equipped with a four-point harness. A rotary buckle, also known as a quick release fitting (QRF), is incorporated as part of the right lap strap. Turning the QRF in either direction simultaneously releases both shoulder straps and the left lap strap. A rectangular tab at the 12 o'clock position on the QRF allows the wearer to release only the shoulder straps, by hooking a thumb or finger behind the tab and pushing forward (Figure 8).

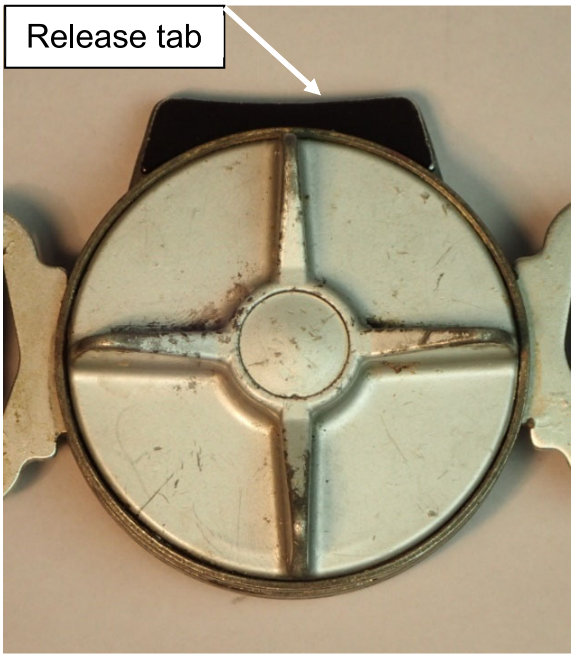


Figure 8
Seat harness QRF

The shoulder straps are mounted on a metal bar above each seat. Structural attachment for each lap strap is achieved by a metal shackle and bracket, which is integrally mounted in a composite plate bonded to the cockpit wall.

Sustainer engine

The glider is equipped with a Rotax 275 two-stroke, single-cylinder sustainer engine driving a two-blade, fixed-pitch, wooden propeller. The engine is normally stowed inside the fuselage behind the cockpit and the extension/retraction mechanism is electrically powered.

The engine can be operated from the front cockpit only. An engine control unit on the right armrest comprises the main switch for the engine electric system, a red pilot light which illuminates when the main switch is ON, an ignition toggle switch and an EXTEND/RETRACT rocker switch (Figure 9).

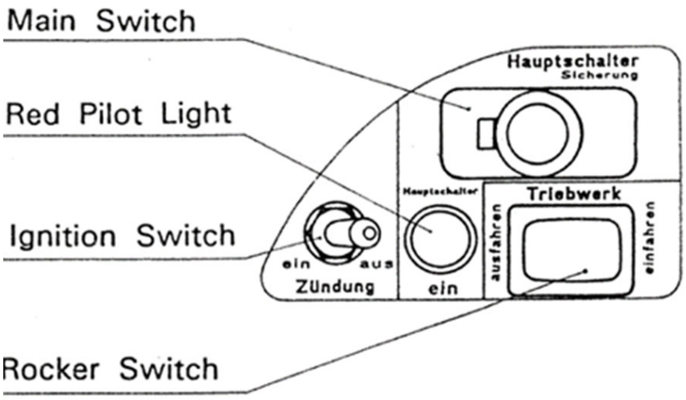


Figure 9

Engine control unit

The cable-operated throttle, choke and propeller brake are actuated by levers mounted on the right side of the cockpit wall. A pull-start handle mounted in the right footwell, operates an impulse starter. G-CFST's engine had been retrofitted with a cable-operated decompressor valve to assist engine starting, removing the need to use the engine pull-start handle in flight (Figure 10).

G-CFST was fitted with an 8.5 litre composite fuel tank in the wheel well and a 15 litre flexible fuel bag in the left wing. The fuel shutoff valve is operated by a lever on the left side of the cockpit and the electric fuel pump is operated by a toggle switch on the front instrument panel.

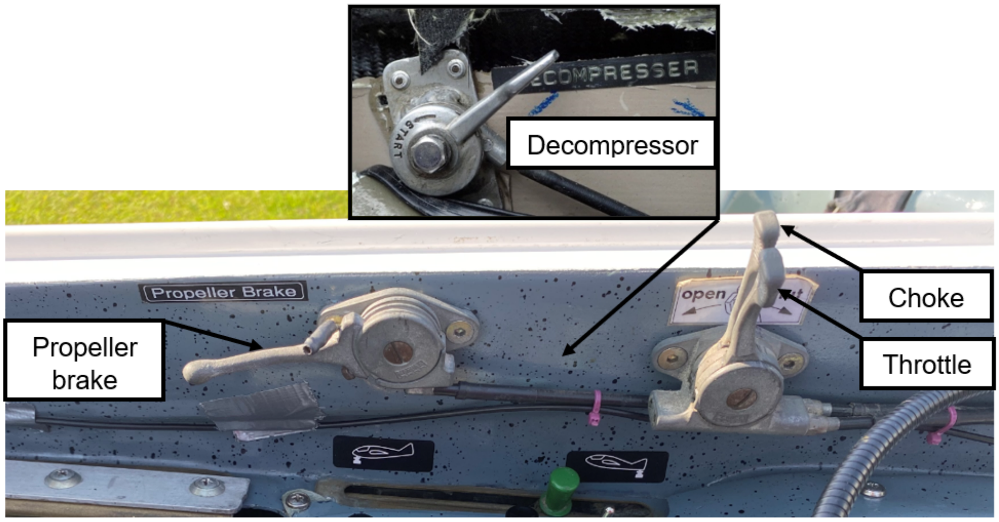


Figure 10

Engine controls on another ASH 25 E (main image)
showing position of decompressor lever on G-CFST (inset)

Engine starting

The ASH 25 E flight manual[4] describes the following initial actions for extending and starting the engine, whether inflight or on the ground:

- *Fuel shut-off valve:* OPEN
- *Main switch:* ON *(red pilot light)*
- *Continue to press switch on "*EXTEND*" setting until signal sounds for about one second*
- *Ignition:* ON
- *Propeller brake:* OFF *(released)?*

For an inflight start, the following actions are then required:

- *Air speed 110 to 120 km/h (60 to 65 kt)*
- *Throttle 1/3rd forward*
- *Choke:* OPEN *(fully forward!)*
- *Firmly pull starter until engine turns over*
- *Reduce airspeed and apply full throttle (watch the rate of revolutions!)*

The flight manual procedure does not cover the use of a decompressor. In the case of G-CFST's engine, the decompressor would be held OPEN by the pilot as the glider was being dived to achieve an airspeed of 60 – 65 kt. This removes cylinder compression, allowing the propeller to windmill in the airflow. The lever would then be moved to the START position, closing the decompressor and allowing the engine to start.

Starting the engine on the ground requires slightly different throttle and choke settings and three to four strong pulls of the pull-start handle.

Flight manual cautions

The flight manual contains two cautions relating to the operation of the ASH 25 E's engine:

> *'The power-plant of a powered sailplane must not be regarded as a life insurance, for instance for crossing unlandable areas.'*
>
> *'If the situation is so critical as to make a crash landing likely as no landable terrain can be reached, the power-plant should be retracted - even with the propeller out of vertical or not quite stopped - about half-way. This not only improves the gliding performance…but also reduces the risk in case of a crash landing.'*

Footnote

[4] Flight manual for Powered Sailplane ASH 25 E, Alexander Schleicher GMBH & Co., Segelflugzeugbau, D-36161 Poppenhausen/Wasserkuppe, dated October 1989.

Accident site

The accident site was in a narrow sloping field on the edge of Cheltenham, within the grounds of a school. It was bordered to the north and west by residential areas and to the south and east by school grounds (Figure 11).

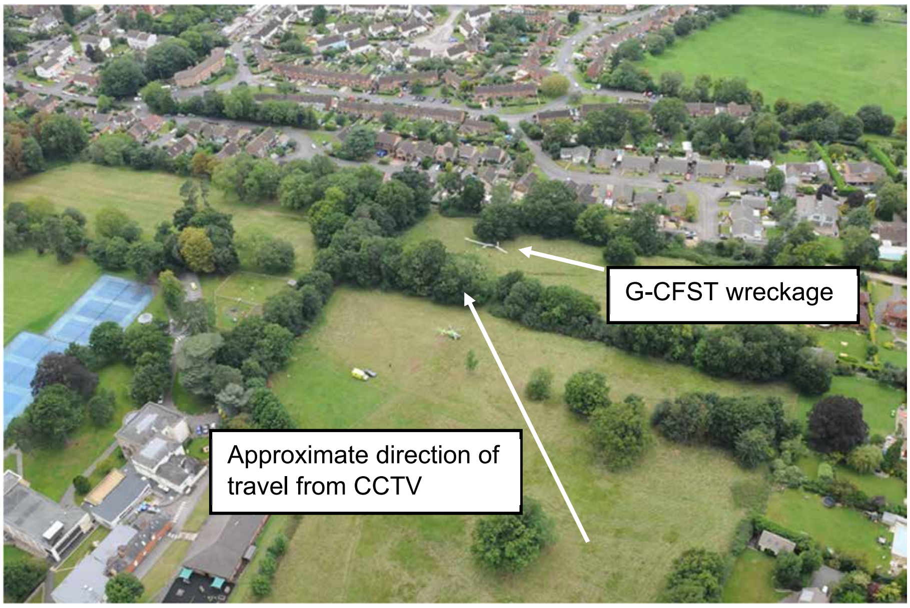


Figure 11

Accident site

The wreckage of the glider was situated below the canopy of a large oak tree. Several large branches had broken and fallen on top of the wreckage, indicating that the glider had struck this tree. It was also apparent that the tops of some of the trees which formed the boundary with the adjacent field had been trimmed (Figure 12). Damage to the leading edge and lower surface of the outer right wing was consistent with it having struck the tops of these trees. This was subsequently confirmed by CCTV recordings.

Figure 12

Trees struck by the right wing from above (left) and from the adjacent field (right)

An impact crater approximately 45 cm deep corresponding to the profile of the glider's nose, indicated that the glider had struck the ground in a steep, almost vertical nose-down attitude. A clear indentation in the grass had been made by the leading edge of the left wing. Disruption to the front cockpit included crushing of the sidewalls and disturbance of the flight control runs, seat structure and floor but the cockpit retained a substantial degree of structural integrity. The shoulder straps on the pilot's harness were found undone, but the lap straps were engaged in the QRF. Neither the first people on scene nor the first responders had released the pilot's shoulder straps.

The engine was deployed but the engine pylon had bent forward approximately 90° from its normal deployed orientation, such that the engine was lying parallel to the top of the glider above the rear cockpit (Figure 13). The landing gear was retracted. The tail boom had fractured just behind the engine bay and the left outer wing had separated at the wing joint, leaving a section of broken spar protruding from the inner wing. The control rods for the airbrake, aileron and flap were bent rearwards and had exited through the trailing edge wing structure at the location of the wing break. The left airbrake was extended.

The presence of all major components of the glider and the compact distribution of wreckage indicated that the glider had been structurally intact prior to striking the trees.

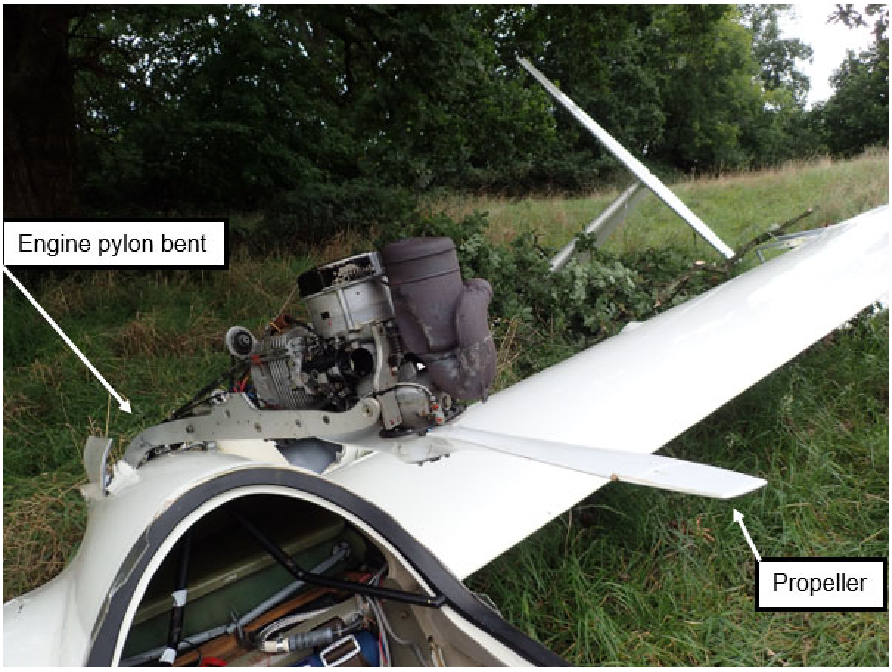


Figure 13

G-CFST wreckage showing position of engine

Detailed aircraft examination

Engine, engine controls and fuel

The engine was free from external damage but the damage sustained by the extension actuator and pylon was consistent with it being in the extended position when the ground impact occurred. The propeller was intact and largely undamaged with the exception of two small cracks in the hub and a small nick on the trailing edge of one blade. There was no evidence of rotational scoring which might be expected if the propeller was rotating at impact.

Apart from the ignition switch, which was in the OFF position, the position of the engine controls was broadly consistent with the expected positions for engine starting. There were 6.5 litres of fuel in the fuselage tank and 8.5 litres in the left wing tank. Both the fuel shutoff valve and its selector lever were found partially open. The operating linkage runs inside the front seat left armrest which had been disturbed during the impact, so it was not possible to determine its pre-impact position. The fuel pump switch was found in the OFF position.

Damage to the engine support structure precluded running the engine in the installed condition. The engine, engine controls and fuel pump were removed from the wreckage to facilitate a ground run. The engine started on the fourth pull of the pull-start handle and appeared to operate normally. Due to the propeller damage the engine was only run for a matter of seconds, so its continued operation was not assessed.

Flying controls

It was not possible to determine the pre-accident position of the flying controls due to the extent of the disruption to the control runs, but the left airbrake most likely extended when the left outer wing separated.

Seat harnesses

The structural attachments for the shoulder straps at each seat and those for the lap straps on the rear seat, were intact. The composite mounting panels for the left and right lap straps of the front seat, had each separated from the cockpit wall at the bond line.

The fabric straps appeared to be in good condition. Identification labels on several of the straps were missing, faded or torn, but were legible and indicated that they were manufactured in 1989. Both QRFs functioned normally when operated and the release tabs required positive operation to release the shoulder straps.

Aircraft performance

Gliding performance

Interpolation of the performance charts (Flight Polars) in the ASH 25 E flight manual indicated achievable glide ratios of approximately 1:45 at 70 kt and 1:50 at 60 kt for G-CFST at a representative all-up-weight in the clean configuration or with soaring flap selected. While the flight manual does not contain performance tables for flight with the engine deployed and not running, other ASH 25 E pilots estimated that it reduced the achievable gliding range by approximately 60-70%.

Field landing performance

Two pilots with experience of flying the ASH 25 E expressed the view that, depending on available headwind, slope and surface characteristics, the minimum strip length for a field landing in G-CFST would be between 1,000 and 1,500 ft.

Using the sustainer engine

BGA guidance

In their Managing the Flying Risk document, the BGA offers guidance for pilots flying sustainer gliders which includes the following:

> *'Accident report data indicates that most problems occur due to a late decision to start the engine…Having a pre-considered and personally agreed minimum height for engine start – effectively a pilot's own 'red line' - is very important. …. Recognize* [sic] *that descending beneath this height effectively discards the engine option…As should always be the case when flying cross-country, constantly monitor the available landing options. Have a landing option selected before deploying the engine.'*

Club guidance

The gliding club's Chief Flying Instructor (CFI) would informally brief club pilots new to sustainer aircraft that, when contemplating deploying the engine in flight, they should assume that it will not start and to configure for a field landing before deploying the engine. He also suggested that they use 1,500 ft as a minimum height to commence a start and if they are below that height, they should commit to a field landing with the engine stowed.

Experience of engine operation on G-CFST

A review of the pilot's flying logbooks showed that he had the habit of annotating 'E' against flights on G-CFST where he had used the engine, but the last such annotation was against a flight in December 2018. It was not determined whether he did not use the engine in flight after this date, or whether he stopped annotating this in his logbook.

G-CFST's co-owner had flown many hundreds of hours in the glider with the pilot and normally occupied the rear seat. If it became necessary to use the engine in flight, he would typically fly the glider to achieve the necessary airspeed, while the pilot operated the engine controls. He stated that the engine could sometimes be problematic; it did not always fully extend, required a lot of height to start and sometimes did not start. It was also difficult to start on the ground.

The passenger, who was familiar with flying in G-CFST with the pilot, also reported that the engine very often didn't start. He estimated that height loss when starting the engine in flight was typically 400 - 500 ft but recalled one occasion, when the engine had not been used for some time, where the pilot attempted to start the engine at 4,000 ft and it was 1,500 ft before it fired.

Meteorology

The weather at the time of the accident was reported as "good, with moderate westerly winds." A weather observation from Gloucester Airport taken four minutes after the accident recorded a wind velocity of 260°/11 kt and no significant cloud below 3,200 ft.

Glider pilots can record their flights on the BGA Ladder[5], an '*informal, year-long soaring competition intended for UK-based glider pilots.*' In addition to logging time and distance achievements, they can also add comments on, for example, the weather conditions they experienced. The following notes were uploaded by three glider pilots who were flying in the vicinity of Cheltenham on the day of the accident:

> *'The best lift was south of Cheltenham but it looked mostly unlandable there'*
>
> *'Not quite enough wind from the right direction for ridge to work properly, a lot of wave interference, lots of spreadout*[6] *and weak thermals all made it rather challenging'*
>
> *'…ridge not quite working then a combination of spreadout and wave interference'*

Personnel

Pilot

The pilot was the holder of a BGA Glider Pilot's Licence with three Diamond Badges[7]. He started gliding in 1973 and had amassed over 6,000 flying hours. Of those hours, more than 4,400 were logged in multi-seat gliders. He was a well-respected member of the gliding club whose members spoke highly of his flying ability and dedication to gliding.

On a series of winter check flights, in November 2019, the instructor noted an occasional lapse in decision making which he attributed to the pilot "showing the signs of ageing." His handling skills were still of a good standard and, with the pilot about to embark on a period of dual flying in Australia over winter, a decision on how best to manage the situation was deferred. The pilot then did not fly in the UK again until after the national COVID-19 lockdown restrictions were eased in May 2020. He initially regained currency by flying in the club's gliders before returning to the air in G-CFST on 7 June.

In early July the pilot was involved in a potential upset on an aerotow where the towing pilot released the tow cable because the pilot got too high behind the tug. Following the incident, the club imposed a 'no-aerotow' restriction on the pilot, but later revised it to 'dual-only[8]' limitation. The club's rationale for the limitation was twofold; to address any pilot incapacitation risk due

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Footnote

[5] https://www.bgaladder.net [accessed 2 November 2020].

[6] Where convective clouds spread out under an inversion creating a layer of stratocumulus cloud which wholly or partially blocks the sun's rays from the surface, thereby reducing thermal convection.

[7] Goal Diamond for a flight of over 300 km, Distance Diamond for a flight of over 500 km and Height Diamond for climbing to 5,000 m.

[8] Requiring him to only fly G-CFST when accompanied by an experienced pilot capable of landing the glider in an emergency.

to the pilot's age and to help or prompt his airborne decision making should it be necessary. This was a proactive informal risk mitigation measure by the club and there was no policy, procedure or precedent for the arrangement. The club described themselves as "feeling their way" in managing the situation and were planning to review the appropriateness of the limitation as the gliding season progressed. It was anticipated that, if deemed necessary, the next step would have been to prevent the pilot from acting as PIC. The club expressed the view that higher level guidance for the management of ageing pilots would be welcome.

Before the accident flight, the pilot had flown on four occasions with four different pilots after the 'dual-only' restriction had been established. The fourth occasion was with the club CFI on 2 August 2020. While he had appeared to take the 'dual-only' limitation well, the pilot disagreed with the need for it and wanted to prove to the CFI that it was not necessary. None of the pilots who had flown with him on the three previous occasions had raised any concerns with the club over the pilot's flying but had informally mentioned occasionally prompting him for a decision. Having subsequently flown with the pilot, the CFI remained of the opinion that, while still up to solo standard, he would nonetheless benefit from someone accompanying him to help manage his flights.

Passenger

The passenger reported that, on their many previous mutual flights, he and the pilot would regularly share the flying and navigation tasks. He was aware that the club had required the pilot to be accompanied when flying G-CFST but had not been specifically briefed as to why. His assumption was that it was a pilot incapacitation precaution and to assist with heavy manual tasks like ground handling and raising the landing gear in flight.

Prior to the accident fight, they last flew together in May 2018 in the passenger's Duo Discus glider.

Ageing pilots

Human performance limitations in relation to flying are widely documented in aviation textbooks and guidance literature such as the CAA's *Flight Crew Human Factors Handbook*[9] and *The Skyway Code*[10]. Decision making is discussed in both publications and was an important area of focus for the investigation.

Older pilots are not necessarily less-safe pilots and poor decision making can affect pilots of all age and experience levels. Nonetheless, age-related deterioration in eyesight, hearing, mobility, memory, cognition and decision making are recognised as having an impact on piloting ability. Data from the CAA's website[11] for the years 2000, 2011 and 2018, indicates that the average age of non-commercial pilots in the UK is increasing (Figure 14).

Footnote

[9] *CAP 737 Flight Crew Human Factors Book*, published by the UK CAA. Available at https://publicapps.caa.co.uk/docs/33/CAP%20737%20DEC16.pdf [accessed 4 February 2021]

[10] *CAP 1535 The Skyway Code Version 2*, published by the UK CAA. Available at https://www.caa.co.uk/General-aviation/Safety-information/The-Skyway-Code [Accessed 8 February 2021]

[11] CAA-published data on the age and sex of the UK holders of National and EASA non-commercial pilots' licences with a valid medical certificate. Available at https://www.caa.co.uk/Data-and-analysis/Approved-persons-and-organisations/Datasets/Licence-holders-by-age-and-sex [accessed 22 February 2021]

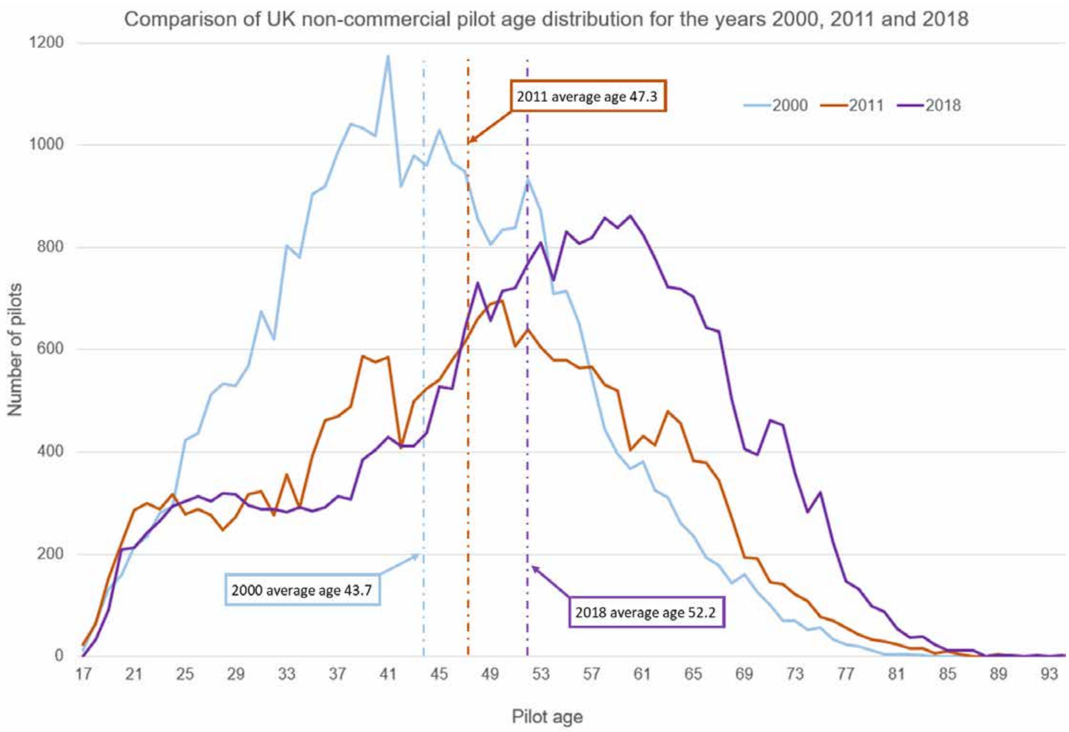

Figure 14

Age distribution of non-commercial UK pilots for the years 2000, 2011 and 2018

Although the broad effects of ageing are well known, there is great variability on how any specific decline will affect an individual pilot and chronological age is not a reliable metric to predict age-related impairment. As quoted in an AOPA[12] Air Safety Institute research review on the subject of 'Ageing and the General Aviation Pilot'[13] , '*Not only does age affect the different cognitive functions to different degrees, the time of onset of significant age effects also differs across cognitive functions.*'[14] While experience, knowledge, aptitude and wellbeing can offset or delay the effects of ageing, there will inevitably come a point where the most sensible option for an individual is to retire from flying as PIC.

One challenge for organisations supervising ageing pilots is that if a pilot has a valid medical and can pass periodical flying checks it is difficult to argue for grounding them when subjective concerns are raised. Unless precipitated by an accident or incident, without an objective metric for making the decision, it relies on individual pilots to be honest with themselves and for supervisors to be candid enough to reach a shared acknowledgement that their days as PIC are over. Family, friends and peers can play a part in encouraging and supporting pilots when that decision has to be made. This is especially important for pilots not affiliated to clubs or sporting associations.

Footnote

[12] Aircraft Owners and Pilots Association, an American political organisation advocating for general aviation.

[13] *Ageing and the General Aviation Pilot* published by AOPA. Available at https://www.aopa.org/-/media/files/aopa/home/pilot-resources/safety-and-proficiency/accident-analysis/special-reports/1302agingpilotreport.pdf?la=en [Accessed 5 February 2021]

[14] Tsang, Pamela S. Age and pilot performance. In '*Aviation Training: Learners, Instruction and Organization*', edited by Ross A. Telfer and Phillip J. Moore. Aldershot: Avebury Aviation, 1997. Pages 21-39.

Following this accident, the British Gliding Association began a consultation process with its member clubs with the aim of developing formal guidance to support the management of pilots of any age who might benefit from flying with a safety pilot or relinquishing PIC status.

Medical

Injuries to persons

In his post-mortem report, the pathologist found that the pilot died from '*the combined effects of multiple traumatic injuries*.' There was no indication of medical impairment or incapacitation of the pilot before the final collision.

The post-mortem examination did not reveal any definitive evidence to suggest that the pilot had been wearing his harness shoulder straps at the time of the accident but could not exclude the possibility. The pathologist's report further indicated that, discounting injuries potentially sustained as a result of his upper torso being unrestrained, the pilot's other injuries would not have been survivable.

The passenger sustained only minor injuries and there were no third-party casualties.

Medical requirements for glider pilots

For pilots holding a BGA Glider Pilot's Licence the medical requirements are detailed in the BGA's Laws and Rules (BGA Operational Regulations)[15] which state:

> *'[Regulation 14] …To fly a glider solo or with another pilot, a pilot needs to hold a driving licence…Additional and higher requirements apply to instructors and those pilots carrying passengers. Details of all acceptable and alternative means of compliance are contained in 'BGA Pilot Medical Requirements.'*

The pilot was not an instructor neither was he carrying an inexperienced passenger; therefore, the medical requirements that applied to him were those in Paragraph 3 of the *BGA Laws and Rules* (BGA Pilot Medical Requirements)[16]:

> *'Acceptable evidence of fitness for pilots of gliders; solo flight or with another pilot: A driving licence issued by an EU nation (or the UK or the Crown dependencies).'*

The pilot held a current UK driving licence which was due to expire on 11 May 2023.

Footnote

[15] *BGA Laws and Rules: BGA Operational Regulations Version 1.1,* Effective date 29 Feb 2020. Available at https://members.gliding.co.uk/library/bga-requirements-guidance/operational-regulations-of-the-bga [accessed 29 September 2020].

[16] BGA Laws and Rules: BGA Pilot Medical Requirements, Version 1.3, Effective date 25 Aug 2016. Available at https://members.gliding.co.uk/wp-content/uploads/sites/3/2015/04/Medical-Requirements.pdf [accessed 29 September 2020].

Assessment of ongoing medical fitness

BGA member clubs can place more stringent medical restrictions on individual pilots should it be deemed necessary. The BGA recommendation is that medical advice should be sought before additional limitations are imposed.

The club had not imposed a recognised medical restriction on the pilot and he had not declared any medical condition that would affect his fitness to fly. The post-mortem report did not reveal any pre-existing medical conditions pertinent to flying and the pathologist did not find any '*obvious features of disease that would be likely to significantly impair or diminish his judgment or cognitive faculties*.'

Medical requirement for a safety pilot

Where the holder of a Class 2 or LAPL[17] medical certificate is considered at increased risk of incapacitation compared to his peer group the awarding medical examiner can impose an Operational Safety Pilot Limitation (OSL). Under the EU regulatory framework[18], '*the holder of a medical certificate with an OSL limitation shall only operate an aircraft if another pilot fully qualified to act as pilot-in-command on the relevant class or type of aircraft is carried on board, the aircraft is fitted with dual controls and the other pilot occupies a seat at the controls.*'

In their Safety Pilot Information Sheet[19], the CAA define a safety pilot as '*a pilot who is current and qualified to act as Pilot-In-Command (PIC) on the class/type of aeroplane and carried on board the aeroplane for the purpose of taking over control should the person acting as the PIC become incapacitated*.' They are not a designated flight crew member and hold the legal status of passenger.

There is no equivalent OSL process or procedure for pilots who are flying under the BGA rules and exercising the privileges of a self-declaration medical.

Organisational information

Regulatory body

At the time of the accident, the BGA was the sporting body overseeing gliding in the UK. Pilots exercising the privileges of a BGA Glider Pilot's Licence were required to comply with the BGA Laws and Rules. In addition to their Laws and Rules, the BGA publish several protocol documents as guidance for pilots. One of these documents, Managing the Flying Risk[20], aims to '*provide pilots and clubs with guidance on how to better understand, minimise and manage the hazards associated with gliding operations, including with powered gliders and tug aircraft. It does not replace any existing law, which should always take precedent*.'

Footnote

[17] Light Aircraft Pilot's Licence.

[18] Commission Regulation (EU) No 1178/2011 Annex IV, Subpart B, Section 1, MED.B.005.d.2.ii dated 25 November 2011. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R1178&from=EN [accessed 5 November 2020].

[19] 20130121SafetyPilotInformationAndBriefingSheet.pdf v7.1 dated January 2013. Available at: https://www.caa.co.uk/WorkArea/DownloadAsset.aspx?id=4294974324 [accessed 1 October 2020].

[20] Managing the Flying Risk v14,1 effective date 12 July 2020. Available at https://members.gliding.co.uk/library/bga-requirements-guidance/managing-flying-risk-guidance [accessed 29 September 2020].

Crew status for single-pilot operations

For a single-pilot operation such as gliding, apart from pilots on an instructional flight with a flying instructor, the only defined crew role is that of PIC. While the PIC can ask anyone on board to assist with the operation of the aircraft, that does not confer crew status on the individual, even if they are a qualified pilot on type or acting as a safety pilot under the OSL provisions.

Crew resource management

Crew Resource Management (CRM) is the effective use of all resources available to a pilot to assure a safe and efficient flight, thereby contributing to better decision making by helping to reduce error and stress. While CRM training was initially developed to improve multi-crew cooperation many elements can be read across to single-pilot operations. Effective CRM combines various skill areas including, situational awareness, workload management, planning and briefing, decision making and communication. The Skyway Code and CAP737 are two of the readily available reference documents which discuss CRM and its applicability to GA and glider flying.

For pilots flying solo, advice from instructors and fellow club members, the assistance of air traffic control and aviation reference documents are examples of supplemental resources that can be accessed before, during and after flight.

Section 12 of Managing the Flying Risk is dedicated to the topic of qualified pilots flying together in two-seat gliders (mutual flying) and addresses some of the associated CRM considerations. It highlights the importance of agreeing who will act as PIC and discussing how either pilot can raise their concerns effectively when airborne. Passengers who are also pilots can offer invaluable assistance provided the ground rules for collaboration and communication are clearly understood.

Other than for pilots on flying instructor training programmes, glider pilots do not routinely undertake CRM training.

Other information

Ridge soaring - general

The term ridge soaring relates to gliders taking advantage of lift generated on the windward side of an escarpment or line of hills when the wind is blowing approximately perpendicular to the high ground. The optimal lift zone is generally found above the windward slope just below the ridge line and extends upwards, angled into wind (Figure 15). Beyond the ridge line the air descends again to follow the terrain, leading to lee side sink. To gain maximum benefit from ridge soaring pilots aim to fly parallel to the ridge and within the optimum lift zone. The amount of lift generated and position of the optimal zone depend on the wind profile and the terrain characteristics of the ridge. With a wind direction more than 45° off perpendicular to the ridge the lift generation process is less effective. Variable physical characteristics of the ridge can affect the lift generating capability for a given wind direction.

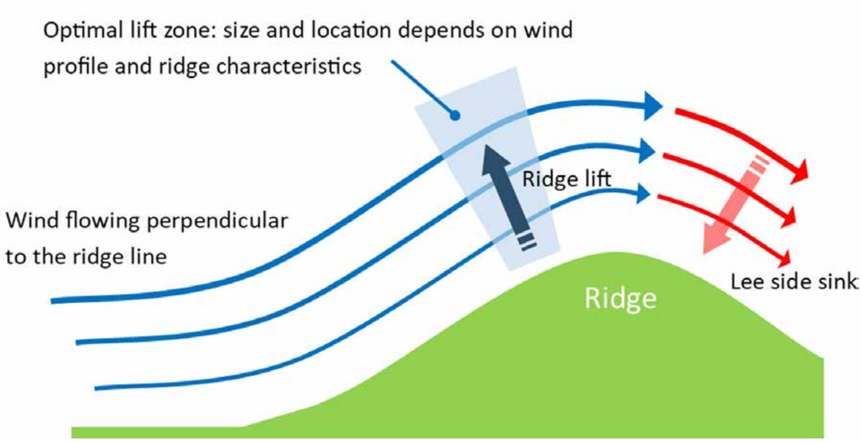

Figure 15

Cross section of imaginary ridge showing lift and sink zones

Lee side sink can be a particular issue when crossing spurs or bowls, such as the one at Birdlip. Crossing a bowl, a glider would experience uplift approaching the boundary spur and then downdraught as it entered the bowl (Figure 16). Taking a direct route across the mouth of such a bowl is the recommended approach[21] to avoid the lee side sink.

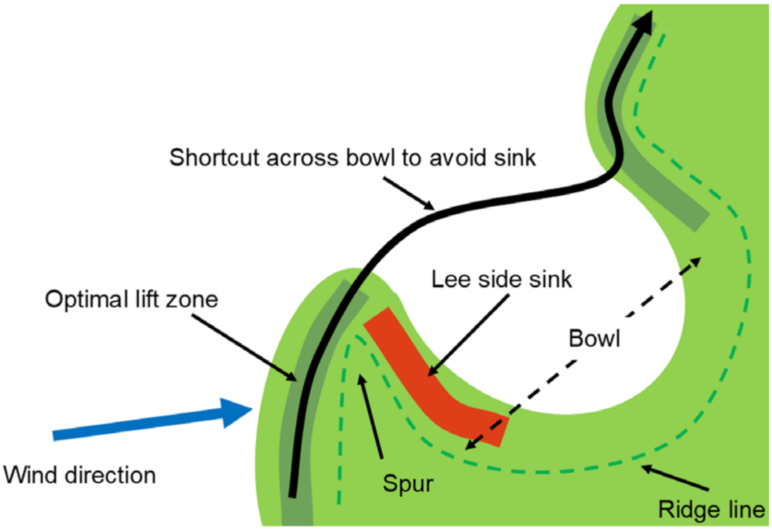

Figure 16

Simplistic view of bowl effect vs ridge lift

Soaring on the Cotswold Ridge

The irregular profile of the Cotswold Ridge and its location in the lee of the Brecon Beacons can give rise to unpredictable and unreliable soaring conditions. As the ridge line changes direction the upslope lift can vary significantly. With a westerly wind, lee wave effects downstream from the Welsh hills can produce interference that reduces available lift. Having

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Footnote

[21] FAA Glider Flying Handbook, Chapter 10: Soaring Techniques. https://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/glider_handbook/media/gfh_ch10.pdf [accessed 29 September 2020].

flown from Aston Down for most of his gliding career, the pilot was familiar with the challenges posed by the Cotswold Ridge. Fellow club members referred to him as “an aficionado on the ridge.” Given the pilot’s extensive experience of soaring on the ridge, it is possible that he had developed his own ‘gate-height[22]’ for committing around the Cheltenham Bowl and that he was above it on the accident flight. The investigation was not able to determine if this had been the case. The club’s instructors did not conduct soaring training on the ridge and did not issue gate-height guidance to pilots using it.

While there are areas where towns and villages abut the lower slopes, for most of its length there are ample options for gliders to land out on fields to the west of the ridge. One area where options are limited is where it passes to the east of Cheltenham. Between Hartley Hill to the south and Prestbury to the north, the built up area of Cheltenham occupies most of the land below and to the west of the escarpment. If flying above ridge level, pilots would have an option to head east to the flatter land beyond the summit, otherwise, turning back towards Shurdington or heading north towards the racecourse beyond Prestbury are the shortest available escape routes.

Seat harness and QRF

QRFs similar to that used on G-CFST are common in many aircraft and glider types. The BGA provided anecdotal information that some UK glider owners using similar QRFs had experienced inadvertent operation of the release tab and had since had this function inhibited. The harness manufacturer, which purchases the QRFs from another supplier, advised that it had previously developed a modification to inhibit operation of the release tab. This was done at the request of several glider manufacturers, to prevent the shoulder straps coming undone in aerobatic flight. The modification is incorporated as standard from new on certain aerobatic-rated gliders and is available on request for individual glider owners.

The investigation considered whether the pilot’s shoulder straps could have become disengaged during the accident sequence, due to inadvertent operation of the release tab either as a result of impact loads or other factors.

The pilot had been wearing a USB logger device on a lanyard around his neck. Because it was obscured by clothing, the logger’s position with respect to the QRF was not observed at the accident site. Prominent areas on the back face of the QRF are intended to guard against forward release of the tab (Figure 17). The shape of the logger was such that it could fit in the recess behind the release tab. Post-accident simulations showed that the reclined seating position in the ASH 25 E and length of the lanyard meant that the logger could rest in proximity to the QRF. There were many variables such as exact seating position and height of the wearer and the logger was easily dislodged with movement if positioned behind the QRF. It was therefore considered unlikely that the logger could have interfered with the release tab on the QRF, but the possibility could not be ruled out.

Footnote

[22] Threshold altitude, below which he would not attempt to circumnavigate the Bowl.

Figure 17

Seat harness QRF showing rear face (left) and USB logger (right)

The harness manufacturer stipulates a recommended maximum life of 12 years for the harness, including the QRF. Historically the BGA has permitted seat harnesses to be operated 'on condition' subject to annual inspection and agreement by the certifying engineer. G-CFST's Self Declared Maintenance Programme (SDMP) included a documented deviation from the recommended harness life.

The QRF manufacturer advised that it was designed to be an 'on condition' product, with no recommended service life. It indicated that service-related wear of internal locking pins can occur in QRFs with long term usage and these would typically be replaced on QRFs returned for overhaul. It did not find any reports in its records relating to unintended release of the shoulder straps, either due to wear or other reasons.

G-CFST maintenance

General

G-CFST was manufactured in 1989 and was jointly owned by the pilot and another club member. The pilot assumed the role of 'lead' owner, holding the aircraft documents and maintenance paperwork. The glider underwent its most recent annual inspection and Airworthiness Review Certificate (ARC) renewal on 24 March 2020, at which time the BGA inspector also created a SDMP, on behalf of the owners. At the time of the accident G-CFST had accumulated 3,974 flight hours and 1,692 launches.

Engine maintenance requirements

The ASH 25 E maintenance manual[23] originally required that the engine was overhauled every 300 hours or six years, whichever occurred first. The Rotax 275 operator's manual

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Footnote

[23] Maintenance manual for the powered sailplane ASH 25 E, Alexander Schleicher GMBH & Co., Segelflugzeugbau, D-36161 Poppenhausen/Wasserkuppe, dated January 1995.

specified that this should be done after 300 hours of operation. The engine manufacturer subsequently ceased to support the Rotax 275 and this requirement was replaced by Service Bulletin (SB) 505-010R1 dated 5 September 2006[24], which provided an updated 'on condition' maintenance schedule requiring maintenance inspections at one, two, three, five and six year intervals. SB 505-010R1 was categorised as 'mandatory' by the engine manufacturer but it was not mandated by an airworthiness directive (AD).

Generic Requirement (GR) 24 '*Light aircraft piston engine overhaul periods'* of Civil Aviation Publication (CAP) 747 *'Mandatory Requirements for* Airworthiness' contains provisions for the maintenance and operation of light aircraft piston engines beyond their maximum overhaul life. Rotax engines were initially excluded from GR 24, but in 2013, Rotax 275 engines installed in powered gliders became eligible to be operated 'on condition' under the provisions of GR 24. This required continued compliance with SB 505-010R1.

On its website, the BGA publishes a Compendium, which is a collection of documents intended to help members identify relevant airworthiness information for a particular aircraft or engine. With respect to the Rotax 275 the Compendium refers to two BGA Technical News Sheets (TNS) 5-2006 and 1-2013 which each refer to SB 505-010R1 and indicate that the maintenance schedule described therein applies to all BGA aircraft with applicable engines.

On 24 March 2020, following the introduction of Part M Light (Part-ML)[25] under Regulation (EU) 2019/1383, GR 24 ceased to be applicable to EASA aircraft types, including gliders. Under Part-ML, continued 'on condition' operation of an engine beyond its recommended overhaul life requires the owner to declare and sign a deviation from the manufacturer's recommended maintenance in the aircraft's SDMP.

Engine maintenance

The BGA inspector had carried out the annual inspections and ARC renewal on G-CFST since 2016. G-CFST's engine had been operated 'on condition' for many years and the inspector commented that it was in reasonable condition when he became involved. During G-CFST's recent annual inspection, the BGA inspector serviced the engine which involved replenishing the gearbox oil, cleaning the spark plug and checking the operation of the decompressor, fuel pump and engine extension/retraction system. He also carried out a cylinder compression test, noting the compression as 50 psi. This was typical of the engine maintenance he carried out at each annual inspection.

Footnote

[24] SB 505-010 is applicable to the Rotax 275, 501, 505 and 535 models and was subsequently updated to Revision 1 (SB 505-010R1) on 4 May 2007. It is available on the Rotax website by searching for Service Bulletins relevant to the 505 model: https://www.flyrotax.com/services/technical-documentation.html

[25] Part-ML is a continuing airworthiness standard for all EASA-regulated general aviation light aircraft (including gliders) which formally transfers responsibility for all aspects of owning and maintaining an airraft to the aircraft owner. It requires aircraft to be subject to a minimum inspection programme, which may be incorporated within an SDMP. Part-ML allows owners flexibility to develop a maintenance programme specific to their particular aircraft and to declare deviations from recommended maintenance. Deviations must be agreed by the certifying engineer, documented within the maintenance programme and signed by the owner.

The BGA inspector commented that he had not noticed any substantial degradation in its condition during this time[26], nor had the owners reported any significant engine problems to him. He was aware that the engine was a source of worry for the owners as it was increasingly difficult to find spare parts. As such they were trying to limit the amount the engine was run to prolong its life. There was an engine hours logger fitted to the glider but the owners considered it unreliable and there was no information relating to engine operating hours recorded in G-CFST's logbook. Only the second of G-CFST's two logbooks was located covering the period from 2015 onwards.

The BGA inspector stated that he inspected the engine each year based on the generic engine inspection requirements of BGA Glider Maintenance Programme and those listed in the Rotax 275 Operator's Manual. These inspection items were carried across when he created the SDMP. He was not aware of SB 505-010R1 or the information in the BGA Compendium which referred to it. Neither G-CSFT's logbook nor the associated work packs for previous annual inspections made reference to SB 505-010R1[27] and G-CFST's owners had not identified its existence to him. As it was not mandated by an AD, he did not come across SB 505-010R1 when he searched for ADs applicable to G-CFST. As a consequence, there were some inspections that were not performed.

When creating G-CFST's SDMP he did not include a deviation for operation of the engine beyond the manufacturer's recommended life, as the engine had already been operating 'on condition' for many years and he considered there would be no change to this under the SDMP.

Analysis

General

Ground marks and the distribution of the wreckage showed that the glider struck the ground in a steep nose-down attitude and was structurally intact before it struck the trees. Examination did not reveal any pre-accident defects which would have affected the controllability of the glider.

Engine

Although the engine was deployed, it was not operating at the time of the accident. With the exception of the ignition switch, which was OFF, the configuration of the engine controls was broadly consistent with an attempt to start the engine. The ignition switch is visually similar to the fuel pump switch and it is possible it was moved post-accident during attempts to turn off the fuel pump.

The engine was reported by several sources to have been difficult to start, both in the air and on the ground and did not start when the pilot attempted to start it prior to the accident flight. During post-accident testing, the engine started on the fourth pull of the pull-start

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Footnote

[26] The paperwork for the 2019 annual inspection noted the cylinder compression as 4 Bar (58 psi) and as 5 Bar (72.5 psi) in 2016, 2017 and 2018.

[27] A work pack from 2008 made reference to a '6-year check' being performed on the engine.

handle, in line with the ground start procedure from the flight manual. In the installed condition, the pull-start cable undergoes several changes of direction. With the engine and its controls removed from the glider for testing, a direct, in-line, pull force could be applied to the starter, which may have contributed to the ease of starting. Continued operation of the engine was not assessed.

Ground testing could not replicate the elapsed time or height required to start the engine in flight, nor take account of using the decompressor. But it indicated that the engine was most likely capable of starting, given available height and time to perform the required sequence of actions and the appropriate airspeed.

Observation on engine maintenance

The engine was no longer supported by the engine manufacturer and it had been operated 'on condition' for many years. It was inspected and serviced annually, including at the recent annual inspection. The engine had not been inspected in accordance with a required SB and G-CFST's recently-created SDMP did not include a documented deviation from the manufacturer's recommended engine maintenance schedule.

These aspects were not causal or contributory to the accident but are reported as they may have relevance to other gliders equipped with engines which were operating 'on condition' prior to the introduction of Part-ML.

> Following this accident, the BGA undertook to write to all BGA Inspectors and owners of gliders with engines that are no longer supported by the engine manufacturer, to remind them of the maintenance requirements and the need to document any deviations from recommended maintenance in the aircraft's SDMP.

Survivability

The pilot's shoulder straps were found undone and had not been released by personnel attending the pilot after the accident. It was not established whether the pilot did not secure them prior to the flight, intentionally released them during the flight or if they became disengaged during the accident sequence. Anecdotal information from the BGA indicated the potential for inadvertent operation of the release tab on this type of QRF and a modification to prevent this was available from the harness manufacturer. It was considered unlikely that the USB logger worn around the pilot's neck could have interfered with operation of the release tab, but the possibility could not be discounted. The post-mortem examination indicated that the extent of the injuries sustained by the pilot were such that they could have resulted in a fatal outcome, even if effective upper body restraint had been present.

With the engine deployed, the impact forces caused substantial damage to the pylon, such that the engine came to rest just above the rear cockpit. In this case the passenger did not suffer injuries as a result. However, it underlines the importance of the guidance in the flight manual to stow the engine if a crash landing becomes inevitable, as a means of reducing the risk of injury to occupants.

Licensing

The pilot held a valid BGA Glider Pilot's Licence.

Medical

Under the BGA Laws and Rules, the pilot was required to self-declare his medical fitness to fly and had done so in February 2019. The pilot held a current driving licence at the time of the accident, thus satisfying the medical requirements stipulated in the BGA's Rules and Laws.

While the club had imposed a 'dual-only' limitation on the pilot because he was "showing signs of ageing," the pilot did not have an identifiable medical condition that would have stopped him from driving or flying. With a valid driving licence and no known declarable medical condition, the pilot's self-declaration medical was valid on the day of the flight.

Club imposed limitation

The 'dual-only' limitation imposed on the pilot was a pragmatic first step towards mitigating potential risk associated with the perceived impact of age on the pilot's decision making. The intention had been to review the measure as the gliding season progressed. The club did not have a formal process to follow and described themselves as "feeling their way" regarding how best to proceed. At the time of the accident flight, the club management did not consider there was enough evidence on which to base a decision to prevent the pilot flying as PIC.

Crew status

The pilot was PIC for the accident flight and the rear seat occupant held passenger status, with no legal authority to override decisions made by the PIC. The passenger was aware of the 'dual-only' limitation on the pilot but had not been formally briefed in his capacity as accompanying pilot. He was not acting in a recognised safety pilot role.

Intervention

Successful and timely in-cockpit intervention by a non-handling pilot, even in a multi-pilot environment, can be difficult to achieve. When the non-handling pilot is flying as a passenger in a single-pilot operation they have no legal authority to interfere with the conduct of the flight, intervention can only be effective if the PIC empowers the passenger to raise concerns. Even when empowered, deference to a more experienced and capable colleague, friendship and a PIC-to-passenger authority gradient are some factors that caninhibit effective intervention. The BGA's guidance on mutual flying recommends airing such topics on the ground before flight as a way of bolstering CRM and avoiding the potential for later awkwardness. It also reminds pilots that the final decision for any course of action is the responsibility of the PIC.

Having flown together on many previous occasions the two friends did not feel the need to discuss the specifics of cockpit management, authority gradient or empowerment before the accident flight.

Gliding performance

The wide variability between the altitude measurements from the various navigational recorders on the glider meant that an accurate calculation of G-CFST's achieved gliding performance was not possible. Loggers A and B broadly correlated with the eyewitness account of the glider passing 'just below' his level on the 270 m contour line at Hartley Hill and were used as the basis for an indicative analysis of the flight's vertical profile but definite conclusions could not be drawn.

Comments from pilots posting on the BGA Ladder confirm the passenger's observation that the Cotswold Ridge was not generating good soaring conditions on the day of the accident. Nonetheless, having released the aerotow at 2,100 ft amsl, the glider covered 16.5 nm before the engine was deployed at an altitude of approximately 590 ft, equating to an average achieved glide ratio of 1:65. It could not be determined to what extent ridge lift, rather than simply tailwind, contributed to this figure.

G-CFST was below ridge height as it flew parallel to it south of Cheltenham. During this leg, the wind direction meant that the ridge would not be expected to produce significant lift, but the pilot might reasonably have anticipated that they would gain height tracking northbound from the Charlton Kings area.

The passenger considered it probable that the pilot expected, even if the ridge wasn't working well, that he would have enough height to reach the racecourse for a field landing. A simplistic comparison of the notional glide performance of G-CFST is included at Figure 18. This shows that from an assumed altitude of 885 ft (270 m) abeam the witness on Hartley Hill, a 1:50 glide path would have been sufficient to maintain terrain clearance when following the hypothetical yellow track line to the racecourse. This calculation does not take account of obstacles, such as buildings or trees, on the flightpath or of any head or tailwind component. Data from the loggers placed the aircraft just below 800 ft passing the witness. The five logger-derived altitude reference points depicted in orange indicate that, likely due to a tailwind, G-CFST was achieving a greater than 1:50 glide ratio around the bowl before the engine was deployed.

From Point 5 on the graphic, while the racecourse airstrip was theoretically in range, the pilot had no contingency height in reserve. Heading north from Point 5 would have looked daunting, requiring descent from approximately 230 ft agl towards hostile[28] rising ground. Terrain clearance at the highest ground elevation on track would likely have been less than 100 ft. From that point, with the terrain gradient approximating close to 1:50, and without factoring in trees and buildings en route, unless it found additional lift, the glider would have been at ultra-low-level for the remainder of the flight (Figure 19).

Footnote

[28] An area with no viable options for a successful field landing.

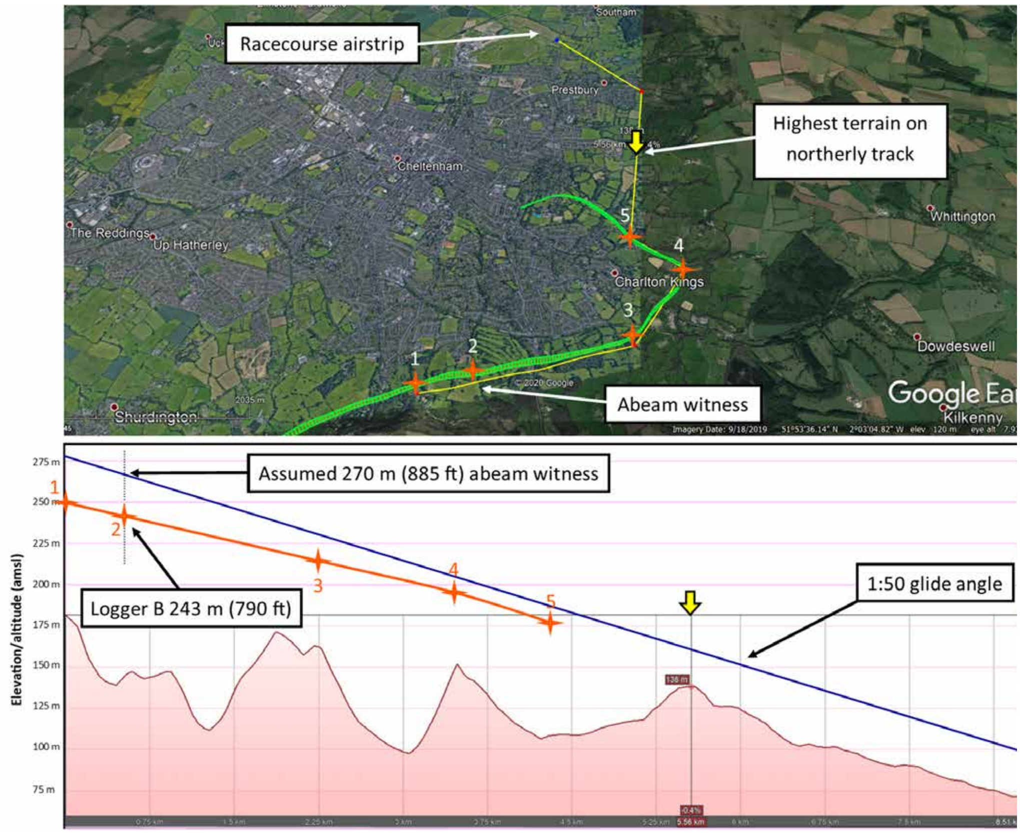

Figure 18

Glide angle and terrain elevation profile comparison (Image ©2020 Google)

Figure 19

View to the south-east from Cheltenham racecourse
(Image Landsat/Copernicus ©2020 Google)

A comparative analysis for escaping to the south-west is at Figure 20. Assuming a 1:50 glide ratio with engine stowed, at 50 kt airspeed and compensating for a 15 kt headwind[29], the glider would theoretically have achieved a 1:35 glide angle over the ground. Starting from an altitude of 590 ft and following the yellow track line on Figure 20, a 1:35 descent profile appears insufficient to clear the built-up area of Cheltenham. While the glider may have been unable to reach open ground beyond the town, it could have reached the playing fields in the middle of the built-up area. Although reachable, none of the playing fields were long enough in which to safely land an ASH 25 E.

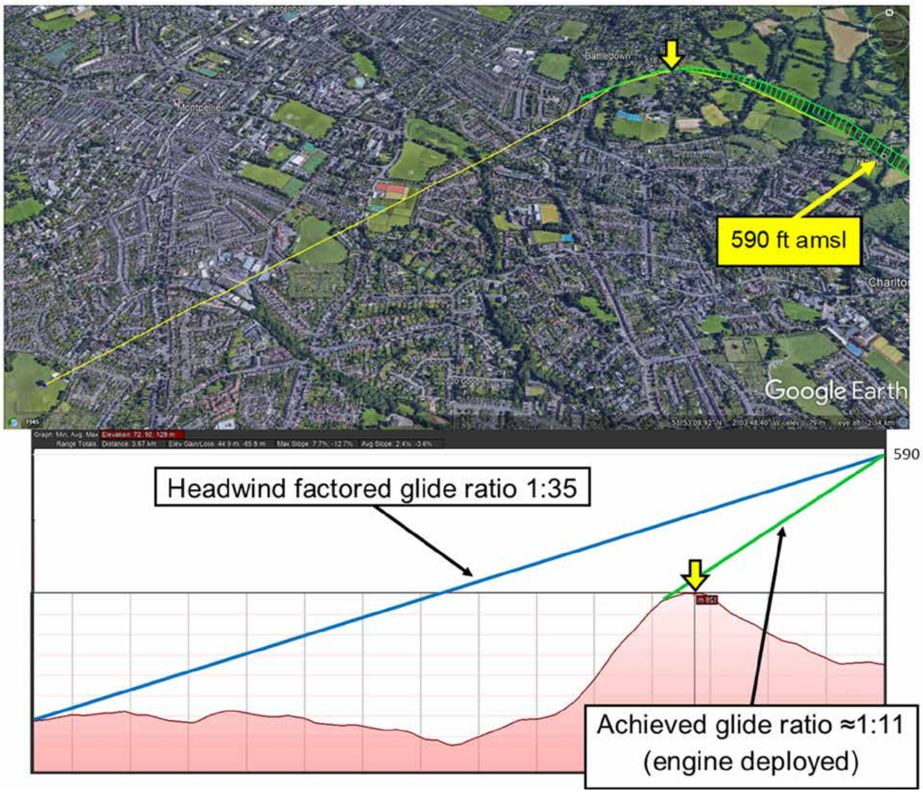

Figure 20

Comparison of notional 1:35 glide angle vs terrain profile across Cheltenham
(Image ©2020 Google)

Engine deployment

The ASH 25 E is an early example of a glider with a sustainer engine and the procedure to start the engine in flight is more time consuming and complex than that on many more modern types. The time taken to deploy the engine and the several steps needed result in unavoidable height loss during a start attempt. When the engine did not start immediately, there would have been insufficient time remaining to follow the steps required to stow the engine. After engine deployment the average glide angle achieved approximated to 1:11.

Footnote

[29] Based on the reported wind of 260°/11 kt at Gloucester Airport.

Pilot decision making

The investigation was not able to determine why, having found the soaring conditions unfavourable, the pilot continued following the ridge behind Cheltenham from an altitude which left limited options for a successful outcome. The passenger reported recognising that continuing would be hazardous and prompting the pilot to divert to Gloucester Airport but was not able to convince the pilot to accept his advice.

Once committed behind Cheltenham at low altitude, the pilot found himself faced with three unappealing options as he passed Charlton Kings:

- To descend towards rising hostile ground to the north, trusting that he would have enough height to clear the high ground short of Prestbury and be able to reach a safe landing area beyond.
- To turn into wind over Cheltenham and hope to have enough height to clear the built-up area for a potentially compromised field landing, either in the playing fields or on open ground beyond the town.
- To attempt an engine start at a height from which success would be highly unlikely.

Anecdotal evidence was that the pilot knew starting the engine would require in excess of 400 ft. At the point of engine deployment, the glider was approximately 200-250 ft agl and heading towards rising ground, making a successful start highly improbable. How the pilot arrived at the decision to deploy the engine could not be determined, but the investigation considered it an indication that he thought the other options were untenable and that starting the engine was the only avenue left to try. Being unaware of the intention to deploy the engine, the passenger was unable to influence the pilot's decision to trade the glider's remaining height for an engine start outside viable deployment parameters.

While acknowledging the known effects of ageing on a pilot's general cognitive function, the investigation did not find direct evidence linking the pilot's age to his decision making on the accident flight.

Conclusion

The accident occurred because the glider was flown over an area and at an altitude where a successful field landing could not be assured. While the pilot had been flying under an informal 'dual-only' limitation related to the perceived effects of ageing, the investigation was not able to determine to what degree age was a factor in his decision making on the accident flight. With an ageing pilot population, the effective and fair management of those with declining physical and cognitive capabilities is likely to remain an ongoing challenge for supervisors and regulators. Formal guidance, such as that proposed by the BGA, could help those empowered with overseeing GA and gliding operations make more informed and transparent supervisory decisions in this regard.

Failing to recognise when they are approaching the point of no return for continued safe flight is not the sole purview of ageing pilots; it is a constant hazard in all forms of aviation and for pilots of every experience level. Effective CRM is an important risk mitigation tool for single-pilot operations, not just something to be employed by multi-pilot crews. While passengers do not have legal authority to intervene, if properly empowered as part of an effective CRM strategy, they can make a valuable contribution to the safe conduct of flights.

Safety action

Following this accident, the British Gliding Association:

- Began a consultation process with its member clubs with the aim of developing formal guidance to support the management of pilots of any age who might benefit from flying with a safety pilot or relinquishing PIC status.
- Undertook to write to all BGA Inspectors and owners of gliders with engines that are no longer supported by the engine manufacturer, to remind them of the maintenance requirements and the need to document any deviations from recommended maintenance in the aircraft's SDMP.

Published: 29 April 2021.

ACCIDENT

Aircraft Type and Registration:	DJI Phantom 4 RTK (UAS, registration n/a)	
No & Type of Engines:	4 electric motors	
Year of Manufacture:	2020 (Serial no: 0V2GDC6RA30246)	
Date & Time (UTC):	2 December 2020 at 1209 hrs	
Location:	Newtongrange, Dalkeith, Midlothian	
Type of Flight:	Commercial Operations (UAS)	
Persons on Board:	Crew - N/A	Passengers - N/A
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Damage to motors, propellers, arms, landing gear and fuselage	
Commander's Licence:	Other	
Commander's Age:	50 years	
Commander's Flying Experience:	98 hours (of which 98 were on type) Last 90 days - 5 hours Last 28 days - 2 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The UAS, a DJI Phantom 4 RTK, was being operated in an automated flight mode to survey a railway track and surrounding infrastructure when one of the four propellers detached whilst in-flight. The aircraft rapidly descended from a height of 70 m (230 ft) where it struck the ground in the rear garden of a house. No persons were injured.

This investigation has reviewed the new UAS regulations introduced on 31 December 2020 concerning the safe overflight of people and data available to assist in risk assessments. Two Safety Recommendations are made to the UK CAA.

History of the flight

The UAS, a DJI Phantom 4 RTK, was being operated commercially[1] to capture survey data of a railway track and adjacent infrastructure near to Newtongrange railway station. This was part of an extensive survey of approximately 45 km of railway track between the towns of Newcraighall, located to the north of Newtongrange, and Tweedbank to the south. This work was to be completed in separate phases, with the first phase taking

---

Footnote

[1] A commercial operation involves a flight or flights 'in return for remuneration or other valuable consideration'. The full definition is available at https://www.legislation.gov.uk/uksi/2016/765/article/7/made [accessed 28 February 2021].

place between Newcraighall and Newtongrange. The survey work was being conducted on behalf of Network Rail[2].

On the day of the accident, the aircraft was being flown from two different takeoff and landing sites (TOLS). There was no precipitation and the visibility was 10 km with the wind from a south-westerly direction at about 11 kt. The aircraft was flown using its automated flight mode[3] whilst remaining within visual line of sight (VLOS) of the pilot and at a horizontal range of less than 500 m. The pilot was also accompanied by an observer. Having successfully completed two flights, the UAS was shut down and the aircraft, with its propellers removed, was placed into its transport case. The pilot and observer then drove to the next TOLS, which was located in the carpark of Newtongrange railway station.

The propellers were refitted to the aircraft and a flight lasting about 20 minutes was successfully completed. The battery was then replaced with a fully charged unit before the aircraft took off at 1149 hrs for the next flight (Figure 1). This included overflying the railway track, adjacent industrial buildings, and a housing estate at a height of about 55m (180 ft) agl before landing back at the TOLS at 1200 hrs.

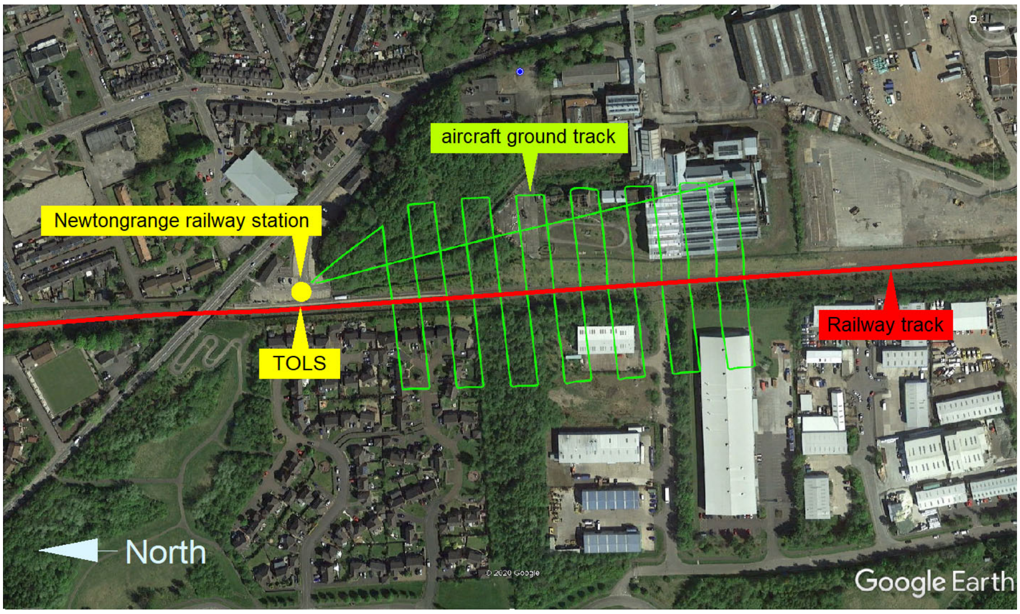

Figure 1

Aircraft ground track prior to the accident flight
© 2020 Google, Image © Maxar Technologies

The pilot, having checked that the aircraft battery had sufficient charge, then programmed the next flight route. This was for the aircraft to fly at a height of about 70 m (230 ft) agl, whilst remaining approximately overhead the railway track. The route would take the aircraft initially to the south of the TOLS, and then to the north before returning to land.

Footnote

[2] Network Rail owns, operates, and develops Britain's State railway infrastructure.

[3] In automated flight mode the aircraft can take off, fly between preset positions and then land without the intervention of the pilot.

The aircraft took off at 1206 hrs (Figure 2) and followed the programmed route, whilst the pilot and observer monitored its progress. At 1209 hrs, the aircraft reached its northerly turning point, where it slowed and commenced its turn back towards the TOLS. This coincided with the aircraft's camera capturing a survey photograph of the railway track and houses below (Figure 3). Shortly after this, the pilot reported that the UAS controller emitted a short "beep". Whilst the observer continued to watch the aircraft, the pilot checked the controller, but no error messages were displayed. The aircraft then rapidly descended vertically. As the aircraft neared the ground, the pilot and observer lost sight of it and, shortly after, a series of error messages were displayed on the controller.

The observer stated that, as the aircraft had descended, it appeared as though the "aircraft's motors had stopped and that it was on its back in free fall".

The pilot and observer subsequently found the aircraft in the rear garden of a terrace house (Figure 3) about 20 m from the railway track and below where the loss of control had occurred. The house was part of a large, densely populated housing estate and there were no people in the garden when the accident occurred. However, when the overhead image (Figure 3) was taken, a member of the public was 10 m from where the aircraft subsequently struck the ground.

The aircraft's motors, propellers, arms, landing gear, camera and fuselage were damaged (Figure 4). Inspection of the aircraft's battery shortly after the aircraft was found, showed that it had about 50 % charge remaining. The left rear propeller had detached and was not found.

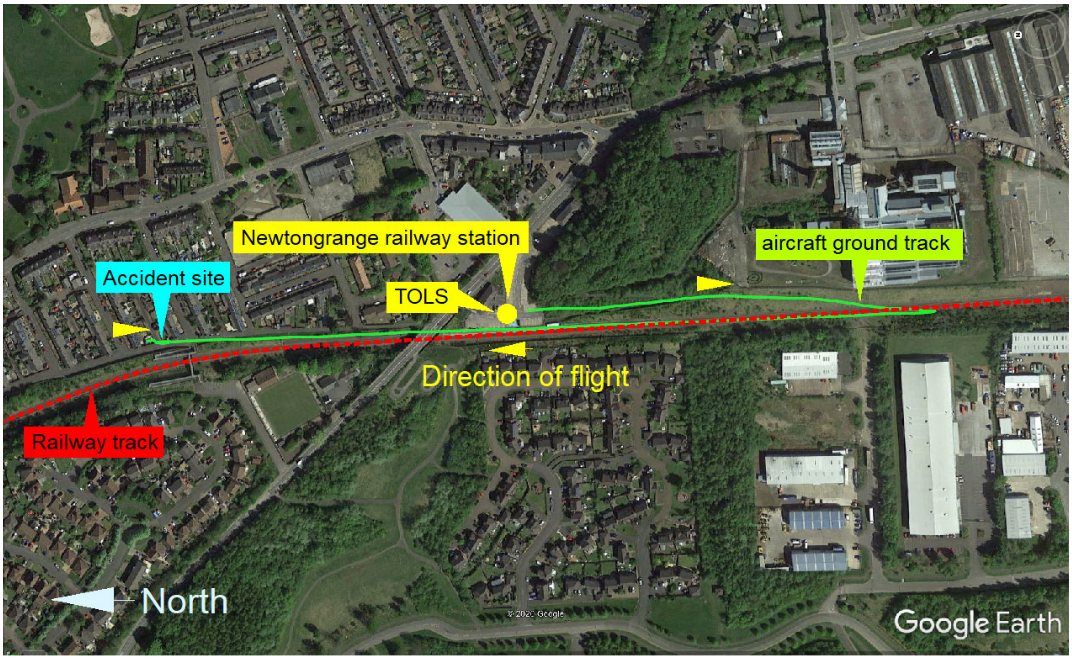

Figure 2

Aircraft ground track during the accident flight
© 2020 Google, Image © Maxar Technologies

Figure 3

Image captured by the aircraft shortly before the loss of control

Figure 4

Aircraft after being recovered from garden

Recorded information

A recorded log of the accident flight was downloaded from the aircraft by the operator and provided to the AAIB and the aircraft manufacturer. This indicated that, just after the aircraft had completed its turn back towards the TOLS, the left rear motor had suddenly increased to its maximum speed. This coincided with the aircraft rapidly spinning and tumbling whilst descending vertically to the ground. The aircraft's four motors continued to operate as it descended.

The data indicated that, from a height of about 60 m, the aircraft descent rate increased beyond that associated with free fall. This was because of thrust from the propellers whilst the aircraft was inverted. The final speed of the aircraft at impact was estimated to have been 36 m/s (~70 kt) and its kinetic energy was about 900 Joules[4].

UAS information

The DJI Phantom 4 RTK is a quadcopter aircraft and has a maximum takeoff mass of 1.391 kg (Figure 5). The accident aircraft had been purchased new in October 2020 by the operator and had accumulated four hours of flight time. There are several versions of the DJI Phantom 4, of which the RTK provided enhanced GPS capability.

The design of the aircraft allows for its propellers to be quickly fitted and removed. This is accomplished by a 'push, twist and release' process that engages and disengages the propeller hub with the motor locking mechanism. The aircraft manufacturer recommended that the propellers were removed when transporting the aircraft.

The manufacturer provided online guidance to assist operators in checking their aircraft, which included a visual inspection of it and its propellers for signs of damage. The manufacturer did not provide a maintenance schedule, such as if, or when, parts of the aircraft may require routine servicing or replacement.

Figure 5

Phantom 4 RTK and controller

Footnote

[4] The Joule is a unit of energy equal to the work done by a force of one newton acting through one metre.

UAS examination and fault analysis

The operator notified the AAIB of the accident on 11 December 2020. Prior to notifying the AAIB, the operator had sent the aircraft wreckage to a dealer in the UK, who forwarded it to the aircraft manufacturer's facility in the Netherlands. The aircraft was repaired by the manufacturer shortly after receiving it and returned to the operator.

The manufacturer analysed the flight log and stated that the loss of control had occurred because the left rear propeller had detached in flight.

The AAIB asked the manufacturer if the accident aircraft had been subject to a detailed inspection to identify why the propeller may have detached. The manufacturer did not confirm if they had inspected the aircraft in detail, but referring to the in-flight loss of propellers, they stated that they had '*currently not seen any recurring pattern of similar cases*'.

UAS accidents reported to the AAIB

Between February 2015 and January 2021, the AAIB received 190 notifications of incidents involving UAS. This included 73 accidents where a loss of control occurred, of which 69 aircraft had a maximum takeoff mass (MTOM) of less than 25 kg. These accidents had occurred to a number of different manufacturers and models of UAS.

17 accidents involved DJI Phantom 4s, of which nine were reported in 2020. This included an accident on 1 December 2020 involving a RTK model, for which the pilot attributed the cause to a possible propeller failure or in-flight loss of a propeller. The AAIB also identified information on the internet indicating another in-flight loss of a propeller from a DJI Phantom 4 RTK.

UAS loss of control accidents resulting in injury to people

The Australian Transport Safety Bureau (ATSB) is investigating an accident involving a DJI Inspire 2 UAS that occurred on 15 January 2021 at Darling Harbour, New South Wales, Australia. The initial ATSB report[5] states that while conducting aerial photography, the aircraft was flown to approximately 10 m above ground level when the pilot reportedly lost control of the aircraft. The aircraft flew away and subsequently collided with the window of a building, causing it to break. A person in the building sustained minor injuries. The ATSB has indicated that the final report will be published during Q3 of 2021.

Operational requirements and UAS regulations

UAS regulations prior to 31 December 2020

At the time of the accident, any person or organisation commercially operating a UAS aircraft in the UK with a mass of no more than 20 kg[6] required permission from the CAA. This permission was commonly referred to as Permissions for Commercial Operations (PfCO).

Footnote

[5] https://www.atsb.gov.au/publications/investigation_reports/2021/aair/ao-2021-001/ [accessed 28 February 2021].

[6] The ANO refers to a UAS falling into this category as a Small Unmanned Aircraft (SUA).

The applicant for a PfCO needed to show pilot competence and provide an operations manual, which detailed the scope of the organisation and the procedures to be followed.

The operator of the accident UAS held a PfCO and had several trained pilots that operated under this permission. It also operated another DJI Phantom 4 RTK, a DJI Matrice, DJI Inspire (quadcopters) and a WingtraOne (fixed-wing, vertical takeoff and landing) aircraft.

The operator's PfCO included a requirement to report an accident within 72 hours of occurrence, and its operations manual referred to reporting all accidents and incidents to the AAIB.

The operator had permission to overfly uninvolved persons[7] with their UAS, as long as it was no closer than 50 m to them (except that during takeoff and landing this distance could be reduced to 30 m). However, this does not absolve the operator of its responsibilities under the ANO regarding overflight, which included Article 94 '*(2) The remote pilot of a small unmanned aircraft may only fly the aircraft if reasonably satisfied that the flight can safely be made'*[8]. To assist operators in this matter, the CAA published Safety Notice SN-2020/002[9] in January 2020. This provided guidance and best practice information for operators to consider when overflying uninvolved persons.

SN-2020/002 included the following guidance:

- 'Only fly directly over people when absolutely necessary to achieve the aim of the flight, and minimise the time doing so.'
- 'When flying over uninvolved people remote pilots should, whenever reasonably possible, maintain some horizontal separation between their aircraft and those uninvolved people.'
- 'Wherever reasonably possible, consider the use of technologies such as……… use of ballistic recovery system (e.g. parachutes) to reduce the risk of harm to uninvolved people following a loss of control of the small unmanned aircraft.'

Risk assessment

The operator of the accident UAS had produced a risk assessment and method statement for the survey flights it intended on making between Newcraighall and Newtongrange. This included the use of its DJI Phantom 4 RTKs, DJI Matrice and WingtraOne UAS. The risk assessment used a 5x5 matrix and incorporated an assessment of the failure of the aircraft (Figure 6).

The operator's initial risk score of ten (moderate) concerning the potential failure of the aircraft was not based on published failure rates for the types of UAS it operated, as the operator

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Footnote

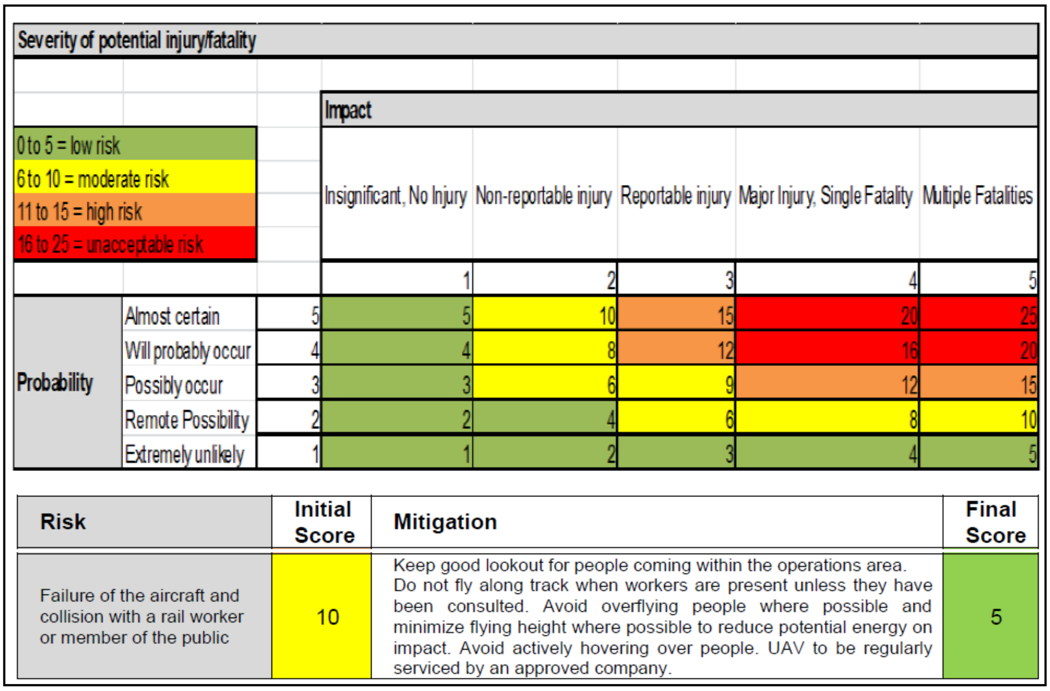
[7] People that are not a part of the flying operation (ie third parties). This includes people in the open and occupants of any vehicle, vessel or structure.

[8] A small unmanned aircraft was an aircraft of a mass of 20 kg or less.

[9] https://publicapps.caa.co.uk/docs/33/SafetyNotice2020002.pdf [accessed 28 February 2021].

did not have access to such information. Instead, the operator had used an assumed value based on an awareness of previous UAS incidents, which included a UAS flyaway incident[10] that occurred to a different operator whilst surveying Network Rail infrastructure.

To reduce the risk of colliding with people and causing injuries that could be fatal, the operator cited several mitigations. These included minimising overflight of uninvolved persons. However, discussions with the operator indicated that it was not always practicable to achieve this, as the flights could often take place in densely populated (congested) areas. Discussions with other commercial operators also indicated similar difficulties. The operator considered that its stated mitigations would result in a final risk score of five (low risk).



Severity of potential injury/fatality

🟩 0 to 5 = low risk
🟨 6 to 10 = moderate risk
🟧 11 to 15 = high risk
🟥 16 to 25 = unacceptable risk

			Impact				
			Insignificant, No Injury	Non-reportable injury	Reportable injury	Major Injury, Single Fatality	Multiple Fatalities
			1	2	3	4	5
Probability	Almost certain	5	5	10	15	20	25
	Will probably occur	4	4	8	12	16	20
	Possibly occur	3	3	6	9	12	15
	Remote Possibility	2	2	4	6	8	10
	Extremely unlikely	1	1	2	3	4	5

Risk	Initial Score	Mitigation	Final Score
Failure of the aircraft and collision with a rail worker or member of the public	10	Keep good lookout for people coming within the operations area. Do not fly along track when workers are present unless they have been consulted. Avoid overflying people where possible and minimize flying height where possible to reduce potential energy on impact. Avoid actively hovering over people. UAV to be regularly serviced by an approved company.	5

Figure 6

Operator's risk assessment of aircraft failure and mitigating actions

UAS regulations in the UK from 31 December 2020

New UAS regulations in the UK were introduced on 31 December 2020. These were adopted from Commission Implementing Regulation (IR) (EU) 2019/947 and Commission Delegated Regulation (DR) (EU) 2019/945 to harmonize UAS regulations within Europe. This included the following three categories under which a UAS is to be operated:

- Open category (less than 25 kg) – operations that present a low (or no) risk to third parties. Operations are to be conducted in accordance with basic and predefined characteristics and are not subject to any further authorisation requirements. The Open category is divided into operational

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Footnote

[10] https://assets.publishing.service.gov.uk/media/5f3beeabd3bf7f1b17facec6/Aerialtronics_Altura_Zenith_ATX8_na_011019_05-20.pdf [accessed 28 February 2021].

subcategories A1 (fly over people), A2 (fly near to people) and A3 (fly far from people). Within each subcategory are five classes of UAS which are C0, C1, C2, C3 and C4.

- Specific category – operations that present a greater risk than that of the Open category, or where one or more elements of the operation fall outside the boundaries of the Open category. Operations will require an operational authorisation from the CAA based on a safety risk assessment.
- Certified category – operations that present an equivalent risk to that of manned aviation and will be subject to the same regulatory regime (ie certification of the aircraft, certification of the operator, licensing of the pilot).

The Open category will apply to hobbyist users and some commercial operators. In this category, only an aircraft with a mass of less than 250 grams and, for aircraft introduced after 1 July 2022, a maximum velocity of 19 m/s, is permitted to fly over uninvolved persons but it must never be flown over an assembly of people (crowd). An aircraft of 250 grams or more, or one able to impart more than 80 Joules of kinetic energy, must not be flown over uninvolved persons.

The Specific category will typically apply to many commercial operations in the UK. To operate in this category an operator must have obtained an operational authorisation from the CAA. Holders of a currently valid PfCO may continue to operate under the same privileges until the PfCO expiry date, or 1 January 2022, whichever is earlier. After this, the operator will need to apply for an operational authorisation. During annual renewal of an operational authorisation, pilots are required to provide evidence of logged flight hours to the CAA. Operators are also required to record, and retain for two years, a log for each aircraft operated, which is to include the aircraft model, number of flights, flight hours, defects, repairs and any incidents or accidents.

Operators applying for an operational authorisation may apply under a Predefined Risk Assessment (PDRA). CAP 722[11] Edition 8, section 2.3.2 states:

> *'A PDRA is a shortened set of prescriptive conditions that must be complied with by a UAS operator in order to conduct a pre-determined type of operation. In these cases, the CAA conducts the risk assessment, rather than each individual operator, and then publishes a short series of requirements (covering topics such as remote pilot competency, ops manual contents etc) that the UAS operator must provide to the CAA as part of a 'shortened' application for an operational authorisation. This is a prescriptive set of instructions that must be followed, leading to a 'known' operation with a known and understood risk, that must be authorised on the basis of following the set of instructions. Much like following a cake recipe exactly, the intention is to produce an identical cake*

Footnote

[11] Civil Aviation Authority Unmanned Aircraft System Operations in UK Airspace – Guidance CAP 722 Edition 8. https://publicapps.caa.co.uk/docs/33/CAP722%20Edition8(p).pdf [accessed 28 February 2021].

> *every time; and an identical safety risk is presented by the operation. This type of approach would apply to operations that would most likely be conducted by a large number of operators (i.e. it is a pre-defined scenario), but the safety mitigations are relatively simple.'*

CAP 722 Edition 8 provides two PDRAs, of which UKPDRA01 is applicable to aircraft with a MTOM of less than 25 kg, and UKPDRA02 for aircraft with a MTOM of between 25 kg and 150 kg.

UKPDRA01 provides the same operating privileges to those previously available under a PfCO, in that an operator may still overfly uninvolved persons as long as they are no closer than 50 m to them (or less if agreed with the CAA) ie a 50 m 'bubble' around people. The PDRA states that operators must produce an operations manual, which details how flights will be conducted, and pilots must have a General VLOS Certificate (GVC). The GVC is a qualification that satisfies the pilot competency requirements for VLOS operations within the Specific category.

The CAA confirmed that UKPDRA01 is applicable to operators carrying out the same type of operation as that of the accident flight, and that mitigation against injuring uninvolved persons is provided by operators having an operations manual and trained pilots. The CAA considered that these mitigations were appropriate as they had been in place previously as part of the PfCO and also that no uninvolved persons had been injured to date.

Following discussions with the CAA in 2019, the AAIB's understanding was that the new UAS regulations applicable to the Specific category would incorporate the concept of standard scenarios. These were understood to provide mitigating safety actions relative to the tasks involved, such as when operating in congested areas and overflying uninvolved people. CAP 722 Edition 8 includes a section for standard scenarios but only states:

> *'Reserved for future use.*
>
> *Note: The concept of 'standard scenarios' is omitted in the retained version of the UAS IR and therefore will not be used in the UK for the foreseeable future.'*

During the AAIB investigation into this accident, the CAA stated that standard scenarios were omitted from CAP 722 because they were not applicable when the EU regulations were adopted and that the CAA considered that UKPDRA01 provided a 'simpler and more comprehensive' solution than standard scenarios.

Risk of injury due to falling objects

The AAIB has previously[12] highlighted the potential for injury from a falling unmanned aircraft based on the dropped object prevention scheme (DROPS)[13]. This provides an indication

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Footnote

[12] https://www.gov.uk/aaib-reports/aaib-investigation-to-dji-matrice-210-uas-registration-n-a-16-march-2019, https://www.gov.uk/aaib-reports/aaib-investigation-to-dji-m600-pro-uas-registration-n-a-131219 [accessed 28 February 2021].

[13] https://www.dropsonline.org [accessed 28 February 2021].

as to the possible outcome[14] of a blunt object in free fall striking a person wearing personal protective equipment (ie hard hat, eye protection). The scheme is based on an object with an energy of 40 Joules or more upon impact with a person.

Analysis using the DROPS calculator indicated that a blunt object with the same mass as a DJI Phantom 4 RTK (1.391 kg) and falling from a height of 8 m (~25 ft) agl or more, could result in a fatal injury to someone wearing a hard hat.

In 2013, a research paper[15] for the Australian Civil Aviation Safety Authority (CASA) reviewed the severity of an injury following a collision with remote piloted aircraft (RPA) that have a mass of between 0.5 kg and 20 kg. The CASA paper stated that the highest risk of injury was during an impact to the head, with energies[16] of between 40 and 120 Joules being '*dangerous*' and more than 120 Joules as '*causing severe damage to humans*'.

The CASA research paper considered that the three parameters determining injury severity were aircraft mass, velocity at impact, and local radius (diameter) of the aircraft part contacting a person. The conclusions of the research included:

- *'A 2kg RPA at 10m/s is predicted to cause skull fracture, even when impacting with its flat side (equivalent to a 2kg aluminium plate dropped from a height of 5m).'*

- *For a 2kg RPA*, *the highest tolerable velocity for the head impact is below 7.5m/s (15kts). A minimum RPA part diameter of 10cm is required for this case. The impact energy is equivalent to a solid 11cm aluminium sphere dropped from a height of 3m.*

- *The velocities in the loss-of-control scenario, in which the RPA descends from altitudes >60m reaching its terminal velocity, lie far above the determined acceptable values (typically above 30m/s). At such high impact velocities practically any RPA mass is likely to cause unacceptably severe injuries.'*

Previous AAIB Safety Recommendations

On 9 January 2020 the AAIB published its report on an accident involving a DJI Matrice 210[17] that occurred at Temple Newsam, Leeds, where the aircraft fell to the ground during an outdoor event attended by several hundred people.

Footnote

[14] It is not possible to be definitive due to varying factors such as where an object strikes a person or if it penetrates the body.

[15] https://www.casa.gov.au/files/human-injury-model-small-unmanned-aircraft-impacts.pdf [accessed 28 February 2021].

[16] The kinetic energy is a function of the mass of an object and its velocity at impact. For the same mass in free fall, the higher the object is above the ground, the higher the kinetic energy is at impact.

[17] https://www.gov.uk/aaib-reports/aaib-investigation-to-dji-matrice-210-uas-registration-n-a-16-march-2019 [accessed 28 February 2021].

This report contained the following Safety Recommendation to the CAA:

Safety Recommendation 2020-002

It is recommended that the Civil Aviation Authority specify the conditions that must be met for an unmanned aircraft to be flown safely over people.

In response to Safety Recommendation 2020-002, the CAA published SN-2020/002 and provided the following response:

> *'The CAA believes that this recommendation is met through the introduction of the European Commission's new regulations pertaining to UAS that will be implemented in the UK on 31 Dec 20. With the extant regulations, there are no specific requirements that must be met for UAS to be flown over people; the existing rule set specifies that uninvolved third parties must be avoided by a 50m 'bubble,' which allows for overflight. Advice on the requirements to achieve this safely were covered through the release of Safety Notices and assessment of individual Operational Authorisations, but it was not within our remit to change the legislation directly to disallow overflight or enforce these requirements.*
>
> *The new regulations specify that the 50m 'bubble' will be replaced by a 'cylinder,' meaning that UAS cannot fly within a 50m horizontal distance of uninvolved 3rd parties when operating in the A2 and A3 categories. The A2 category also demands extra requirements in terms of pilot competence and product standards. Overflight in the A1 category is permitted and mitigated by the mass limit of 250g and additional product standards.'*

Based on an understanding that the new regulations introduced on 31 December 2020 would address Safety Recommendation 2020-002, the response from the CAA was assessed by the AAIB as 'Adequate'.

Network Rail UAS operations

Surveying of Network Rail's infrastructure was overseen by its Air Operations department, which used a combination of helicopters and UAS. This department held a PfCO and operated about 80 UAS flown by 43 pilots. About 95% of the fleet was made up of Mavic, Phantom, Inspire and M200/210 quadcopter aircraft manufactured by DJI, with the remaining 5% made up of Disco fixed-wing and Anafi quadcopter aircraft manufactured by Parrott, and a Robot Aviation FX10 fixed-wing aircraft. The UAS surveying activity was also supplemented by four operators under contract; these are referred to as Framework companies.

Network Rail advised that its use of UAS was a balance between the risk of an aircraft injuring a person and that posed to people having to work in close proximity to hazards if a UAS was not used. Its pilots were advised to minimise overflight of uninvolved persons. For Framework companies, they were expected to adhere to their PfCO or operational authorisation and the requirements of the ANO.

Network Rail oversee about 1,000 flights per year, of which approximately:

- 35% are flown by its own pilots, of which 35% are training flights to stay current and 65% are for operational requirements.
- 35% are Framework company flights.
- 30% are flights made by external operators that have a requirement to fly a UA within 50 m of the railway track.

Network Rail had Work Instructions (WI) that set out, among other aspects, the operating arrangements for its own pilots, Framework company pilots, or any external organisation's pilots wanting to operate a UA near or overhead the Network Rail infrastructure. The WI specified that unless permission was provided by Network Rail, all other pilots should not fly a UA closer than 50 m to its infrastructure. Depending upon PfCO or operational authorisation limitations, Network Rail pilots and Framework company pilots could operate a UA vertically to a minimum of 20 m and 5 m laterally during daytime from the railway track and, at night, these limits were increased to 50 m and 25 m respectively.

The WI also included minimum equipment requirements for its, and Framework companies' UAS. These included a return-to-home[18] function and that system technology compliant with the operators' CAA permission and approved operations manual, was fitted.

Network Rail had previously considered the use of parachute technology to limit the energy of a falling UAS. However, concerns were raised about inadvertent operation and possible entanglement in the overhead line electrification system, which would create alternate risks.

In November 2020 Network Rail introduced a UAS Flight Management System (FMS) that was used to collate and share information on flight planning to ensure that aircraft were not operated in the same area at the same time. The FMS also collates operational information such as the aircraft make, model and weight of aircraft for in-house, Framework and any external operators' flights near Network Rail infrastructure. It also keeps a record of the flight hours for in-house flights and the associated pilot. Network Rail also collate information on incidents and accident involving its in-house, Framework and external operations near its infrastructure.

In January 2021, Network Rail precluded the use of DJI Phantom 4s in support of its survey activities. Furthermore, they advised that they intend to carry out trials using a UAS with a MTOM of less than 250 grams for when there is a need for UAS operations over uninvolved people. The FMS is also being updated to provide a 'risk map' to include information on areas having known hazards, such as transmission masts that could affect UAS operations.

Footnote

[18] In normal operation the RTH function would automatically land the aircraft at its takeoff position.

Analysis

Failure of the DJI Phantom 4 RTK's propeller

Analysis of the recorded flight log indicated that the left rear propeller had detached from the aircraft in flight. This resulted in a loss of control, with the aircraft descending rapidly and vertically to the ground.

After the propellers were fitted and before the accident flight, the aircraft had successfully completed two flights and flown for more than 30 minutes. This indicates that the propeller had probably been fitted correctly prior to flight and therefore either the propeller or its locking mechanism to the motor may have failed. The manufacturer did not confirm if it had carried out a detailed inspection of the aircraft and therefore it was not possible to determine the cause of the in-flight separation. However, the manufacturer stated that it had '*currently not seen any recurring pattern of similar cases'.*

In 2020, the AAIB was notified of nine accidents involving DJI Phantom 4s of which one was an accident on 1 December 2020 where the pilot of a RTK model attributed the accident to a possible propeller failure or in-flight loss of a propeller.

Notification of accidents to the AAIB

The AAIB was notified nine days after the accident occurred, by which time the operator had already sent the damaged aircraft to the manufacturer. It is important that the AAIB is notified of accidents and serious incidents in a timely manner, and within the time frames required by a PfCO or operational authorisation issued by the CAA which, for this operator, was 72 hours. This is so that the appropriate evidence can be secured and that aspects such as the subsequent inspection of a UAS can be coordinated by the AAIB. CAP 722 provides information on reporting UAS accident to the AAIB and CAA. Further information can also be found on the AAIB website[19].

UAS failure rates

Neither the operator in its risk assessment, nor the CAA in UKPDRA01, based mitigating actions on data published for UAS failure rates per flying hour. Whilst it is recognised that UAS manufacturers would be understandably reluctant to publish such information, large operators such as Network Rail are collating aircraft usage data, and UK operators are also now required to record usage data for each aircraft in addition to individual pilot flight hours to support annual applications to the CAA for the renewal of an operational authorisation. Collation and dissemination of such data would enable, in particular for operations involving overflight of people, the actual risk to uninvolved persons on the ground to be assessed with greater accuracy.

Footnote

[19] https://www.gov.uk/government/publications/investigating-accidents-to-unmanned-aircraft-systems/investigating-accidents-to-unmanned-aircraft-systems [accessed 28 February 2021].

Therefore, the following Safety Recommendation is made:

Safety Recommendation 2021-023

It is recommended that the Civil Aviation Authority collate up to date information regarding the failure rates per flying hour for unmanned aircraft systems operating in the Specific category, or previously under a CAA Permission for Commercial Operations, to facilitate effective risk assessments.

Operation of UAS over uninvolved persons

Aircraft such as the DJI Phantom 4 RTK series rely upon their propulsion system for lift. If propulsion is lost, aircraft of this type typically fall vertically to the ground.

The DROPS analysis indicated that a DJI Phantom 4 RTK (1.391 kg) falling from a height of 8 m (~25 ft) or more could result in a fatal injury to someone wearing a hard hat. The accident aircraft descended from a height far in excess of this, at 70 m, and at a descent rate greater than free fall because of thrust from its three operating propellers whilst it was inverted. The CASA research paper stated that energies of between 40 and 120 Joules were '*dangerous*' and more than 120 Joules as '*causing severe damage to humans*' when struck on the head. The energy at impact of the accident aircraft was calculated to be 900 Joules. It is therefore highly likely that a fatal injury would have occurred had a person been struck from above.

The new UAS regulations introduced in the UK on 31 December 2020 preclude the overflight of uninvolved people when operating in the Open category with an aircraft with a MTOM of more than 250 grams, or one that is able to impart more than 80 Joules of kinetic energy. However, commercial operators holding a PfCO or operational authorisation issued by the CAA may overfly uninvolved people with a UAS of more than 250 grams and that is able to impart more than 80 Joules of kinetic energy.

Discussions with the CAA in 2019 indicated that the new regulations would introduce standard scenarios, through which predefined safety mitigations for a particular task would be specified, such as operating in a congested area over uninvolved persons. However, standard scenarios have not been adopted into UK regulations and the CAA has published UKPDRA01 and UKPDRA02 as alternatives.

The CAA stated that when operating a UAS of less than 25 kg in the Specific category, UKPDRA01 provides mitigation against injury to uninvolved persons by requiring operators to have an operations manual detailing how flights will be conducted, and pilots to have a GVC. However, this accident, and others, have shown that pilot training does not provide mitigation against failures that result in a loss of control and where aircraft fall vertically to the ground. For these types of failure, an operations manual may also not provide suitable mitigation, unless overflight is precluded, or where the energy of an aircraft falling to the ground is required to be minimised.

SN-2020/002 recommended limiting the amount of overflight and to maintain a lateral distance from people to reduce the risk when overflying uninvolved persons. However, discussions with the operator of the accident aircraft, and other operators, indicated that this was not always possible to achieve when operating in congested areas.

The operator's risk assessment for a failure of the UAS included mitigations to reduce the energy at impact by limiting the maximum height permitted when overflying people. However, the operator, under the requirements of the PfCO, also had to maintain a minimum height of 50 m when flying over uninvolved persons. An aircraft falling from 50 m would be highly likely to cause a fatal injury to a person being struck by it, and the operator's mitigating action would not have been effective in reducing the severity of such injuries.

SN-2020/002 does refer to the use of technology, such as fitting a parachute system that would reduce the energy when descending to the ground following a failure. However, this is only recommended, not required, when operating over uninvolved persons. Furthermore, the use of a parachute can introduce additional risks such as that identified by Network Rail who raised concerns that inadvertent operation could result in entanglement in the overhead line electrification system.

The operator's mitigating actions also referred to performing routine maintenance of the UAS. However, the manufacturer of the DJI Phantom 4 RTK did not provide guidance or requirements for this activity. Therefore, it was unclear as to how this was to be effectively implemented by the operator, and also, specific to this event, if such maintenance could have reduced the risk of a propeller detaching.

The operator's initial risk score for the failure of its UAS was based on an assumed score rather than published information, as this is not available. The CAA also stated that the mitigating actions in UKPDRA01 were not based on data but that the same mitigations had been in place for several years as part of the PfCO and that no person had been injured to date. Since 2015, 73 accidents involving UAS aircraft have been reported to the AAIB where a loss of control occurred, of which 69 had a MTOM of less than 25 kg. It is unclear if the current mitigations intended to prevent injury to uninvolved persons are adequate or that it has been due to chance that a person has not been injured.

This investigation indicates that UAS operations in the Specific category pose a risk to uninvolved people on the ground being struck by an aircraft relying solely upon its propulsion system for lift, following a failure of that propulsion system. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2021-024

It is recommended that, until an analysis of failure rates per flying hour has demonstrated an acceptable level of safety, the Civil Aviation Authority should consider prohibiting the overflight of uninvolved persons for those unmanned aircraft operating in the Specific category which rely solely upon their propulsion system for lift that would, following a failure of the propulsion system, impact the ground with a kinetic energy exceeding 80 Joules.

Conclusion

The DJI Phantom 4 RTK struck the ground in the rear garden of a house whilst conducting an aerial survey. The manufacturer stated that the accident had been caused by the left rear propeller detaching from its motor. Failure of UAS aircraft that then fall to the ground pose a risk of injury to people on the ground which is not mitigated by the current UK regulations or the published guidance and policy material. Information on the failure rate of UAS are also not available on which to determine the risk of overflying uninvolved persons. Two Safety Recommendations are made to the CAA to address these issues.

Safety action

In January 2021, Network Rail precluded the use of DJI Phantom 4s in support of its survey activities. Furthermore, they advised that they intend to carry out trials using a UAS with a MTOM of less than 250 grams for when there is a need for UAS operations over uninvolved persons. The FMS is also being updated to provide a ‘risk map’ to include information on areas having known hazards, such as transmission masts that could affect UAS communications.

Published: 20 May 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.

ACCIDENT

Aircraft Type and Registration: Cirrus SR 22, N8163P

No & Type of Engines: 1 Continental IO-360 SER piston engine

Year of Manufacture: 2004 (Serial no: 1391)

Date & Time (UTC): 31 July 2020 at 1203 hrs

Location: Cotswold (Kemble) Airport, Gloucestershire

Type of Flight: Private

Persons on Board: Crew - 1 Passengers - 2

Injuries: Crew - None Passengers - None

Nature of Damage: Damage to landing gear, propeller and left wing on N8163P and damage to the right wing on a parked aircraft

Commander's Licence: Private Pilot's Licence

Commander's Age: 67 years

Commander's Flying Experience: 698 hours (of which 199 were on type)
Last 90 days - 5 hours
Last 28 days - 1 hour

Information Source: Aircraft Accident Report Form submitted by the pilot and enquiries by the AAIB

Synopsis

N8163P was about to touch down at Cotswold (Kemble) Airport when the left wing dropped and touched the runway. The pilot attempted a go-around, but the aircraft landed to the side of the runway and travelled across the grass before colliding with a parked aircraft. No injuries were sustained, but both aircraft were substantially damaged.

The loss of control occurred when the pilot delayed touching down because the aircraft landing ahead had not vacated the runway as he expected. Early decision making on initiating the go-around and aircraft handling at slow speed were identified as factors in this accident.

History of the flight

The pilot departed Solent Airport with two passengers for a flight to Cotswold (Kemble) Airport and first contacted Kemble Information en-route to request joining information and PPR[1] (Prior Permission Required). While downwind for Runway 08 he was informed that he was number two in the circuit with one landing ahead.

Footnote

[1] The Air Information Publication, Part 3, and Pooleys Flight Guide (2020) both state that the aerodrome is "*Strictly PPR by telephone*".

The pilot reported that the weather was good with a moderate crosswind and the approach was stable. His last observed airspeed was 78 kt with the intention of touching down at approximately 75 kt He was visual with the landing aircraft and planned his touchdown assuming the aircraft ahead would vacate the runway at the intersection adjacent to A3 (Figure 1). On reporting “final to land’”, the Flight Information Service Officer (FISO) advised that the runway was occupied by an aircraft that was vacating the runway. However, it did not leave at A3, but carried on taxiing until it reached the end of the runway and vacated at A1. The pilot reported that he had to hold off the landing until he was given permission to “land at his discretion” as he crossed the threshold.

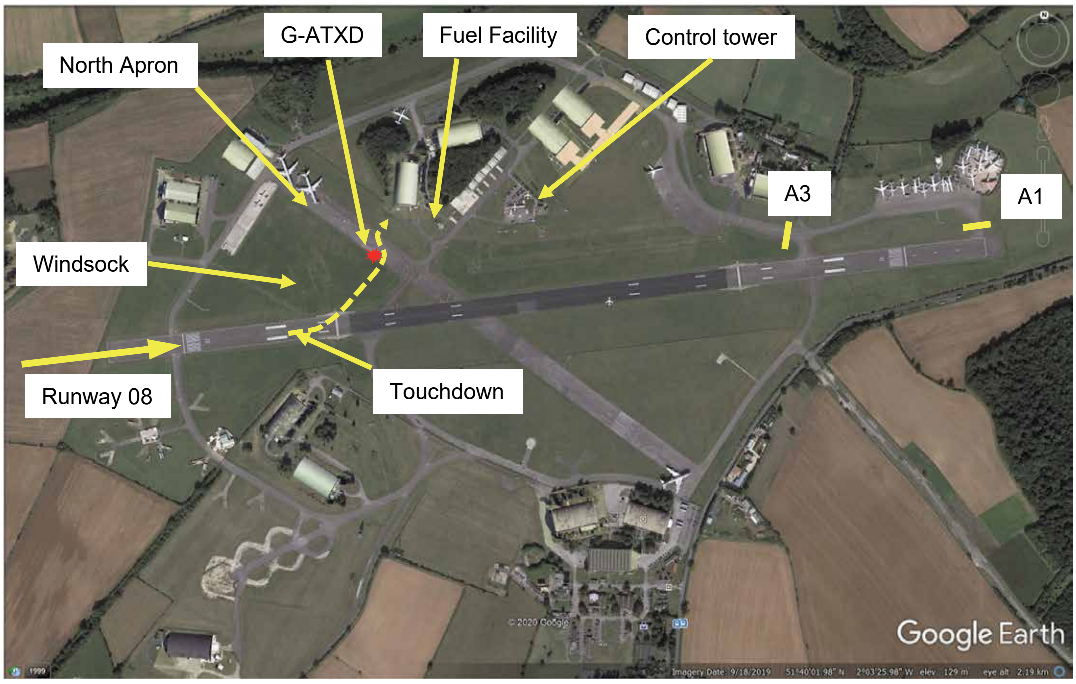

Figure 1

Cotswold (Kemble) Airport and track of N8163P

N8163P was still airborne when it reached the first touchdown zone markings. The left wing was then seen to drop and contact the runway. The aircraft touched down on the grass and travelled along the ground at an angle of approximately 45° to the left of the runway heading until it reached the North Apron where it collided with a parked Piper PA-30 aircraft, G-ATXD (Figure 2).

Figure 2

Track of N8163P

During the collision, the left wing of N8163P struck the right wing of G-ATXD causing N8163P to slew to the left and travel sideways across the apron. N8163P finally came to rest on the grass between the apron and the fuel facility. All the occupants were helped to safety by the AFRS, who were quickly on the scene.

The pilot reported that he assumed the aircraft abruptly veered to the left and departed the runway due to a gust of wind. He did not recall hearing the stall warner operate. He reported that he attempted a go-around while he was on the grass but thought the high air temperature meant he did not get the lift he was expecting.

Aircraft damage

Both aircraft were badly damaged:

G-ATXD

The aileron and lower surface of the right wing were severely damaged. There was also a substantial fuel leak.

Figure 3
Damage sustained to Piper PA-30, G-ATXD

N8163P

There was abrasion damage to the left-wing tip consistent with it having contacted a hard surface and scratches that were most likely caused by the torn metal on the right wing of G-ATXD. Damage to the propeller blades was consistent with them striking soft ground or stones. The right main landing gear had broken off from the mounting structure and punctured a hole in the top skin of the wing. The right main wheel had detached and abrasions on the tyre were consistent with it being abraded as the aircraft slid sideways across the apron. The nose landing gear was twisted but remained attached.

Figure 4

Damage sustained to Cirrus SR22, N8163P

Meteorology

The weather reported by the airport was CAVOK, temperature 29°C, with the wind from 080° at 14 kt. Analysis of a Closed Circuit Television (CCTV) recording of the movement of the windsock, sited between the touchdown markers and the apron, showed the instantaneous wind to be approximately 160° and 15 kt when the aircraft crossed the threshold (Figure 5). While there was some movement of the windsock, there was no visual evidence of gusts.

Closed Circuit Television

From a CCTV recording, the attitude of N8163P appeared normal as it crossed the threshold when it then appeared to fly parallel with the runway. As it reached the first set of touchdown markers the left wing dropped and contacted the edge of the runway before the aircraft settled on its landing gear on the grass (Figure 5). The aircraft continued to travel across the grass on a heading approximately 45° to the left of the runway heading.

When the aircraft was several metres from the runway, the effect of the propeller wash could be seen on the grass and the aircraft appeared to have a slightly nose high attitude. The speed and attitude of the aircraft was constant, and the effect of the propwash on the grass was visible until the aircraft collided with G-ATXD.

Figure 5

Still from CCTV footage of N8163P as the left wing dropped

Analysis

The loss of control occurred as the pilot delayed touching down until the aircraft ahead cleared the runway.

The pilot had conducted several maintenance flights during the first public health restrictions and three local flights after they had been lifted in July 2020. All the flights were flown from Solent Airport. While the pilot was familiar with Cotswold Airport, having flown there many times before, he reported that he had not practiced crosswind landings for “some time”.

The pilot reported that the approach was stable. The windsock close to the threshold showed that there was a relatively steady crosswind of around 15 kt, which was within the aircraft’s crosswind limit of 21 kt. It is, therefore, unlikely that the wing drop occurred because of a gusting crosswind.

As the pilot checked the rate of descent to delay touching down, it is likely that it was the handling of the aircraft at low speed, while countering the effects of the crosswind, that resulted in the loss of control. The CCTV recording and abrasions to the wing tip show that the left wing struck the runway before the aircraft touched down on the grass. It is possible that the damage to the propeller occurred at this time, but it more likely occurred after the left main landing gear collapsed.

The pilot reported that his actions in attempting a go-around following the loss of control were instinctive. However, with an air temperature of 29°C, and a tailwind, the aircraft may not have had sufficient performance to become safely airborne before reaching surrounding obstacles. The collision with the unoccupied parked aircraft occurred at high speed and caused substantial damage to both aircraft.

Comment

This accident highlights the importance of making an early decision to go-around and to allow sufficient time for aircraft landing ahead to clear the runway. On this occasion clearance to land at ‘the pilot’s discretion’ was not given until the aircraft reached the threshold. Following the loss of control, the wing tip struck the ground and the pilot would not have known the extent of the damage to the aircraft; therefore, it would have been a safer option to stay on the ground.

Continuing the go-around while the aircraft was on the ground and pointing towards a parking area, hangar and fuel facility increased the risk to third parties. Slowing the aircraft would have given the pilot and third parties more time to respond.

ACCIDENT

Aircraft Type and Registration:	Rotorway Executive 90, G-BVTV
No & Type of Engines:	1 Rotorway RI 162 piston engine
Year of Manufacture:	1995 (Serial no: 5243/6599)
Date & Time (UTC):	4 November 2020 at 1030 hrs
Location:	Landmead Farm Airfield, Oxfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Main rotor blades destroyed and rotor mast bent; damage to the fuselage and landing gear
Commander's Licence:	Private Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	1,674 hours (of which 142 were on type) Last 90 days - 28 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Following some manoeuvres in the low hover, the pilot intended to join the circuit but elected to land briefly in order to adjust his headset. As the helicopter touched down it continued to roll to the left, damaging the rotor blades and coming to rest on its left side. The pilot was able to self-evacuate from the helicopter with minor injuries.

History of the flight

The pilot prepared the helicopter for flight with the intention of conducting some circuits. The weather was good, with a light and variable wind from the west. After lifting into the hover, he checked the temperatures and pressures were acceptable, and then hover taxied across the airfield. En route the pilot performed some practice manoeuvres in the low hover. He then taxied to the south side of the airfield with the intention of joining the circuit, but decided to adjust his headset prior to departure. The pilot touched down on flat ground, but reported that the helicopter felt as though it was touching down on sloping ground, and it continued to roll over to the left. The pilot was unable to counter this before the rotor blades touched the ground and the helicopter came to rest on its left side.

The pilot was able to exit the aircraft without assistance and suffered only minor injuries. There were no witnesses to the accident.

Accident site

The pilot provided a sketch of the crash site relative to the departure point, shown in Figure 1.

Figure 1

Flightpath and crash site location sketch provided by the pilot

The photograph of the helicopter after the accident shown in Figure 2 was also provided by the pilot.

Figure 2

Image of the helicopter post-accident

Aircraft information

The pilot reported that the helicopter had been involved in a run-on landing following an engine off, forced landing two weeks prior to the accident. He highlighted the possibility that the landing gear may have been compromised during this event. However, the maintenance provider who inspected the helicopter following this incident reported that there was no evidence of any damage.

Aircraft examination

The aircraft was recovered to a maintenance facility after the accident but was considered an insurance loss, so detailed examination of the airframe was not carried out. The main damage to the helicopter can be seen in Figure 2. The left skid was distorted and had fractured. The rear landing gear leg on the left side was also completely fractured close to the mounting point with the fuselage. The maintenance provider inspected the fracture surface of the leg tube and advised that there was no evidence to suggest that the fracture had progressed over a period of time, rather than being an immediate overload failure.

Conclusion

The sketch provided by the pilot and the damage to the helicopter were both consistent with a dynamic rollover having occurred. This was likely to have been initiated by the rear tip of the left landing gear skid catching the ground, while there was still sideways motion of the helicopter to the left. Based on the limited evidence available, it was considered unlikely that there was pre-existing damage to the landing gear leg which had contributed to this.

ACCIDENT

Aircraft Type and Registration:	EV-97 TeamEurostar UK, G-CIKT
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2014 (Serial no: 2014-1000)
Date & Time (UTC):	8 August 2020 at 1600 hrs
Location:	Peterborough/Conington Airport, Cambridgeshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Wing leading edges damaged
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	461 hours (of which 319 were on type) Last 90 days - 10 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

A student was undertaking a conversion lesson onto the EV-97 TeamEurostar. The wind was 17 kt from 050° with "strong and sharp" gusts reported. It was agreed during the pre-flight briefing that the instructor would take control on the base leg and land the aircraft.

The instructor reported that as the aircraft was about to touchdown on Runway 010, there was a strong gust of wind and it 'ballooned' before landing heavily. The aircraft bounced and drifted to the right as the instructor initiated a go-around. However, the aircraft touched down in long grass and continued its motion until it struck a fence.

The instructor believed that nearby trees affected the strong wind causing it to be gusty. The crosswind component, as the aircraft touched down, was near the aircraft's maximum operational limit of 16 kt.

ACCIDENT

Aircraft Type and Registration:	DJI Mavic Pro 2	
No & Type of Engines:	4 electrical motors	
Year of Manufacture:	2018 (Serial no: 163DFAF0019QP1)	
Date & Time (UTC):	19 August 2020 at 1033 hrs	
Location:	Seal Sands, Middlesborough	
Type of Flight:	Commercial Operations (UAS)	
Persons on Board:	Crew - N/A	Passengers - N/A
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Damage to landing gear, motor arm and propellers	
Commander's Licence:	Other	
Commander's Age:	56 years	
Commander's Flying Experience:	131 hours (of which 131 were on type) Last 90 days - 18 hours Last 28 days - 13 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The DJI Mavic Pro 2 unmanned aircraft (UA) was being used to carry out some aerial filming at a construction site. The aircraft was being operated by a remote pilot (RP) who was supported by an observer. At the time of the accident the RP was completing a tracking shot around personnel working on the site. Prior to this sequence of filming he had been recording in Full Point of View (FPOV) mode but to record the personnel working on the site he had changed to a High Quality (HQ) mode. Changing from FPOV to HQ video reduced the angle of view from 77° to 55° and therefore the aircraft needed to fly further away from the subject to capture a similar view. As the tracking shot was being flown the observer communicated to the RP that the UA was being flown close to a tower adjacent to the construction site. Based on the view that the RP had on the controller monitor, he determined that the UA was between the tower and the steel structure he was taking footage of, but had not accounted for the adjustment he had made for taking the HQ video footage. This positioned the aircraft further away from the subject than it appeared. The RP continued to complete the tracking manoeuvre during which the aircraft collided with the tower causing the UA to fall to a gantry platform approximately 20 m below. There were no injuries.

As a result of this accident the operator has introduced measures to help prevent reoccurrences. This includes using propeller guards when operating in areas with possible obstructions and when flying with avoidance sensors switched off. The operator has also introduced a requirement that all RPs create a virtual fence[1] for each flying site within which the UA can operate safely.

AAIB Comment

This accident exemplifies the need to maintain full situational awareness throughout any flight. In this instance the observer had communicated to the RP that there was a possibility of collision with an object, but the RP disregarded this information because it did not conform to his mental model of the situation.

Footnote

[1] An artificial boundary, using GPS coordinates, defined by the operator or remote pilot within which UA can fly freely. The UAS positioning system will not allow the aircraft to fly outside of this boundary.

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only investigations reviewed March - April 2021

12-Jul-20 **Rans S6-ES** **G-CCTV** Plaistows Airfield, Hertfordshire

Approximately 10 minutes after takeoff for a local flight the pilot noticed smoke in the cockpit. He elected to land in a field after switching the engine and fuel off. The nosewheel and engine cowling were damaged during the field landing.

31-Mar-21 **Mission M108** **G-CJJW** Belle Vue Airfield, Devon

The aircraft landed further along the runway than intended and was unable to stop before overrunning the upwind threshold at low speed. The aircraft suffered some damage due to contact with a hedge.

07-Apr-21 **Beech V35B** **G-BONZ** Meppershall Airfield, Bedfordshire

During an attempted landing, G-BONZ touched down heavily and bounced back into the air. As the aircraft settled back onto the ground its nosewheel collapsed. The aircraft pivoted through 180° before coming to rest, nose-down, just beyond the right edge of the runway. The pilot reflected that, in hindsight, he should have gone around rather than continuing with the steep approach that led to the bounce.

11-Apr-21 **Spitfire Mk 26** **G-CIXM** Popham Airfield, Hampshire

The aircraft suffered an engine failure after takeoff. The aircraft made a heavy landing, which resulted in distortion of one landing gear leg.

18-Apr-21 **DH82A Tiger Moth** **G-ACDI** Teffont Magna, Wiltshire

The aircraft was taxiing and struck a stationary fence with its wing tip causing damage to the wing.

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).

AIRCRAFT ACCIDENT REPORT CORRECTION

AAIB File:	EW/C2019/01/03 (AAIB-25527)
Aircraft Type and Registration:	Piper PA-46-310P, N264DB
Date & Time (UTC):	21 January 2019 at 2016 hrs
Location:	22 nm north-north-west of Guernsey
Information Source:	AAIB Field Investigation

AAIB Aircraft Accident Report 1/2020, page 102 refers

In April 2021, it was noted that Figure B-4, Appendix B, showed an error in the planned progression of the search vessels.

The corrected and the original versions of the figure can be seen below.

Corrected version of Figure B-4:

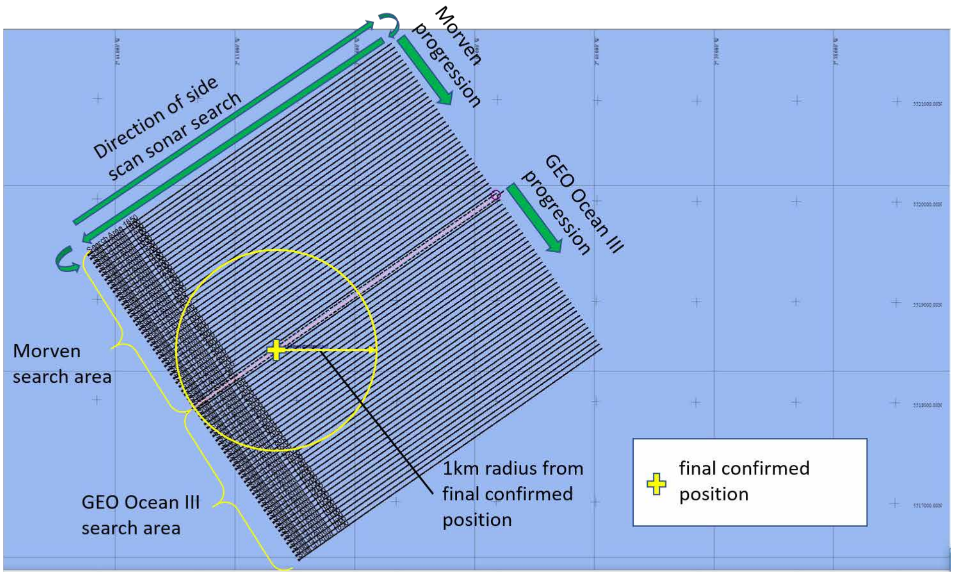

Figure B-4
Seabed search strategy

The original figure can be seen over page.

The online version of the report was corrected on 26 April 2021.

Original version of Figure B-4:

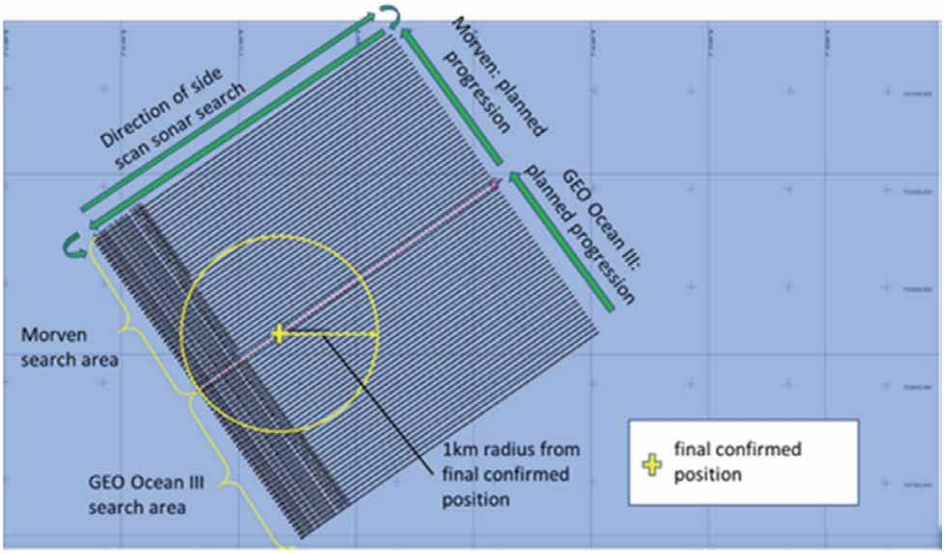

Figure B-4

Seabed search strategy

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

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