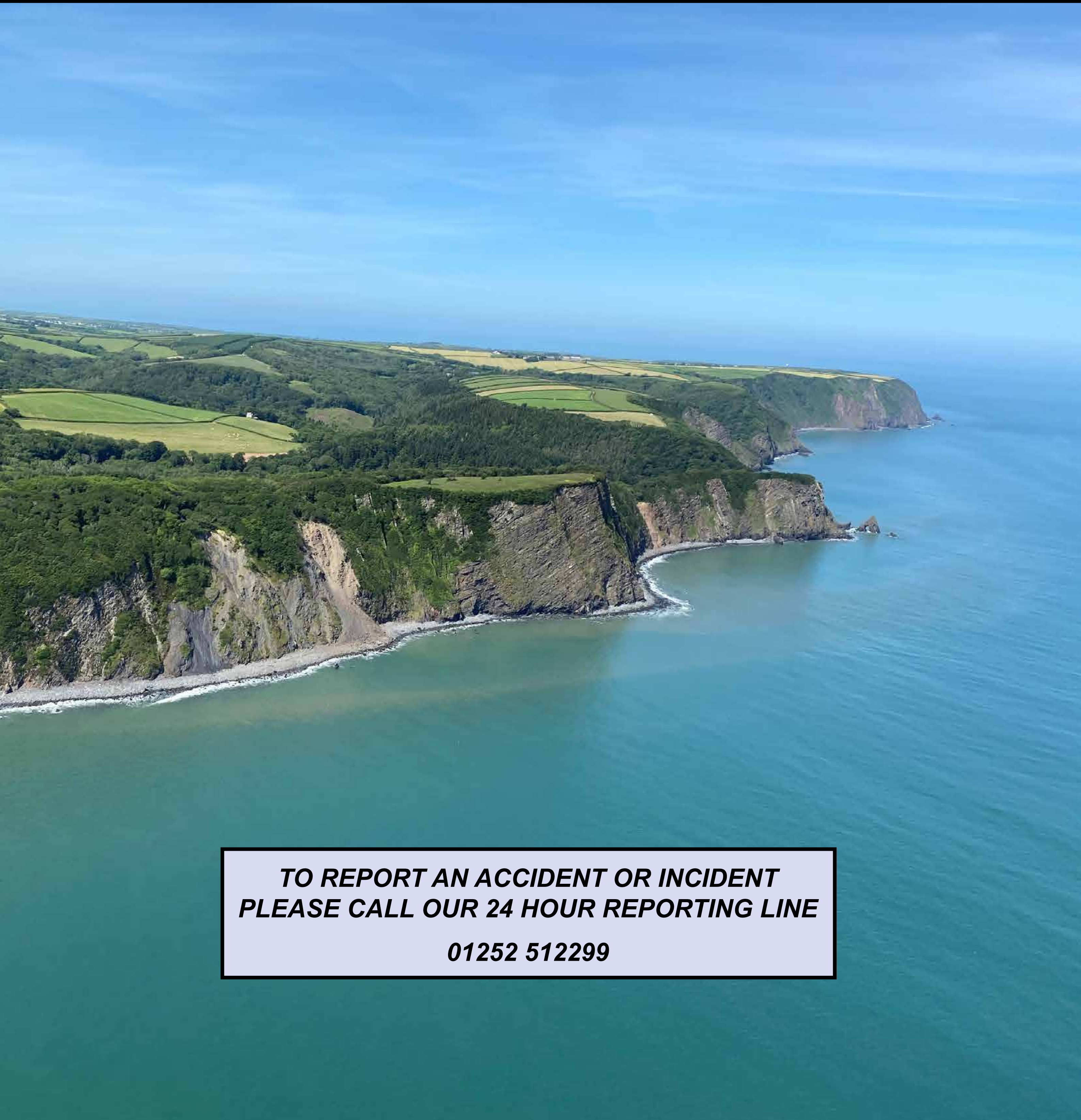
# AAIB Bulletin 8/2022



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This bulletin contains facts which have been determined up to the time of compilation.

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None

**(ALL TIMES IN THIS BULLETIN ARE UTC)**

# AAIB Field Investigation Reports

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

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

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

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | DA 40 NG, G-CTSB |
| **No & Type of Engines:** | 1 Austro E4-A piston engine |
| **Year of Manufacture:** | 2015 (Serial no: 40.N283) |
| **Date & Time (UTC):** | 12 December 2020 at 0926 hrs |
| **Location:** | Cranfield Airport, Bedfordshire |
| **Type of Flight:** | Aerial Work |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - 1 (Serious) Passengers - N/A |
| **Nature of Damage:** | Aircraft destroyed |
| **Commander's Licence:** | Commercial Pilot's Licence |
| **Commander's Age:** | 23 years |
| **Commander's Flying Experience:** | 1,229 hours (of which 779 were on type)<br>Last 90 days - 70 hours<br>Last 28 days - 33 hours |
| **Information Source:** | AAIB Field Investigation |

### Synopsis

The pilot was seriously injured when the aircraft stalled and then struck the ground shortly after takeoff from a height of about 100-200 ft. It had been loaded with five containers of de-icing fluid, contrary to the approved training organisation's prohibition on the carriage of cargo and dangerous goods. One container, loaded in the front right footwell close to the flying controls, limited the control stick's available forward movement.

The aircraft was near its maximum permitted takeoff weight and aft centre of gravity limit when it departed. This, together with the limited control authority available, caused the accident.

The investigation found that aspects of the management of the Approved Training Organisation may have contributed to the accident. The de-icing fluid was probably incorrectly classified by the manufacturer as a non-dangerous good, with incorrect safety information supplied.

One Safety Recommendation is made regarding the use of recording facilities on digital flight instrument systems.

## History of the flight

The pilot was an instructor with a large commercial Approved Training Organisation (ATO). The evening before the accident he had been contacted at home by the Head of Training Delivery asking whether he would complete two student flying progress checks the next day. The checks were due to be carried out at Bournemouth Airport, 90 nm from the pilot's home base at Cranfield Airport. The pilot agreed to do the checks and was given permission to fly from Cranfield to Bournemouth in one of the school's aircraft if the weather was suitable. If not, the plan was for him to drive to Bournemouth from his home, a journey of about three hours.

On the day of the accident the pilot left home at about 0700 hrs and drove to Cranfield Airport, a journey of about one and a half hours. During the journey he made calls on his mobile phone to assess the weather and check that it would be suitable to fly to Bournemouth. Deciding it was, he continued to Cranfield rather than changing direction towards Bournemouth. He was also contacted during the journey by the Head of Training Delivery, asking if he could bring some containers of de-icing fluid to Bournemouth in the aircraft as cargo. The pilot called staff at Cranfield, ahead of his arrival, to ask them to take some containers of fluid to the aircraft in time for him to load them prior to his departure.

Due to the injuries sustained in the accident, the pilot had little, if any, recollection of further events involving the flight. Other sources of information indicate that on his arrival at Cranfield Airport he spent time in the company operations room trying to determine with another instructor the weight of the containers he was planning to carry. He then went to the aircraft and, with the assistance of a member of the operations staff, loaded five 25 litre containers of de-icing fluid into it. One container was placed upright on the empty front right seat and one on each of the two rear seats. Another container was placed upright in the rear left seat footwell. The remaining container was placed upright in the front right footwell.

The operations staff member assisting with the loading reported that the pilot checked that the flight controls, including the rudder pedals, had full and free movement after loading the containers. He stated that the containers in the rear of the aircraft and in the front footwell were not restrained in any way, but could not recall whether the container on the front seat was restrained by the seatbelt.

The pilot was reported to have boarded the aircraft and the operations staff member returned to the hangar. The staff member did not see the pilot doing a daily check or walk-round of the aircraft, which was not visible from the operations room. The technical sheet on which the check should have been recorded has not been found.

At 0920 hrs the pilot was given taxi clearance and was asked by ATC whether he would be departing IFR or VFR. The pilot replied he would be departing IFR towards the Compton VOR, climbing to 4,000 ft, and requested a basic service. At 0925 hrs he was cleared for takeoff from Runway 21.

ATC cameras recorded the aircraft commencing its takeoff run and becoming airborne after about seven seconds. The aircraft's wings were then seen to rock slightly. About five seconds after takeoff the right wing was seen to drop and be recovered, followed immediately by the left wing dropping. The aircraft was by then in a descent from a height of about 100 - 200 ft and continued in a left turn, hitting the ground to the side of the runway, about a third of the way along its length. The entire flight lasted approximately 12 seconds.

An aerodrome fire and rescue vehicle doing a wildlife patrol at the time witnessed the accident and initiated an emergency response before attending the scene. ATC also independently initiated an emergency response at 0927 hrs and an additional aerodrome fire and rescue vehicle was in attendance within one minute. Other off-airport emergency service assets arrived at the scene about 25 minutes later. The pilot was extricated from the aircraft and flown by air ambulance to hospital, having sustained serious injuries.

## Recorded information

The aircraft was fitted with a Garmin G1000 fully integrated flight, engine, communication, navigation and surveillance instrumentation system. This had the facility to allow a significant range of flight and engine data parameters to be recorded onto an SD memory card, if one were installed in the unit. At the time of the accident the operator did not use this capability and there was no memory card inserted in the unit on the accident aircraft.

## Aircraft information

The DA 40 NG is a four-seat, low-wing, single-engine aircraft with a fixed tricycle undercarriage. It is fitted with dual controls and a control column located in a cut-out in the base of each front seat (Figure 1). The rudder pedals have an adjustment mechanism fitted to allow them to slide backwards or forwards along a rail to accommodate different pilot leg lengths. Aircraft trim can be adjusted by either an electronic switch on the flying controls or a trim wheel situated on a console between the front seats.

**Figure 1**

Flight control stick DA 40 NG

Behind the rear seats, but within the cabin, is an area that can be used to carry bags and other similar items. It is provided with a net to secure them during flight.

G-CTSB had recently undergone a 1,000 hour service. This included a flight test the day before the accident, following which no outstanding problems were reported, and the aircraft had been released to service.

## Aircraft examination

Initial examination of the aircraft was carried out by the operator. The AAIB carried out two further examinations of the aircraft to determine whether the de-icing fluid containers had potentially restricted the flying controls during the flight.

The aircraft was severely damaged in the impact, with the left wing and tail breaking off. There was also damage to the cockpit area with three of the de-icing containers having been ejected during the impact. Two containers remained in the aircraft, one in the front right footwell and another trapping the pilot's left arm against the side of the cabin.

Images of the aircraft taken after the accident show the de-icing fluid container positioned in the footwell of the front right seat (Figure 2). Once removed, this container was found to have been punctured on the lower part of its forward face (as found) and on the base adjacent to the forward face damage (Figure 3).

**Figure 2**

Container as found in wreckage (used with permission)

**Figure 3**

Lower forward face of container recovered from footwell of aircraft

These features indicate that the container had been positioned in the footwell in an upright position prior to the accident. The damage is consistent with the container moving forward during the accident, into the seat rudder pedal adjustment rail. This led initially to the forward face of the container being breached, followed by damage to the base of the container as it rode up over the rudder pedal adjustment rail. A scuff mark (Figure 4) was also identified on the top left surface of the container. This indicated that the container moved underneath the instrument panel during the impact sequence, providing additional confirmation that the container was upright during the accident, as the top surface would not have been scuffed if the container was laid either horizontally, or at an angle.

**Figure 4**

Scuff on upper front surface of container

Another container recovered from the accident site was found to have damage consistent with it being positioned on the front right seat. A crease along the front face of the container and damage to the right side of the instrument panel combing suggested that the container was forced against the combing during the impact sequence (Figures 5 and 6).

**Figure 5**

Crease in container

**Figure 6**

Damage to right instrument panel combing

The AAIB inspected another DA 40 aircraft with the same cockpit layout to determine whether, with a container in this position, there would have been any control restrictions. The elevators were placed in their neutral position and the distance from the left control stick to the edge of the instrument panel measured (approximately 188 mm). A further measurement was then made with the control stick moved fully forwards (approximately 126 mm). A surviving undamaged container was then positioned upright in the right footwell and the control stick moved as far forward as possible. This resulted in the base of the stick contacting the container with the stick being approximately 230 mm from the instrument panel. The position of the container was adjusted, placing it at an angle by moving the base into the footwell as far forward as possible until it contacted the rudder pedal adjustment rail. The stick was then moved as far forwards as possible and, again, it contacted the container. The distance between the stick and instrument panel was approximately 172 mm. The results are shown in Figure 7.

Container upright

Container at an angle

**Figure 7**

Control stick position measurements

This demonstrated that with the container in the upright position the control stick could not be moved forward of the control neutral point, and only slightly forward of the neutral point with the container lying at an angle with its base as far forward as possible (Figure 8).

**Figure 8**

De-icing fluid container positioned at an angle with its base in contact with the rudder pedal adjustment rail

The operator reported that in its initial inspection of the aircraft after the accident all cockpit switches were found to have been correctly selected for takeoff. The pilot's rudder pedal position adjusting lever was found to be out of its housing. The trim lever was also found in a slightly nose down position, away from the marked takeoff position. A subsequent examination by the operator of the rudder and elevator controls revealed no anomalies, other than those caused by the accident. It is possible that the position of both the rudder pedal adjusting lever and trim lever were the result of the impact and associated damage to the tail.

When sent by the operator for inspection the propeller governor was found to be fully serviceable. The operator also removed the Engine Control Unit (ECU) and sent it to the engine manufacturer for inspection. It too was found to be serviceable. There were no engine faults recorded in the ECU memory and all recorded parameters appeared normal for the takeoff.

The ECU inspection report summary stated that the engine power lever was advanced to the 100% position and remained there for 20 seconds before being reduced to 17%. This coincided approximately with the right wing-drop. It then remained at 17% for 4 seconds before being advanced again to the 100% position. The report states that '*very shortly thereafter'* the ECU electrical connection was lost as the engine stopped.

### Aircraft documents

The aircraft documents were recovered from the aircraft after the accident, including the technical log which had been damaged. The documents included the Certificate of Airworthiness and Airworthiness Review Certificate, both of which were valid.

There was a record of the 1,000 hour inspection completed on 9 December 2020. This recorded the aircraft hours as 2,986.9 flying hours at the time of the inspection, although the time recorded on the technical log before the inspection was 2,969.5 hours.

The technical log contained sheets titled *'Notes for Crew'*, which had the following wording at the top of each page:

> *'This document replaces the Blue Folder referred to in the Operations Manual. It does not replace the Technical Log pages, but supplements those pages. The main purpose is to provide an historical log of this particular aircraft's unserviceability's* [sic] *and technical observations. If the aircraft's commander determines that the aircraft is unserviceable, then the unserviceability is recorded on the appropriate Technical Log page and is also recorded in these pages. Whilst the demand for a double entry may seem onerous, it does provide pilots with a tool for trend analysis of faults over a period of time. These pages will be retained in the Technical Log. Additionally, observations that the commander considers do not warrant a declaration of unserviceability should be recorded in these pages; observations that may help towards a more complete analysis of a problem. Where an item is recorded as an unserviceability, reference must be made in the appropriate column to indicate the Technical Log page.'*

Three such sheets were recovered from the aircraft after the accident, all of which were full; the first entry being on 16 May 2018 and the last on 7 September 2020. There were several anomalies on the sheets, including items that hadn't been entered into the technical log but which referred to a technical log entry. When checked, these entries did not exist.

All the entries on the first two sheets were recorded as having been cleared. Whilst none of the eight entries on the most recent sheet were recorded as cleared, the relevant technical log pages were missing. Three entries did not include the name of the person entering the details. Some of the entries were of faults that should be entered into the technical log. One such entry recorded a missing screw which allowed the strut cowling to hang down.

The ATO stated that, as the result of an internal review, the technical log had been re-designed, removing the *'Notes for Crew'* pages. The new technical log was introduced on 1 October 2021.

Several of the Acceptable Deferred Defects Record (ADDR) entries in the technical log for G-CTSB between 5 September 2018 and the last on 31 July 2020 were incomplete.

The recording on 13 May 2019 of a fault with the ADF included several subsequent open entries which made the status of the defect unclear. An entry dated 20 November 2019 recorded the ADF as totally unserviceable and an entry dated 31 July 2020 deferred the fault to the next Scheduled Maintenance Inspection (SMI). The fault was not rectified during the aircraft's subsequent 100 hour inspection on 18 August 2020 and remained unrectified until the 1,000 hour inspection on 9 December 2020. The ADDR entry was closed on 12 December 2020, the day of the accident, but the entry in the *'Notes for Crew'* remained open.

A technical log entry for *'fuel leaking from the starboard wing with engine running'* was made on 9 December 2020, immediately after the 1,000 hour inspection. This was investigated but no fault was found and the entry was cleared on 10 December 2020. The aircraft subsequently completed 2.1 flying hours between the 1,000 hour inspection and the accident. No *'Notes for Crew'* log page was found which recorded this fault. It is possible that the sheet was either lost during the accident or not completed.

## Survivability

The cockpit area was badly disrupted during the impact and the pilot hit his head, leading to serious injuries including memory loss. The aerodrome fire service attending the scene reported that the pilot's left arm had been trapped against the side of the aircraft by one of the de-icing fluid containers, which remained full. They reported another container was found in the front footwell in an upright position.

The aerodrome fire service reported they checked the labels on the containers and considered the contents did not present a safety risk based on the information provided. They stated that their response to dangerous goods relied upon identifying the United Nations (UN) number[1] which allowed them to source the relevant information on how to handle the material and any associated risks.

## Weight and balance

Instructors and students were provided with laminated weight and balance charts and were required to complete weight and balance calculations prior to each flight. The pilot reported that several of them, including himself, used software to make these calculations. He stated that the use of such programmes was well known within the company and appeared to be accepted by senior managers; the ATO did not agree with that statement.

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**Footnote**

[1] An internationally recognised numbering system assisting in the classification of dangerous goods. See section *Dangerous goods.*

The pilot stated that, due to his loss of memory, he could not recall calculating the weight and balance of the aircraft on the day of the accident. The weight and balance programme on his phone indicated it had been accessed on the day of the accident.

The pilot reported he had taken a flight bag and kneeboard with him. A 'land away kit' had already been stored in the baggage area within the aircraft, but it is not clear where the pilot's bag was placed. The company used a combined standard weight of 5 kg for the land away equipment carried in the baggage area and a pilot's bag. The pilot of G-CTSB would use a weight of 65 kg for himself on his weight and balance calculator. It is not clear what weight he would have used for the de-icing fluid containers had he made a calculation, but a full container weighed 29.1 kg.

The aircraft technical log and refuelling receipts indicate that the aircraft was refuelled the day before the accident, leaving it with full fuel tanks equivalent to 28 US gallons (89 kg). Taxi fuel used in calculations was 1 US gallon (3.04 kg).

Calculations using weights for the pilot of 65 kg, five full containers of de-icing fluid each weighing 29.1 kg, pilot's bag and land away kit of 5 kg, and fuel of 85.82 kg gave a takeoff weight of 1,249.46 kg. This was 60.54 kg under the maximum takeoff weight of 1,310.0 kg. The aircraft C of G arm using the same figures was 2.526 m aft of the datum (2.53 m limit), 0.004 m within limits (Figures 9 and 10).

| | Weight (kg) | Arm (m) | Moment (kg.m) |
|---|---|---|---|
| **Aircraft basic weight** | 948 | 2.474 | 2345 |
| **Pilot** | 65 | 2.3 | 149.5 |
| **Front passenger** | 58.2 (2 x 29.1 containers) | 2.3 | 133.86 |
| **Rear seat x 2** | 87.3 (3 x 29.1 containers) | 3.25 | 283.735 |
| **Takeoff fuel** | 85.96 | 2.63 | 226.075 |
| **Baggage (standard)** | 5 | 3.65 | 18.25 |
| | | | |
| **Total weight** | 1249.46 | | 3156.420 |
| **Centre of gravity** | 2.526 | | |

**Figure 9**

Aircraft centre of gravity calculation

### Aircraft performance

Using information published by the manufacturer, the aircraft would require 582 m to achieve a screen height of 50 ft in the reported conditions at the time of the accident, at the maximum permissible aircraft takeoff weight of 1,310 kg, and with takeoff flap set. The ground roll at this weight was calculated at 388 m, or just under 22% of the available runway length.

The Aircraft Flight Manual (AFM) gave a rotation speed at the calculated takeoff weight of 67 KIAS. The pilot commented that the DA 40 had a tendency to become airborne when nearing Vr, requiring a forward control input to hold it on the ground and a feeling of 'wheelbarrowing'. On rotation the aircraft's initial climb speed should have been 72 KIAS with a stall speed between 60 - 62 KIAS (Figure 11).

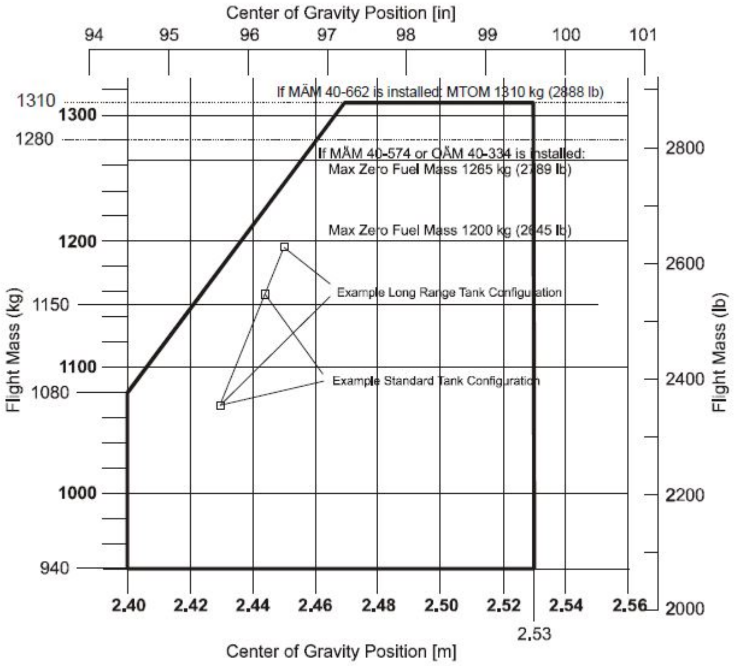
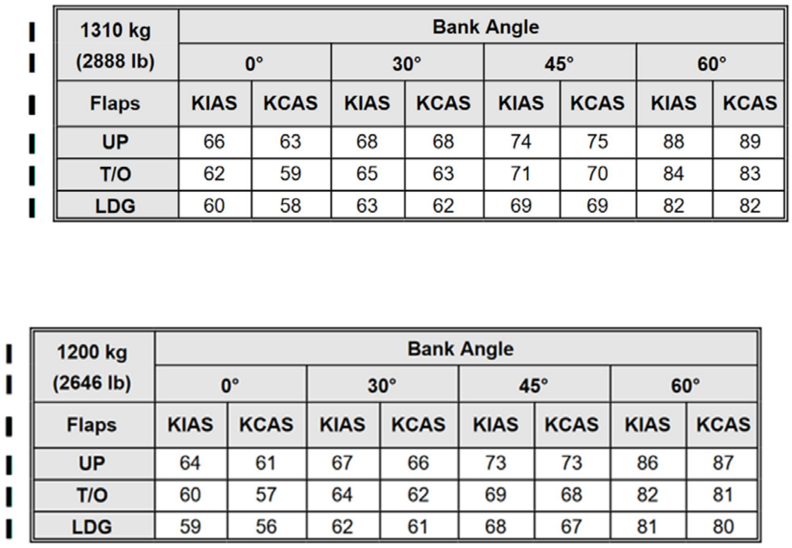


**Figure 10**

Permissible Centre of Gravity Range



| 1310 kg<br>(2888 lb) | Bank Angle | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0° | | 30° | | 45° | | 60° | |
| Flaps | KIAS | KCAS | KIAS | KCAS | KIAS | KCAS | KIAS | KCAS |
| UP | 66 | 63 | 68 | 68 | 74 | 75 | 88 | 89 |
| T/O | 62 | 59 | 65 | 63 | 71 | 70 | 84 | 83 |
| LDG | 60 | 58 | 63 | 62 | 69 | 69 | 82 | 82 |

| 1200 kg<br>(2646 lb) | Bank Angle | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0° | | 30° | | 45° | | 60° | |
| Flaps | KIAS | KCAS | KIAS | KCAS | KIAS | KCAS | KIAS | KCAS |
| UP | 64 | 61 | 67 | 66 | 73 | 73 | 86 | 87 |
| T/O | 60 | 57 | 64 | 62 | 69 | 68 | 82 | 81 |
| LDG | 59 | 56 | 62 | 61 | 68 | 67 | 81 | 80 |

**Figure 11**

DA 40 NG stall speeds

## Meteorology

The route from Cranfield to Bournemouth at the time of the accident was affected by an occluded front, which was predicted to sit over Bournemouth at about 1200 hrs. The low-level forecast published at 0800 hrs predicted widespread broken or overcast cloud conditions during the morning, with a base at between 1,500 and 2,500 ft amsl. The forecast freezing level was between 3,000 and 5,000 ft amsl.

The METAR for Cranfield at the time of departure indicated that there was broken cloud at 700 ft agl in the area of the airfield and a visibility in excess of 10 km. Other METARs showed an improvement in the cloud base along the proposed route towards Bournemouth to above 2,500 ft.

The METAR for Bournemouth covering the planned arrival time indicated few cloud at 1,500 ft and a visibility in excess of 10 km.

The relevant TAFs predicted some temporary improvement in the weather for Cranfield later in the day and an increase in the cloud base at Bournemouth to 2,500 ft from the middle of the day.

The operator permitted the pilot to fly with a minimum cloud base of 600 ft and a minimum visibility of 1,800 m.

## Aerodrome information

Cranfield Airport has a single runway, Runway 03/21. Runway 21 was active at the time of the accident and had a published TODA of 1,799 m.

In December 2018, temporary approval was granted to operate a remote ATC tower: the Cranfield Airport Digital Air Traffic Control Centre (DATCC)[2]. The DATCC was located in a building adjacent to the airport with full operating approval being issued in December 2020. Initially the DATCC was only used part-time but moved to full-time operations in March 2020, due to restrictions imposed by the COVID-19 pandemic. The DATCC provided more space than the conventional tower for the controllers to be separated from one another.

The DATCC used cameras located at the runway mid-point to cover a 360° view of the airfield, which was displayed to controllers on 14 large monitors within the control centre (Figure 12). The introduction of the DATCC had resulted in few operational changes for the controllers, and none concerning the initiation and management of an emergency response. The controllers reported that their view of the runway and taxiway surfaces was better due to the location of the cameras, but it was acknowledged that the image presented could suffer at range due to pixilation. Additionally, weather conditions could not be reliably assessed using the cameras, as there was a tendency for the visibility to look better than it was. Therefore, 'out-of-the-window' meteorological observations were still required.

Current CAA policy on Remote Aerodrome ATS is built on Annex I to EASA Decision 2019/004/R[3]. Chapter 5, paragraph 6 of this document states ICAO philosophy is to record and retain all data used to support the provision of ATS. For Remote Aerodrome ATS, this then extends the recording and retention of data to include elements specific to Remote Aerodrome ATS, including the visual presentation, the binocular functionality and other technical support systems such as aerodrome ambient sound reproduction.

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**Footnote**

[2] In the UK such systems are referred to formally as Remote Aerodrome ATS, and sometimes called digital towers.

[3] Extant EU legislation not currently adopted into UK law.

**Figure 12**
DATCC Cranfield (used with permission)

ICAO specifies[4] that the image presented to the controller is to be recorded and retained to support accident and incident investigation. This includes the processed data presented to, and used by, controllers to support their decision-making, including both the view of the aerodrome and its vicinity. It also includes any overlaid data and information. In addition, the sensor data, ie the original data, may also be recorded to further support accident and incident investigation.

Current CAA policy for the approval of Remote Aerodrome ATS recommends the recording of visual display units (VDU) and aerodrome ambient sounds, but does not mandate it. However, it is mandated where VDUs use the overlay and/or integration of surveillance data.

The CAA commented that in moving towards the mandating of recording, a number of requirements need to be met. These include setting minimum technical standards for visual display systems, such as the quality of the picture, the screen update rate and the fidelity of recording required. The required length of time and storage arrangements for the data also needs to be established. This has yet to be agreed. The existing technical requirements have been established by Eurocae in ED-240A, *'Minimum Aviation System Performance Standards (MASPS) for Remote Tower Optical Systems'*. That ED only describes the technical requirements for optical systems (cameras) being used. Work is underway to produce ED-240B, which will include much of the data required to be able to establish many of the technical requirements, but it may be some time before this is available. The CAA stated that until this and the other technical requirements are published, it is unable to mandate the recording of non-surveillance visual display systems (VDS).

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**Footnote**

[4] ICAO Annex 11, 6.4.1 and Note 1 to ICAO Doc 4444, 7.1.1.2.1.

## Pilot information

Managers, instructors and other staff interviewed during the investigation all described the pilot as an intelligent and enthusiastic individual who was willing to do anything to help. They reported he had a 'can do' attitude and was easy to get on with. The pilot's career in aviation had started in January 2016 when he trained for an ATPL, completing an integrated course in June 2017. He then stopped flying for a year before, in June 2018, undertaking a flying instructor's course with the same school with which he had completed his ATPL training. This school had by then changed ownership and, on completion of the course in August 2018, the pilot began working as an instructor for a subsidiary of the company overseas.

The pilot completed an Instrument Rating Instructor qualification in July 2019 and, in November 2019, transferred to the company's training base at Cranfield Airport as an instructor, being promoted to Deputy Chief Flying Instructor (DCFI) for the base in February 2020. At the time he had approximately 1,000 total flying hours.

The pilot stated that officially he reported to the Chief Flying Instructor (CFI) at Bournemouth. However, he considered that as he generally had more contact with the Head of Training Delivery in managing the day-to-day flying programme, the Head of Training Delivery was effectively his line-manager.

The pilot's training records showed he had undertaken ground training, including stalling, on 24 August 2020. He had also completed a Class Rating Instructor's course in September 2020 for the DA 42. The course included stalling and the course assessment of competence recorded that the exercises were completed to a good standard.

The pilot stated he had received training in dangerous goods as part of his original ATPL qualification. He was aware of the basic markings that dangerous goods carried and, based on the markings on the containers of de-icing fluid, had not considered they constituted dangerous goods. The pilot said he was not aware of the Operations Manual prohibition on carrying dangerous goods or the restriction on carrying cargo. He also stated that had he considered the de-icing fluid may have constituted dangerous goods, he would have sought confirmation on whether he was permitted to transport it.

The pilot recalled on a previous occasion, in either January or February 2020, being given containers of de-icing fluid to transport from Bournemouth to Cranfield by air. He remembered several containers of fluid had already been loaded into the aircraft cabin when he boarded, and that the handles had been tied together with rope.

## Organisational information

The ATO was operated by a company providing commercial pilot training through several bases in different countries. At the time of the accident the company operated two flight training bases in the UK, the main one at Bournemouth with an additional base at Cranfield.

The Cranfield base had started operations in July 2019, largely in response to a need to provide extra capacity for the training taking place at Bournemouth. It originally operated a mixed fleet of DA 42 twin-engine and DA 40 NG single-engine aircraft, but in February 2020 the DA 42s were relocated to Bournemouth.

There had been several changes of management posts within the company in the UK in the months preceding the accident.

Flying operations at Bournemouth were overseen by a CFI who had been promoted in early Spring 2020 from his position as DCFI of the DA 42 fleet. His position as DCFI had not been filled at the time of the accident and he was effectively still running the DA 42 training whilst overseeing the rest of the flying operation as CFI. There was also a DCFI at Bournemouth in charge of the DA 40 operation.

The company considered Cranfield was a satellite base to Bournemouth and so had not appointed a CFI, relying instead on a DCFI to run the operation there under the CFI at Bournemouth. In addition, there had been no DCFI in post at Cranfield until three months after the base had opened, the base being run in the interim by managers based at Bournemouth. The first DCFI at Cranfield left the company after two months in post, leaving it vacant again until the appointment in February 2020 of the pilot involved in the accident.

The company stated that the CFI's focus was largely on the bigger operation at Bournemouth Airport, where he was based, rather than operations at Cranfield. This had been influenced by travel restrictions imposed by the COVID-19 pandemic. The company reported an average of 94 students at Bournemouth around the time of the accident, compared with 18 at Cranfield.

The company structure at the time of the accident included a Global Head of Training and a Global CFI. These positions had responsibility for the flying operations being conducted by company bases in the UK, Portugal and New Zealand. Both lived in the UK, living closer to Cranfield than Bournemouth, and each spent time at the Cranfield base using the offices there and occasionally carrying out some training flights. The company considered this added a degree of oversight to the operation at Cranfield in the absence of a CFI based at the location.

The flying programme at both Bournemouth and Cranfield was overseen by the Head of Training Delivery, based at Bournemouth, who had been in post from July 2019. He had previous aviation experience and was familiar with areas of the Operations Manual on which he relied, such as flight time limitations. He was not aware of the prohibition on carrying cargo or dangerous goods and believed that on occasion items had been moved between Bournemouth and Cranfield by air, including aircraft spares and paper for office use.

At the time of the accident there were four members of staff covering ground operations at Cranfield, overseen by a manager based at Bournemouth. There was a basic written operations guide for each base, but these did not contain guidance on carrying cargo or dangerous goods. As operations staff were not required to read the operations manual, they might not have known of the prohibition on carrying cargo or dangerous goods.

After the accident the Global CFI was appointed to oversee the Cranfield base. This manager subsequently left the company and a management re-structure in November 2021 resulted in the Cranfield base once again being managed by a DCFI, the position being filled on an interim basis.

## Other information

### *Stalling*

The operator provided briefing information on identifying the stall and incipient stall, as well as the various recovery techniques required.

This information described the symptoms of the incipient stall as:

- High nose
- Low IAS
- Sloppy controls
- Stall warning horn
- Light buffet

It also described the standard stall recovery which, it highlighted, in the circuit was to be commenced at the first sign of a stall.

STANDARD STALL RECOVERY (SSR)

- Control column centrally forwards
- Full power – balance
- Symptoms/Warnings gone hold attitude
- Level wings
- Smoothly select the Vy climb attitude

It noted that there should be very little loss of height in conducting the recovery.

### *Dangerous goods*

Dangerous goods are defined by ICAO as *'articles or substances which are capable of posing a risk to health, safety, property or the environment'*[5] and their carriage by air is subject to specific rules and restrictions.

The International Air Transport Association publishes its Dangerous Goods Regulations annually, classifying dangerous goods by name, UN number, class and packing instructions. The UN number is a four-digit number assigned to each hazardous material by the United Nations Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals. It is used to identify a hazardous article or substance, or a particular group of hazardous articles or substances.

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**Footnote**

[5] Annex 18 - The Safe Transport of Dangerous Goods by Air 4th Edition, ICAO, 2011.

Dangerous goods must be properly packaged and clearly labelled with the UN number, classification and shipper's details[6]. Personnel working with dangerous goods must be trained to do so and operators can only transport dangerous goods with regulatory approval. Responsibility for the contents, packing and labelling lies with the shipper.

*Operator documents and manuals*

The ATO made documents including an Operations Manual available electronically, with pilots required each month to confirm they had read and understood the contents. Its documents policy stated: '*Effective document control is essential in order to maintain a consistent level of standards and practices across the ATO'*.

The Operations Manual contained information on the ATO operating bases in the UK, Portugal and New Zealand, but did not mention the Cranfield base. The company stated that relevant documents specific to Cranfield had been published separately. Some elements of the manual were out of date and the organisation commented that it was not user-friendly and was difficult to interpret.

**Part B, Section 2.25 of the Operations Manual stated:**

> *'2.25 Carriage of Dangerous Goods and/or Cargo*
>
> *Under no circumstances, may* [ATO] *aircraft carry dangerous goods as defined by the rules (Part CAT, NCO UK ANO, NZ CAR).*
>
> *Cargo carried is limited to aircraft equipment and to personal baggage such as a flight case or overnight bag. Any cargo carried is to be secured so that it cannot present a hazard to the safe conduct of the flight. Cargo carried is to be limited to a minimum practical amount and must be included in the mass and balance calculation.'*

After the accident the operator published Safety Notice 01/2021, dated 22 December 2020. This stressed the importance of being conversant with the contents of the Operations Manual. It also repeated the entry on the carriage of cargo and dangerous goods and stated that de-icing fluid was defined as dangerous goods.

A revision to Safety Notice 01/2021 was published later, stating that it superseded the original version. It contained new information regarding the carriage of cargo and dangerous goods to be added to the Operations Manual and information on the carriage of life rafts and ballast. The reference in the original safety notice to de-icing fluid being considered dangerous goods had been removed.

Although it was a revision, the safety notice had the same title and date of issue as the original version. The operator commented that the original notice had only recently been published and that there would be no confusion caused by the addition of information on the carriage of life rafts and ballast.

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**Footnote**

[6] ICAO Annex 18 The Safe Transport of Dangerous Goods by Air, 4th Ed.

*Pilot roster*

The pilot usually worked from Monday to Friday, taking two days off over the weekend. On the week of the accident he had worked from Monday to Wednesday. This included, on the Wednesday, an instructional flight at Cranfield followed by a flight to Bournemouth to conduct two progress tests there, before then flying back to Cranfield.

The pilot had then taken two days leave on Thursday and Friday and was due to have two rostered days off over the weekend. On the Thursday he received a private aerobatics lesson but reported he had otherwise rested for the two days of leave. On the Friday evening he received the call asking whether he could undertake the flight tests at Bournemouth the following day.

When interviewed, the pilot stated he did not consider himself fatigued and, had he done so, would have declined the request to work on the Saturday.

*Aircraft de-icing*

Both the DA 40 NG and DA 42 could be de-iced on the ground using de-icing fluids specified in the relevant Aircraft Manual. This included two branded fluids and AL-5 / DTD406B fluid from any source. AL-5 / DTD406B fluid was also suitable to be used in the DA 42 in-flight de-icing system, being carried in a small tank on the aircraft for this purpose.

The operator used ground de-icing units at Bournemouth which allowed the fluid to be sprayed over an aircraft to remove any frost or ice which may have formed whilst parked.

Cranfield Airport prohibited the use of de-icing fluid for environmental reasons.

Early in 2020 several containers of de-icing fluid had been sent to Cranfield, where they were stored in the flying school's storeroom, inside the building housing the company office. This had been intended for use in the DA 42 aircraft based there. Once these aircraft had relocated from Cranfield the remaining containers were left in the storeroom, with six containers still there at the time of the accident.

During the week before the accident there had been a problem with the de-icing units at Bournemouth which had led to delays in the flying programme. The Head of Training Delivery, whilst not responsible for this aspect of the operation, had checked with the duty operations staff on the day of the accident whether the problem had been resolved. During the conversation, he had been informed that there were only sufficient stocks of de-icing fluid remaining at Bournemouth to allow about two days of further operations. He was also informed that there were still stocks of the fluid remaining at Cranfield, something he was not aware of. Accordingly, the Head of Training Delivery contacted the pilot of G-CTSB to ask him to bring some of the de-icing fluid with him that morning. As this had been at a weekend, the Head of Training Delivery was on a day off at home when he organised this.

*De-icing fluid*

DTD406b was one of many UK military standards belonging to the Directorate of Technical Development, giving rise to the prefix DTD. All DTD standards became officially obsolete in 1999 although DTD406b is still commonly used as a product standard and name in the aviation industry.

The operator had purchased twenty-four 25 litre containers of Marcon DTD406b de-icing fluid early in 2020, for use both for de-icing aircraft before flight and in the DA 42 in-flight de-icing system. The fluid was purchased direct from a company in Slovakia.

Each container (Figure 13) had a label affixed (Figure 14). The label stated the contents as DTD406b de-icing fluid consisting of 85% ethylene glycol (ethanediol), 5% ethanol or isopropanol, and 10% distilled water. It did not carry a UN number, but did carry markings and wording identifying that gas, mist and vapours should not be inhaled, nor the fluid ingested. It also provided a web address for safety data which, when tried, did not exist.

**Figure 13**
25 litre container as carried in G-CTSB

The operator held a safety data sheet (SDS) for the de-icing fluid, which referred to it as a combustible liquid and gave a packing number, but no UN number.

The AFM contained the following:

> *'WARNING*
>
> *The approved de-icing fluids are harmful. They are Glycol based with different additives. Refer to the Material Safety Data Sheets for proper handling which are available from the supplier of the de-icing fluid.'*

Marcon International s.r.o.

Produced in the EU for
Marcon International s.r.o.,
Bieloruska 10, 82106 Bratislava,
Company Registration 35812311

DTD406b

For use in aircraft de-icing systems

Use where fluid to specification DTD406b is approved in the aircraft flight manual and in accordance with the procedures in that manual and/ or the aircraft maintenance manual.

Comprised of: ethylene glycol (ethanediol) 85%, ethanol or isopropanol 5%, distilled water 10%

100% Biodegradable.
Dispose of empty container in accordance with local and national regulations.

FOR SAFETY DATA VISIT
www.deanticing.com/DTD406b

Harmful if swallowed. If swallowed, seek medical advice immediately and show this container or label.

Do not breathe gas/mist/vapours.
Do not eat, drink or smoke when using this product.

25L Plněno: 12/2020

**Figure 14**

Label affixed to each container of de-icing fluid

In the original version of Safety Notice 01/2021, dated 22 December 2020 the de-icing fluid was considered dangerous goods. This statement did not appear in the revised version of the notice published shortly afterwards. The operator's report into the accident stated that the de-icing fluid being carried in the aircraft was not classified as dangerous goods.

The information available on the label and SDS was insufficient to enable the CAA to determine whether the de-icing fluid constituted dangerous goods. It considered the information to be incomplete in some areas but stated that the presence of isopropanol would normally classify it as dangerous.

Another established manufacturer of de-icing fluid, when shown the safety data sheet and container labels, commented that it would be unacceptable to list the contents as containing '*either ethanol or isopropanol*' as only actual constituents should be listed. It also commented that *'Plneno 12/2020'*, which appeared on the container labels, suggested the containers were filled in December 2020, although in fact they were purchased some months before.

The AAIB commissioned an independent evaluation of the Marcon DTD406b de-icing fluid, the labelling of the containers and the SDS provided.

The evaluation found the following inconsistencies in the hazard information and labelling.

- The SDS did not identify the de-icing fluid as a flammable liquid constituting dangerous goods for transport or storage. It found, by looking at SDS documentation for three similar de-icing mixtures, all of which are designated as being flammable, that there were grounds to question the classification of Marcon DTD406b.

- The flashpoint of Marcon DTD406b was stated in the SDS as being in excess of 110°C. Flashpoint is used as a primary indicator in the classification of flammable liquids, with only those with flashpoints below 60°C considered flammable. Given the much lower flashpoints (ca 54°C) for similar de-icing formulations, the stated value appears inconsistent. It was also noted that as Marcon DTD406b formulation may contain either ethanol or propanol-2-ol, it would be expected that the flashpoint would vary between batches depending on which is used.
- Additional documentary evidence showed that dilute (2-5% by volume) solutions of propanol-2-ol in water give rise to flashpoints in the region of 50-65°C, further indicating that the Marcon DTD406b had been incorrectly classified.

The report pointed to Health and Safety Executive (HSE) publication HSG51 *'Storage of Flammable Liquids in Containers'* for guidance. The report also highlighted that even if the de-icing fluid was not considered flammable, it was combustible and, being in plastic containers, would serve to contribute to and spread a fire. As such it suggested the current storage arrangements described required improvement.

In conclusion the report found that, in line with similar de-icing products, Marcon DTD406b should be classified as a flammable liquid and thus be regarded as dangerous goods for the purposes of both transport and storage.

Attempts to contact the manufacturer in Slovakia revealed that Marcon International no longer existed.

### ATO internal investigation

The ATO carried out its own investigation after the accident.

Regarding a test carried out with an identical container placed in the front footwell of another DA 40 NG aircraft, it stated:

> *'The investigator did a full and free check of the controls with the container as placed in the footwell. Although he could get full and free movement, it did come up against the lid of the container in the full forward stick position (down elevator). In the investigator's opinion it would not have prevented the pilot from applying enough forward stick to un-stall the aircraft.'*

The report concluded that the accident was probably due to the aft position of the centre of gravity, causing a marked nose-up pitch on takeoff which was then incorrectly handled by the pilot.

The report made several recommendations and stated that safety actions had already begun. These included a review of induction training for operations staff, the introduction of a human factors training programme for all operational staff, and the training and qualification of management personnel. It also included the analysis of an automated tool to calculate mass and balance, and considered additional resources to accelerate an update of the Operations Manual.

### CAA inspection

The CAA first conducted an inspection of the operator's Cranfield base on 18 March 2019, prior to it becoming operational. The CAA conducted a further inspection on 18 June 2019, after it opened. Neither inspection raised any major issues.

As part of the AAIB's investigation, the CAA noted the addition of eight training organisations to the ATO over the two years before the accident and continuous management changes across the organisation. On 18 December 2019 the CAA placed the ATO under 'Special Attention' status due to delays in student training and to a lack of resources available for the number of students taken on. This was resolved by 21 July 2021.

An unannounced inspection on 10 March 2020 at Cranfield and a further unannounced inspection at Bournemouth on 7 August 2020 each resulted in three Level 2 findings[7]. These were resolved by 10 June 2020 and 12 October respectively.

The CAA carried out a review of information provided as a result of the accident involving G-CTSB and the initial investigation by the ATO. This resulted in three more Level 2 findings being made on 4 February 2021, related to the carriage of unrestrained dangerous cargo and the effectiveness of management.

For the latter three Level 2 findings the CAA set an initial rectification target date of 5 March 2021, later extended to 12 April 2021 and then to 12 May 2021. The three findings remained open awaiting revision of the Operations Manual. This was originally due on 31 August 2021 and was made available to the CAA until 18 November 2021.

The CAA reported it had continued to monitor the situation at the ATO and an unannounced visit was made to the Cranfield base on 25 November 2021. This was followed by a meeting between the CAA and the ATO on 9 December 2021. It was apparent that the COVID-19 pandemic had resulted in a significant reduction in the demand for training, leading to a further rationalisation of the organisational structure. At both the visit and the meeting the ATO satisfied the CAA that sufficient measures had been put in place to address the three findings of 4 February 2021. The CAA therefore closed these Level 2 findings on 15 December 2021.

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**Footnote**

[7] A Level 2 finding is issued by the CAA when any non-compliance is detected with the applicable requirements of Regulation (EC) No 216/2008 and its Implementing Rules, with the organisation's procedures and manuals or with the terms of an approval or certificate which could lower safety or hazard flight safety.

## Analysis

### *Direct cause*

Neither the ATO nor AAIB investigations identified a technical fault with the aircraft that may have caused or contributed to the accident. The aircraft had recently emerged from maintenance and had completed a successful test flight on the day before the accident. Whilst a fuel leak had been identified, this is reported to have been resolved and, on its own, should not have resulted in the accident.

The takeoff run available was more than sufficient for the aircraft weight and prevailing conditions. The aircraft was within both its maximum takeoff weight and centre of gravity limits, although it was close to both. Whilst near these limits, the pilot should have had sufficient skill and experience to operate the aircraft under such conditions if it were capable of being operated normally. The position of the centre of gravity would, however, have exaggerated any nose-up tendency of the aircraft after takeoff.

The AAIB investigation found that during the accident flight the de-icing fluid container placed in an upright position in the front right footwell would have caused a significant restriction in the forward movement of the control stick at takeoff. It is possible that the absence of full and free movement was masked, as contact with the container was probably with the base, rather than the top, of the control stick. This might have given the impression that the stick had reached its natural full forward position, unrestricted by the container.

Whilst the speed of the aircraft at rotation was not determined, based on the pilot's comments it is possible that without adequate control input the aircraft would have become airborne at a speed below the correct rotation speed. The restricted forward movement of the control stick would have made a corrective nose-down pitch input difficult or impossible. This is consistent with the incipient stall indicated by the wing rocking seen on the ATC video.

Whilst the pilot had previously demonstrated his proficiency at stall recovery, the restriction caused by the container would have prevented him reducing the angle of attack to recover. It is possible that the reduction in power recorded on the ECU was a reaction to his inability to otherwise control the high nose-up pitch attitude. Although the wing drop was initially recovered, the wing appears to have remained sufficiently stalled to drop again at the point the pilot appears to have applied power instinctively in a further attempt to recover the situation immediately before impact.

### *Pre-flight preparation*

The pilot used his car journey into Cranfield to check the weather was suitable, and it is not clear how much further pre-flight planning he had done on his arrival at the airport. He was familiar with the route to Bournemouth and had flown it only a few days before the accident. His announced intention to ATC to fly at 4,000 ft would have put the aircraft at an altitude where icing conditions were forecast.

The pilot was not seen to complete the required daily or walk-round checks; equally, the aircraft was not visible from the crew room in the hangar. It is therefore possible that the pilot completed the checks, unseen, in the time between the operations staff member leaving the aircraft and the aircraft being seen to taxi a few minutes later.

Both the Head of Training Delivery and the pilot stated that they had been unaware of the prohibition on carrying cargo and dangerous goods, although it was present in the Operations Manual. They were aware of, or had been involved in, the previous carriage of cargo in a manner that may have suggested to them it was an accepted practice within the company. The information available at the time was insufficient to enable both individuals to determine whether the de-icing fluid constituted dangerous goods. Had relevant information been included in the ground operations guides this might have assisted ground staff to consider whether it was appropriate for the containers to be carried.

It is not clear if or to what extent the pilot carried out a weight and balance check. Calculations made after the accident indicated it was possible to carry five containers in the positions described whilst remaining within the aircraft limits. However, as loaded, they were unsecured and could become a hazard in flight. The presence of the container in the right front footwell ultimately led to the accident.

### *ATO operations*

The pilot had become the manager of the Cranfield base with little relevant experience and the CFI to whom he officially reported was able to provide only limited support. This was partly due to the restrictions presented by the COVID-19 pandemic, but the CFI himself was trying to fulfil a number of roles due to the lack of a replacement in his previous post.

The lack of a separate entry for the Cranfield base in the Operations Manual contrasted with the inclusion of other bases around the world that had no relevance to the UK operation. The ATO itself considered that the Operations Manual was hard to read and out of date. This reduced its value in fulfilling its intended purpose. The standard of the ground operations guides and management of the numbering of the re-published safety notice indicated a lack of rigour in the management of published documents within the ATO.

There was evidence of practices that varied from published procedures, such as the carrying of cargo and the use of privately created, unapproved, software for calculating aircraft weight and balance (it being noted that the operator told the AAIB it did not approve of this).

### *Technical log*

The supplemental *'Notes for crew'* sheet introduced by the ATO within the aircraft documentation was additional to the normal technical log and ADDR requirements. Its stated purpose was to allow an aircraft's fault history to be monitored and to enter technical observations.

The difference between a technical observation and a fault may be subjective and could lead to the sheet being used to avoid grounding an aircraft, in place of an engineer rectifying or deferring a defect formally. Inspection of the technical log indicated incorrect recording or clearing of defects, including where a fault that potentially restricted control movement was entered as an '*acceptable deferred defect*'. In one case a fault deferred until the next SMI was not addressed during the subsequent inspection.

Whilst it is possible the tech sheet for the accident flight was lost because of the accident, it is also possible that it was not completed in the first place.

These circumstances indicate there was not appropriate discipline in the use of technical logs and technical oversight within the ATO.

*Marcon DTD406b De-icing fluid*

The AAIB investigation sought specialist advice to determine whether Marcon DTD406b should be considered a dangerous good and, whilst the result was not definitive, it is likely the fluid had been inappropriately labelled. This could present a hazard to those using, transporting or storing the fluid. It also presented a hazard to those coming into contact with it in emergency situations such as this accident.

The available information on Marcon DTD406b was such that the ATO had been similarly unsure about the status of the de-icing fluid. Initially it assessed that the fluid constituted dangerous goods, but then changed its view. This appears to be why the information contained in the original safety notice (stating that de-icing fluid should be considered a dangerous good) was removed in the subsequent revision.

As there was already a prohibition on the carriage of cargo, the mislabelling of the fluid should not in itself have led to it being carried. As the pilot stated, it is possible, had the container been clearly labelled as containing dangerous goods, that this might have caused him to seek further advice.

Whilst Marcon DTD406b may no longer be in production, it is important that the status of Marcon DTD406b de-icing fluid is properly established and that any appropriate action is taken. The HSE, in its role overseeing the UK registration, evaluation, authorisation and restriction of chemicals regulations, stated that as the manufacturer no longer existed, no action could be taken to ensure the appropriate labelling of any remaining stocks. It also considered it likely only small amounts, if any, of the product remained in existence. The CAA stated that it will publicise the information regarding Marcon DTD406b contained in this report, to improve awareness should stocks remain.

*Data availability*

The Garmin G1000 instrumentation system is widely used and its facility to easily record flight and engine data parameters is potentially beneficial. Since the accident the operator stated it has installed SD memory cards in all aircraft where this facility exists. The AAIB has experience of several other recent investigations where operators were either not aware of this capability or did not use it. This has resulted in important data not being available. Such information may be equally of use to operators in normal circumstances. In order to ensure this capability is more widely known and understood, the following Safety Recommendation is made:

**Safety Recommendation 2022-013**

It is recommended that the Civil Aviation Authority promote the use of the recording facility on Garmin 1000 instrument systems and its potential benefits.

The fact the DATCC was operational at the time of the accident meant that the video cameras covering the runway were also operational. There was no regulatory requirement for the recordings to be retained, although in this case they were.

Since the accident, Cranfield Airport Air Navigation Service has issued supplementary instruction CIMS-CF-ATC-001-SI 02/21 regarding the impounding of recordings. This exceeds the current CAA regulatory requirement and will result in all video recorded by this digital tower being retained after an accident or serious incident, in addition to RTF and radar recordings.

There are other digital towers operating in the UK and this accident serves to reinforce the importance of ensuring such recordings are retained. It is important that both industry and regulators work together to set and implement the required standards to ensure future systems employ this important development in investigation capability.

*Organisational issues*

The AAIB investigation found that aspects of the ATO's management created the circumstances in which staff would find ways to address shortcomings in the operation, for example in the conduct and organisation of flights such as this one. This probably contributed to the circumstances of this accident.

A reduction in student numbers due to public health restrictions resulted in further change within the ATO and affected some of the remedial steps taken as a result of the accident.

The operator was granted three extensions to put in place the necessary measures to rectify issues related to the CAA findings resulting from the accident. The CAA closed all three findings seven months after the expiry of the last of these extensions. Closure was provisional on updates to the Operations Manual, and the CAA has stated that it is still not satisfied with the volume of the Operations Manual relevant the ATO's airline academy.

To the extent that safety shortcomings may not have been adequately addressed by previous regulatory inspections, this indicates that suitably resourced and continued regulatory oversight is necessary to ensure the required standards are being met.

## Conclusion

The accident was caused by a control restriction preventing sufficient nose down pitch input to properly control the aircraft and avoid stalling. The restriction was caused by an unsecured de-icing fluid container placed in the front right footwell. Four other unsecured containers had been placed on seats and in the rear footwell, with the aircraft near its maximum permitted takeoff weight and aft centre of gravity position.

The de-icing fluid was incorrectly classified by the manufacturer and incorrect safety information was supplied.

Aspects of the approved training organisation's operational management appear to have influenced behaviour in the organisation, contributing to the circumstances of the accident.

*Published: 21 July 2022.*

## ACCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Piper PA-46-350P (Modified), G-HYZA | |
| **No & Type of Engines:** | 2 YASA electric motors (common shaft) | |
| **Year of Manufacture:** | 1997 (Serial no: 4636130) | |
| **Date & Time (UTC):** | 29 April 2021 at 1425 hrs | |
| **Location:** | Near Cranfield Airport, Bedfordshire | |
| **Type of Flight:** | Other | |
| **Persons on Board:** | Crew - 2 | Passengers - None |
| **Injuries:** | Crew - None | Passengers - N/A |
| **Nature of Damage:** | Left wing detached, landing gear collapsed and nose cowl distortion | |
| **Commander's Licence:** | Airline Transport Pilot's Licence | |
| **Commander's Age:** | 63 years | |
| **Commander's Flying Experience:** | 34,620 hours (of which 1,588 were on the basic type, 12 were on the modified electric variant)<br>Last 90 days - 59 hours<br>Last 28 days - 19 hours | |
| **Information Source:** | AAIB Field Investigation | |

### Synopsis

The electrically powered aircraft was undertaking experimental flight tests, under E Conditions[1], when power to the electrical motors was lost. A forced landing was carried out close to Cranfield airfield during which the aircraft was severely damaged.

The loss of power occurred during an interruption of the power supply when, as part of the test procedure, the battery was selected OFF with the intention of leaving the electrical motors solely powered by the hydrogen fuel cell. During this interruption the windmilling propeller generated a voltage high enough to operate the inverter protection system, which locked out the power to the motors. The pilot and observer were unable to reset the system and restore electrical power.

Five Safety Recommendations were made regarding Civil Aviation Publication (CAP) 1220, *'Operation of experimental aircraft under E Conditions'*. The operator has also taken Safety Action to address a number of findings from this accident.

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**Footnote**

[1] Annex A in this report provides an overview of E Conditions.

## Introduction

G-HYZA was being operated as part of an experimental and development programme to provide aircraft propulsion systems with zero emissions and lower noise. This was to be achieved using electric motors supplied with electrical power from hydrogen fuel cells. Much of the technology used in the programme had been transferred from other transport modes and industrial applications. The company behind the project was founded in the USA in 2017 and, at the time of the accident, the experimental flight testing was being carried out at Cranfield Airport by the European division.

The piston engine on G-HYZA had been replaced with two electrical motors suppled with electrical power from a high voltage lithium (HV) battery and a hydrogen fuel cell (HFC). The aircraft was operated by a crew consisting of a pilot and a flight test observer. The accident occurred during Phase 3 of the programme which was establishing the optimal conditions for flight with the electrical propulsion system powered only by the HFC. As part of the risk mitigation, G-HYZA was restricted to operating within a 2 nm test area centred on Cranfield Airport and was not permitted to fly when other aircraft were flying in this area.

## History of the flight

On the morning of the accident flight, G-HYZA was flown for approximately 16 minutes on test flight 85. The flight test team debriefed the results and prepared the aircraft for flight 86. The plan for this flight was for the HV battery to be switched off at the end of the downwind leg then, if able, to fly three or more circuits at 1,000 ft aal using the HFC only to provide electrical power. The flight test team discussed experimenting with combinations of higher airspeeds and propeller rpm that would reduce the aircraft angle of attack and improve the mass flow of air through the radiator which provided cooling for the HFC. This was considered as a potential strategy to manage a slow rise in temperature in the HFC which they had observed in previous flights when flying on that power source alone. The test card for flight 86 was not amended to reflect this intention.

At 1406 hrs, following a normal start using both the HV battery and HFC to provide electrical power, the HV was switched off to preserve its electrical capacity. The aircraft taxied to the holding point and was cleared to line up on Runway 03. The weather was fair with good visibility and light winds from 010°. The aircraft entered the runway and backtracked to the threshold where the pilot commenced a run-up of the propulsion system to ensure the HFC could achieve thermal stability within the flight test parameters. Once the temperatures in the HFC were stable, the pilot switched on the HV battery to bring both power sources online and commenced the takeoff run. As the aircraft accelerated and the power lever was advanced, the observer operated the high temperature override switch[2] to maintain the temperature of the HFC within the operating limits.

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**Footnote**

[2] The high temperature override switch manually overrides the automatic temperature regulation valve in the HFC, which was found to be slow to react to power demands.

After takeoff, the pilot turned onto the crosswind leg and climbed to the circuit height of 1,000 ft agl. During the downwind leg of the right-hand circuit, the pilot stated the power was set to 95 kW, the propeller to 2,500 rpm and the airspeed to 100 kt. Once stabilised at these parameters, which were at variance with the flight test card conditions, the observer confirmed that the HFC operating temperatures were within limits. He then instructed the pilot to reduce power to 90 kW to assess the effect on the airspeed, which reduced to approximately 95 kt. The pilot increased the power to 95 kW to regain the target speed. The pilot set the power by reference to his display unit which was located below the throttle quadrant. When he looked up from this task, he recognised that the aircraft was in a late downwind position. He turned onto base leg and commented that they were losing speed in the turn. The observer suggested that they could increase power to 120 kW to regain the lost airspeed, then reduce power before turning off the HV battery to re-establish the test conditions. He also suggested a reduction in propeller rpm. The pilot increased power to 120 kW but did not reduce the propeller rpm. As he started to turn onto final, the pilot briefed that once he had established straight and level flight he would reduce the power slightly and turn off the HV battery leaving the electrical motors powered by the HFC. He called final on the radio and was cleared by ATC to fly through at circuit height (Figure 1).

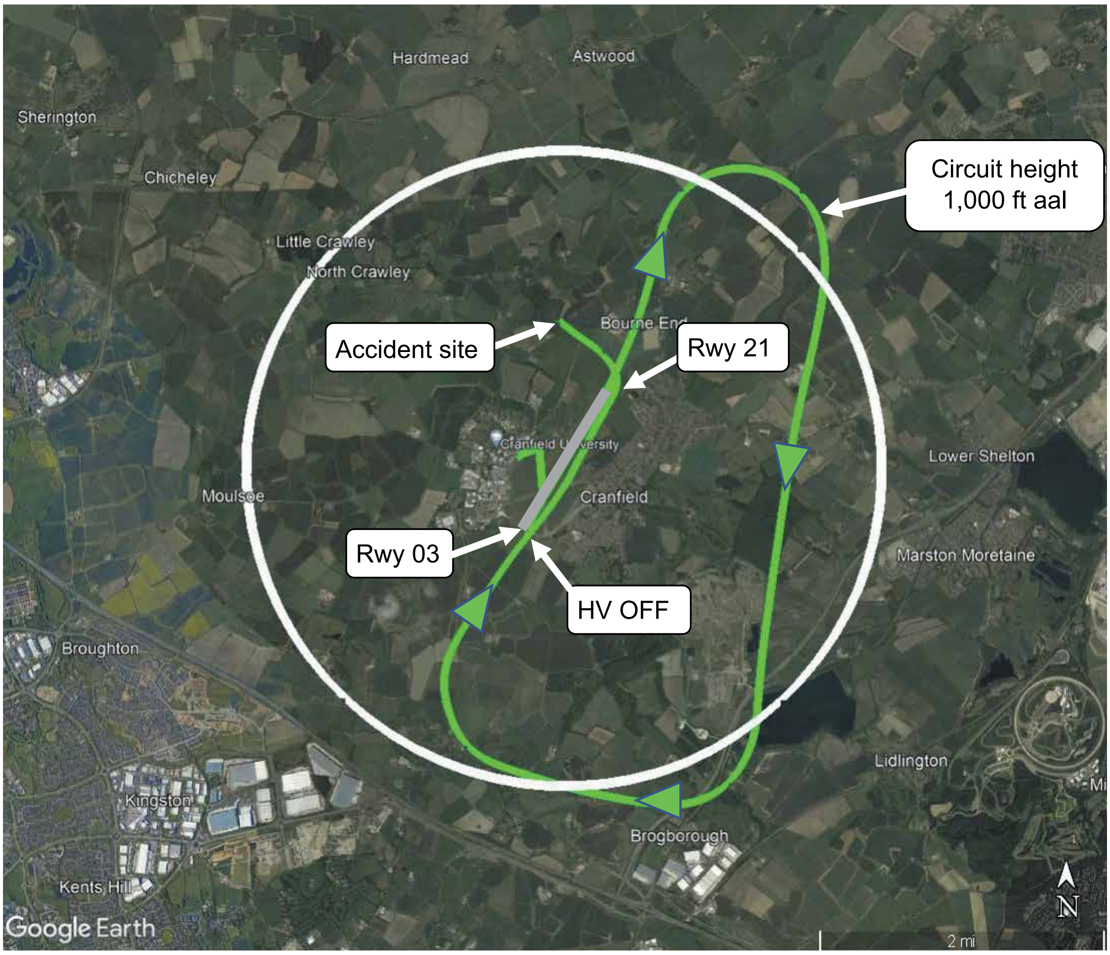

**Figure 1**

G-HYZA track overview (green).
White circle depicts 2 nm boundary of the flight test area

Approaching the runway threshold at approximately 940 ft agl, the pilot reduced power to 90 kW, set the airspeed to 90 kt then selected the HV battery to OFF. Immediately, all electrical drive to the propeller was lost. The pilot and observer made several unsuccessful attempts to reset the system to restore power from the HFC with the observer stating the action to be taken and the pilot making the switch selection. The observer instructed the pilot to select the HV battery to ON to reconnect the alternative power source. HV power was not restored so the observer instructed the pilot to attempt a system reset with the HFC in the OFF position. Electrical power was still not restored and at 440 ft agl the observer declared "THE VOLTAGE IS TOO HIGH", to which the pilot replied, "WE'VE GOT TO DO SOMETHING QUICK". The observer called for a further reset attempt and adjusted the power lever. The aircraft had now travelled the length of the runway and was at approximately 320 ft aal when the observer reported that power could not be restored.

The pilot transmitted a MAYDAY call and initiated a turn to the left to position for a landing on Runway 21. Almost immediately he recognised that he did not have sufficient height to complete the manoeuvre so lowered the landing gear and selected full flap for a forced landing in a field that was now directly ahead on a north-westerly heading. The aircraft touched down at approximately 87 kt ground speed on a level grass field. The pilot applied the brakes, and the aircraft continued its movement until it struck, and passed through, a hedge during which the left wing broke away. The nosewheel and left main wheel entered a ditch and the aircraft came to an abrupt stop. The pilot and observer were uninjured and exited the aircraft through the upper half of the cabin door.

The airport fire service arrived quickly at the scene. The observer returned to the aircraft and vented the hydrogen tank to atmosphere and disconnected the HV battery to make the aircraft safe.

## Aircraft information

### *General*

G-HYZA was a modified Piper PA-46-350P, Malibu Mirage, built in 1997. The aircraft was previously registered as N866LP and was modified with a HV battery supplying power to two electric motors. After the modification it was flown in the UK on a FAA experimental permit. Once the HV battery trials were complete, the aircraft was re-registered as G-HYZA and fitted with a single HFC, in addition to the HV battery, and flown under CAA Civil Aviation Publication (CAP)1220, E Conditions[3].

The original piston engine had been replaced with two Yokeless and Segmented Armature (YASA) electric motors on a common shaft driving an electrically actuated variable pitch propeller. As is common on single engine aircraft, the variable pitch propeller did not have a feathering capability. The electric motors were cooled by a circulatory sealed liquid cooling system.

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**Footnote**

[3] Civil Aviation Authority (2019). CAP1220 *Operation of experimental aircraft under E Conditions.* http://publicapps.caa.co.uk/docs/33/CAP1220EConditions_Edition2_Nov2019.pdf [Accessed November 2021]

The aircraft flying controls and landing gear were unchanged. The cabin pressurisation system components were not required and had been removed. The emergency exit on the right side of the cabin was not accessible due to the location of the hydrogen storage tanks. The fuel tanks remained within the wings but were empty and inert.

The cockpit instruments included a moving map display, that showed the boundary of the Cranfield Aerodrome Traffic Zone, which was also the boundary of the flight test safety area. Blanking plates were fitted to the instrument panel where the engine instruments had been fitted. Two display screens were fitted to show the power plant and motor parameters, one was located on the cockpit centre console next to the pilot, and the other on the right side of the cockpit next to the observer's seat.

A 24 V aircraft battery and dual alternators, driven by a power take-off from the electric motor drive shaft, was used to provide electrical power to the avionic equipment.

### *Powertrain*

The electrical power could be configured in one of three modes:

- Combined (Hybrid) mode. HV battery and HFC selected ON to give a combined maximum nominal power of 200 kW
- HV battery only. HV battery selected ON and HFC OFF to give approximately 50% power of 100 kW
- HFC only. HFC selected ON and HV battery OFF to give approximately 50% power of 100 kW

The power demand from the motors was set by the power lever[4]. The propeller speed was controlled by an electric governor with the desired rpm selected using a rotatory control fitted to the side of the power lever quadrant.

### *High Voltage battery*

The HV battery consisted of one battery pack comprising Li-NMC 'pouch' cells, which provided 368 V, 50 Amp hour and 16.25 kWh. This had been demonstrated as being capable of powering the electric motors, without the HFC, in-flight for approximately 20 minutes at predicted loads.

The HV battery was mounted in a shock proof carrier attached to the hydrogen storage tank mounting framework.

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**Footnote**

[4] The power lever was the repurposed throttle lever located on the centre console.

*Hydrogen Fuel Cell*

The HFC used hydrogen from the storage tanks and oxygen from the air to generate electricity.

The HFC consists of a negative anode and a positive cathode separated by a polymer electrolytic membrane. Air is passed over the cathode and hydrogen ($H_2$) is channelled across the surface of the anode where it splits into positive ions (H+) and negative electrons (e-). The positively charged ions pass through the membrane to the cathode; however, the negatively charged electrons are unable to pass through the membrane and instead travel through an electrical circuit, to the cathode, where they produce an electrical current to power an electrical load shown as a motor (M) in Figure 2. The positive ions and negative electrons then combine with the oxygen ($O_2$) in the air at the cathode to produce heat and water ($H_2O$) as by-products of the process. The water and any unused hydrogen exit through the exhaust.

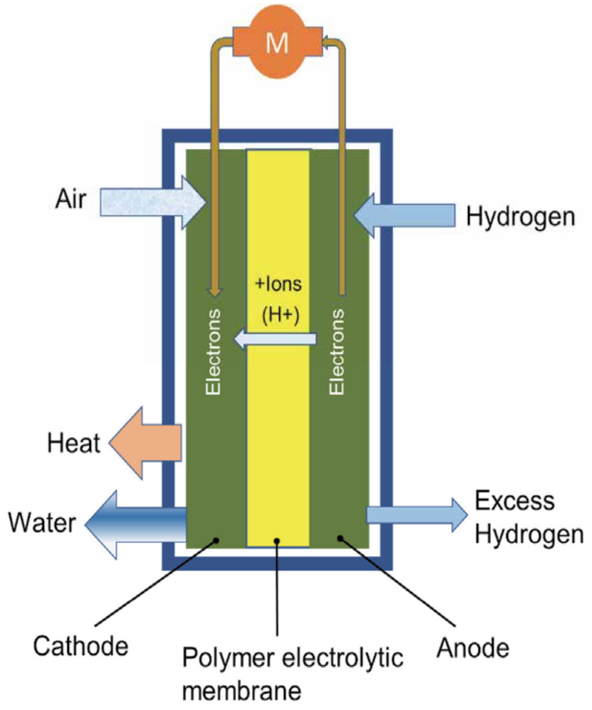

**Figure 2**

Operation of the hydrogen fuel cell

The temperature of the HFC must be maintained within an optimal range to ensure efficient generation of electricity. This was achieved by use of a coolant which was circulated through air cooled radiators mounted behind the propeller and controlled by an automatic HFC temperature management system. A high temperature override switch mounted on the instrument panel allowed the crew to override the automatic control of the temperature regulation valve. The flow of the hydrogen and air (oxygen) were precisely controlled to enable the HFC voltage output to build up and stabilise as a rapid or sudden load could cause an undervoltage.

*Hydrogen storage*

The aircraft carried sufficient hydrogen for approximately one hour of circuit flying. The hydrogen was stored in three high pressure gas cylinders connected to a manifold pressure regulator and shutoff valve. The cylinders were mounted in a frame attached to the seat mounting points on the cabin floor.

The cabin was fitted with a hydrogen detection and warning system. Electrically driven ventilation fans were also fitted in the bulkhead at the rear of the cabin to ensure fresh air constantly passed through the cabin to remove any hydrogen that had leaked out. A manually operated dump valve allowed for the rapid venting of the hydrogen to atmosphere.

*Inverters*

Two inverters, wired in parallel, converted the 300 to 400 V DC output from the HV battery and HFC to the AC input required by the electrical motors. The electrical power was applied to the inverters by DC contactors. Each motor (M1 and M2) had its own inverter, which contained software to provide protection against several fault conditions including out of tolerance voltage and current. For some faults, the inverter would latch a hard fault and 'lockout', which cut power to the motor (M1 or M2) from the affected inverter. This included overvoltage and undervoltage conditions. The threshold for an overvoltage lockout was 820 V.

A simple schematic diagram of the system is shown in Figure 3.

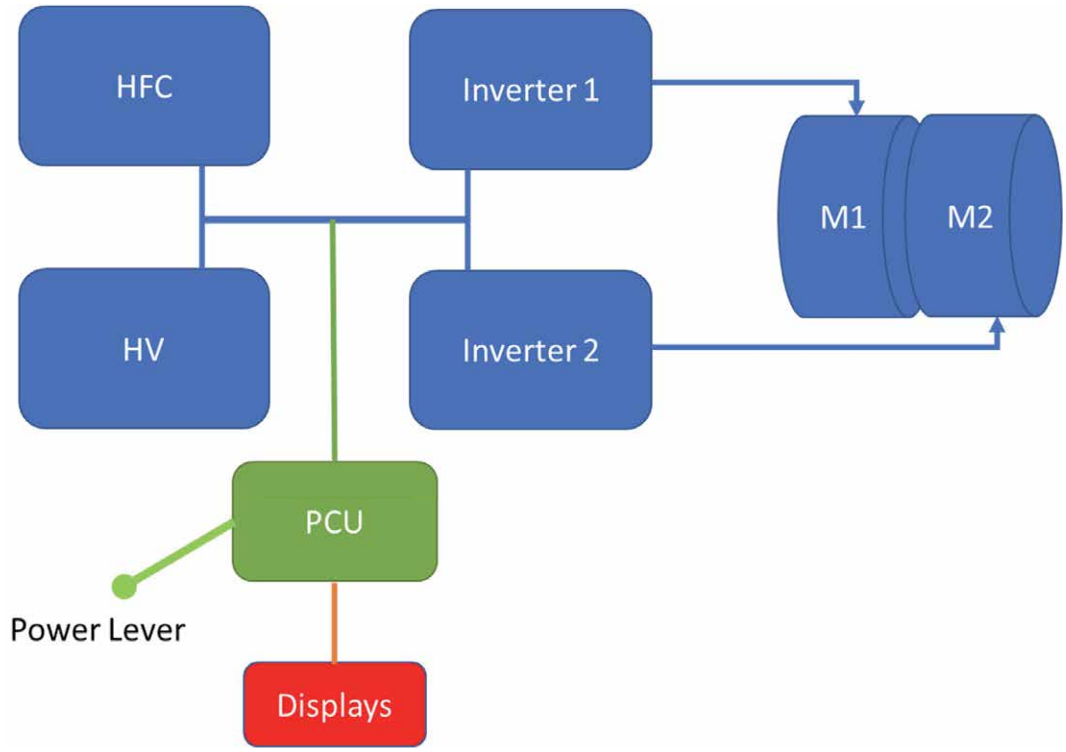

**Figure 3**

Power system schematic

*Programmable control unit*

A programable control unit (PCU) loaded with bespoke software controlled the delivery of power to the motors by sequencing the contactors to enable the HV battery and HFC power to be delivered to the inverters without causing voltage 'spikes'[5]. It also ensured that the power lever position and demands were manageable to protect the power supply and inverters from over voltage. The data for the system displays came from the PCU. The fault clear button on the power lever provided a signal to the PCU to enable any latched faults in the inverters or HFC to be reset.

The PCU did not have a 'soft start' or ramp feature meaning that if an inverter was reset and the power lever position was not at idle, a step demand in power would be commanded. This step demand could exceed the available power which could lead to an undervoltage condition in the HFC, which would be detected by the inverters and trigger an inverter lockout.

*Electric motor principles*

In the event of a loss of electrical power to the motors in-flight, the propeller would windmill turning the motors which would then act as generators with the electrical energy produced being fed back to the inverters. The voltage produced would be dependent on the propeller rpm but could be sufficient to trigger the overvoltage protection which would cause the inverters to lockout. The back EMF of electrical motors is well known, and the principle is used on electrical road vehicles to provide regenerative braking. The operator advised that the control system had been designed such that at zero throttle setting, the motors would always receive a positive driving current just below that required to turn the propeller, which was intended to counter the back EMF and prevent activation of the inverter overvoltage protection logic.

Testing of the drive train system was carried out, which included ground runs and fast runway taxi tests. The results were compiled in an internal report dated 15 April 2021 and used to inform the next phase of the flight test programme. The ground testing covered all aspects of the operation of the power systems and included test procedures to check and clear a number of fault conditions; the taxi tests did not include the change of power source during the fast runway tests. Also, no wind tunnel testing or back-driving of the propeller on the ground was carried out to explore the magnitude and effect of the back voltage on the high voltage electrical system. However, the operator advised that there were no over voltage occurrences when the throttle was closed during the fast taxi tests up to rotate speed.

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**Footnote**

[5] Voltage spikes, also known as surges, may be created by a rapid build-up or decay of a magnetic field, which may induce energy into the associated circuit.

*Powertrain electronic displays*

The electronic displays showed the electrical power supply system status, HV battery control and configuration information in both numerical and graphical format.

Two display screens were fitted to show the power plant and motor parameters, one was located on the cockpit centre console next to the pilot, and the other on the right side of the cockpit next to the observer's seat (Figure 4). The pilot used the display below the throttle quadrant to adjust power and rpm settings throughout the flight. Of note, when the pilot's hand adjusted the power, it could obscure this display.

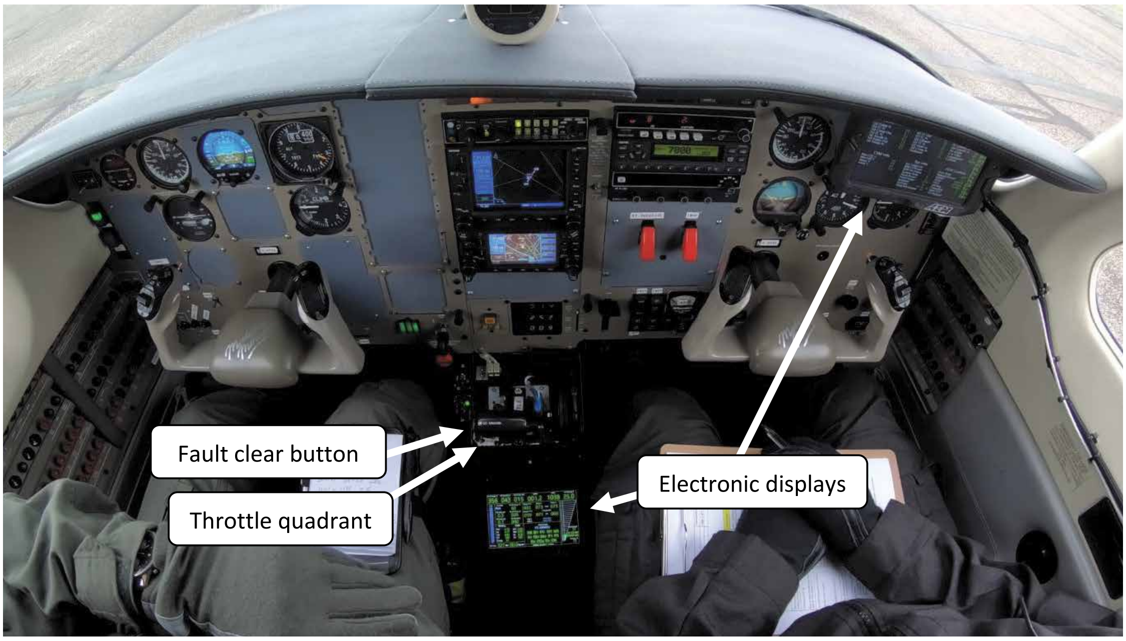

**Figure 4**
View from onboard camera of cockpit instrument panel

The pilot's display had a viewable area of 175 mm x 110 mm. It showed 28 parameters and 24 status, caution or warning captions in a variety of font sizes down to 4.5 mm (Figure 5).

The key parameters displayed in a larger font in field (1) at the top of the display were used by the pilot to operate the aircraft and were defined as:

- HV Voltage – Voltage measured at the inverter input showing the average of the two inverter DC bus voltages
- HV current – The sum of all the inverter current consumption
- HV power – The product of HV current and HV voltage
- Power consumption – Power integrated kW x hr
- RPM – Propeller / motor rpm
- LV Voltage - 28 V supply

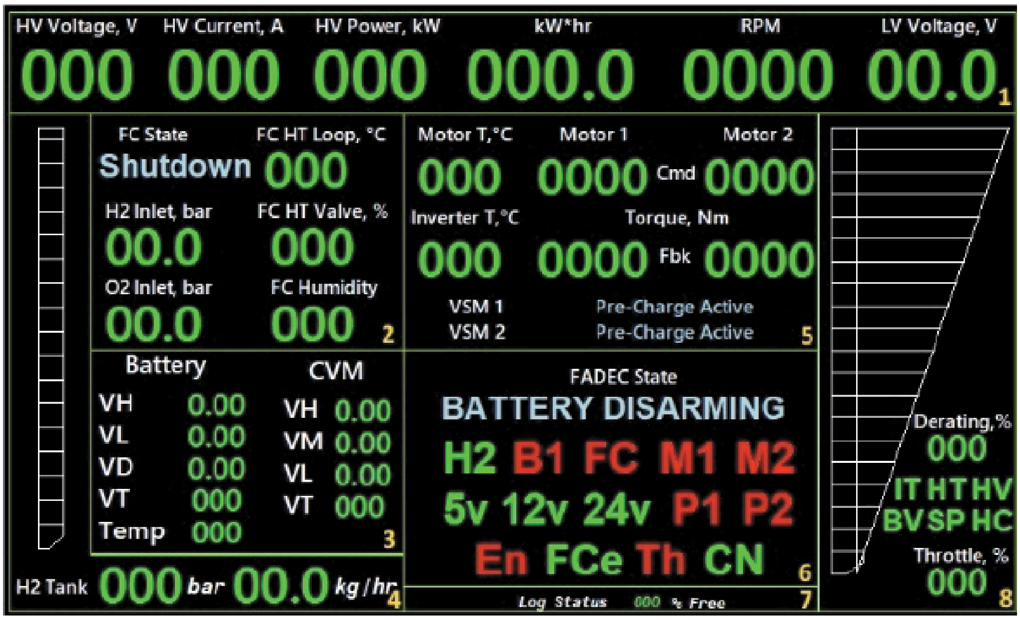

**Figure 5**

Parameters displayed on pilot's powertrain electronic cockpit display

In the *'FADEC State'* field (6), each system had its own symbol displayed in green if no faults were detected. If a fault was detected, the symbol would change to either amber or red, depending on the severity of the fault detected. Aviation standards exist for caution and warning alerts detailed in the EASA Certification Standard 23.1322[6] and US Federal Aviation Regulations 23.1322[7]. The flight manual did not contain a description or key to the amber and red captions and there were no associated emergency procedures for each. There were also no associated audible warnings with these fault monitors.

The certification basis[8] of the PA-46 contains requirements for the design of electronic displays that represent good practice within aviation. As an E Conditions aircraft, G-HYZA was not required to comply with these standards; however, CAP1220 refers to guidance in CAP659[9] *'A guide to Approval, Construction and Operation of Amateur Built Aircraft'*. To assist those undertaking projects, Appendix 1 of this document sets out the design criteria for different types and weights of aircraft. The weight of G-HYZA would place it under Certification Standard (CS) 23, which includes a section on instruments and displays.

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**Footnote**

[6] Certification Specifications (CSs) | EASA (europa.eu) [Accessed April 2022]

[7] FAR Part 23 Sec. 23.1322 effective as of 02/01/1977 (faa.gov) [Accessed April 2022]

[8] FAA Historical CFR Part 23 Amdt. 23-20, Effect 09/01/77. Further information is available in EASA CS 23.1311, Subpart F – Equipment : Electronic display instrument systems, Amdt 4, June 2018.

[9] https://publicapps.caa.co.uk/modalapplication.aspx?catid=1&pagetype=65&appid=11&mode=detail&id=146 [accessed April 2022]

## Accident site

An assessment of the accident site was made from witness and photographic evidence.

The aircraft landed in a field which was 210 m wide, approximately 445 m in length, corner to corner, and bounded by a road and hedges. It touched down approximately one third along the length of the field and after 290 m struck a hedge where the left wing detached from the fuselage and the nose landing gear collapsed. The propeller, nose cowling and tailplane were also damaged (Figure 6). The aircraft remained upright, leaning to its left side sufficient to prevent the lower step section of the cabin door from fully opening. There was no fire.

**Figure 6**

G-HYZA accident site

## Aircraft examination

An examination of the aircraft by the operator found the following:

- The nose landing gear had been forced upwards into the nose area and caused bending and displacement of the motor and HFC mounting frame by approximately 25 mm.
- The nose structure showed no other damage except for the pulling through of a fastener holding the coolant header tank, which was still attached and free from leakage. All the other components remained attached and in place with the mounting frame displacement being taken up by the flexing of the wiring and non-rigid pipework.
- The HV battery contactor box, also located in the nose area, was crushed such that the insulation within the cover was touching the top of some of the contactor terminals.
- There was no evidence of leakage from the motor cooling oil and inverter / HFC cooling systems.

- The hydrogen storage tanks, regulator and distribution systems were visually undamaged and there was no leakage. This was confirmed by the fact that the hydrogen detectors did not trigger.
- The cabin mounting structure for the hydrogen storage tanks and HV battery showed no signs of movement or damage, and all the attached items were retained in their original position.
- The egress path between the cockpit and the cabin exit door remained clear.

## Conducting an experimental flight test programme

Schedule 3 of the Air Navigation Order (ANO) 2016 sets out two paths for the conduct of an experimental flight test programme in the UK for non-Part 21 aircraft. These are B Conditions and E Conditions. Flight testing of a Part 21 aircraft may only be conducted by UK Part 21 Subpart J approved organisations using a UK Part 21 Subpart P Permit to Fly.

### *B Conditions*

B Conditions enable either experimenting with or testing of an aircraft. They can also be used to enable the aircraft to qualify for the issue or validation of a Certificate of Airworthiness, Permit to Fly or the approval of a modification to an aircraft.

Flight testing under B Conditions can only be carried out by an organisation specifically approved for the management and control of flights under those conditions such as holders of approvals under British Civil Airworthiness Requirements (BCAR) A8-1 and/or A8-9.

### *E Conditions*

E Conditions, which were first published under CAP1220 in November 2015, enable a UK registered, commercially or amateur built, non-EASA aircraft with a Maximum Take off Mass (MTOM) of 2,000 kg or below to test a concept in the air without having to comply with the more stringent requirements of B Conditions.

A dossier of information on the project is compiled by a competent person who also signs the *'declaration to operate'* under these regulations. The declaration is the only document required to be provided to the CAA, though they may ask to see the full dossier. The background to the development of E Conditions, and a number of aspects relevant to this accident, are included in Annex A.

## Requirements of E Conditions

### *Competent Person*

E Conditions uses the mechanism of management and oversight by a competent person to keep the risk to third parties at an acceptably low level. The competent person takes sole responsibility for the safe conduct and management of the entire experimental test programme and is required to produce a dossier of information on the aircraft and the test programme, which includes a signed declaration.

CAP1220 states:

> *'It is anticipated that, where necessary, the Competent Person will enlist the help of other individuals with the appropriate skills and experience as required.'*

A footnote to this statement states:

> *'It is strongly recommended that even where the Competent Person can fulfil multiple or all roles the involvement of other technical experts should be sought for the purpose of peer review.'*

The responsibilities of the competent person include assessing all risks throughout the flight test programme; not permitting any flights to take place until they are satisfied that identified risks are mitigated to an acceptable level; and attending flight test briefings.

Any current member of the Royal Aeronautical Society (RAeS) who has obtained their Chartered Engineer status (CEng) through the RAeS is automatically eligible to be a competent person. At the time of this accident, 13 individuals had been registered for the role of competent person and nine projects were being progressed under E Conditions, not all of which had flown. G-HYZA was one of the more complex projects to have flown under E Conditions.

Members of the CAA and RAeS working group, that developed E Conditions, stated that the underlying intention was that the competent person would have a close involvement in the test flying programme.

*The declaration*

The declaration is submitted to the CAA by the competent person and contains a brief description of the project as well as the details of the competent person, test pilot and the registered aircraft owner. The competent person is also required to sign as accepting a number of statements which includes:

> *'I confirm that I will keep the registered aircraft owner and Test Pilot appropriately briefed on all aspects of the test programme…*
>
> *I declare that before the flight test programme commences, I will undertake all necessary risk assessments and must be satisfied that all risks in respect of the flight test programme have been mitigated to an acceptable level and that, in particular, the level of risk to uninvolved parties will be low enough to be acceptable….*
>
> *I declare that, throughout the flight test programme:*
>
> - *I will make such changes to the risk assessment and dossier of information as appear appropriate in light of the information gathered in connection with the programme; and*

- *I will keep under review the risks in respect of the flight test programme and in the event that I cease to be satisfied that all risks in respect of the flight test programme have been mitigated to an acceptable level, and in particular that the level of risk to uninvolved third parties is low enough to be acceptable, I will not permit a flight to take place.'*

## G-HYZA E Conditions dossier

### *Background*

The flight test programme was being carried out over four phases with the first two phases having been satisfactorily completed:

- Phase 1 was started in the US using another modified PA-46, registration N504EZ, and completed in the UK on G-HYZA, when registered as N866LP, under an FAA experimental permit. Phase 1 used a HV battery to demonstrate control and performance of the propulsion system.
- Phase 2 was carried out under E Conditions in the UK with the HFC fitted in addition to the HV battery to make it a hybrid aircraft. It was recorded in the introduction of the Phase 3 dossier that *'Overall, the second phase was a success with exception of an incident during Flight Test 52 where an in-flight shut-down of the system was required and a dead stick landing resulted'.*

Phase 3 required the introduction of an additional hydrogen storage tank with the HV battery and HFC power system remaining unchanged. The dossier authorising Phase 3 was dated 21 April 2021. The content of the dossier had been provided by the operator's staff and compiled and approved by the competent person with the assistance of his colleagues.

### *Phase 3*

The aim of Phase 3, which was intended to last for seven hours spread over 14 flights, was to conduct longer duration flights at Cranfield before cross-country flights were attempted. Details of the test program were set out as subparts of Phase 3.

> Subpart 3.1 was to establish the operational parameters of the larger hydrogen capacity storage system. Specifically, it was designed to establish the aircraft performance parameters, thermal characteristics, efficiency, endurance, and range. The dossier stated that '*the proposed tests provide a logical and incremental build up in system experience, with flight durations slowly increasing*'. The accident happened during this phase.
>
> Subpart 3.2 was designed to expand the flight envelope within Cranfield airspace, and to demonstrate the elements required for an intermediate A to B flight of approximately 60 nm. The intention was to validate the systems over longer duration flights and to gather reliability data.

> Subparts 3.3, 3.4 and 3.5 were introduced as subsequent aims. Firstly, to fly the aircraft to a new operating base. Then to continue test flying at the new base with a larger hydrogen storage capacity to support and demonstrate an extended range flight of up to 200 nm. The flight requirements of these subparts of the programme were not presented in the dossier but were to be constructed using the data obtained from the completion of subparts 3.1 and 3.2.

The dossier cleared G-HYZA for Phases 3.1 and 3.2 of the programme only. The specific test procedures and requirements were set out in tables detailing the number of flights required, the objectives and system conditions required for each flight, including the planned power and rpm settings. All the flights were planned to be conducted in the normal and extended circuits at Cranfield. The dossier clearly stated that all the risks associated with the programme were defined within the documented risk assessment and related solely to system failures rather than flight manoeuvres.

The dossier for Phase 2 and 3 provided no guidance on the functional links between the individuals in charge of flight test activity, or how coordination between teams and individuals affecting the flight testing would be achieved.

## Risk assessments

### *Loss of propulsion*

E Conditions requires risk assessments to be carried out and suggests the use of a hazard identification and risk assessment method (details are at Annex A). The method used for Phase 3 was consistent with the suggested approach and classified the severity, likelihood and tolerability of each risk and listed any mitigations.

The risk assessment determined the probability of a loss of thrust to be 0.008 per flight hour and classified the risk severity as 2B, which means the probability is *'improbable'* with a severity of '*hazardous*'. This gave a tolerability criterion of *'moderate risk'* with a recommendation *'Schedule performance of a safety assessment to bring down the risk index to the low range if viable'.*

One of the occasions when propulsion might be lost is when switching between the two electrical power sources. The AAIB was informed that the mitigation for this risk was to switch power sources when the aircraft was at the end of the downwind leg where it could glide to the runway. However, this mitigation had not been included in the risk assessment and the only mention in the dossier was in Part C where the flight test programme required the power source to be changed at the end of the downwind leg without giving a reason why.

Propulsion loss was considered to have procedural mitigations that were '*no different from any other single engine aircraft where the possibility of a dead stick landing in a field is a possibility.'* The procedures and mitigations intended to minimise the risk of propulsion loss resulting in an off-airfield landing were:

- Inclusion in the Aircraft Flight Manual (AFM) of a '*power loss in flight*' emergency procedure.

- Avoiding flying above populated areas.
- Identification of possible emergency landing zones away from populated areas prior to flight. The pilot reported that this was done by reference to Google Earth.
- Hardware and software modifications made in response to an event that occurred during Phase 2, flight 52, which included the introduction of the fault clear button that would allow the inverters to be reset in-flight.
- A procedural requirement in the test plans to switch between the hybrid and HFC only energy source at the end of the downwind leg.
- Pilot qualification and experience.
- A process for post-flight learning.

*Off-airfield landing*

The area surrounding the climb-out path of Runway 03 at Cranfield is predominantly agricultural in nature, with a lattice of public roads, farm tracks, agricultural buildings and farmsteads. The fields are generally less than 500 m in length and frequently bounded by hedges and ditches.

E conditions states that:

> *'…the competent person must make it clear that all reasonable precautions have been taken to minimize risk to any third party',*

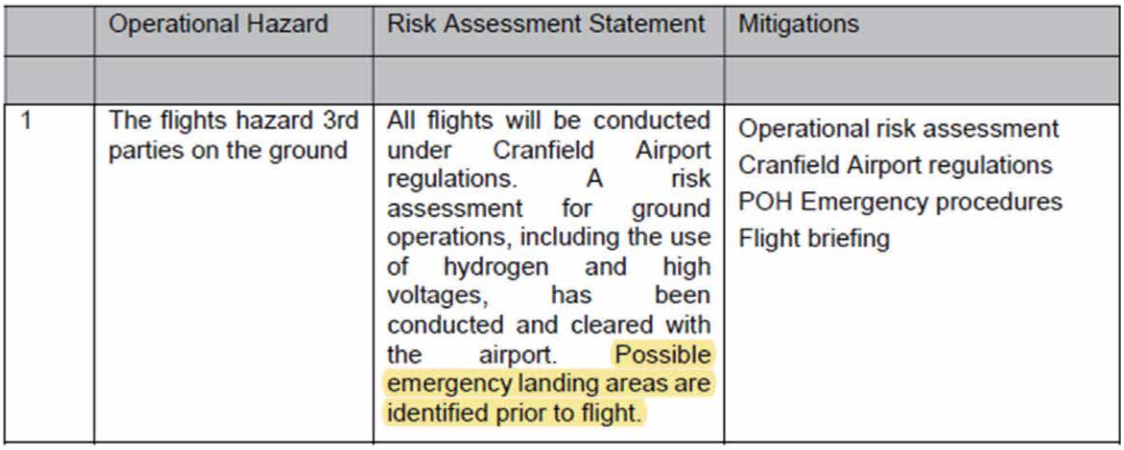
This includes persons on the ground and that:

> *'…the risk of serious injury to uninvolved third parties must be determined to be extremely improbable',*

where E Conditions define extremely improbable as:

> *'…almost inconceivable that the event will occur'.*

To satisfy the requirement that risk to third parties was extremely improbable, it would be necessary to demonstrate in the risk assessment that suitable areas existed that would allow the aircraft to be landed and stopped with a reasonable expectation that it would not encroach on areas either inhabited or frequently accessed by third parties on the ground. No such assessment was included in the dossier other than the operational hazard contained in the risk assessment and highlighted in Figure 7. A detailed study of possible landing areas, aircraft landing performance, and the risk to third parties had not been carried out.



| | Operational Hazard | Risk Assessment Statement | Mitigations |
|---|---|---|---|
| | | | |
| 1 | The flights hazard 3rd parties on the ground | All flights will be conducted under Cranfield Airport regulations. A risk assessment for ground operations, including the use of hydrogen and high voltages, has been conducted and cleared with the airport. Possible emergency landing areas are identified prior to flight. | Operational risk assessment<br>Cranfield Airport regulations<br>POH Emergency procedures<br>Flight briefing |

**Figure 7**

Operational Hazards from dossier risk assessment

## Operator's management of the test programme

The operator had established an internal flight test organisation for the project, and while functional links between the individual post holders existed, they were largely informal and not subject to a documented process. The operator did not nominate an individual responsible for risk and safety management who was independent of the flight test and management teams, as that responsibility was placed on the competent person by E Conditions.

Personnel involved with the project could be described broadly as belonging to one of the following sub-groups:

- The flight crew: the pilot and flight test observer.
- The flight test team: the flight crew, the ground crew that prepared and signed off the aircraft for each flight, and the engineering leads that assisted in the review of data from each test flight.
- The experimenting team: the wider team of people who undertook the project to design and build the experimental aircraft and conducted the flight test programme. Not all these individuals were co-located with the flight test team with some of them located in the USA.

The operator had also nominated a project manager who undertook and coordinated a number of their supporting activities.

## Competent person

### *Qualifications and experience*

The competent person was academically qualified in aeronautical engineering and had worked in the aerospace industry for over 30 years. He was a Fellow of the RAeS and a CEng. He considered that he was most knowledgeable in structures engineering though he had worked in a variety of areas during his career.

He was contracted to the G-HYZA project on a consultancy basis through his employer, a specialist aerospace company offering a range of services and approved as a design organisation under EASA Part 21 Subpart J . He was involved in two other electric aviation projects, with his employer, including one that planned to demonstrate the use of hydrogen fuel cell technology for passenger carrying airline services. G-HYZA was the first time he had acted as the competent person on an E Conditions project.

*Role of competent person*

The competent person undertook his role on G-HYZA in parallel with his work with his employer. He described himself as "busy" and perceived the competent person role as like being head of design on a B Conditions project.

When he initially became involved with the G-HYZA project, his place of work was co-located with the experimenting team located at Cranfield. From March 2020 he started to work from home due to restrictions associated with the COVID-19 pandemic and continued to primarily work remotely for the entire time leading up to the accident. Most of the communication between the competent person and the operator was by email and video conference.

The competent person reported that protection of the operator's intellectual property was an important consideration. He stated that the operator provided all the information and documents he requested but did not proactively offer additional information or progress updates. He also needed to share some information within his own organisation because he required assistance to assess the electrical and avionic aspects of G-HYZA and in reviewing the safety system analysis reports generated by the operator.

The competent person commented that most of his work on E Conditions was "getting to the point where the aircraft is safe to fly." His involvement in the project once test flying had commenced was "limited" and he was not involved in any flight-by-flight briefing process. He reported that he expected that the operator would approach him with any proposed deviations to the flight test programme and cited deviating from the parameters on the test card as an example of something he would expect to be informed of. However, he commented that "What would trigger that action wasn't really laid down." Therefore, no formal feedback process had been established to ensure the competent person was updated with data from flight test activity that could challenge the risk analysis as the programme evolved. The competent person was not aware of any technical issues experienced in the earlier Phase 3 flights.

### Pilot

The pilot held the position of principal test pilot, which was defined in the dossier as the individual nominated by the competent person who would '*take responsibility for the safe conduct of airborne trials*'. He conducted all the flights in the test programme and held a current ATPL with a single engine piston rating; multi engine piston rating; PA-46T single engine turbine rating; IR and flight instructor rating. He had amassed 34,620 hrs on all aircraft types of which 1,588 hrs were as PIC on the conventional PA-46 and 12 hrs on the experimental PA-46 electric variant.

The pilot did not hold a formal test pilot rating, nor was he required to do so to participate in the test programme under E Conditions[10]. The operator reported that the pilot was appointed as the principal test pilot due to his extensive previous flight test experience, including:

- Over 50 hours as test pilot for a similar programme where a diesel engine was retrofitted to Cessna 172 and Piper PA-28 airframes.
- LAA approved for test flights of home-built prototype aircraft.
- Approval to conduct CAA Certificate of Airworthiness testing on PA-46 and PC-12 aircraft.
- Piper PA-46T post-production flight testing.

The pilot last received Crew Resource Management (CRM) training in 2014 and was not required by regulations to undergo recurrent training for non-commercial operations.

### Flight test observer

*Qualification and experience*

The observer was recruited by the operator in March 2020 as the lead engineer for the development of the HFC. His role evolved over the course of the programme, particularly during the phase requiring the integration of the HFC into the airframe, and he came to be regarded as the most suitable person to assist the pilot due to his knowledge of the systems. His involvement in the programme in the capacity of a flight test observer started in June 2020.

The observer had extensive experience in the field of HFC design and engineering, but had not completed any flight test training, nor was he required to do so under E Conditions. He had undertaken approximately 10 hours of PPL training in a private capacity. In a previous employment with a helicopter manufacturer, he had gained some limited experience as an observer on test flights.

*Role of observer*

The dossier described the observer's role variously as a *'passenger who shall act as a flight test observer',* and in a later section as a '*Flight Test Engineer*' who would record *'other parameters and observations'* during the flight. There was no formal definition of the role or description of duties that were expected to be conducted in flight. E Conditions state that:

> *'Observers should only be carried if it is considered that it would be beneficial to overall safety for an observer to participate in the testing and that this justifies the hazard to the additional person.'*

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**Footnote**

[10] CAP1220 – '*Operation of experimental aircraft under E Conditions*', published by the CAA: '*The minimum requirement for carrying out test flying on an experimental aircraft is a valid pilot's licence with the appropriate ratings applicable to the class of aircraft in question and to comply with the applicable medical and recency requirements of the licence and associated ratings.'*

The operator regarded the observer's role as necessary for the successful conduct of the test programme and interviews with the flight test team revealed that a single crew operation was never considered. The observer believed that his role as part of the flight test crew was to "manage the propulsion system in the air" and to provide specialist knowledge of that system to the pilot.

The competent person assumed that the role of the observer was as documented in the dossier and stated that if the role was more like that of a flight test engineer it would have required more scrutiny to check that the person doing the role was suitably qualified and experienced for the role.

### Flight test director

The operator established the role of flight test director, which was filled by a senior member of the operator's management team. The roles and responsibilities of this position were not defined in the dossier and there was no requirement to do so under E Conditions, which places sole responsibility for the management of the test programme on the competent person. The flight test director had daily contact with the flight test team. The holder of this role did not have any flight test training or aviation experience.

### Crew training

E Conditions makes the following recommendation in relation to flight crew training:

> *'Testing may be preceded by a training and work-up programme during which specific flight test techniques and sortie profiles are rehearsed. This is particularly relevant to any testing that involves elevated risk profiles.'*

and that*:*

> *'Crew Resource Management (CRM) principles should be considered as part of the flight test planning process.'*

The observer had not received any training for his role or in the principles of CRM. The pilot and observer had both completed ground emergency egress training.

### Flight test process

A number of steps were required before the aircraft was cleared to start the flight test programme and included: a flight test readiness review (FTRR); signing of the certificate of clearance; and preparation of the flight test cards.

#### *Flight Test Readiness Review*

The operator's experimenting team conducted an internal FTRR on 14 April 2021. While the operator's review was not required by E Conditions, the objective of a FTRR was, according to the operator, to *'make sure that unresolved issues are flagged and that the team are happy to proceed*'. A separate FTRR was conducted by the competent person on 20 April 2021, with key personnel from the operator, following which the certificate of clearance was issued. The FTRR delegated responsibility to the pilot for the preparation of each sortie flight test plan.

*Certificate of clearance*

The certificate of clearance was issued before flight testing commenced and was signed by the competent person and the test pilot. The certificate covered information relevant to the conduct of the test programme and according to E Conditions:

> *'…should be amended or replaced by a new certificate whenever a change is made to the aircraft design standard or to any document or action referenced by the Certificate of Clearance.'*

The certificate issued by the competent person for the operator's test programme, dated 21 April 2021, referred to Part C of the dossier which contained the *'details and phasing'* of the flight test programme. For flights 85 and 86 this stipulated the rpm settings to be used and included the requirement that the switching of power sources must be performed at the end of the downwind leg of the circuit. This requirement was not listed in the certificate of clearance under the section '*Other Restrictions Considered Necessary',* which did list*:*

- '*Flight over populated areas is prohibited.*
- *All operations must remain within 24 minutes of any diversionary airfield due to 24V battery capacity*.'

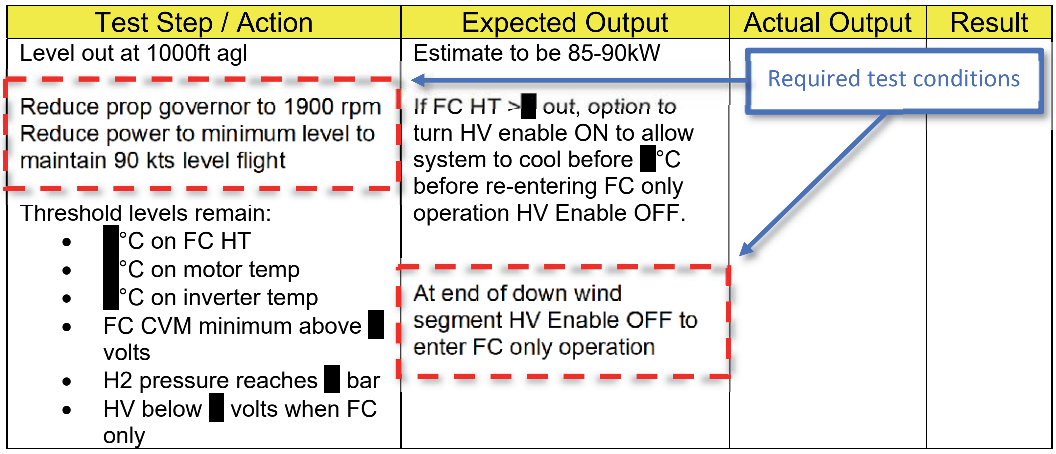
Contrary to the details in the certificate of clearance, during flight 86 a different rpm was used; the power source was also selected at other locations around the circuit during flights 85 and 86.

*Flight test cards*

Once the certificate of clearance was issued, the flight test team sought input from members of the experimenting team to establish how the propulsion system could be managed and controlled and how it had performed during previous flights. A series of test cards was then created containing a description of the test points to be flown on each sortie, including instructions necessary to conduct the flight and any special procedures required. Test cards were managed by the flight test team and were not subject to independent review by the competent person. An extract from the test card for the accident flight is shown at Figure 8. The flight test team, which included the flight crew, reviewed the contents of the test cards during the pre-flight briefing.

*Post-flight debrief*

At the end of each flight the results were shared with the flight test team in a post-flight debrief; the competent person did not attend. The observer placed the completed test card, log data and flight video on a network drive to enable others to access the information from remote locations. However, there was no formal process to share the results with the experimenting team or the competent person, and there was no feedback process to indicate that individuals had seen the information.



| Test Step / Action | Expected Output | Actual Output | Result |
|---|---|---|---|
| Level out at 1000ft agl | Estimate to be 85-90kW | | |
| Reduce prop governor to 1900 rpm<br>Reduce power to minimum level to maintain 90 kts level flight | *If FC HT >*[redacted] *out, option to* turn HV enable ON to allow system to cool before [redacted]°C before re-entering FC only operation HV Enable OFF. | | |
| Threshold levels remain:<br>• [redacted]°C on FC HT<br>• [redacted]°C on motor temp<br>• [redacted]°C on inverter temp<br>• FC CVM minimum above [redacted] volts<br>• H2 pressure reaches [redacted] bar<br>• HV below [redacted] volts when FC only | At end of down wind segment HV Enable OFF to enter FC only operation | | |

**Figure 8**

Redacted[11] extract from test card for the accident flight – flight 86

Some of the operator's staff mentioned that in previous phases everyone in the experimenting team had reviewed and discussed the data from every flight. However, fewer post-flight discussions and reviews had taken place in the lead up to the accident. The operator's project manager, and one of the lead engineers, reported that prior to the accident they intended to improve the sharing of information by bringing the experimenting team together as a matter of routine but this had not yet been implemented.

## Flight 85

Flight 85 was conducted on the morning of the accident flight and shared common test conditions with the accident flight, flight 86. At the end of the downwind leg of the first circuit, on flight 85, the pilot reduced the propeller rpm to 1,900 rpm and then selected the HV battery OFF to fly on HFC only in accordance with the test card. The DC voltage measured at each inverter spiked to just less than 800 V which did not represent an overvoltage condition.

As flight 85 progressed, the crew observed a temperature rise in the HFC so selected the HV battery to ON to reduce the load on the HFC and allow the temperature to reduce. The HV battery switch was cycled on three more occasions to assist with HFC cooling before temperatures in the HFC became stable enough to allow a third circuit to be flown on HFC power only. With the propeller rpm at approximately 1,900 rpm, each time the HV battery was switched the DC input voltage to the inverters spiked, but in all cases stayed below 800 V. After the initial selection of the HV battery switch to OFF, subsequent switch selections were made at various positions in the circuit without incident, but contrary to the agreed conditions stated in the test card.

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**Footnote**

[11] Data redacted as commercially sensitive.

## Recorded information

The aircraft was fitted with an extensive recording system to help facilitate the test programme. This included data from the fuel cells, battery, inverters, GPS and five cameras located at various internal and external locations, which also recorded the pilot's headset audio. Data was recovered from the recording system for the accident flight and provided to the AAIB as part of the investigation.

After takeoff, the aircraft achieved an average vertical speed of approximately 425 ft/min. Circuit altitude of 1,300 ft amsl (approximately 1,000 ft aal[12]) was achieved just under three minutes after takeoff at the start of the downwind leg. Airspeed data was not recorded but the ASI could be read using the cockpit video recording. During the crosswind leg, the aircraft track extended beyond the 2 nm boundary (see Figure 1).

During the downwind leg the airspeed stabilised at 100 kt with propeller rpm approximately 2,500 rpm and HV power at 95 kW. Power lever adjustments were made to achieve 90 kW but due to a subsequent loss of airspeed the crew decided to revert to 95 kW. These adjustments required the pilot to read the figures at the top line of the lower display to confirm the power setting which required him to look down into the cockpit.

Once the adjustments were completed, the pilot looked to the right and commented to the observer on where the airfield was. The aircraft turned onto base leg during which it again flew beyond the 2 nm boundary.

During the turn, the pilot acknowledged that the airspeed reduced in order to maintain the altitude. The observer suggested some measures to get back to the test points of airspeed and HV power. He also suggested reducing the propeller rpm once the aircraft was straight and level. The pilot acknowledged the suggestions, and stated "ONCE YOU LOSE THE SPEED, YOU JUST CAN'T GET IT BACK".

The power lever was advanced in the base leg turn to capture the test airspeed of 95 kt and then reduced on final to achieve an HV power of 90 kW and airspeed of 90 kt.

At 1421:34 hrs, the pilot selected the HV battery OFF using a switch in the overhead panel. The aircraft was located 650 m (Figure 9) from the displaced threshold of Runway 03 at 1,300 ft amsl (942 ft aal).

The recorded power lever position was 41% and the motor rpm was 2,310 rpm. The pilot returned his hand to the power lever which then obscured his view of the lower display (Figure 10).

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**Footnote**

[12] Cranfield Airport is 358 ft amsl.

**Figure 9**

G-HYZA track

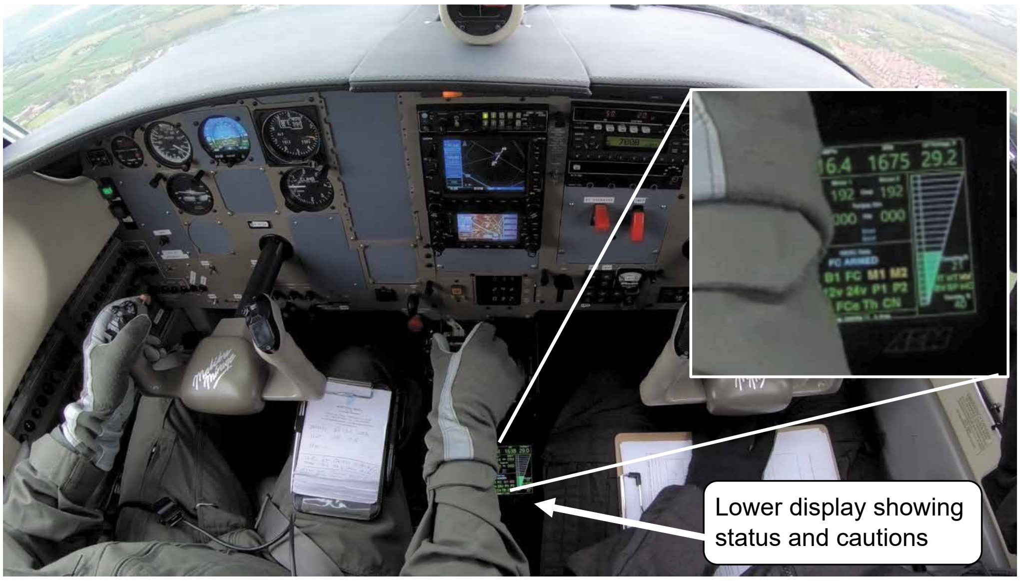

**Figure 10**

G-HYZA cockpit camera view, just after HV selected OFF, showing zoom of lower display

The on-board camera showed that immediately after the HV battery was selected OFF, the displays showed M1 and M2 initially in red, then amber, representing motor fault conditions. Four seconds later, the pilot noted the loss of power. Five seconds after this, the observer stated, "YOU'VE LOST THE INVERTER, PUSH THE BUTTON".

Power was still available from the HFC, although the voltage increased to 440 V. This was due to the load no longer being applied to the HFC which had defaulted to an 'open circuit voltage' state. As the propeller rpm was high, the motors acted as a generator feeding a large voltage into the inverters. Recorded inverter voltage reached 825 V which triggered an inverter lockout cutting all power to the motors.

The pilot pushed the fault clear button with the recorded power lever position still at 41%. This successfully reset the inverter; however, as the power lever was not at idle, the step demand for power after the reset could not be provided by the HFC leading to a voltage drop. This was detected by the inverter as an undervoltage and caused an additional lockout.

The observer instructed the pilot to select HV battery ON which was successful. However, due to the combination of an increased HFC voltage and continued windmilling action of the propeller, the inverters detected further overvoltage conditions which led to further lockouts. After HV battery was selected ON, further attempts were made to restore power over the next 38 seconds with the observer acknowledging that "THE VOLTAGE IS TOO HIGH". This included resetting the HFC and HV battery supplies with the fault clear button selection at various power lever positions, with no visual reference to checklists. The troubleshooting required the pilot to look down to the power lever and display and then look up to the HFC and HV battery switches in the overhead panel. Despite these attempts, power could not be restored to the motors. Figure 11 shows these data parameters throughout the event.

The observer then stated to the pilot "NO, YOUR CALL, WE'VE LOST EVERYTHING". This occurred 54 seconds after the HV battery was initially selected off with the aircraft located 90 m from the end of Runway 03, offset slightly to the right at 676 ft amsl (318 ft aal).

### *Forced landing*

The pilot transmitted a MAYDAY call stating that they had "LOST POWER AND COMING BACK TO TRY TO GET ON TO TWO-ONE" while commencing a turn to the left. This was followed with a transmission stating that they were landing in a field.

The pilot lowered the flaps and landing gear, touching down in a field at a groundspeed of 87 kt, 23 seconds after the MAYDAY call. Touchdown occurred approximately one third into the field with the aircraft eventually impacting the ditch and hedge at the far end at a groundspeed of 45 kt.

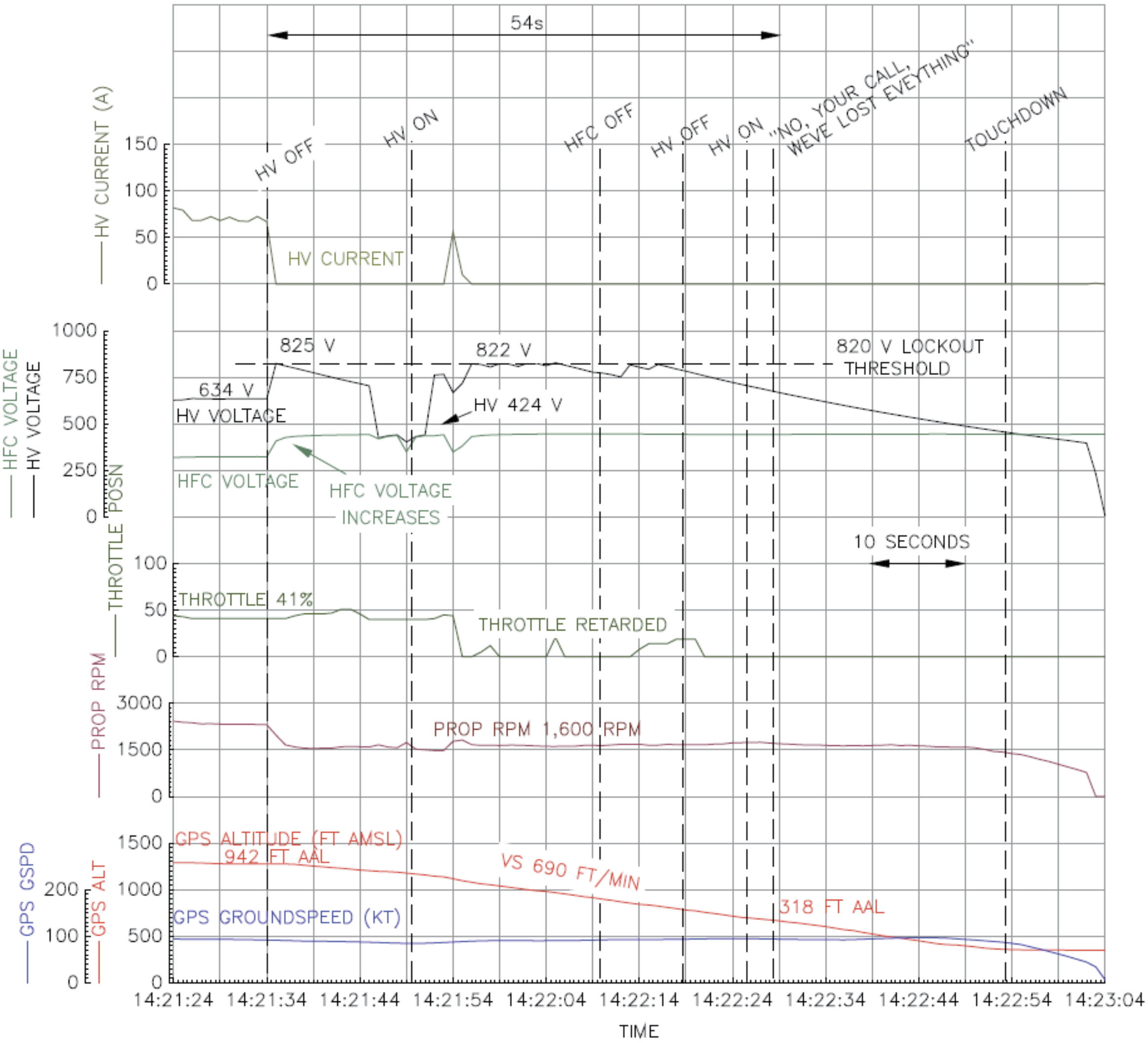

**Figure 11**

G-HYZA flight data parameters

## Weight and balance

During the process of modifying G-HYZA and the subsequent phases of flight testing, it became necessary to operate the aircraft at a higher maximum weight than that certified for the aircraft type. The operator commissioned a third-party report which provided suitable mitigations for this increase and the dossier listed the following increased weights:

| *‘Parameter* | *Basic Aircraft* | *Modified Aircraft* |
|---|---|---|
| *Maximum Take-off Weight* | *4300lb* | *4350lb* |
| *Maximum Landing Weight* | *4100lb* | *4350lb* |
| *Maximum Zero-Fuel Weight* | *4100lb* | *4350lb’* |

## Aircraft performance

*Predicted performance*

The operator stated that G-HYZA retained the aerodynamic characteristics of a basic Piper PA-46 and that the handling, control and stability characteristics were unchanged. Glide performance was assumed to be unaffected by the modifications and was planned for 2 nm per 1,000 ft. This was the basis for the 2 nm test area around Cranfield to ensure the aircraft could safely return to the airfield following a complete loss of power at circuit height.

Based on test data gathered from Phase 2, the operator calculated the predicted takeoff and climb performance for the aircraft in the Phase 3 configuration. The data indicated that the aircraft could safely take off on the runways available at Cranfield and achieve a climb rate of 572 ft/min at a takeoff weight of 4,320 lb and speed of 90 kt. This rate of climb equated to a climb gradient of 6.3%. Annex B in the dossier stated, *'This is below the Part 23 requirement of 8.3%, although it is acceptable for the test flights planned'.* The operator included the following note in the Aircraft Flight Manual (AFM) Supplement for Phase 3 to address the rate of climb performance:

> ***'5.7 PERFORMANCE GRAPHS***
>
> *The following performance graphs must be read with consideration that the modifications to the aircraft may reduce performance. Therefore the data below should be used for guidance only.'*

*Actual performance achieved during flight tests*

The pilot reported that the actual rate of climb in Phase 2 was 500 ft/min and due to the 8% increase in weight the rate of climb in Phase 3 was around 300 ft/min. The pilot observed that the aircraft felt "heavy" to fly compared with the Phase 2 configuration, and that it was "flying like it was staggering". However, the recorded data from the accident and two preceding flights show that a rate of climb of 425, 465 and 436 ft/min was achieved in the climb to circuit height.

The reduced climb performance increased the time G-HYZA took to reach circuit height, which in turn meant running on both power sources for longer than anticipated. The pilot reported that each cycle of using the HV battery to halve the load on the HFC to allow cooling would take around 3 to 4 minutes. In combination, these factors increased the rate of depletion of the HV battery, which reduced the time available to complete the test schedule as a reserve of HV battery capacity was required to ensure at least one power source was available should the HFC fail.

The competent person was unaware that the aircraft did not achieve its predicted performance during the first flight of Phase 3.

### *Landing performance*

The AFM indicated that for a full flap landing at 78 KIAS on a paved, level, dry surface at MLW, the landing distance required (LDR) from 50 ft was 1,950 ft (594 m) with a landing roll of 1,000 ft (305 m). The CAA published "*Safety Sense Leaflet 7c Aeroplane Performance*[13]" which states that unfactored manufacturer's data should be considered the minimum acceptable for planning. It includes additional factors to be considered for a number of scenarios including the landing surface condition. For example, dry grass requires a 15% factor plus an additional factor of 43% which increased the distances to 3,207 ft (977 m) and 1,645 ft (501 m). While the CAA strongly recommends these factors are applied to non-commercial flights, they are not normally required to be considered during an emergency landing.

## Previous technical issues and actions taken

During phase two and three there had been four notable technical events:

- Flight 52 on 6 November 2020. Total loss of power in-flight; aircraft completed a power off landing on the runway.
- Flight 80 on 23 April 2021. While operating on both power sources, the HFC shutdown in-flight; aircraft landed using HV battery power only.
- Flight 81 on 26 April 2021. The HFC shutdown on the ground during the run-up and the flight was aborted.
- Flight 83 on 27 April 2021. Inverters locked out on landing; power restored after reset procedure carried out.

### *Flight 52*

Flight 52 was subject to detailed analysis by the operator which led to several software changes and two modifications to introduce the fault clear button and an alteration to the HFC air intake. A number of procedural changes were also made.

### *Flight 80 and 81*

Flights 80 and 81 had been subject to internal review by the flight test team and the cause of the HFC shutdowns was identified as 'flooding' due to the accumulation of condensate from excessive HFC cooling. Procedures were modified to prevent reoccurrence, including an amendment to the test cards to conduct the propulsion system run-up on the runway threshold, immediately before take-off, and not at the holding point where previous delays had led to excessive cooling. The competent person was not aware of these actions and no review of the existing safety assumptions was carried out.

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**Footnote**

[13] CAA (2013). *Safety Sense Leaflet 7c: Aeroplane performance*. https://publicapps.caa.co.uk/docs/33/20130121SSL07.pdf [Accessed November 2021]

*Flight 83*

The incident on flight 83 was recorded on the test card after the flight as:

> *'steep descent resulted in full power reduction at around 500 ft. This resulted in both inverters giving "Error!" due to 819v overvoltage. Fault Clear on runway to restore power.'*

A review of the recorded data revealed that at the time of the incident, the power lever was at 0% demand, propeller 2,050 rpm with voltage peaking at 825 V. The issue was discussed with the flight test team, but as the flight crew did not consider it significant, a safety investigation was not carried out. The flight test director and the competent person stated they were not aware of this event.

### Safety management

In addition to the safety management elements required under E Conditions, the operator had in place several other elements including an emergency response plan and a culture of continuous improvement as they worked towards becoming an approved design organisation. However, there was no formal safety reporting process in place, nor was their required to be. Nevertheless, the response to flight 52 showed that in practice the operator did investigate and responded to events that were recognised as significant. Mandatory Occurrence Reports were sent to the CAA following the loss of power during flight 52 on 6 November 2020 and the accident flight on 29 April 2021.

Immediately following this accident, the operator appointed a team of experts who were independent of the G-HYZA programme to conduct an internal investigation. This investigation resulted in the operator taking a number of safety actions which included the following:

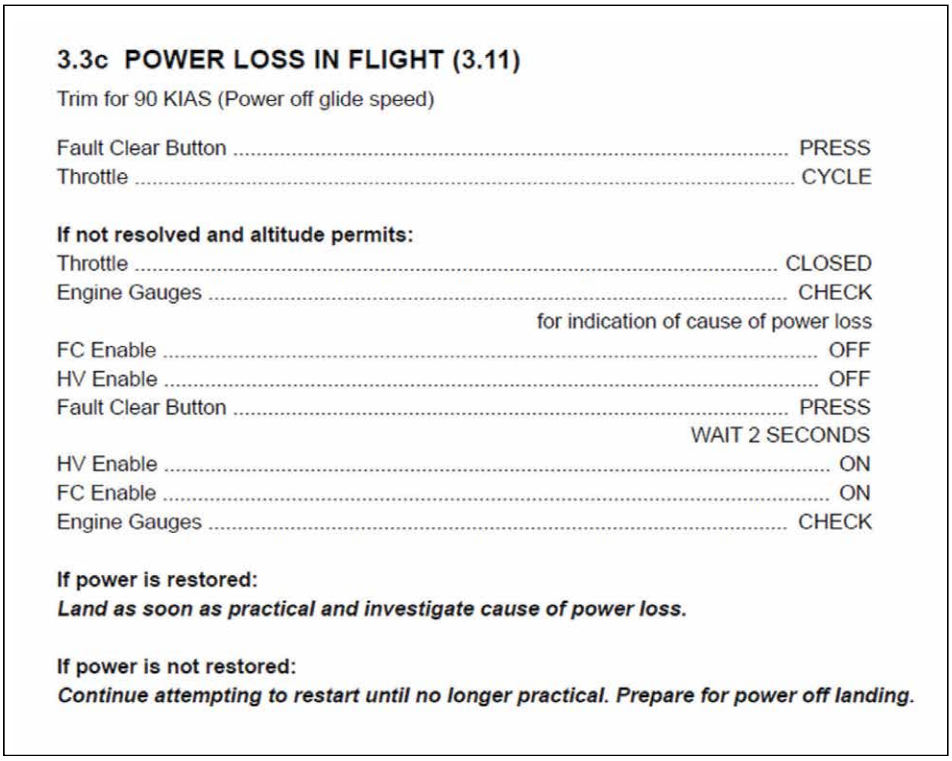
- The design for the operator's future project would incorporate the learning in terms of handling back-EMF [voltage] due to windmilling.
- Future prototype testing would be limited to non-critical redundant situations until the powerplant design matures.
- The design and flight test of future programmes would follow CAA/EASA part 21J and aviation industry best practice.
- A safety management system based on a 'just' aviation culture would be established and include occurrence reporting, investigation, and corrective actions functions.
- Commercial pressure would be actively managed to ensure that it does not compromise safety.

## Aircraft Flight Manual

*Supplement*

The operator produced a supplement to the basic Piper PA-46 AFM to provide the limitations, procedures and information required to operate G-HYZA. The document was designed to be read in combination with the manufacturer's approved AFM.

The supplement contained an emergency procedure for a power loss in flight (Figure 12), which was dated 12 April 2021.



**3.3c POWER LOSS IN FLIGHT (3.11)**

Trim for 90 KIAS (Power off glide speed)

Fault Clear Button .................... PRESS
Throttle .................... CYCLE

**If not resolved and altitude permits:**
Throttle .................... CLOSED
Engine Gauges .................... CHECK
for indication of cause of power loss
FC Enable .................... OFF
HV Enable .................... OFF
Fault Clear Button .................... PRESS
WAIT 2 SECONDS
HV Enable .................... ON
FC Enable .................... ON
Engine Gauges .................... CHECK

**If power is restored:**
***Land as soon as practical and investigate cause of power loss.***

**If power is not restored:**
***Continue attempting to restart until no longer practical. Prepare for power off landing.***

**Figure 12**

Power loss in flight emergency procedure

A subsequent section of the supplement entitled '*Amplified Emergency Procedures (General)'*, contained the following guidance for loss of power:

> *'If the preceding steps do not restore power, prepare for a power off landing.*
>
> *If power is not regained and altitude permits, continue attempting to restart until no longer practical and then proceed with the Power Off Landing procedure.'*

Neither the manufacturer's AFM, nor the operator's supplement was carried on board G-HYZA during the accident flight. While there was no requirement to carry these documents on board, they contained the emergency check lists which might have to be referenced in-flight.

### *Design of power loss in flight emergency procedure*

The operator's lead for airworthiness and certification was the author of the emergency procedures in the supplement, which included the action of pressing the fault clear button. He had consulted with the lead engineer for the HFC for technical input with the intention of producing a document from a "theoretical perspective". This procedure was never conceived to be used by a pilot unassisted by a technical expert.

Engineers from the operator, who had in-depth knowledge of other system aspects, indicated that pressing the fault clear button before reducing the power lever to idle would prevent the system resetting. This was due to the associated rapid onset of power required, and the fault would persist. They had not been consulted over the content of the emergency procedure.

The competent person reported that he reviewed the emergency procedure in detail.

## Organisation

### *Introduction*

The AAIB interviewed the operator's staff employed in key positions at the time of the accident, and one of the project's funding organisations. A review of the findings from the operator's internal investigation, covering organisational aspects, was also carried out.

### *People*

A large proportion of the staff involved in the G-HYZA programme were recruited in late 2020 and early 2021. The project team consisted of specialist engineers who focused on specific system aspects including the HFC, drive train, software, power electronics and mechanical integration. While the majority of these specialists were from outside the aviation industry, they worked in collaboration with individuals who had a strong aviation background, which included the airworthiness lead, the licenced aircraft engineer who maintained the aircraft, and the competent person.

### *Pace of development*

The electric aviation propulsion development space was competitive with a small number of organisations vying to be the first to market. The project had evolved with some changes of scope and extensions of timescales beyond the original plan to achieve a long-range flight on HFC only within a year of the start of the project. Nevertheless, they had achieved the world's first flight of a commercial grade hydrogen-electric aircraft. They had also commenced their next project to modify a 19-seat twin engine aircraft by replacing one of the engines with a zero emission drivetrain and to test fly it under B conditions.

The operator's investigation found that the experimenting team had a high workload and there was pressure on them to achieve a long duration demonstration flight by the end of May 2021. A milestone for the operator's 19-seat aircraft project also required significant preparation that was scheduled on the day before the accident. The operator's investigation found that some staff were showing signs that pressure was influencing them to make decisions based primarily on expediency.

*Commercial aspects*

The operator was in a period of rapid growth and had attracted sufficient funding to progress towards its goals. They had to report to some external parties on progress against the project plan and as the programme had already been extended, they appeared eager to avoid having to request any further extensions. However, there was no apparent threat of funding or investment being withdrawn if the planned test flying programme required more time to complete.

*Operating bases*

The operator had parallel and interdependent development programmes based in the UK and overseas. Within the UK, the operator was in the process of moving their base from Cranfield to another UK airport. The pilot and observer were still based at Cranfield for the flight testing of G-HYZA and many in the UK part of the experimenting team had already moved and began working in parallel on the 19-seat aircraft project.

At Cranfield there had been some operational constraints that, in the opinion of some of the staff, presented difficulties for the project. There was a perception that there would be fewer constraints at the new base.

*Culture and working practices*

The operator's staff appeared passionate about their mission and highly motivated to make aviation more sustainable. A fast pace of work and "goal-oriented problem solving" were prized within the organisation and this was communicated by the flight test director and the chief executive who were often present and actively engaged in the technical detail. As an example of this, the flight test director and the chief executive were present at Cranfield on the day before the accident flight and engaged with the observer in a lengthy discussion about how to solve a cooling problem which lasted until late in the evening.

The engineering team had a high degree of autonomy and the ability to request whatever resources they needed to solve problems. There were few prescribed procedures, and it was common for individuals to devise practical workarounds or adaptations to overcome problems or constraints.

When asked about safety during the interviews, staff at all levels agreed that it was important, but none of the interviewees proactively talked about safety as a key priority or value within the operator. There was no evidence that any member of the team had ever been asked or encouraged to compromise safety to progress the project.

## Analysis

*Introduction*

The accident occurred because the aircraft lost propulsion when the HV battery was switched off to allow the motors to be supplied solely by the HFC when the aircraft was not in a position where it could safely glide to the runway.

*Reason for loss of propulsion*

When the HV battery was switched off, the sequencing of the contactors, to allow the HFC alone to provide electrical power, resulted in a momentary interruption of the power supply to the motors. During this brief period the propeller was driven by the airflow which caused the motor to act as a generator. The resulting voltage was high enough to cause the inverter overvoltage protection to lockout the power supply to the motors.

The pilot attempted to reset the system with the HFC ON and the HV battery OFF by pressing the fault clear button. However, the power lever remained at 41% and as the motor control logic did not have a 'soft start' or ramp demand function, the HFC alone could not respond fast enough to meet the demand from the PCU. Consequently, the voltage at the HFC reduced and the invertor undervoltage protection operated locking out the inverters again. The HV battery was selected ON and the fault clear button selected several times at different power lever positions, which did reset the inverters but the high voltage resulting from a combination of increased HFC voltage and the windmilling propellor continued to trigger the overvoltage protection.

A similar flight test profile had been flown earlier in the day, as part of flight 85, when the propeller was operating at approximately 1,900 rpm. Data from that flight showed that while there was a momentary voltage spike when the HV battery was switched off, the lower propeller rpm meant the motors did not generate a high enough voltage to trigger the inverter overvoltage protection.

*Previous losses of propulsion*

Propulsion had been lost on two previous occasions (during flights 52 and 83), when the windmilling propeller resulted in the inverters locking out as a result of a high voltage. On both occasions the aircraft landed safely. The installation of the fault clear button following flight 52 was expected to allow the system to be reset, but an inverter lockout occurred again on flight 83 during the descent to land. This loss of power on flight 83 was not reported to either the competent person or the flight test director as the crew did not consider it to be significant at the time. Consequently, no investigation was carried out to establish the cause.

*Procedure for clearing invertor lockout*

Following flight 52, the AFM supplement was amended to include the procedure for clearing the inverter lockout by use of the fault clear button. After establishing a safe glide, the next step in the procedure was to press the fault clear button and then cycle the power lever. However, the members of the team who developed the procedure did not recognise that if the fault clear button was pressed with the power lever in any position other than idle, the system would see a load demand and try to respond. This was not a particular problem for the HV battery, but the HFC might not be able to react rapidly enough and the consequent drop in voltage could be sufficient to trigger an undervoltage condition at the inverters. Moreover, the PCU did not include an algorithm to ramp the voltage to maintain the demands on the HFC within achievable limits. Some members of the experimenting team were aware that the power lever should be retarded before pressing the fault clear button, but they were not involved in the development of the AFM procedure. The competent person also reviewed the AFM procedure, but it is likely that he did not have a detailed enough knowledge of the system to understand that the power lever first had to be retarded.

*Propeller windmilling*

If an electric motor is back driven, such as by a windmilling propeller, it will produce a voltage with the electrical energy produced being fed to the inverters. Ground or wind tunnel testing, encompassing the entire electrical system operating under simulated flight conditions, might have alerted the engineers to the magnitude of the voltage that the motors could generate when being driven by the propeller. A series of tests was undertaken after flight 52 and prior to the start of Phase 3; however, while the testing included fast taxi runs, the change of power source was not made during these tests. Consequently, no tests were carried out to establish the effect of the back voltage in the electrical distribution system from a windmilling propeller.

The engineers understood that the windmilling propeller generated a back voltage and after flight 52 made software changes to reduce the delay in the system during the reconfiguring of the power source. They also increased the high voltage threshold. However, by not carrying out relevant ground testing they did not appreciate the potential magnitude of the back voltage that might occur.

*Loss of power from the HFC*

The HFC had also shut down during flight 80 and during the run-up on the ground on flight 81 leaving the motors to be supplied by the HV battery only. On both occasions the cause was attributed to excessive HFC cooling. While the change to the operating procedures and amendment to the test cards were intended to prevent a reoccurrence, the competent person was not made aware, and no review of the risk assessment was carried out.

*Aircraft performance*

The predicted performance of G-HYZA was checked during the first flight of Phase 3 when the pilot reported that the rate of climb of 300 ft/min was significantly below the predicted 572 ft/min. Recorded data showed that a rate of climb of 425, 465 and 436 ft/min was achieved during the final three flights. This reduced performance would increase the time for the aircraft to reach the test height of 1,000 ft, which would require it to run for longer on both power sources. It was also have been necessary to have used the HV battery to offload the HFC to allow it to cool when required. Consequently, as the HV battery had a duration of around 20 minutes, it would have been difficult for each flight to complete the three or more circuits specified in the flight test card, while maintaining a minimum capacity to ensure a powered landing in the event of the HFC failing.

The competent person was not aware of the lack of performance and neither the certificate of clearance nor the risk assessment were reviewed following the finding that the predicted performance was not achievable.

*Pre-flight decision making*

In order to resolve the cooling problem with the HFC, a decision was made by the flight test team, following the flight in the morning, to experiment with the aircraft parameters by increasing the speed and rpm, and reducing the angle of attack to improve HFC cooling in-flight. Power and rpm settings were specified in the test programme within the dossier and were therefore associated with the certificate of clearance signed by the competent person and the principal test pilot. However, no changes were made to the flight test card and the planned changes were not discussed with the competent person, so he did not have the opportunity to review the certificate of clearance or the risk assessment prior to the flight. The flight test team appeared to see this adaptation as an incremental change within the remit of establishing the operational parameters of G-HYZA. They did not consider this change presented an additional risk or anticipate the effect it would have on the propeller windmilling speed and the possible effect on the electrical distribution system.

The plan was also not widely discussed with other engineers in the experimenting team. There was no formal process to require it and informal review and discussion with the whole team had become less frequent over time due to workload on the two parallel projects and the move to the new operating base. This had been recognised as an issue by some of the operator’s staff, but they had not had time to improve the situation before the accident occurred.

The flight test team were highly motivated to achieve the project’s goals because they believed in the potential of the technology and the need to improve sustainability in aviation. They were influenced to make an expedient decision by the culture within the operator and the competitive environment they were working in. None of the flight test team had formal flight test training or experience in a professional flight test programme, so there was nothing within their own experience to influence them to take a more cautious and systematic approach.

*Accident flight*

After the aircraft took off, it climbed and flew outside of the flight test area before turning to join the downwind leg where it reached the test altitude of 1,000 ft aal. The aircraft was established on the test conditions briefed prior to the flight, and the power setting was reduced to establish the impact on the aircraft performance. While the crew discussed the effect of the power change, the aircraft flew beyond the end of the downwind leg and out of the test area. The pilot was delayed in recognising their position in the circuit as his attention was focused on the power settings on his display, mounted below the throttle quadrant, and the flight instruments.

Once he recognised that he had flown past the planned point to change the power configuration, the pilot could have elected to fly through the circuit and re-establish the test conditions in the position required by the test card before selecting the HV battery OFF. However, it is likely that the decision to turn towards the runway and then select the HV battery OFF, was influenced by the flight earlier in the day when the changeover of power sources was successfully performed at various positions in the circuit. Previous testing of the changeover on the ground would have further reinforced his confidence in the system and the ability to reconnect the HV power source if required. The crew were also aware of the limited endurance of the HV battery and that it imposed a restriction on the duration of the test flight if its capacity was used for longer than necessary. After the accident, the pilot reported that flying an additional circuit to reposition on the downwind leg would have imposed an unnecessary drain of the HV battery. This decision was contrary to the specified mitigation in the test plan for the change of power source to be carried out at the end of the downwind leg. It was also contrary to the guidance in CAP1220 that '*ad-hoc testing should not occur*.'

### *Handling of the emergency*

The pilot quickly identified the loss of power from the aircraft response rather than the display indications. Nine seconds after the loss of power the observer stated that the inverters had been lost. The aircraft was at 880 ft above the airfield.

The location of the system status display and the absence of aural warnings meant critical information regarding the motor operation was not readily available to the pilot. The only indication of a loss of power was a change in colour of the small symbols M1 and M2 on the cluttered system status display, which was obscured when the pilot's hand was on the power lever.

A copy of the emergency procedure, contained in the AFM supplement, was not carried on the aircraft. During the emergency the pilot did not call for the emergency check list, but instead the observer directed the pilot from memory. While the observer's memory steps were not in accordance with the AFM procedure, his actions did not affect the outcome as the AFM procedure did not include a step to move the power lever to idle before pressing the fault clear button. Therefore, the inverters would have remained locked out even if the AFM procedure had been followed.

The cockpit video showed that the aircraft was flown at its glide speed of 90 - 95 kt throughout the emergency and recorded a relatively straight track along the runway. The decision to attempt to restore power to the motors by switching on the HV battery rather than immediately committing to a manoeuvre to land on the runway was logical: the crew had no reason to expect the power source would not come back online when selected. They had performed the action on many occasions both in the air and on the ground. However, when this was unsuccessful, they continued to troubleshoot and made multiple attempts to reset the system, during which time the pilot's attention was focused inside the cockpit to the detriment of his awareness of position and height. Had the pilot's immediate response to the loss of power been to commit to a 360° turn, a series of 'S' turns or sideslip manoeuvre, it is possible that he could have landed on the runway but the risk of entering an undesired aircraft state, which could result in a loss of control close to the ground, would also have increased.

After 54 seconds the observer concluded that it was not possible to restore power, by which time the aircraft was at 320 ft above the end of the runway and the options for a field landing were extremely limited. The pilot's initial response was to attempt to turn back to land on the opposite runway, demonstrating that he was not aware of their proximity to the ground. However, on starting the turn he immediately recognised the threat and promptly configured the aircraft to land in a field directly ahead. The delay in recognising the aircraft's proximity to the ground revealed the challenge of managing a critical aircraft emergency and the importance of:

- Prioritising immediate actions necessary to ensure safe flight.
- Timely decision making and identifying when to stop troubleshooting to allow a full focus on flying the aircraft.
- Managing the inputs of crew members to ensure the PF remains focused on the task of flying the aircraft first.

*Contingency for a forced landing*

G-HYZA was most exposed during the period between taking off and reaching circuit height in the downwind position for the runway. A loss of propulsion at the end of the downwind leg would have presented a much lower risk as the aircraft could glide to the runway. This was a key factor in the risk mitigation to switch power sources at that point. The dossier stated that fields suitable for an off-site landing had been identified in mitigation of a loss of power scenario. However, there was no consideration of the landing performance, either factored or unfactored, or a detailed analysis of the landing distance available in fields around the airport. There were also few locations within the climb out path of Runway 03 at Cranfield with sufficient obstacle free length to allow for a safe forced landing where the associated risk to third parties could be regarded as *'extremely improbable',* which was a requirement of E Conditions.

*Flight crew*

The dossier stated that the role of the observer was to record '*parameters and observations'* on the flight, but in practice the pilot and observer were operating in a multi-crew environment. The flight test programme was never conceived by the operator to be conducted by a single crew member. The scope of general airmanship, parameters to be monitored, the depth of knowledge required of the propulsion system and the timely management of HFC temperature regulation required the effective coordination of both roles. This was not the understanding of the competent person.

The competent person's understanding of the pilot and observer roles was consistent with the dossier, which was prepared using information he requested from the operator. But the dossier was not an accurate description of the critical role of the observer. The competent person assumed that in the event of an emergency the pilot would execute the drills independently and, therefore, he did not consider the suitability of the observer for the role or require CRM or additional training to be carried out.

*Crew performance*

The pilot last received CRM training seven years prior to the accident, and the observer had never received any CRM training or instruction on how to work in a multi-crew environment.

During the emergency, when faced with confusing and unrecognised system indications, the observer's persistence with attempting to solve the problem, despite the approaching ground, indicates that he did not perceive the threat. It is probable that he considered flightpath management to be the sole responsibility of the pilot. However, the pilot remained confident in the observer's knowledge of the propulsion system and ability to restore power, which delayed his recognition of the emerging threat of ground proximity. It is likely that both individuals would have been better placed to react to the hazardous situation had they received recent CRM training and conducted regular multi-crew emergency handling review exercises as part of a threat and error management strategy. CAP1220 recommends that, '*Crew Resource Management principles should be considered as part of the flight test planning process'*.

### *Design and positioning of displays*

During the accident flight the aircraft flew outside of the test area twice. The opportunity to switch power sources at the end of the downwind leg was missed and the pilot appeared not to recognise his proximity to the ground and his position in relation to the runways when it became clear that he had to conduct a forced landing. One potential factor, which might also have delayed the diagnosis of the power loss, was the design and positioning of the pilot's electronic display which contained important information, such as the rpm and motor power setting, that the pilot required to control the aircraft. However, the display did not conform to aviation good practice for the following reasons:

- The pilot's display unit was not positioned in his primary field of view.
- Most of the display was obscured by the pilot's hand on the throttle, including the warning and caution captions.
- The display was densely populated with many parameters in a small font.
- The warning and caution indications had no attention getting properties.

The cockpit video showed that during the emergency the pilot's attention appeared to be mostly in the cockpit moving between the overhead panel, main instrument panel and his electronic display located beneath the throttle quadrant. While CAP1220 did not require the aircraft to conform with the airworthiness requirements of a Permit to Fly or Certificate of Airworthiness, there are safety benefits in following existing design guidelines, where possible, to ensure that operational risk is kept as low as reasonably practicable and tolerable. In this case, the location of the aircraft controls did not present any issue but the principle of following existing design guidelines remains applicable. The following Safety Recommendation is therefore made to the CAA:

**Safety Recommendation 2022–008**

It is recommended that the Civil Aviation Authority develops guidance in CAP1220, Operation of Aircraft Under E Conditions, regarding the use of existing guidance on the design and positioning of controls and displays used in the operation of the aircraft.

*Risk assessment*

The risk assessment is a fundamental aspect of E Conditions and needs to be carried out prior to the start of each phase and reviewed whenever a new hazard is identified or there is a possible change to the risk.

Loss of thrust had been identified as a hazard and mitigations were recorded in a number of documents, which should have reduced the chance of an off-airfield landing had they been followed. Not all mitigations for loss of thrust were listed in the hazard identification and risk assessment section of the dossier, or in the certificate of clearance. One mitigation was the requirement to switch between the HV battery and HFC at the end of the downwind leg, but this was only documented in the flight test programme. While the flight crew and the competent person were aware of this mitigation, it was not followed. If it had been made more prominent by inclusion as an operating limitation in the certificate of clearance, which was signed by both the competent person and the principal test pilot, it might have been respected by the flight crew.

The risk assessment said that the loss of high voltage electrical power distribution and loss of thrust from two motors had a risk index of improbable, which is defined as *'very unlikely to occur (not known to have occurred')* with a tolerability of *'hazardous'*. However, propulsion had been lost on two previous flights, which meant the basis of the risk assessment was no longer valid and the tolerability was more likely '*high risk'*. Consequently, a review of the risk assessment following the loss of propulsion on flight 83 may have required the certificate of clearance to be suspended until action had been taken to bring the risk index down to the moderate or low range. A review of the risk assessment was not carried out.

Mitigation for a loss of power was to *'Land as soon as possible'* or to undertake a *'dead stick landing in a field',* which was considered to be no different to other single engine aircraft. While this is correct, the likelihood of it occurring exceeded that of other aircraft due to the experimental nature of the propulsion system.

*Organisational factors*

The operator was a relatively new organisation that formed in the USA in 2017. Part of the operation then moved to the UK to take advantage of the regulatory environment of E conditions and available funding. Initially the operator had limited aviation experience in the conduct of experimental test programmes but was still growing in preparation for the 19-seat project that would be flown under B conditions. By the end of 2020 they had recruited an airworthiness and certification lead, both of whom had the relevant experience and qualifications to fill their roles. In March 2021, they recruited a head of design whose focus was on the new project and not G-HYZA.

To manage the project, the operator had established an informal organisation loosely consisting of the flight test and experimenting team led by the flight test director. At the time of the accident some of the team were working in parallel on the 19-seat project and had relocated to the new operating base. Neither the competent person, who was responsible in CAP1220 for managing the project, nor the principal test pilot were employees of the operator. The competent person's availability to oversee the project was constrained by his primary work commitments from his employer, COVID-19 restrictions and the long hours and pace of the project.

It would be difficult for one individual, particularly when their availability is limited, to manage such a complex project without there being a clear organisational structure that defines roles, responsibilities, and reporting loops. No such information was in the dossier or captured elsewhere. Consequently, the competent person was unsighted on much of the detail of the daily operations, and so was not consulted about changes to the flight test programme or informed of a number of significant technical issues. The flight test director had informally assumed many of the responsibilities that CAP1220 required of the competent person.

The experimenting team had a strong personal motivation to make aviation more sustainable and felt that their technology was a viable solution. They were working in a competitive commercial environment with several other projects vying to achieve similar goals first. Most of the other people who worked at the operator displayed a similar enthusiasm and the culture within the operator was accordingly fast paced. Solving problems and making progress was prized. The incentive for solving the cooling problem and therefore being able to fly for longer was to be able to do an A-B flight to the operator's new base. This would have been a great achievement and a clear demonstration of the capability of hydrogen fuel cell technology in aviation. It would also have allowed the operator's team to be reunited at the new base and would have provided more operational freedom when flying G-HYZA. But as the apparent pace of the project increased there appeared to be fewer flight debriefs with the full experimenting team and less information was fed back to the competent person, partly due to concerns regarding his work on a competing project.

While some elements of a Safety Management System were present within the organisation, a safety culture was still emerging as the organisation grew. Sole responsibility for safety was placed on the competent person by E Conditions, but given his availability, and the pace of the programme, it would have been prudent for the operator to also have nominated an individual responsible for risk and safety management, who was independent of the experimenting and management teams. This accident demonstrates the importance in a complex, fast paced, experimental project in putting in place an appropriate safety management system at the start of the programme.

### *E Conditions nominated roles*

The safety of an E Conditions project is dependent on the leadership of the competent person. As well as meeting the eligibility criteria, G-HYZA's competent person had relevant experience that made him an appropriate choice for the role. He had a long and broad engineering experience, and accountability for aircraft design and modification projects in the UK under other regulatory requirements.

The basic eligibility criteria for a competent person ensures they have a level of engineering competence and overall professionalism but does not ensure that they are equipped to provide effective safety leadership in a complex project like G-HYZA. The criteria in

CAP1220 would allow engineers with much less experience than G-HYZA's competent person to be authorised to be a competent person. This project had many different interacting aspects and was conducted in a team culture that was quite different from more typical aviation organisations. It was difficult for the competent person to provide effective leadership as an external contractor, particularly as he was physically remote and had a workload of other projects.

This was the competent person's first E Conditions project. The dossier he prepared was comprehensive and he believed that it would be followed and that his level of involvement in the programme was appropriate. He did not take account of differences between E Conditions and the more familiar EASA Part 21J projects in terms of qualifications, experience, procedures and cultural aspects of the team he was working with and realise that more oversight was needed.

Once the certificate of clearance was issued and test flying started, the competent person's involvement was limited for a combination of reasons. He assumed that G-HYZA's flight test team would behave in a similar way to trained test pilots and flight test engineers, that they would strictly follow the documented processes and would be aware of the issues they should contact him about. Accordingly, neither the competent person nor the operator had established a mechanism to ensure that the competent person was consulted about changes to the flight test programme or about technical issues experienced earlier in Phase 3.

CAP1220 states that, '…*it is for the Competent Person to keep the owner and Test Pilot appropriately briefed on all aspects of the test programme'*. It also requires that the principal test pilot *'will take responsibility for the safe conduct of airborne trials'.* As a cosignatory to the certificate of clearance, the test pilot also had a responsibility to understand the contents of the dossier and advise the competent person on safety issues related to the airborne trials, and on planned changes to the cleared test programme.

Post-flight briefings between the competent person, the operator and the principal test pilot were not always carried out and the competent person was not made aware that the predicted performance was unachievable, or informed of the significant technical issues that occurred on flights 80, 81 and 83. Had the competent person been aware of the previous loss of power events and the plan for the accident flight, he might have introduced some checks and balances such as a review of the risk assessment, additional ground testing or a re-emphasis of the pre-existing risk mitigations. This reveals the importance of establishing a comprehensive and robust feedback process, without which the competent person could not make an informed and timely assessment of the emerging risks as the programme progressed. CAP1220 is already clear about what the expectations on the competent person are.

### *Review of E Conditions*

The technology used in G-HYZA was already established outside aviation and the use of E Conditions provided the operator with a useful steppingstone towards developing a commercially viable, zero emission propulsion system.

At the time of the accident, E Conditions had been in force for a relatively short time. G-HYZA met all the criteria to operate under CAP1220; however, it was at the top end of the weight criteria, was multi-crew and one of the more complex of the nine projects to have started test flying. It was also a fast-moving international project, where many of the engineers did not have an aviation background and those that did were not experienced in experimental flight testing.

The reduction in the burden of regulation makes E Conditions attractive to a wide range of parties who wish to test a proof of concept ranging from relatively simple designs to high-profile, leading-edge technology. The scope of CAP1220 allows for a wide range of experimental projects some of which may be beyond the original intent of the authors in 2015 and beyond the experience and resources of some parties. Complex and commercially dynamic projects, or those involving multi-crew aircraft operation, may require additional provisions to ensure that they can be safely managed. Therefore, the following Safety Recommendation is made to the CAA:

**Safety Recommendation 2022–009**

It is recommended that the Civil Aviation Authority clarify the scope of projects considered suitable to be carried out under CAP1220, Operation of Aircraft Under E Conditions, and introduce additional provisions, where necessary, to cater for the full range of project complexity envisaged.

Apart from the basic details submitted on the declaration, there is no independent review of the suitability of a project for E Conditions or if all the required conditions have been fully addressed in the dossier. That judgement is delegated to the competent person who may be supported in this decision by the operator and the experimenting team where one exists. There is an option for the CAA to review the dossier, but it is unclear what would trigger this additional scrutiny. It was not triggered for G-HYZA, which at the time of the accident was one of the more complex projects conducted under E Conditions. Therefore, the following Safety Recommendation is made to the CAA:

**Safety Recommendation 2022-010**

It is recommended that the Civil Aviation Authority require an independent review of the Dossier for aircraft operating under the provisions of CAP1220, Operation of Aircraft Under E Conditions, to ensure the project meets the intent of the guidance and can be safely managed by a competent person.

There are a number of routes to be a competent person. In this accident, the competent person achieved his competent person status on the basis that he was registered as a CEng and member of the RAeS. CAP1220 states *'Within the scope of E Conditions there will be no limitations imposed on the Competent Person.'* This means that, any chartered aeronautical engineer recognised by the RAeS is automatically considered suitable to lead any E Conditions project as a competent person without further scrutiny or assessment.

Currently, there is no assessment required to ensure the competent person is able to fulfil their responsibilities, considering factors such as organisational relationships, conflicting interests, availability, skills and knowledge. A closer assessment could identify if the individual is suitable, or if additional measures are required, to assist the competent person manage the project. Therefore, to ensure the suitability of an individual to act as a competent person on a project undertaken under E Conditions, the following Safety Recommendation is made to the CAA:

**Safety Recommendation 2022–011**

It is recommended that the Civil Aviation Authority requires that the individual nominated as a competent person under CAP1220, Operation of Aircraft Under E Conditions, has the knowledge, skills, experience, and capacity to manage and oversee the experimental test programme registered on the Declaration.

CAP1220 clearly states that the competent person is responsible for the entire experimental test programme and is required to be involved on a flight-by-flight basis. There is also recognition that an individual might not be able to meet all the expectations of this role and the delegation of some responsibilities and establishment of a team might be required. In this accident a number of informal teams and an organisational structure developed without the necessary responsibility having been delegated. Feedback loops were not effective in ensuring the competent person could fulfil his responsibility in ensuring the safe conduct of the programme.

CAP1220 provides limited guidance on how to organise a complex experimental flight test programme, nor does it address the management of human, organisational and cultural factors that were seen in this accident. The safety of operating under E Conditions could be strengthened through additional guidance and training to help the competent person anticipate and manage factors that may be prevalent. The principal test pilot also has a key role in the safety of the programme, as well as the management and organisation of the flight, and would also benefit from this training and guidance. Therefore, the following Safety Recommendation is made to the CAA:

**Safety Recommendation 2022–012**

It is recommended that the Civil Aviation Authority enhance the guidance for the competent person and principal test pilot in the organisation, management, and conduct of the flight test programme, for an experimental aircraft project operating under CAP1220, Operation of Aircraft Under E Conditions.

### Survivability

The aircraft cabin, hydrogen storage and HV battery pack remained intact during the accident with no evidence of leakage of hydrogen or shorting of the HV battery. The hydrogen system was made safe by the observer operating the manual dump valve which vented the hydrogen to atmosphere.

## Conclusion

The accident occurred when electrical power was lost to both motors as the power source was changed, and the inverters locked out, at a position in the circuit where the aircraft could not safely glide to the runway. A number of factors contributed to the accident:

- Sufficient ground testing had not been carried out to determine the effect of the back voltage from a windmilling propellor on the inverter protection system.
- The emergency procedure to clear an inverter lock out after the protection system operated was ineffective.
- An investigation had not been carried out into a previous loss of power resulting from an inverter lock out, which occurred three flights prior to the accident flight.
- The risk assessment had not been reviewed following the loss of propulsion on two previous flights.
- Ad hoc changes were made to the flight test plan, including the position where the electrical power source was switched, without the knowledge of the competent person.

G-HYZA met all the requirements to be flown under E Conditions and a comprehensive dossier was produced by the competent person. However, this was a complex project, and the competent person was unable to completely fulfil his responsibilities as detailed in CAP1220. The competent person's involvement was restricted in a number of areas due to issues within the organisational relationships, the fast tempo of the project, other work commitments and restrictions from the COVID-19 pandemic. The operator's chief executive and the flight test director took on the day-to-day management responsibility for much of the programme. However neither individual had the necessary safety and flight test experience for that role and their focus was primarily on meeting key project targets.

## Safety Recommendations

The following Safety Recommendations were made to the CAA:

**Safety Recommendation 2022–008**

It is recommended that the Civil Aviation Authority develops guidance in CAP1220, Operation of Aircraft Under E Conditions, regarding the use of existing guidance on the design and positioning of controls and displays used in the operation of the aircraft.

**Safety Recommendation 2022–009**

It is recommended that the Civil Aviation Authority clarify the scope of projects considered suitable to be carried out under CAP1220, Operation of Aircraft Under E Conditions, and any additional provisions that might be required for more complex projects.

**Safety Recommendation 2022–010**

It is recommended that the Civil Aviation Authority require an independent review of the Dossier for aircraft operating under the provisions of CAP1220, Operation of Aircraft Under E Conditions, to ensure the project meets the intent of the guidance and can be safely managed by a competent person

**Safety Recommendation 2022–011**

It is recommended that the Civil Aviation Authority requires that the individual nominated as a competent person under CAP1220, Operation of Aircraft Under E Conditions, has the knowledge, skills, experience, and capacity to manage and oversee the experimental test programme registered on the Declaration.

**Safety Recommendation 2022–012**

It is recommended that the Civil Aviation Authority enhance the guidance for the competent person and principal test pilot in the organisation, management, and conduct of the flight of an experimental aircraft project operating under CAP1220, Operation of Aircraft Under E Conditions.

### Safety Actions

As a result of this accident the operator undertook the following safety actions:

- The design for the operator's future project would incorporate the learning in terms of handling back-EMF [voltage] due to windmilling.
- Future prototype testing would be limited to non-critical redundant situations until the powerplant design matures.
- The design and flight test of future programmes would follow CAA/EASA part 21J and aviation industry best practice.
- A safety management system based on a 'just' aviation culture would be established and include occurrence reporting, investigation, and corrective actions functions.
- Commercial pressure would be actively managed to ensure that it does not compromise safety.

*Published: 7 July 2022.*

## G-HYZA - ANNEX A

# SIGNIFICANT ASPECTS OF CAP1220, OPERATION OF EXPERIMENTAL AIRCRAFT UNDER E CONDITIONS

### Background

In 2006, the Royal Aeronautical Society (RAeS) raised concerns that UK aviation was not moving forward with new ideas or innovative technologies with the same vigour as in the past[1] and that fewer one-off projects were being undertaken. In response, the CAA formed a working group with the RAeS. The group concluded that there needed to be a simpler and more flexible system to enable projects to take to the air and the solution reached was E Conditions, which were first published under CAP1220[2] in November 2015.

A minor revision of E Conditions was published in November 2019 after a review by the CAA and RAeS working group. The working group planned to conduct a further review in 2022.

### Competent person

Under E Conditions, a registered competent person takes sole responsibility for the entire experimental test programme. Their responsibilities are listed in CAP1220 and include:

- Signing the declaration.
- Preparing the dossier.
- Managing the whole programme and taking sole responsibility for its safe conduct.
- Specifying the flight test area.
- Assessing all risks of the flight test programme, especially those to third parties, throughout the flight test programme.
- Signing the certificate of clearance.
- Not permitting any flights to take place until they are satisfied that identified risks are mitigated to an acceptable level.
- Ensuring that all participants in the test team are properly aware of the risks of the test programme.
- Attending flight test briefings.

One route to become a competent person is current membership of the RAeS and professional registration with the Engineering Council as a Chartered Engineer (C Eng) via the RAeS. The Engineering Council's '*Competence and Commitment Standard for*

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**Footnote**

[1] Royal Aeronautical Society (2006). *The design, development and production of light aircraft in the UK. Case for regeneration through regulatory change.*

[2] Civil Aviation Authority (2019). CAP1220 *Operation of experimental aircraft under E Conditions.* http://publicapps.caa.co.uk/docs/33/CAP1220EConditions_Edition2_Nov2019.pdf [Accessed on 29/11/2021]

*Chartered Engineers'* and the '*Statement of Ethical Principles'* in conjunction with the *'RAeS Codes of Conduct'* were considered sufficient to ensure the capability of such engineers to be solely accountable for the safety of E Conditions projects. Nevertheless, E Conditions envisaged that the competent person may need to enlist the help of other individuals to be able to fully fulfil their responsibilities.

Members of the CAA and RAeS working group stated that the underlying intention was that the competent person would have a close involvement in the test flying programme.

### Experimenting team

The experimenting team is the group of people who undertake the project to design, build and undertake the flight test programme. This team acts under the authority of the competent person.

### Principal test pilot

The principal test pilot is nominated by the competent person and is a principal member of the experimenting team. With regard to qualifications and experience, E Conditions states:

> *'No person may act as pilot in command of the aircraft except a person who has been judged by the E Conditions Competent Person to be appropriately qualified and trained for the purpose.'*

### Dossier

The dossier consists of four parts:

- Part A contains the declaration which provides a summary of the flight test programme and confirms that all identified safety risks had been assessed.
- Part B provides details of the aircraft, an assessment of its airworthiness. It also includes the instruments used during the flight.
- Part C provides details of the flight test programme, and specific conditions and limitations relating to the operation of the aircraft. This included the test area.
- Part D contains the risk assessment including any hazard mitigations.

The level and scope of the detail within the dossier is at the discretion of the competent person; CAP1220 provided guidance to assist the competent person in this regard.

### Risk assessment

The following philosophy is to be adhered to:

- The associated risk of serious injury to uninvolved third parties must be determined to be extremely improbable, where '*Extremely improbable has* *been determined to mean 1x 10-6 in FAA AC23.1309-1E. This figure is also an acceptable numerical value for the risk calculations within this guidance.'* and

- The associated risk of serious or fatal injury to the pilot and ground crew should be reasonably mitigated, and the pilot and groundcrew understand and have consented to the residual risk.

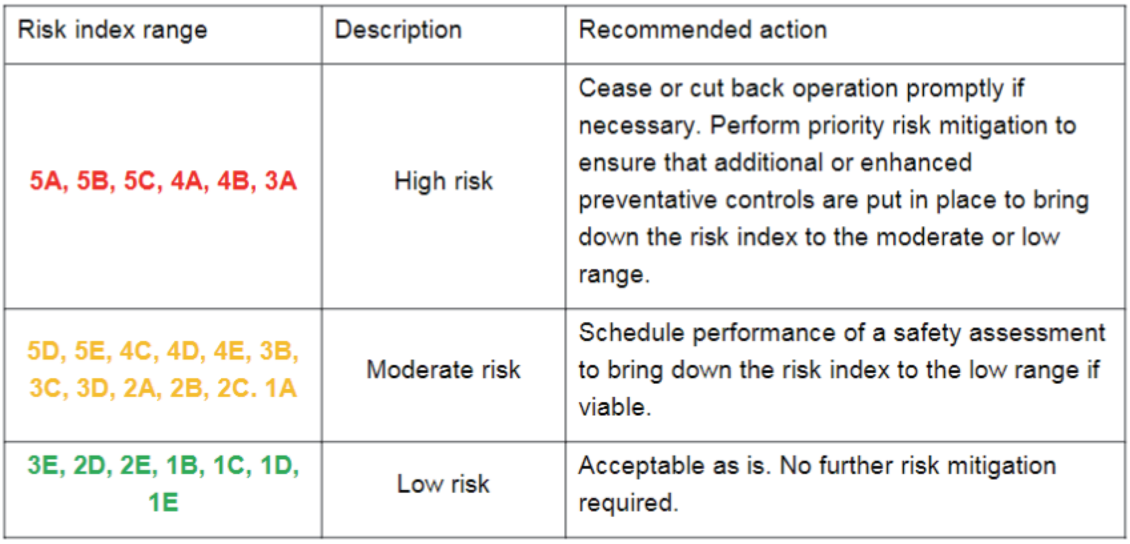
The ICAO Severity Table defines *'Hazardous'*, which has the value *'B'* as:

> *'A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied on to perform their tasks accurately or completely'*

Probability is the likelihood or frequency that a safety consequence or outcome might occur:

| Likelihood | Meaning | Value |
|---|---|---|
| Frequent | Likely to occur many times (has occurred frequently) | 5 |
| Occasional | Likely to occur sometimes (has occurred infrequently) | 4 |
| Remote | Unlikely to occur, but possible (has occurred rarely) | 3 |
| Improbable | Very unlikely to occur (not known to have occurred) | 2 |
| Extremely improbable | Almost inconceivable that the event will occur | 1 |

The tolerability criteria is the combine value where 5A, 5B, 5C, 4A, 4B and 3A are considered as high risk with the following recommended action:



| Risk index range | Description | Recommended action |
|---|---|---|
| 5A, 5B, 5C, 4A, 4B, 3A | High risk | Cease or cut back operation promptly if necessary. Perform priority risk mitigation to ensure that additional or enhanced preventative controls are put in place to bring down the risk index to the moderate or low range. |
| 5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C. 1A | Moderate risk | Schedule performance of a safety assessment to bring down the risk index to the low range if viable. |
| 3E, 2D, 2E, 1B, 1C, 1D, 1E | Low risk | Acceptable as is. No further risk mitigation required. |

### Flight test area

E Conditions aircraft are only permitted to operate in a specified flight test area unless operating a ferry flight with permission of the CAA. This flight test area, including maximum and minimum safe heights, is required to be specified by the competent person.

### Flight test safety

CAP1220 provided guidance on good practice to maximise flight safety and includes the following points:

- Aircrew should be suitably experienced and current to carry out the intended flight test programme.
- Observers should only be carried if it is considered that it would be beneficial to overall safety for an observer to participate in the testing and that this justifies the hazard to the additional person.
- Crew Resource Management principles should be considered as part of the flight test planning process.
- For any flight test, a comprehensive flight briefing should be conducted. The briefing should be attended by the flight crew participating in the flight, the competent person and other specialists as required.
- Each test flight should be planned, and only planned test points should be addressed during any sortie. Ad-hoc testing should not occur.
- The criteria for terminating individual tests should be defined, especially for any testing entailing elevated risk levels.
- Plan the flight, fly the plan – only planned test points should be addressed during any sortie. Contingency test points may be carried into a sortie; however, ad-hoc testing should not occur.

### Certificate of clearance

All flights are required to be covered by a certificate of clearance which is signed by the competent person and pilot.

## ACCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Rotorway Executive 162F, G-JDHN | |
| **No & Type of Engines:** | 1 Rotorway RI 162F piston engine | |
| **Year of Manufacture:** | 1998 (Serial no: 6324) | |
| **Date & Time (UTC):** | 2 April 2021 at 1500 hrs | |
| **Location:** | Near Ledbury, Herefordshire | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - 1 |
| **Injuries:** | Crew - 1 (Minor) | Passengers - 1 (Minor) |
| **Nature of Damage:** | Helicopter damaged beyond repair | |
| **Commander's Licence:** | Private Pilot's Licence | |
| **Commander's Age:** | 54 years | |
| **Commander's Flying Experience:** | Approximately 300 hours (of which 80 were on type)<br>Last 90 days - not declared<br>Last 28 days - not declared | |
| **Information Source:** | AAIB Field Investigation | |

### Synopsis

The helicopter was in a stable cruise when the pilot heard a very loud noise which may have been caused by unburnt fuel igniting in the exhaust. This resulted in the helicopter reacting in a way that the pilot could not rationalise in the short time available, so he successfully autorotated to land in a field. At the end of the ground run, the left skid caught on uneven ground and the helicopter rolled over onto its left side. Both the pilot and passenger managed to escape with minor injuries.

It is suspected that defects in the cylinder 3 exhaust valve sealing may have been the cause of unburnt fuel in the exhaust system.

### History of the flight

At around 1400 hrs on the day of the accident, the pilot prepared the helicopter for a flight to the Brecon Beacons National Park. Earlier in the day he had flown a training sortie in a Bell B206 JetRanger at Shobdon Aerodrome, and the weather had been fair, but he noticed that cloud was starting to build to the west. Consequently, he planned to route east towards the Malvern Hills where the weather was generally fair with light winds from the northeast. After takeoff, the helicopter was established in a cruise at 1,500 ft and 80 mph and the pilot turned towards Ledbury (Figure 1) to route along the Malvern Hills from south to north.

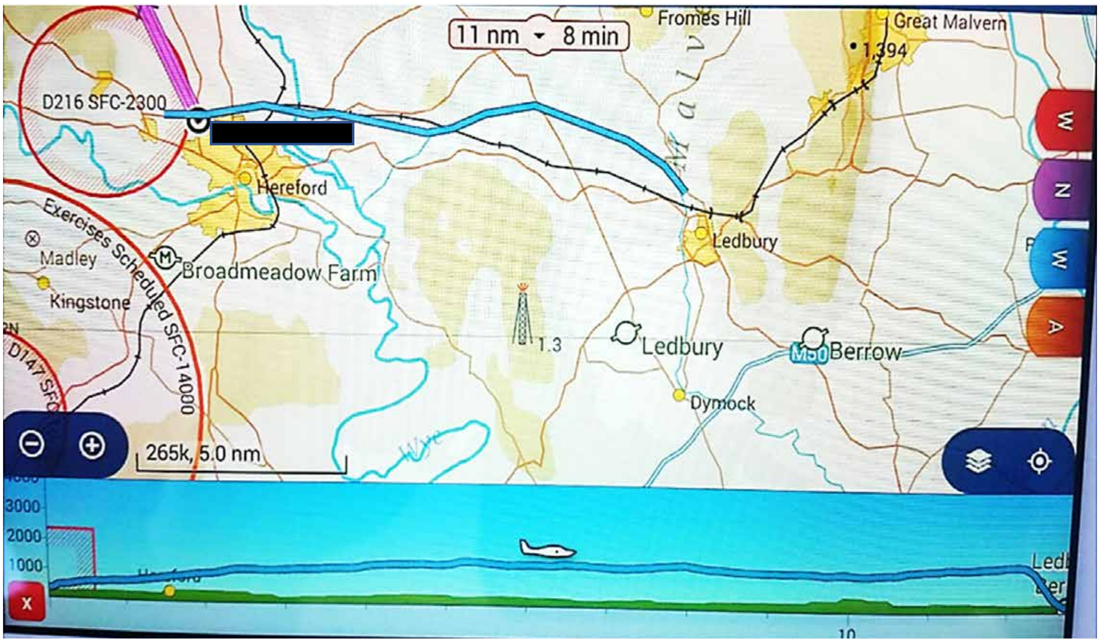


**Figure 1**

G-JDHN's recorded track from SkyDemon application
(used with permission)

As he approached Ledbury, the pilot reported hearing an "almighty bang" that appeared to come from the rear of the helicopter. The noise was sufficiently loud to be described by witnesses on the ground as sounding like an "explosion". The pilot stated that the helicopter "twitched" in yaw to the right as though it had been pushed and then pitched nose up rapidly. His immediate thought was that drive to the tail rotor had been lost but he was confused why the helicopter yawed in the opposite direction to which he expected. He levelled the attitude then entered autorotation by lowering the collective lever. The engine indications appeared normal. The pilot noted that he had applied full left yaw pedal but there appeared to be no response in yaw. He also noticed that the rotor rpm was indicating at the top of or just outside the gauge's arc at 110%.

He assessed the position of the collective lever to be approximately the same as during takeoff and, consequently, expected the rotor rpm indication to be lower. He raised the collective lever further in an attempt to reduce rotor rpm but was concerned that it might reduce it too much. He considered the possibility of a false indication on the gauge so decided to maintain the current collective lever position and focus on reaching the field he had selected for landing.

During the descent the pilot recognised that he was heading towards some polytunnels, so he turned away from them onto a southerly heading. He noted there were power cables in the new approach path but was confident that his glide angle would clear them. He reported having no response from the tail rotor. The pilot flared the helicopter and landed on the rear half of the landing skids at a "walking pace". During the ground run, the front of the left skid dug into a rut in the ground causing the helicopter to pitch forward and roll over onto its left side, after which it came to rest facing north (Figure 2).

**Figure 2**
G-JDHN at the accident site (used with permission)

The pilot evacuated the helicopter and assisted the passenger to escape through the front of the cockpit. Whilst he was doing this, he noticed that fuel was leaking from the right fuel filler cap which had been damaged during the landing. Emergency services arrived on scene quickly having been alerted by eyewitnesses on the ground. The pilot and the passenger were taken to hospital for evaluation of their minor injuries.

## Accident site

The accident site was in a fallow field approximately two miles to the north of Ledbury. The grass was short, but the ground was uneven with some holes. The helicopter was lying on its left side with the tail structure broken in several pieces, although the tail rotor section was still attached by a control cable. Various loose bits of tail structure, including sections of drive belt, were scattered a short distance to the south of the fuselage. The helicopter remained on its left side for approximately two hours until it was recovered back to the pilot's private helipad.

## Recorded information

The primary and secondary Dual Engine Control Units (DECUs) record many engine parameters once a second. The available data was downloaded and three significant parameters, from the primary DECU, were plotted against time since engine start (Figure 3).

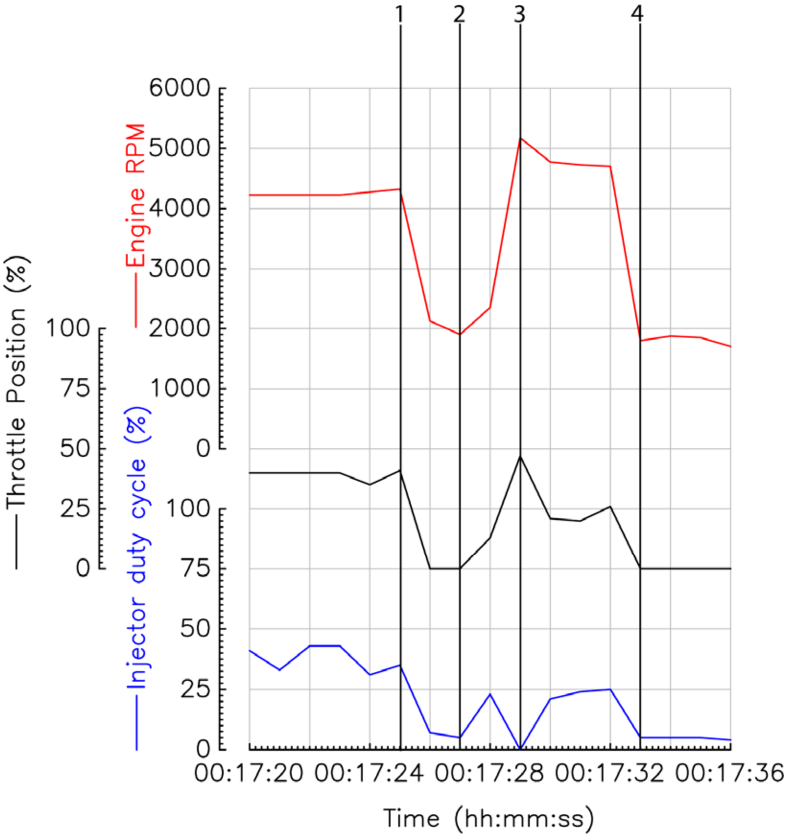


**Figure 3**

Primary DECU download of the significant parameters

The helicopter was in the cruise with all parameters stable up until 00:17:25 where it is considered that the bang occurred (1). Two seconds later the throttle was closed to zero and the engine speed reduced accordingly (2). A further two seconds later the throttle was opened to just above cruise setting, but the engine speed reached 110% (5,175 rpm) and the engine limiter initiated by cutting the injector duty cycle to zero (3). Over the next four seconds the throttle was adjusted and eventually closed (4), and it remained in that position until the fuel was shut off and the engine stopped several seconds before the landing.

## Aircraft information

G-JDHN was a light homebuilt helicopter from a premanufactured kit with a vertically mounted four-cylinder engine driving the main and tail rotor, and the engine accessories. It was built in 1998 and had flown 674 hours, the second highest of all the 162F helicopters on the UK register. It had previously been registered as G-FLIT and was the subject of a 2013 AAIB accident report[1]. In the AAIB database there are 27 reports of Rotorway helicopter accidents and incidents between 1980 and publication of this report, of

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**Footnote**

[1] https://assets.publishing.service.gov.uk/media/54230296ed915d1374000b3b/Rotorway_Executive_162F_G-FLIT_02-13.pdf [accessed 23 March 2022].

which 14 have involved an emergency landing that ended with the helicopter rolling over. The latest evolution of the 162F, the Talon, has much stronger landing gear with longer skids.

The cabin of the 162F is a composite construction with space for two people to sit side by side. The analogue instruments are laid out on the central console with additional gauges in front of the left (pilot's) seat (Figure 4 left). The rotor and engine speed are displayed side by side, in percent, on a dual gauge (Figure 4 right).

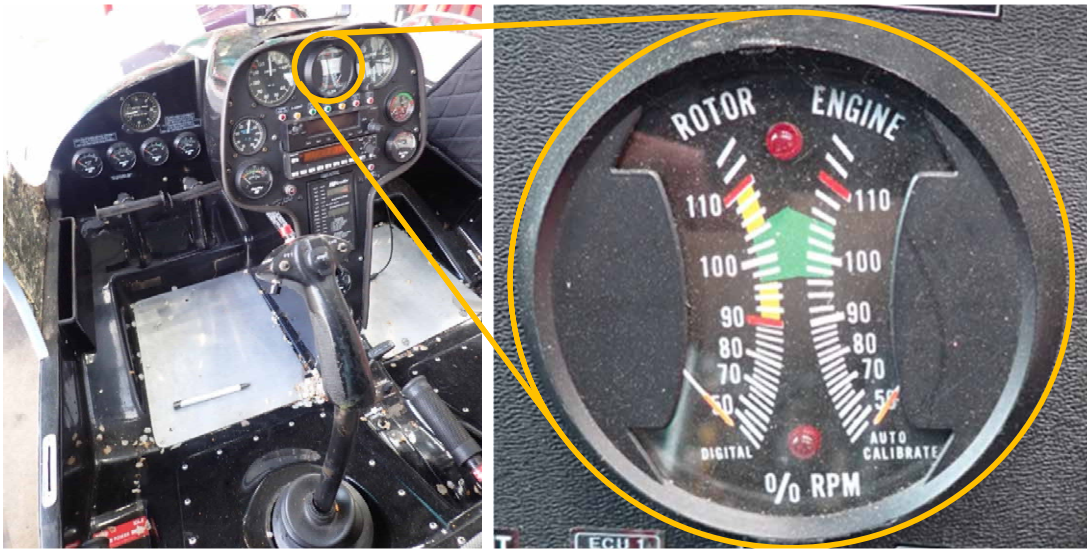


**Figure 4**

G-JDHN cockpit layout (left) and rotor / engine combined rpm gauge (right)

The throttle is operated by a twist grip on the collective lever to the left of the pilot's seat. There is no mechanical or electronic automated control of the throttle when moving the collective lever and so the pilot must manually account for any collective movements with a change in throttle position to maintain the engine speed in the green arc.

The flat-four engine (Figure 5) was designed and built specifically for the 162F helicopter and is installed with the crank shaft oriented vertically. The engine has two valves per cylinder and is water cooled. Fuel metering and timing is controlled by a primary DECU which uses various sensors to ensure optimal running. A secondary DECU, using pre-programmed default values instead of sensor data, is installed in case of a failure of the primary DECU. The drive from the crankshaft is transferred to a secondary drive shaft by four V belts in parallel, with a movable spring-loaded third pulley wheel which is operated as a clutch during start up. The pulley wheel tensions the drive belts by an over centre linkage operated by the pilot pushing on a steel T-handle lever in the cabin bulkhead (Figure 6). Drive to the main rotor head from the secondary shaft is via a triplex drive chain whilst external engine accessories, such as alternator, cooling fan and water pump, are driven from separate V belts. The exhaust pipe from the four cylinders has a single silencer and tail pipe suspended beneath the tail boom.

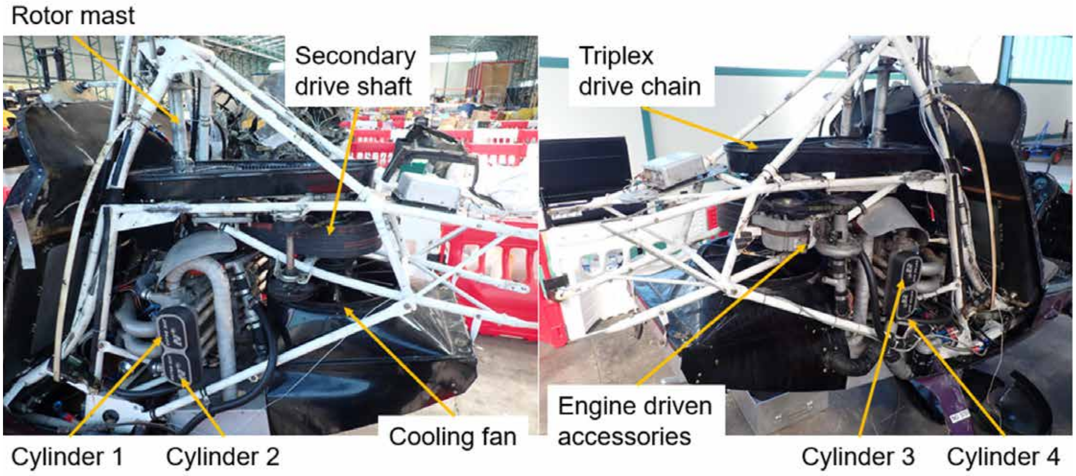


**Figure 5**

G-JDHN engine layout. Helicopter left side (left) and right side (right)

**Figure 6**

Cockpit looking aft with clutch lever disengaged

Drive to the tail rotor is via three V drive belts in series from the secondary drive shaft (Figure 7). The secondary drive shaft is vertical, but the tail rotor drive shaft is horizontal, so there are two intermediate pulleys aligned 30° from the previous pully thereby rotating the drive. All three belts in the system are tensioned by adjusting the position of the last pulley, and the belt tension is checked by the pilot as part of the pre-flight inspection using a special tool to verify 1⅜" deflection with 10 lb of force applied.

The tail drive belts on G-JDHN were replaced during annual maintenance in February 2020, and they were inspected and had their tension checked in February 2021 with no defects found. The belts had accumulated 43.8 hours of operation by the time of the accident flight, well within the replacement requirement of 250 hours or two years.

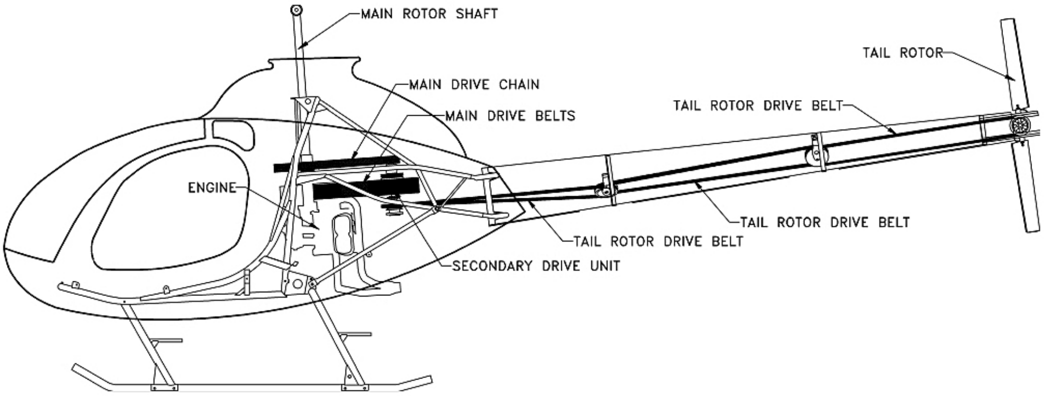


**Figure 7**

G-JDHN Rotor drive system

The helicopter was maintained in accordance with the manufacturer's prescribed schedule and had its last annual check four flying hours prior to the accident flight in February 2021. The helicopter had completed 673 hours and had an engine top end overhaul at 494 hours. The overhaul of the cylinder heads was undertaken by the manufacturer, but no records of the work carried out could be obtained. A cylinder compression test was carried out during each annual check and every year it had passed. The results from the test in February 2021 are included in Table 1 with the pass criteria of 68 psi minimum.

## Aircraft examination

The helicopter was recovered from the pilot's private helipad to the AAIB for further inspection. No pre-existing defects were found with the main rotor drive train, flight controls or external engine accessories. It was noticed that the lock barrel of the right fuel cap was missing. The main body of the cap was still in place, but with the barrel missing it would no longer seal the fuel filler pipe. The body of the cap was undamaged.

The tail boom structure was badly damaged with the tail rotor assembly and vertical fin having broken off as one piece (Figure 8 left), leaving approximately 30 cm attached to the fuselage structure. The lower skid and the upper vertical fin of the tail rotor assembly showed signs of impact with the ground, and there was minor damage to the tail rotor blades from ground contact including the loss of a blade end cap. The rest of the structure had broken into many smaller pieces including the two aluminium castings that supported the intermediate pulleys (Figure 8 middle). On both intermediate pulley wheels there were impact marks and soil lodged into the V grooves. The temperature stickers on the pulleys had not recorded an increase in temperature during operation. All three tail rotor belts had been damaged and the third (nearest the tail rotor) was in two pieces. The belts were examined and were in good condition with no indications that the belts had been slipping or of any other defects. The damage to the ends of the belts was consistent with overload failure (Figure 8 right).

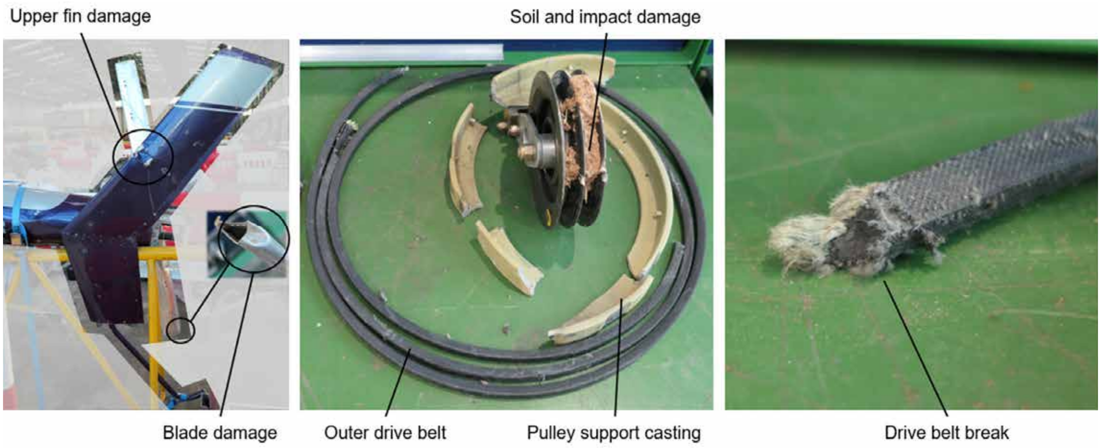


**Figure 8**

Tail rotor, intermediate pulley and drive belt damage

The engine was inspected, and engine oil was found in the inlet manifold, predominately in the common inlet plenum but also in the manifold for cylinder 1 (upper left) and 2 (lower left). Each cylinder was leak tested with 50 psi air with the engine cold and the piston at top dead centre. The results are in Table 1.

| Cylinder | Leak check at 80 psi (Feb 2021) | Leak check at 50 psi AAIB | Comments from AAIB leak test |
|---|---|---|---|
| 1 | 74 psi | 44 psi | Air into the crankcase |
| 2 | 75 psi | 39 psi | Air into the crankcase and 1-2 psi inlet valve leak |
| 3 | 74 psi | 34 psi | Air leaking into the exhaust |
| 4 | 74 psi | 44 psi | Air into the crankcase |

**Table 1**

Results from the cylinder leak tests

The cylinder heads were removed, and engine oil was found in all cylinders but there was no readily visible evidence to explain the leak test results. The inlet valve from cylinder 2 and the exhaust valve from cylinder 3 were removed and examined in detail. The valves and valve seats were examined using an optical microscope at magnifications up to x120. Multiple surface defects were found on both valves and their corresponding seats (Figures 9 to 12).

The width of the contact area between the inlet valve and the seat is approximately 400 µm and the largest surface defect was 640 µm wide, which crossed into the contact area.

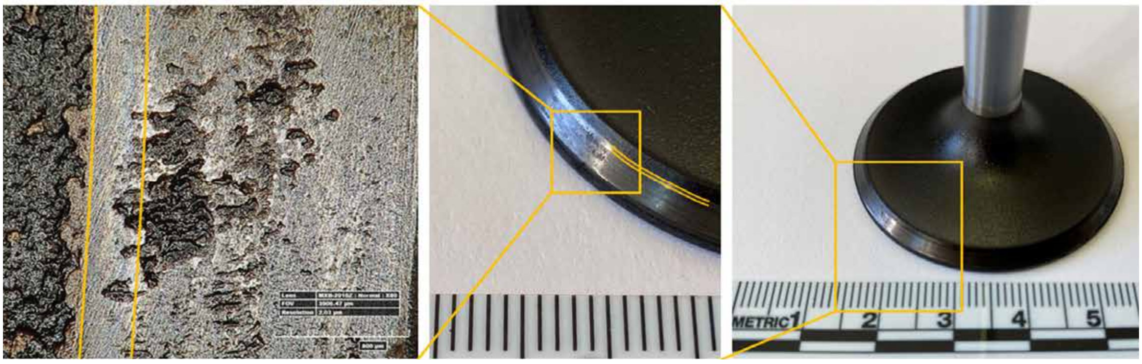


**Figure 9**

Cylinder 2 inlet valve surface defect, valve seat contact area highlighted

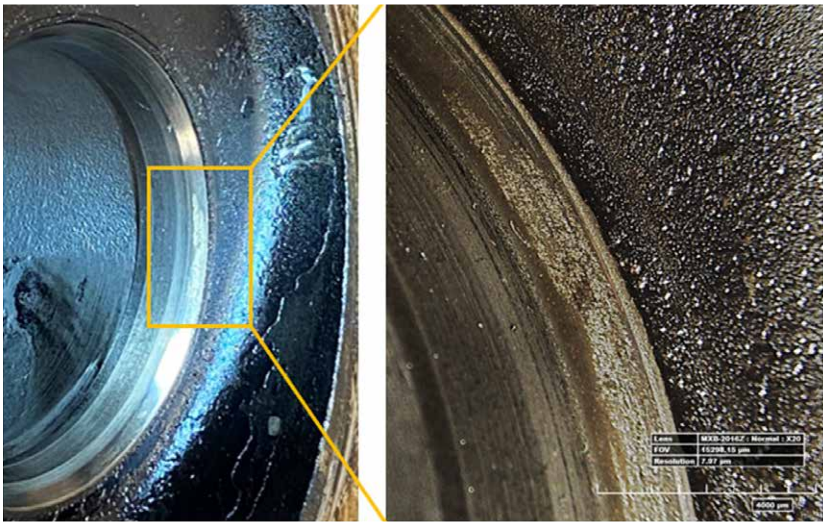


**Figure 10**

Cylinder 2 inlet valve seat surface defects

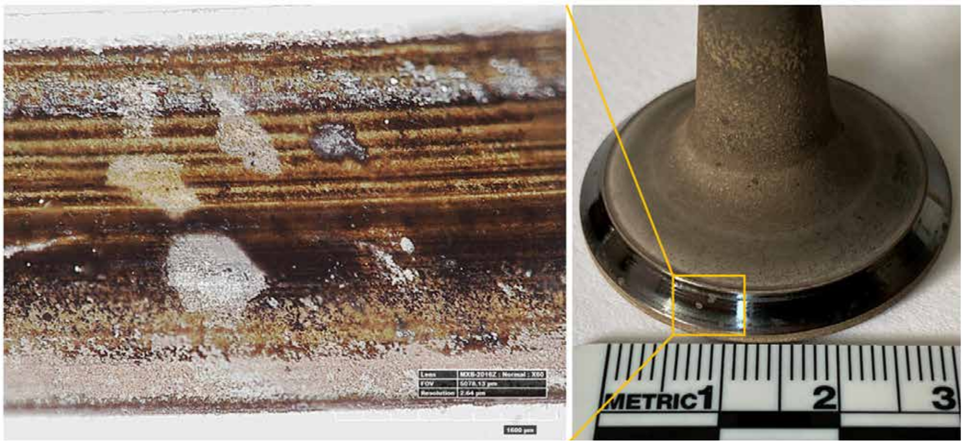


**Figure 11**

Cylinder 3 exhaust valve surface defects

**Figure 12**

Cylinder 3 exhaust valve seat surface defects

## Survivability

When the helicopter rolled over at the end of the ground run, the passenger in the right seat was injured on the left shoulder by the clutch lever. With the clutch disengaged, the 5 mm diameter steel lever protruded approximately 200 mm into the cabin and was angled towards the passenger side (Figure 6). It could not be determined why the clutch disengaged.

A modification is available to replace the lever and over centre linkage with an electro-mechanical actuator to operate the clutch system.

## Personnel

### *Pilot background*

The pilot stated that he started flying in 1993, then after a long break from training he gained his PPL(H) in February 2020, conducting his training on a Robinson R22. He added the 162F to his licence in September 2020. Additionally, he gained a rating on the B206 in April 2021. His total time on these types was approximately 300 hours, of which 80 hours was on the 162F. The pilot did not provide the AAIB with documentary evidence of his hours or recent flying. The pilot had flown the B206 on the morning of the accident flight and reported experiencing no difficulty in switching between helicopter types.

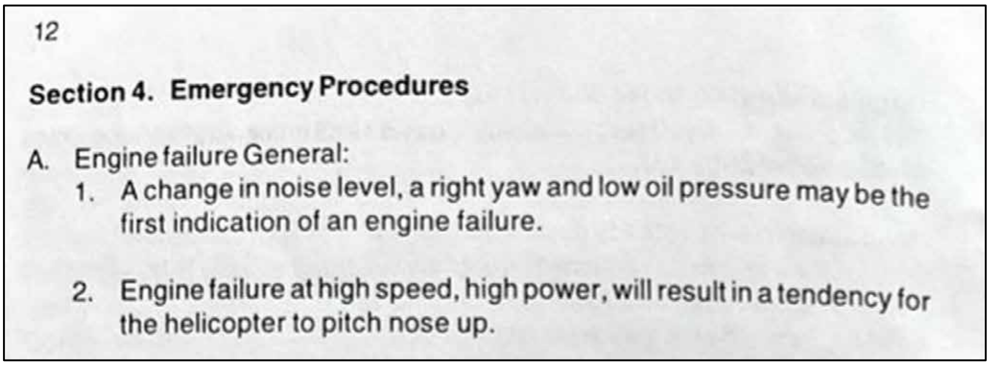
## Aircraft performance

### *Longitudinal oscillation*

The 162F is known to exhibit a longitudinal oscillation in the cruise. If disturbed in level flight, the helicopter tends to oscillate in pitch as it attempts to re-establish the conditions from which it was disturbed. This manifests itself to the pilot as the nose pitching up and down with corresponding movement of the cyclic stick which, if left uncorrected, would lead to unstable flight conditions. The 162F pilot learns to 'dampen' the movement by control inputs on the cyclic stick.

*Engine failure in cruise*

The Flight Manual (FM) contains the following guidance (Figure 13) on dealing with an engine failure and notes that a right yaw and tendency to pitch nose up are characteristics of a loss of power in cruise flight:



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**Section 4. Emergency Procedures**

A. Engine failure General:

1. A change in noise level, a right yaw and low oil pressure may be the first indication of an engine failure.

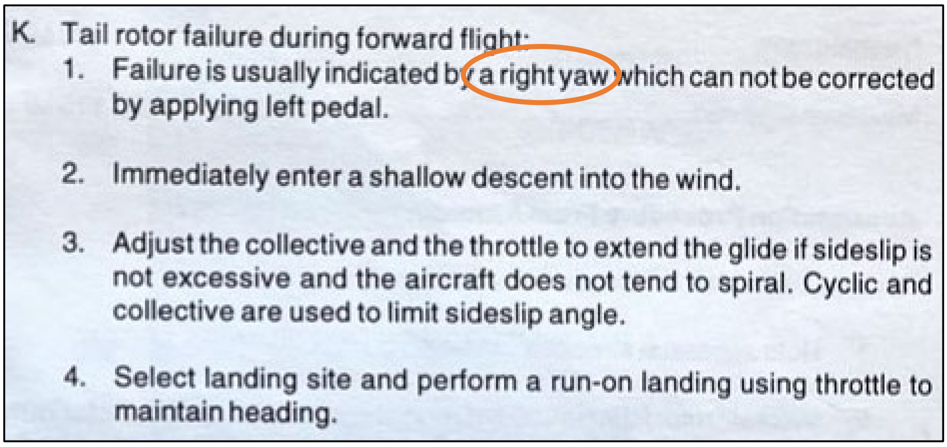
2. Engine failure at high speed, high power, will result in a tendency for the helicopter to pitch nose up.

**Figure 13**

FM engine failure emergency procedure

*Flight Manual guidance on tail rotor failure*

The FM or, on later models, the Pilot's Operating Handbook (POH), is issued with each kit and remains with the aircraft. The issue date is checked as part of the revalidation process of the Permit to Fly and any major changes subsequently issued by the manufacturer are included at the front of the manual as an amendment. G-JDHN's FM contained the following entry for a '*tail rotor failure in forward flight*' (Figure 14), stating that a '*right yaw*' would be indicative of a tail rotor failure:



K. Tail rotor failure during forward flight:

1. Failure is usually indicated by a right yaw which can not be corrected by applying left pedal.

2. Immediately enter a shallow descent into the wind.

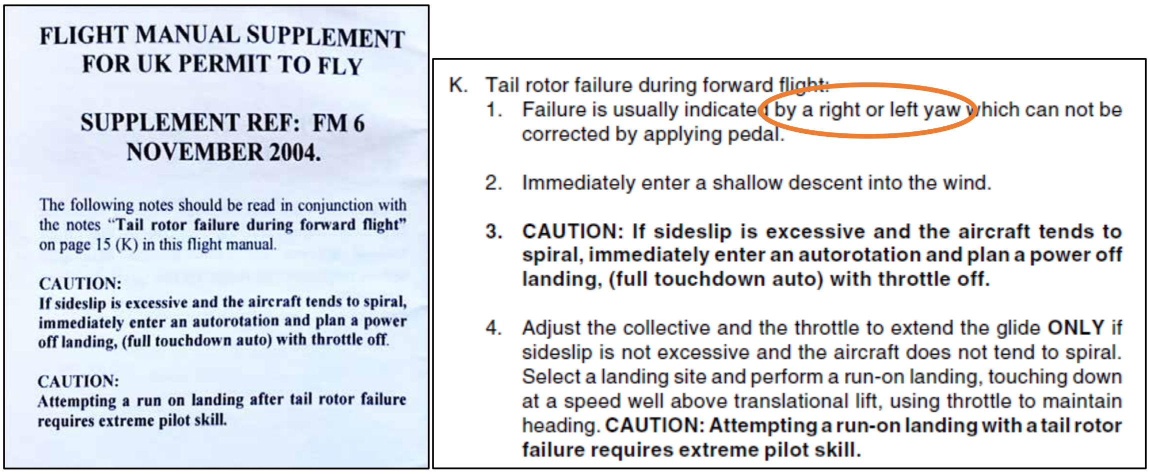
3. Adjust the collective and the throttle to extend the glide if sideslip is not excessive and the aircraft does not tend to spiral. Cyclic and collective are used to limit sideslip angle.

4. Select landing site and perform a run-on landing using throttle to maintain heading.

**Figure 14**

FM tail rotor failure during forward flight emergency procedure

G-JDHN's FM contained an amendment to this emergency procedure, issued in November 2004 (Figure 15 left).



**FLIGHT MANUAL SUPPLEMENT**
**FOR UK PERMIT TO FLY**

**SUPPLEMENT REF: FM 6**
**NOVEMBER 2004.**

The following notes should be read in conjunction with the notes "**Tail rotor failure during forward flight**" on page 15 (K) in this flight manual.

CAUTION:
**If sideslip is excessive and the aircraft tends to spiral, immediately enter an autorotation and plan a power off landing, (full touchdown auto) with throttle off.**

CAUTION:
**Attempting a run on landing after tail rotor failure requires extreme pilot skill.**

K. Tail rotor failure during forward flight:

1. Failure is usually indicated by a right or left yaw which can not be corrected by applying pedal.
2. Immediately enter a shallow descent into the wind.
3. **CAUTION: If sideslip is excessive and the aircraft tends to spiral, immediately enter an autorotation and plan a power off landing, (full touchdown auto) with throttle off.**
4. Adjust the collective and the throttle to extend the glide **ONLY** if sideslip is not excessive and the aircraft does not tend to spiral. Select a landing site and perform a run-on landing, touching down at a speed well above translational lift, using throttle to maintain heading. **CAUTION: Attempting a run-on landing with a tail rotor failure requires extreme pilot skill.**

**Figure 15**

FM supplement FM6, dated November 2004, and revised POH, dated 2005

The two cautions shown in Figure 15 left were subsequently incorporated into a revised POH issued with aircraft manufactured from 2005 (Figure 15 right). The indication, '*left yaw*' was included as an additional possible indication of a tail rotor failure in forward flight.

The manufacturer was consulted regarding the wording of the original FM and the inclusion of *'left yaw'* in a subsequent POH. They commented that due to the recent change in ownership of the company, they were unable to provide an authoritative answer. They suggested that the original manufacturer may have intended the emergency procedure to be applicable to any tail rotor malfunction, which could include loss of tail rotor authority and control malfunctions, hence the direction of yaw could be in either direction.

*Tail rotor*

All conventional helicopters require a system to oppose the torque applied to the main rotor head by the engine(s). On the 162F, the rotor head rotates clockwise (when viewed from above) so the torque reaction will cause the fuselage to yaw to the left (anti-clockwise). The tail rotor produces a thrust to counter this effect and to provide the pilot with directional control. An increase in engine torque will therefore require an increase in thrust produced by the tail rotor. This is achieved by the pilot applying right yaw pedal, which will increase pitch on the tail rotor blades, producing more thrust. If drive to the tail rotor is lost, then the helicopter will yaw to the left until the pilot closes the throttle and enters autorotation, thereby removing the applied torque.

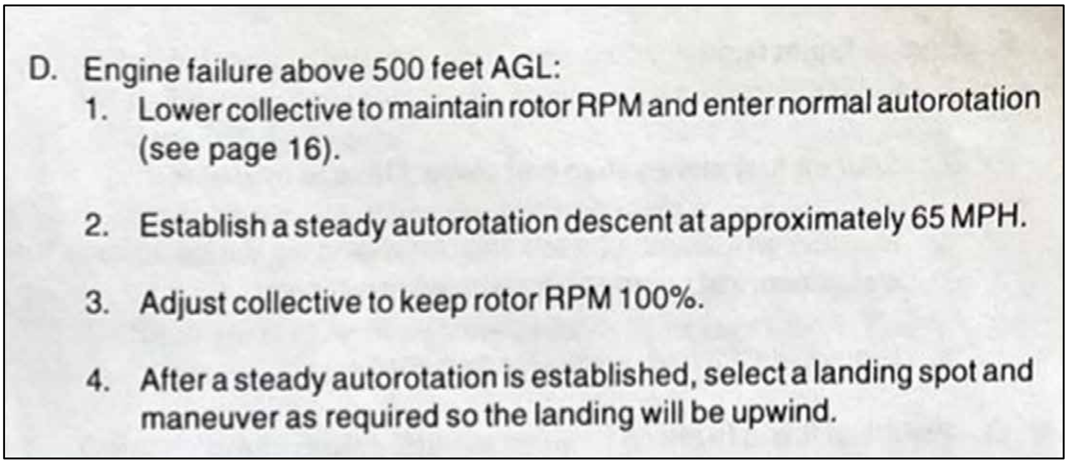
The main rotor blades on the R22 and B206 turn anti-clockwise when viewed from above. If drive to the tail rotor is lost on these types, the helicopter will yaw to the right until the pilot takes appropriate action. Therefore, the actions required are the reverse of the 162F.

*Main rotor blades*

The main rotor blades on the 162F are designed such that when the collective lever is in the fully down position, the angle of the blades is set to negative 2° pitch. The manufacturer stated that this feature was intended to assist the preservation of rotor rpm when entering autorotation. However, supporting documentation for this design intent was not available from the manufacturer for review.

*Autorotation*

The FM contained the following instruction for entering autorotation (Figure 16):



D. Engine failure above 500 feet AGL:

1. Lower collective to maintain rotor RPM and enter normal autorotation (see page 16).
2. Establish a steady autorotation descent at approximately 65 MPH.
3. Adjust collective to keep rotor RPM 100%.
4. After a steady autorotation is established, select a landing spot and maneuver as required so the landing will be upwind.

**Figure 16**

FM actions for engine failure above 500 ft AGL

After entering autorotation by lowering the collective lever to the full down position, the rotor rpm increases quickly, and the nose will drop. The pilot must then raise the collective to increase pitch on the blades into the positive range, hence increasing drag to slow them down. Adjusting the position of the collective lever in this way allows the pilot to control and maintain the rotor rpm within the green arc (96 to 104%).

When the collective lever is fully lowered on the R22 and the B206, the main rotor blades do not move to a negative pitch setting. Therefore, the corresponding range of movement of the collective lever, from the full down position to a setting that maintains rotor rpm within an optimal range for autorotation, is less than that required for the 162F.

When established in autorotation there is no significant torque reaction, so the helicopter will tend to yaw in the direction of rotation of the rotor blades due to friction in the drive train. However, as the tail rotor is still being driven and producing thrust, this rotation can normally be controlled by application of yaw pedal in the opposite direction. If main rotor rpm increases beyond the recommended limits, the tail rotor rpm and consequently the thrust it is producing, will increase requiring more yaw pedal input to control. On the 162F, this will require left pedal input to prevent further yaw to the right.

The Flight Manual contains the following note regarding autorotation training:

> *"NOTE:*
>
> *AUTOROTATION TO THE GROUND IS NOT RECOMMENDED DURING TRAINING AND PRACTICE."*

## Analysis

### *Exhaust after fire*[2]

The pilot established the helicopter in a steady cruise at 80 mph and 1,500 ft when he heard a very loud noise, which he described as an "almighty bang". Various witnesses on the ground described the noise as sounding like an "explosion". The helicopter was examined extensively for sources that could have produced a noise which could be described as an explosion loud enough to be heard on the ground below.

During the engine examination oil was found in the inlet plenum, and two cylinders leaked air during a leak test. After the helicopter rolled over, it was lying on its left side with cylinders 1 and 2 lowest. The helicopter remained in this attitude for approximately two hours before it was righted and lifted onto a vehicle for recovery. Hot engine oil could have passed the piston rings (a labyrinth seal) and into the cylinder head during this time. The defects in the sealing of the inlet valve in cylinder 2 could have resulted in the oil slowly seeping past the valve and into the inlet manifold and plenum.

The defects observed in the sealing faces of the exhaust valve in cylinder 3 may have allowed unburnt fuel to pass the valve and enter the exhaust system during the accident flight. This unburnt fuel would have accumulated in the exhaust until it was ignited by the exhaust gases and caused an explosion or after fire in the exhaust system. This could have produced a loud noise similar to that described by the pilot and reported by the witnesses on the ground. The after fire would have caused an increase in the internal pressure of the exhaust system which would have momentarily restricted the flow of exhaust from the other cylinders. This restriction would have resulted in a hesitation in power output from the engine.

The cylinder 2 inlet valve and cylinder 3 exhaust valve were in poor condition considering the engine had completed 179 hours since a cylinder head overhaul. It was considered that the defects seen were the result of normal operation of the engine over a prolonged period, where localised heating had resulted in a deterioration in the surface. The maintenance requirement to have a top end overhaul every 500 hours would be to rework any damage before it affected engine performance. It was not possible to obtain the records of the top end overhaul at 497 hours and therefore to determine if any work had been carried out on these valves.

---

**Footnote**

[2] After fire – The term is used to differentiate between a detonation after the combustion chamber and contained within the exhaust, and a backfire, which occurs in or before the combustion chamber and travels into the inlet manifold.

The compression test carried out during the annual inspection performed four hours before the accident flight did not show any leaking from the valves, whereas the test after the accident showed an appreciable leak from two valves. The tests differed in the air pressure used (80 psi for the annual inspection and 50 psi for the investigation), and the annual inspection test was performed on a hot engine. During normal engine operation the valves are free to rotate, and it is possible that between the annual inspection and the accident, the exhaust valve in cylinder 3 rotated so that a defect in the valve and the head aligned and created a leak path.

*Uncommanded right yaw and tail rotor control*

The pilot described the helicopter “twitching” to the right then pitching nose up. The investigation could not positively identify the cause of the yaw but considered it possible that a momentary interruption in power, caused by the detonation of unburnt fuel in the exhaust, could produce a transitory yaw to the right. The pilot reported that engine indications appeared to be normal immediately after the noise.

The pilot concluded from the sudden noise and uncommanded yaw to the right that he had lost drive to the tail rotor and consequently entered autorotation and shut off the engine. In the 162F, loss of tail rotor thrust would cause a yaw to the left. The pilot was aware of this apparent contradictory symptom stated that he, but that did not appear sufficient to change his initial diagnosis. There was no evidence to suggest that the wording of the FM influenced his understanding. It is possible that his experience flying the R22 and B206 for approximately 70% of his accumulated hours, where the yaw would be to the right, reinforced his immediate response.

The pilot stated that during the autorotation he applied full left pedal with no response in yaw control. He described the rotor rpm as being at the top, or just outside of the arc, which would also increase the rpm of the tail rotor. The corresponding increase of thrust would have to be countered by a left pedal input to prevent yaw to the right. It is likely that in countering the combined effects of transmission friction and increased tail rotor rpm, left pedal input reached the limits of its travel, reinforcing the pilot’s belief that he had a loss of drive to the tail rotor.

The investigation considered the possibility of a tail rotor drive belt failure but concluded it was unlikely as all three drive belts showed evidence of the same overload failure mechanism. All three belts were in good condition and there was no evidence of the effects of incorrect belt tension which often precedes a belt failure. The belts were new, the tension had been checked recently by the maintenance and repair organisation and the pilot prior to the flight, and the temperature indicators on the pulleys did not show elevated temperatures. It was considered that an inflight failure of the drive belts would not have produced a noise consistent with the description by the pilot and the witnesses on the ground. The increase in tail thrust and inability to apply enough left pedal further suggests the tail rotor was still operational throughout the flight.

### *Pitch up*

The FM stated that an engine failure at high speed and high power would result in a tendency for the nose of the helicopter to pitch up. However, it is not clear to what extent this would occur following a transitory loss of power.

The unexpected loud noise may have induced a 'startle' effect on the pilot, causing him to relax his grip on the cyclic stick. The longitudinal oscillation at cruise speed would have caused the nose to pitch up if it was not damped by the pilot. It is possible that the marked pitch up the pilot reported was caused by a combination of these two factors.

### *Throttle limiter activated*

Immediately after the pitch up response, the data showed that the throttle was fully closed, and it was likely that the collective was fully lowered as a simultaneous action as the pilot entered autorotation. In combination, the pitch up and lowering of the collective lever would have caused the rotor rpm to increase rapidly, and to reduce the rpm the pilot would have had to raise the collective. During normal operations, raising the collective would have led the pilot to open the throttle (to maintain rotor rpm), and the data showed that the throttle was opened two seconds after it had been closed. As the rotor rpm was high the engine would have been unloaded and therefore the engine rpm would have risen quickly. This scenario was consistent with the data, which showed the engine limiter operating approximately four seconds after the noise to prevent the engine over-revving.

### *High rotor rpm*

Once established in autorotation, the pilot noted that the rotor rpm was higher than expected for the position of the collective lever. This presented what appeared to him as contradictory and confusing information. The 162F's collective lever rigging is significantly different to either the R22 or the B206, in that in the fully down position the rotor blade angle is set to negative 2° pitch. During autorotation, there is therefore a correspondingly greater range of movement required to raise the collective lever from the full down position to bring the blades into a positive range of pitch to control rotor rpm. This, and his experience of different types, probably influenced the pilot's expectation of the required collective lever position to control the rotor rpm.

### *Landing and ground run*

The minor damage to the tail boom skid is likely to have happened during the touch down as the deformation was upwards and aft. This would indicate the helicopter initially touched down in a nose high attitude. The helicopter slid along the field for approximately 10 m until the front left skid caught a rut in the ground. The forward velocity was enough to cause the helicopter to pitch forward and roll over, coming to rest on its left side. As a consequence of the rollover the tail boom struck the ground, and it is likely that this resulted in the structure being destroyed and the simultaneous overload failure of all the tail rotor drive belts. It is also likely that during the rollover the locking barrel of the fuel filler cap became dislodged, allowing fuel to leak from the filler cap as reported by the pilot.

The 162F has a propensity to pitch forward and roll over after an autorotation and in the pilot’s manual it states that autorotations should not be practiced to the ground. The later version of the 162F, the Talon, has a stronger landing gear, and skids that are longer and extend further forward to improve landing, with a reduced possibility of causing a roll over.

## Conclusion

Small defects in the sealing area of the exhaust valve in cylinder 3 may have allowed a build-up of unburnt fuel in the exhaust system that ignited in flight. The after fire in the exhaust was reported as an “almighty bang” by the pilot and an “explosion” by ground witnesses. In response to several unexpected indications the pilot successfully landed after an autorotation, but the landing ended with the helicopter rolling over due to a landing skid digging into uneven ground.

*Published: 7 July 2022.*

# 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:** | Agusta A109C, G-HBEK | |
| **No & Type of Engines:** | 2 Allison 250-C20R/1 turboshaft engines | |
| **Year of Manufacture:** | 1996 (Serial no: 7633) | |
| **Date & Time (UTC):** | 15 July 2021 at 0730 hrs | |
| **Location:** | Organford, Dorset | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - None |
| **Injuries:** | Crew - 1 (Minor) | Passengers - N/A |
| **Nature of Damage:** | Helicopter damaged beyond economic repair | |
| **Commander's Licence:** | Private Pilot's Licence | |
| **Commander's Age:** | 50 years | |
| **Commander's Flying Experience:** | 1,187 hours (of which 687 were on type)<br>Last 90 days - 4 hours<br>Last 28 days - 1 hour | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot | |

### Synopsis

On approach to a private landing site, the helicopter experienced an uncontrolled yaw to the right. Despite applying full left pedal the pilot was unable to regain control of the aircraft and opted to cut the power, following which the aircraft hit the ground. In the absence of a mechanical defect, it is possible that the loss of control was due to a loss of tail rotor authority resulting from operating close to or at the controllability limits of the helicopter, or that the helicopter was overpitched, or a combination of both. The helicopter was damaged beyond economic repair and the pilot sustained minor injuries.

### History of the flight

The flight departed a private site in Dorset at 0720 hrs with a planned destination of Dunkeswell Aerodrome in Somerset. After departure the landing gear would not retract, and the pilot kept the speed below 110 kt so as not to exceed the landing gear operating limit of 120 kt. Following a period of troubleshooting, the landing gear remained down and the pilot decided to return to the departure point. He stated he had experienced this problem with the landing gear previously and understood it was an issue with the 'weight on wheels' sensor.

The pilot recalled a very light north-easterly wind as the helicopter approached the landing site from the west. He described the local weather conditions ordinarily experienced at the landing site as predictable and benign. As the speed reduced, the helicopter transitioned from descending flight to slowing flight with the intention of entering a hover. The helicopter began its right turn to head south approximately 100 m from the landing site.

As the helicopter turned to head south toward the landing site, a greater amount of left pedal than usual was needed as the aircraft nose began turning to the right. The pilot increased his left pedal input until he had full left pedal applied, followed by left cyclic inputs to try to control the aircraft. At this point, the helicopter nose was still tending right but the helicopter was now drifting sideways to the left on an easterly track, whilst maintaining an approximate southerly heading (Figure 1). The pilot estimated his ground speed was approximately 15-20 kt. Additional application of the collective made the rotation to the right uncontrollable.

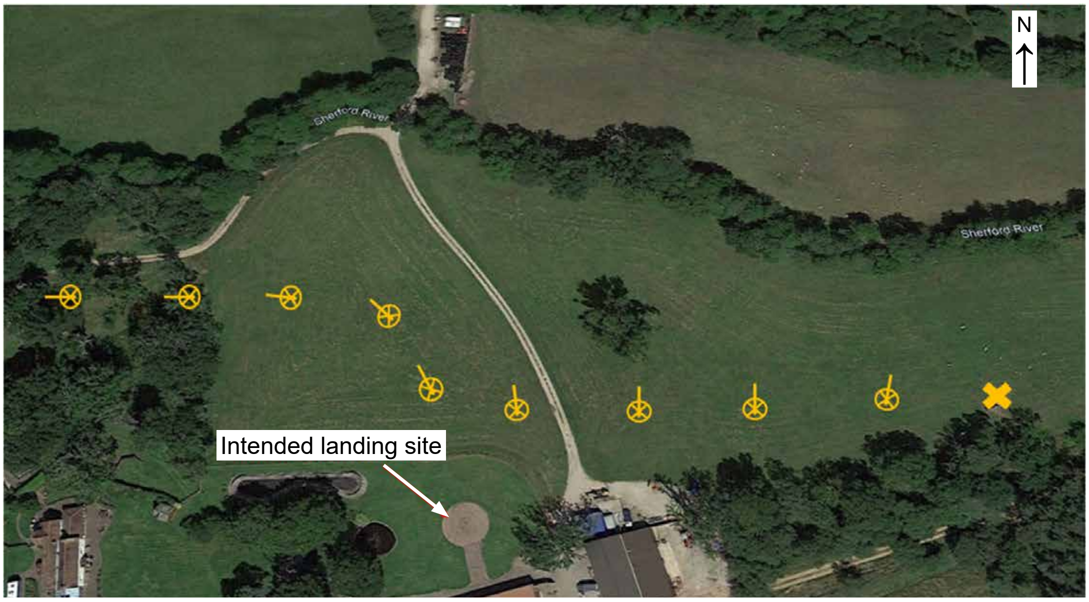


**Figure 1**

Approximate flight path of G-HBEK on approach to the landing site

The helicopter was drifting below the tree line and approaching the end of the field. The pilot reported that he did not want to climb as he was concerned that he might have lost tail rotor drive or control and therefore chose not to abort the landing. As he still did not have directional control of the helicopter, he believed his only option was to cut the power, with the expectation from his training being that the nose would then straighten up. After he did so, he did not regain control and has no memory of the subsequent accident sequence. The pilot did not recall any warnings or cautions prior to the event. The total flight time was approximately 15 minutes.

The helicopter was damaged beyond economic repair. The pilot reported that he did not sustain any visible head injuries. His loss of consciousness may have been caused by high sideways rotational accelerations of his head during the impact sequence.

## Aircraft information

The A109C helicopter is powered by two Allison 250-C20R/1 turboshaft engines. It has a four-bladed main rotor which rotates anti-clockwise and a two-bladed tail rotor. It can accommodate seven passengers in addition to the pilot. The maximum gross weight is 2,720 kg and the actual takeoff weight on the accident flight was 2,240 kg. Its flight manual states that satisfactory stability and control in sideward flight have been demonstrated at all loading conditions, up to and including 20 kt. It further states that when operating at high weights with winds from the right greater than 10 kt, the left pedal stop may be reached.

No flight data or cockpit voice recorder was fitted or required.

## Aircraft examination

The aircraft was examined by the AAIB and representatives from the aircraft manufacturer. The tail rotor blades were damaged but the tail rotor gearbox shaft rotated freely. There was sufficient oil in the tail rotor gearbox and no evidence of overheat. All tail rotor control linkages were secure and applying full left and right pedal in the cockpit produced corresponding tail rotor actuator and blade pitch changes. The tail rotor driveshaft was in good condition along the length of the tail boom. The tail rotor driveshaft had separated from the main rotor gearbox at a spline fitting. There was no damage to the splines, which indicated that the failure probably occurred as a result of the ground impact. The aircraft manufacturer's representative stated that they had only seen this type of spline separation once before and that it was the result of impact forces.

**Figure 2**

G-HBEK at the accident site

## Meteorology

Bournemouth Airport is less than 10 nm from the landing site and publishes METARs every 30 minutes. At the departure time of 0720 hrs it reported wind from 350° at 8 kt with 2-3 octa's of cloud at 2,200 ft and a temperature of 19°C. The next METAR at 0750 hrs reported the wind direction had veered and was now from 020° at 11 kt.

## Loss of tail rotor effectiveness

Loss of tail rotor effectiveness (LTE) manifests as an unanticipated yaw and is defined by the FAA as an *'uncommanded, rapid yaw towards the advancing blade which does not subside of its own accord'*[1]. Without correcting input from the pilot, which in the case of G-HBEK requires left pedal input due to its anti-clockwise main rotor, LTE can result in complete loss of control. LTE is caused by an aerodynamic interaction between the main and tail rotor and is not a technical malfunction.

LTE occurs when the airflow through the tail rotor is altered, resulting in a sudden change to the thrust produced by the tail rotor. This change of tail rotor thrust can be a result of several factors, described by the FAA as including the following:

- *'Airflow and downdraft generated by the main rotor blades interfering with the airflow entering the tail rotor assembly.*
- *A **high power setting**, hence large main rotor pitch angle, induces considerable main rotor blade downwash and hence more turbulence than when the helicopter is in a low power condition.*
- *A **slow forward airspeed**, typically at speeds where translational lift and translational thrust are in the process of change and airflow around the tail rotor will vary in direction and speed.*
- *The **airflow** relative to the helicopter.'*

Combinations of these conditions can create a situation where there is insufficient torque reaction available to control the helicopter in a particular environment.

### *Weathercock stability*

When the wind is from 120°- 240° relative to the helicopter at wind speeds up to 40 kt, the nose attempts to weathercock into it. This can only be stopped by pilot input on the opposite yaw pedal. If a right yaw rate develops and the relative wind is in this region (Figure 3) the yaw rate can rapidly become uncontrollable. Maintaining positive control of the yaw rate is imperative when flying downwind, particularly with high power settings and low airspeed.

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**Footnote**

[1] Helicopter Flying Handbook, Chapter 11 '*Helicopter emergencies and Hazards*' Federal Aviation Administration (FAA), https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/media/hfh_ch11.pdf [accessed 17 December 2021]

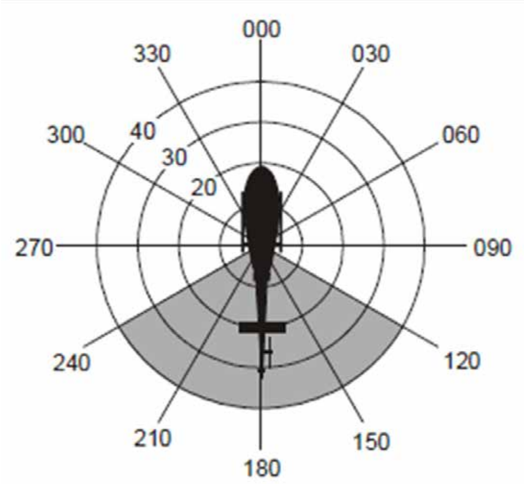

**Figure 3**

Weathercock stability – relative wind from 120° to 240° from 0-40 kt

## LTE guidance

In 2014 the AAIB reported on an event which bore several similarities to this accident[2]. The report into that accident included a safety action by the CAA, which stated its intention to review and update Safety Sense Leaflet 17 *'Helicopter Airmanship'* to include information on LTE.

In response to enquiries following the accident involving G-HBEK, the CAA commented that Safety Sense Leaflet 17 was not in fact updated because at the time it was providing input to an EU common document by the European Helicopter Safety Team (EHEST) '*Helicopter Flight Instructor Guide*'[3]. This document and the current version of the '*EASA Together4Safety Helicopter Flight Instructor Guide*'[4] both offer guidance to flight instructors on LTE. There is information on LTE contained within EHEST leaflet '*Safety Considerations*'[5], which is aimed at all helicopter pilots.

## Overpitching

Overpitching is a condition which occurs when the pilot demands more power than is available by raising the collective[6]. Main rotor blade pitch increases to meet the power demand which, when exceeding the power limit, can result in a power-on rotor stall.

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**Footnote**

[2] https://assets.publishing.service.gov.uk/media/5422eeb0ed915d137100020b/Hughes_369D_G-CCUO_07-14.pdf [accessed 20 December 2021]

[3] *EHEST Helicopter Flight Instructor Guide* available at https://www.easa.europa.eu/document-library/general-publications/helicopter-flight-instructor-guide [accessed 14 January 2022]

[4] *EASA Together4Safety Helicopter Flight Instructor Guide* available at https://www.easa.europa.eu/document-library/general-publications/helicopter-flight-instructor-guide [accessed 14 January 2022]

[5] *EHEST HE1 Safety Considerations*, available at https://www.easa.europa.eu/downloads/22663/en [accessed 21 January 2022]

[6] *Helicopter Flying Handbook*, Chapter 11 '*Helicopter emergencies and Hazards*' Federal Aviation Administration (FAA), https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/media/hfh_ch11.pdf [accessed 17 December 2021]

Overpitching usually occurs on approach when the helicopter experiences a high rate of descent. This may be a result of high operating weight, relative tailwind, high altitude, or an approach at a speed which is too fast or too slow, or a combination of these factors. As the pilot increases the power demand in order to control the rate of descent, the power limit is reached, and further power demand increases the torque as rotor rpm reduces. To keep the nose of the aircraft straight, the pilot must make a corresponding yaw pedal input. If the collective is raised further – normally to reduce the rate of descent – and torque increased, the tail rotor rpm (and therefore thrust) also falls. The relative authority of the tail rotor is reduced, and more pedal input is required to counteract the torque effect until the pedal reaches its limit. The rotation can no longer be controlled as the tail rotor has run out of authority.

As some symptoms are the same, overpitching can sometimes be confused with LTE.

## Analysis

In the absence of recorded data the pilot's recollections were the principle source of information about the flight.

The aircraft examination did not reveal any fault with the tail rotor control system, and the tail rotor driveshaft separation was probably the result of impact; in addition, the pilot did not report any technical warnings or failures other than the original landing gear issue that had prompted his return.

The pilot stated that he was familiar with the weather conditions at the landing site and local weather reports such as from Bournemouth Airport, did not accurately represent the local conditions he would experience when operating at the site. He reported his impression that the weather conditions at the site were seldom beyond the limits of the helicopter and were always more favourable than the weather reports made nearby.

The wind at Bournemouth Airport at the time of departure was reported to be from 350° at 8 kt, which if present at the landing site would have been 170° relative to the helicopter as it took up a southerly heading. The next wind reported at 0750 hrs reported a wind of 020° at 11 kt, a relative direction of 200°. As the accident is estimated to have occurred at 0735 hrs, it is possible the relative wind was from behind the helicopter. This wind combined with the groundspeed of the helicopter as it turned towards the landing site, may have resulted in reaching the controllability limit for the helicopter for the wind conditions.

Events involving LTE ordinarily result in an uncontrollable yaw; however, it is possible that G-HBEK was close to, or at, its maximum demonstrated speed of 20 kt, and that full left pedal was needed to keep the nose from yawing further to the right. In this case, any increase in the relative wind speed or addition of torque by the pilot would have resulted in an increased right yaw, which may have become uncontrollable.

As the helicopter made its right turn towards the landing site, with a high power setting, decelerating and turning downwind, it could have been susceptible to the effects of LTE and overpitching. These might be challenging circumstances without a high level of pilot awareness of the flight conditions and risks associated with a turn downwind near the landing site.

## Conclusion

The flight conditions, phase of flight and behaviour of the helicopter were such that a loss of tail rotor effectiveness, loss of tail rotor authority, or a combination of both, were possible causes of the pilot losing directional control of the aircraft and subsequent ground impact.

## SERIOUS INCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Boeing 737-436, G-POWS |
| **No & Type of Engines:** | 2 CFM CFM56-3C1 turbofan engines |
| **Year of Manufacture:** | 1992 (Serial no: 25853) |
| **Date & Time (UTC):** | 18 June 2021 at 1300 hrs |
| **Location:** | London Southend Airport |
| **Type of Flight:** | Commercial Air Transport (Cargo) |
| **Persons on Board:** | Crew - 2 Passengers - None |
| **Injuries:** | Crew - None Passengers - N/A |
| **Nature of Damage:** | None |
| **Commander's Licence:** | Airline Transport Pilot's Licence |
| **Commander's Age:** | 63 years |
| **Commander's Flying Experience:** | 9,800 hours (of which 4,900 were on type)<br>Last 90 days - 165 hours<br>Last 28 days - 40 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB |

### Synopsis

While turning 90° between two narrow taxiways the right main landing gear left the paved surface, causing damage to taxiway infrastructure. The commander attempted to continue by selecting a high power setting but without success. The operator has updated its briefing sheet to raise crew awareness of the threat of a taxiway excursion when taxiing on narrow taxiways. The investigation also identified shortcomings in the operator's handling of the cockpit voice recorder, procedures for which it has now amended. Detail is provided to assist other operators in this area.

### History of the flight

*Background information*

On the morning of the event the crew started their duty at 0340 hrs. They made their own way to Southend Airport to fly a cargo flight to Leipzig and back to Southend. The crew's normal home base was Stansted Airport. There had been inclement weather overnight and the apron was reported to be covered with standing water.

The flight to Leipzig was uneventful. The planned turn-around time in Leipzig was four hours, during which the crew were required to remain on board. Prior to departure, there was a technical issue with the commander's Electronic Horizontal Situation Indicator (EHSI). In consultation with the operator's maintenance engineer by phone, the commander removed all power from the aircraft. When the aircraft was re-powered, the EHSI was operating normally and there were no fault indications. The flight departed Leipzig ahead of schedule.

*Incident flight*

The commander was PF and the co-pilot was PM. The flight to Southend was uneventful, although the commander reported a low level of distraction created by the perceived risk of the EHSI failure reoccurring. The cloud base at Southend was reported at 600 ft with a wind from 040° at 9 kt. The crew declined an offer from ATC to land on Runway 23 as the landing performance was more limited. This was due to the reported tailwind and a partially damp runway following earlier rainfall.

The aircraft flew an ILS approach to land on Runway 05. The aircraft was cleared by the ATCO to vacate the runway at Taxiway A and to then taxi via A and Z to hold short of Runway 05 at B1 holding point (Figure 2). The commander had not taxied this way previously and commented to the co-pilot they would be backtracking on the runway to D. The co-pilot had taxied on this route once before and the commander had taxied on several occasions at night in the opposite direction. The normal taxiway routing was via A and C1 before crossing the runway to D parking apron.

While taxiing along Z the aircraft reached a groundspeed of 17 kt, slowing to 8 kt to commence the turn. The commander reported that he did not adopt the procedure for taxiing on narrow taxiways as he was turning onto a wider taxiway and believed he was following the yellow taxi line. He recalled taxiing at a slow speed as all he could see ahead was grass.

While the aircraft was in the right turn onto Taxiway B, ATC cleared it to enter and backtrack Runway 05 to vacate at D. The co-pilot then commented on the aircraft's proximity to the grass at which point the commander believes it had already left the taxiway. The commander stated that the aircraft was still moving slowly and his natural reaction was to increase power in order to return to the taxiway. Simultaneously, ATC asked whether assistance was required but received the response "*I think we can power out*". The commander reported increasing the power but, by the time the engines had spooled up, the aircraft had lost momentum and subsequently came to a stop. ATC instructed the aircraft to hold position and wait for assistance. The crew complied, shut down the engines and secured the aircraft. Figure 1 shows where the aircraft came to rest, with its nosewheel approximately 2 m right of the yellow taxi line.

The fire brigade, aircraft engineers and handlers attended the aircraft in its location between Taxiways B and Z. The cargo was offloaded in situ and the crew were collected by an operations vehicle. Following guidance from the manufacturer, the aircraft was subsequently towed to a hangar and underwent a maintenance inspection. There was no damage found and the aircraft was released to service two days later. The lower portion of two taxiway edge lights - the stalks, frangible couplings and synthetic tripods - were damaged beyond repair, however the light fittings remained serviceable. Some cable ducting along the taxiway edge was damaged and a portion of the taxi edge was reinstated.

**Figure 1**

Stopped position of the aircraft

## Personnel information

The commander and co-pilot both held valid licences and their medicals were in date.

## Airport information

Southend Airport has one runway 05/23. The LDA in both directions is 1,604 m and the runway is 36 m wide. The operators Operation's Manual Part A (OMA) defines a narrow runway as any runway with a width less than the standard 45 m. Standard and narrow taxiways are not defined. ICAO Doc 9157[1] lays out the minimum width of a taxiway pavement for a Code C aircraft with a wheelbase less than 18 m is 15 m – applicable to a B737-400 which has an outer main gear wheel span of 6.4 m – with a requirement of 3 m clearance from the outer main gears to the taxiway edge.

Taxiway F has a declared width[2] of 27 m. The Southend Airport Aeronautical Information Publication (AIP) aerodrome chart (Figure 2) depicts this width continuing through the runway intersection, along B to the B1 holding point, following which the taxiway appears to narrow.

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**Footnote**

[1] International Civil Aviation Organization (ICAO), 2005. *Aerodrome Design Manual Part 2 Taxiway, Aprons and Holding Bays 4th Ed*. Montreal: ICAO.

[2] From electronic Aeronautical Information Publication (eAIP) available at https://www.aurora.nats.co.uk/htmlAIP/Publications/2021-09-09-AIRAC/html/index-en-GB.html [accessed 9 September 2021]

**Figure 2a**

AIP Ground Chart for Southend Airport

**Figure 2b**

Aircraft taxi route

Taxiways F and B were previously used as a runway but had been used as taxiways for some time. Taxiway B was resurfaced in 2017 during which the portion south of B1 was physically narrowed. Despite this apparent variation in width north and south of B1, B has a declared width of 15 m. Taxiway markings can be seen to represent the 15 m approved width on the physically wider portion (Figure 3). Figure 3 also shows that south of B1, Taxiway B surface is asphalt and concrete which provides a visual contrast in appearance to Taxiway Z which is asphalt.

**Figure 3**

Aerial view of Taxiways B and Z and the representation of approved taxiway width north of B1 (Image from Google Maps)

Taxiway B is depicted as wider than Taxiway Z and of a constant width on both ground charts which were available to the crew (Figures 4a and 4b). However, Taxiway Z has a declared width of 15 m, which is the same as Taxiway B.

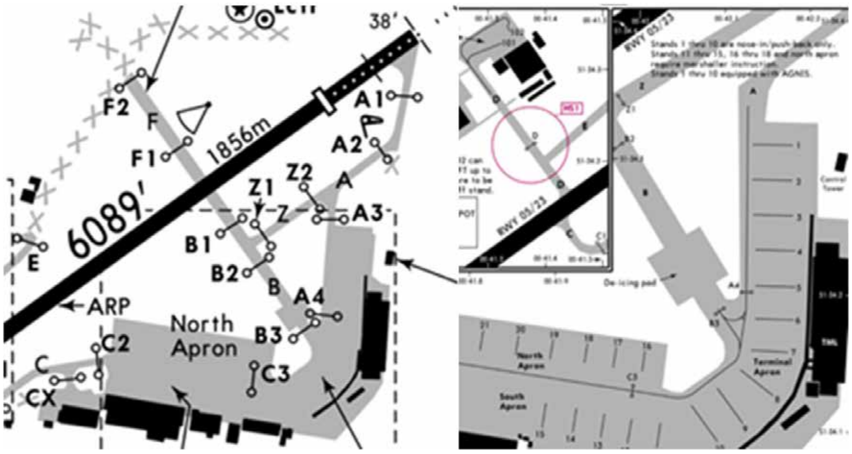

**Figure 4a** **Figure 4b**

Taxiways Z and B intersection – Southend Airport Jeppesen Ground Chart (4a) and Parking Chart (4b)

The commander stated he believed Taxiway B was wider than Taxiway Z both from his assessment of the ground charts and his visual perception when taxiing.

## Air Traffic Control

The operator ordinarily parks on the apron north of the runway and accessed by Taxiway D. The crew and ATC both reported that the normal taxi routing from Runway 05 to this parking area would be via A and C before crossing the runway to D.

ATC stated there is no airport restriction on the clearance they can issue for taxi routings. However, it was reported that a B737 from another operator had previously refused to taxi on Z and this was reported to the airport operator.

On this occasion, ATC issued what was described as a non-standard routing based on a preceding aircraft's request to assess weather before departure.

## Procedures and manuals

### *Operations and aircraft manuals*

The OMA states that crew of Boeing types are not required to undergo any specific training for narrow runway operations and there is no reference to taxiing on narrow taxiways. The Boeing 737 Classic Flight Crew Training Manual (FCTM) states that pilots should '*consider displacing the aircraft to the far side of the runway or taxiway before initiating the turn'* when making a sharp turn from a runway or wide taxiway to a very narrow taxiway. However, this guidance does not directly apply to this scenario, as the aircraft was turning to a taxiway of the same width and which had the appearance of being wider.

The Civil Aviation Authority's CAP 637[3] provides the following guidance:

> *'At major aerodromes in the UK, the taxiway width is determined to ensure a specified minimum clearance between the outer wheels of the largest aircraft that the taxiway is designed to accommodate and the taxiway edge. The minimum wheel to edge clearance is assured in turns provided that the pilot keeps the 'Cockpit' over the taxiway centreline.'*

Based on the guidance in Boeing FCTM and CAP 637, there was no requirement for the crew to adopt a non-standard approach to this taxi routing.

### *Operator's briefing sheet*

London Southend Airport is categorised by the operator as a category B+ aerodrome due to its narrow runway. A company briefing sheet is required for all narrow runway operations and one is published for Southend Airport. The briefing sheet refers to OMA guidance on narrow runway operations. At the time of the event, the briefing sheet required crew to vacate the runway at Taxiway B due to what it refers to as taxiway restrictions of 15 m to the south of the airfield, despite Taxiway B also having an approved width of 15 m. On this flight, the aircraft was instructed by ATC to vacate the runway at Taxiway A.

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**Footnote**

[3] Civil Aviation Authority (CAA), 2007. *CAP 637 Visual Aids Handbook, 2nd Ed.* Norwich: TSO.

*Use of thrust during ground operations*

There is no limitation in the operator's manuals on the use of thrust during ground operations. However, the B737 FCTM states that thrust use during ground operation demands sound judgement and technique.

## Crew resource management

The pilots both commented that they had worked effectively together throughout the duty period. The co-pilot stated he felt comfortable to raise any concerns. The co-pilot further stated that he realised the aircraft was close to the grass too late and that he recognised the responsibilities of the PM to call any deviation from the planned flight or taxi path.

## Other information

*ICAO definition of accident and serious incident*

Annex 13 to the Convention on International Civil Aviation[4] (Annex 13) defines an accident as an occurrence in which an aircraft is missing, inaccessible, or significantly damaged; or in which a person is fatally or seriously injured by, among other things, direct exposure to jet blast. It defines a serious incident as an occurrence involving circumstances indicating that there was a high probability of an accident.

*Notification and response*

Southend Airport notified the AAIB of the serious incident involving G-POWS at 1553 hrs on the day of the occurrence. The aircraft operator did not notify the AAIB, stating that it did not classify the occurrence as a serious incident.

Based on the information it received, the AAIB determined that a safety investigation was required, and that it was not necessary to attend the scene immediately. The operator was advised and it acknowledged by email that evening that the AAIB was conducting an investigation.

*Investigation by the operator*

The operator determined from recorded flight data that power settings of up to 86.2% $N_1$ were applied during the taxiway excursion, the maximum being applied for less than two seconds. Though this did not result in significant damage or injury, the operator considered that the use of high power during the taxiway excursion represented a risk of major accident for which the remaining barriers were not effective, including the risk to people behind the aircraft of exposure to jet blast.

The operator stated that it listened to the cockpit voice recorder following the occurrence. This is prohibited if an investigation has been opened by a State safety investigation authority such as the AAIB, as in this case.

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**Footnote**

[4] Annex 13 to the Convention on International Civil Aviation - *Aircraft Accident and Incident Investigation*, 12th Ed, July 2020, published by the International Civil Aviation Organization (ICAO), which sets out the standards and recommended practices for aircraft accident inquiries.

*Regulations on the disclosure of cockpit recordings*

Because of their sensitive nature and importance in safety investigation, cockpit voice and image recordings are accorded a high level of protection internationally.

Note 1 to Appendix 2 of Annex 13 states:

> *'The disclosure or use of* [records listed in Chapter 5.12 of Annex 13, including cockpit voice recordings and airborne image recordings and any transcripts from such recordings]*, in criminal, civil, administrative, or disciplinary proceedings, or their public disclosure, can have adverse consequences for persons or organizations involved in accidents and incidents, likely causing them or others to be reluctant to cooperate with accident investigation authorities in the future. The determination on disclosure or use required by 5.12 is designed to take account of these matters.'*

This is reflected in the legislative scheme in the UK.

Division CAT.GEN.MPA.195 of retained Regulation EU 965/2012[5] (EU 965) addresses the disclosure of audio recordings from flight recorders:

> '(f) *Without prejudice to Regulation (EU) No 996/2010*[6] *and Regulation (EU) 2016/679 of the European Parliament and of the Council:*
>
> > (1) *Except for ensuring flight recorder serviceability, audio recordings from a flight recorder shall not be disclosed or used unless all of the following conditions are fulfilled:*
> >
> > > (i) *a procedure related to the handling of such audio recordings and their transcript is in place*
> > >
> > > (ii) *all crew members and maintenance personnel concerned have given their prior consent*
> > >
> > > (iii) *such audio recordings are used only for maintaining or improving safety'*

Retained Regulation EU 996/2010 (EU 996) on the investigation and prevention of accidents and incidents in civil aviation addresses the protection and disclosure of cockpit voice recordings in the context of an accident or serious incident investigation conducted in accordance with Annex 13 (an "Annex 13 investigation"). The relevant provisions of EU 965 are explicitly *'without prejudice to'* (and therefore subordinate to) EU 996.

In EU 996, a 'safety investigation' is specifically one carried out by a State safety investigation authority such as the AAIB, and not by any other person or organisation such as an operator.

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**Footnote**

[5] EU965/2012 CAT.GEN.MPA 195 (f) https://www.legislation.gov.uk/eur/2012/965/annex/IV/division/SUBPART/section/1/division/CAT.GEN.MPA.195 [accessed on 13 Jan 2022].

[6] https://www.gov.uk/government/collections/aaib-regulations-and-mous [accessed June 2022]

Article 13(2) of EU 996 prohibits removal of or sampling from an aircraft and its contents except for specific purposes in relation to a State safety investigation. Article 13(3) states that any person involved in an accident or serious incident shall take all necessary steps to preserve documents, material and recordings relating to the event, in particular to prevent erasure of recordings of conversations and alarms after the flight.

Article 14(1)(g) of EU 996 specifies that cockpit voice and image recordings shall not be made available or used for purposes other than safety investigation.

Regulation 24 of the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018 (the UK Regulations)[7] states that any person who, without reasonable excuse, contravenes any of the prohibitions in Article 13(2) or fails to take the necessary steps described in Article 13(2) also contravenes the UK Regulations.

Failure to protect sensitive safety information may also be an offence under Regulation 25 of the UK Regulations.

*Operator handling of CVR*

The operator's safety department stated in email and telephone correspondence with the AAIB, on the day of the occurrence and subsequently, that it was aware the AAIB was conducting an investigation. It also stated that when it accessed the CVR in relation to this occurrence, it did so in accordance with EU 965. It later indicated that it was not sure the AAIB investigation was of a sort that brought EU 996 into force.

Given its own uncertainty, the operator suggested that a description of the circumstances in which it listened to the CVR in this case might help others understand the effect of the regulations. Accordingly:

Operators should note that the prohibitions in EU 996 on the disclosure of protected information are in force for all AAIB investigations, whether or not an AAIB Inspector visits the site of an occurrence and remain in force after the conclusion of its safety investigation.

EU 965 does not permit an operator to use material, such as a CVR recording, that is protected by EU 996. Use of a CVR recording is only permitted in accordance with EU 965 once it is established that no State safety investigation will take place.

The operator's safety department told the crew of G-POWS in written correspondence that it wished to listen to the CVR because the AAIB had asked it to investigate. The AAIB had not asked it to do so. The operator's safety department also told the crew of G-POWS that it wished to interview them to *'ensure all items are covered off for the MOR and the AAIB'* and stated that the information it sought was required for *'the official ICAO Annex 13 report'*. These communications are likely to have given the impression to the crew that the operator was acting on behalf of the AAIB, which was not the case.

---

**Footnote**

[7] https://www.gov.uk/government/collections/aaib-regulations-and-mous [accessed June 2022]

The AAIB seeks the information it requires directly from those able to provide it and does not ask operators to act on its behalf. In particular, the AAIB never asks operators to listen to a CVR or interview crew on its behalf.

*Process where EU 965 is applicable*

In this case, because the AAIB was conducting a safety investigation, the protections of EU 996 were in force and EU 965 could not provide for the operator to listen to the CVR. Had the AAIB not been investigating, the operator would still be prohibited from disclosing or using the audio recordings from the CVR, except under the conditions specified in EU 965.

Guidance documents produced by the operator, in force when it listened to the CVR, did not contain a procedure for the handling of the recording or its transcripts as required by EU 965. The operator subsequently incorporated such a procedure into its manuals, including a consent form which must be signed by all crew members before a CVR recording can be accessed.

*Oversight*

Regarding the process by which the operator accessed the CVR in this case, the CAA found that the operator was unable to demonstrate an adequately robust procedure for the handling of CVR data following a safety incident. The operator has amended its procedures as described above.

The CAA stated that is has written to the Safety Managers and Nominated Persons for flight operations of all air operator certificate holders, providing additional guidance on the proper handling of cockpit recordings, including on the primacy of EU 996 over EU 965. This guidance specifies that, before listening to a CVR in accordance with EU 965 following an occurrence, operators will seek written confirmation from the AAIB of the status of any safety investigation into that occurrence.

## Analysis

*Visual illusions*

There were several cues which led the pilots to believe the taxiway onto which they were turning was wider than it was. This included the inaccurate ground charts, the operator's briefing sheet and the colour of the taxiway surfaces. This contrasting colour of the taxiways may have exposed the pilots to the irradiation illusion[8], where a light or bright object appears larger than it is when contrasted with a dark object of the same size. These cues were further compounded by the physical widening of the paved surface beyond the turn, which would have been visible from the flight deck when the aircraft was approaching the turn, perhaps to a greater extent than the narrower portion of Taxiway B.

---

**Footnote**

[8] An optical illusion which is defined by Oxford Reference as *'any visual illusion arising from the fact that light areas of an image tend to appear larger than dark areas'* at https://www.oxfordreference.com/view/10.1093/oi/authority.20110803100011483 [accessed 9 September 2021]

*Use of thrust*

Setting a $N_1$ thrust as high as 87.4%, even if momentary, poses a jet blast risk to other aircraft, vehicles, and personnel in proximity to the aircraft. Foreign object damage caused by high engine thrust can affect airport operations as it relates to airplane structure, flight controls, equipment and personnel.

The commander recalled his instinct to 'power out' of the grass, and if the ground had not been sodden following a period of significant rainfall, the wheel may not have become stuck in the soft ground. The crew did not verbalise any consideration given to jet blast, and no operator or manufacturer limit was exceeded. The guidance in the FCTM requiring '*sound judgment and technique*' could be interpreted to allow for the selection of high thrust setting in circumstances where safety is not compromised.

Research carried out by Boeing[9] indicates that the effect of jet blast can be experienced up to 1,900 ft behind the aircraft, it also details the reduction in the severity from a typical exhaust wake speed of 260 kt at the empennage to between 43 kt – 88 kt beyond 200 ft. The aircraft was positioned 660 ft from the nearest movement area and the crew confirmed they were aware that their position on the airfield was clear of other aircraft movements and apron operation. The company report confirmed the aircraft was still moving, albeit at 1 kt, when the maximum power was set. This suggests the aircraft had some momentum which may have encouraged the crew's belief that they could resolve the situation by applying more power.

## Conclusion

It is probable that the departure of the right main gear from the paved taxiway was due to the crew's incorrect belief they were turning onto a wider taxiway. A combination of unfamiliarity with the routing, inaccurate charting, visual illusions, and a misleading company briefing sheet are likely to have been contributory factors.

In response to this event, the operator promulgated a memo to aircrew which contained updated text for the company briefing sheet for Southend Airport. An additional paragraph on the threat of a taxiway excursion was added to the briefing sheet, which warns crews to exercise '*extreme caution*' when taxiing from Taxiway B and Taxiway Z. The memo further stated *'All B737 Flight Crew shall review ALL of Chapter 2.5 "Ground Operations" from the 737 Classic Flight Crew Training Manual...'*.

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**Footnote**

[9] https://www.boeing.com/commercial/aeromagazine/aero_06/textonly/s02txt.html [accessed 7 October 2021]

## SERIOUS INCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Boeing 737-8K5, G-TAWY | |
| **No & Type of Engines:** | 2 CFM CFM56-7B27E turbofan engines | |
| **Year of Manufacture:** | 2012 (Serial no: 37246) | |
| **Date & Time (UTC):** | 9 March 2022 at 0840 hrs | |
| **Location:** | Manchester Airport | |
| **Type of Flight:** | Commercial Air Transport (Passenger) | |
| **Persons on Board:** | Crew - 8 | Passengers - 178 |
| **Injuries:** | Crew - None | Passengers - None |
| **Nature of Damage:** | Minor damage to the tail skid and paint damage on the aft drain mast | |
| **Commander's Licence:** | Airline Transport Pilot's Licence | |
| **Commander's Age:** | 63 years | |
| **Commander's Flying Experience:** | 22,000 hours (of which 6,000 were on type)<br>Last 90 days - 62 hours<br>Last 28 days - 20 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the commander and further enquiries by the AAIB | |

### Synopsis

During takeoff on a training flight the trainee co-pilot rotated the aircraft too rapidly, causing the aircraft's tail to strike the runway. The co-pilot had experienced several delays during his training which would have made it harder to learn the correct technique. His low experience coupled with a slight crosswind is likely to have exacerbated the situation.

### History of the flight

The flight was the fifth line training sector for a new co-pilot[1]. It was a scheduled flight from Manchester Airport to Fuerteventura in the Canary Islands. The co-pilot was the pilot flying. The weather conditions in Manchester included a surface wind from 170° at 13 kt giving an 11 kt crosswind on Runway 23R. The wind speed was forecast to increase later in the day.

Prior to the flight the commander and co-pilot discussed the takeoff including the required rotation rate and crosswind technique. Whilst on stand, with the aircraft hydraulics powered, the commander demonstrated, and the co-pilot practiced, the correct control inputs.

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**Footnote**

[1] 'Line training' is training conducted during normal operations under the supervision of an authorised training pilot, to prepare the trainee for normal operations without such supervision.

The start-up and taxi to the runway were uneventful. The crew again discussed the takeoff technique at the holding point, as they waited to depart. Once lined-up on the runway the commander handed control to the co-pilot for the takeoff. The crew had used performance figures for a wet runway, which generated a lower $V_1$.

The takeoff roll was normal until $V_1$. The co-pilot was concentrating on applying rudder to maintain the centreline; he thought the wind was gusty as he needed to keep adjusting the pressure on the rudder pedals. After $V_1$ the aircraft started to drift slightly downwind. The commander considered that the gap between $V_1$ and $V_R$ may not have been appreciated by the co-pilot, as it was greater than he had experienced previously, and it may have caused a degree of surprise and distraction. The co-pilot initiated the rotation at $V_R$. The commander described the initial rotation as "a bit quick but within the normal and safe range". However, as the pitch attitude reached approximately 9°, the commander felt the rotation rate increase markedly. He had his hands on the controls and tried to reduce the rate but was unable to prevent the tail striking the runway. Both pilots felt a bump as it did so.

The pilots continued the takeoff and followed their cleared departure routing. There were no adverse indications, and the aircraft was flying normally. Initially the commander intentionally left the landing gear extended to focus on the flight path, but then omitted to retract it until after the flaps were retracted. Once established in the climb the commander contacted the cabin crew to confirm if they had heard anything abnormal on the takeoff. The cabin crew at the back of the aircraft confirmed they had heard "a very big bang" on takeoff.

The commander advised ATC that the aircraft's tail had struck the runway and they were likely to be returning to Manchester. He declared a PAN and requested they stop the climb at FL100 and take up a suitable hold. Once established in the hold they reviewed what had happened, discussed their options, and consulted the tail strike checklist in the QRH[2]. They decided to return to Manchester for an overweight landing. The commander decided not to depressurise the aircraft, contrary to the QRH, as he felt it was safer to allow the cabin to depressurise normally during the imminent descent[3].

The commander briefed the cabin crew for a precautionary landing and made an announcement to the passengers. Once they had completed their briefing the flight crew commenced an approach back to Runway 23R at Manchester. The commander elected to be pilot flying. The subsequent approach and landing were uneventful although the commander did report there was significant windshear just prior to touch down. The aircraft landed at 0921 hrs.

They briefly stopped the aircraft on the runway to speak to the airport fire service and confirm everything was normal, then taxied to stand without further incident.

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**Footnote**

[2] QRH - Quick Reference Handbook

[3] The operator commented that they believe the safest course of action would have been for the commander to complete the QRH tail strike checklist in full.

Once parked on stand, damage was found to the tail skid and the aft drain mast. A later detailed inspection showed that the damage was limited to the crushable cartridge in the tail skid. The tail skid shoe was worn but still within limits for continued operation. The damage to the aft drain mast was only paint damage.

## Recorded information

The CVR and FDR were reviewed by the AAIB. Both contained recordings of the incident flight. The CVR was used to support the history of flight above.

The FDR data was used to create Figure 1. The plot shows pitch attitude, pitch rate, control column force, radio altitude and airspeed during the rotation on the incident flight and the aircraft's three previous flights. The plot also shows wind speed and direction and normal acceleration for the incident flight. The data showed the pitch rate peaked at 7.1°/sec and reached a maximum pitch attitude of 13° on the incident flight[4]. Roll inputs are not shown on Figure 1 but the data showed a left roll input, sufficient to deploy the left spoilers, was made as the aircraft started to rotate[5].

The plot shows a marked difference between the steady pitch rate and control column force on the previous flights and the increasing force and rate on the incident flight.

After takeoff, the landing gear was retracted at 3,500 ft and 247 kt.

## Co-pilot's training history

The co-pilot joined the operator in 2019 after obtaining his commercial pilot's licence. He completed a jet orientation course followed by a type rating course with a third-party training organisation. He completed an operator conversion course in March 2020, but his training was then interrupted by public health restrictions associated with the COVID-19 pandemic. He completed refresher training in the simulator followed by base training in the aircraft in July 2021. After a further delay and some additional refresher training in the simulator, his first two line training sectors were completed on 27 January 2022. His third and fourth line training sectors were completed on 7 March. This incident flight occurred two days later, on the co-pilot's fifth sector. He had 15 hours and 40 minutes on type.

The training notes from the co-pilot's first two sectors noted that his rotation rate had been slightly slow and gave guidance to achieve the required 2 to 2.5°/second rate. Notes from his third and fourth sectors mentioned not allowing the rotation to stagnate at 10° and ensuring a continuous rotation to the target 15° attitude.

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**Footnote**

[4] The Boeing 737 Flight Crew Training Manual states that the tail strike pitch attitude is 11°.

[5] The Boeing 737 Flight Crew Training Manual crosswind takeoff section states – '*Use of excessive control wheel may cause spoilers to rise which has the effect of reducing tail clearance*'.

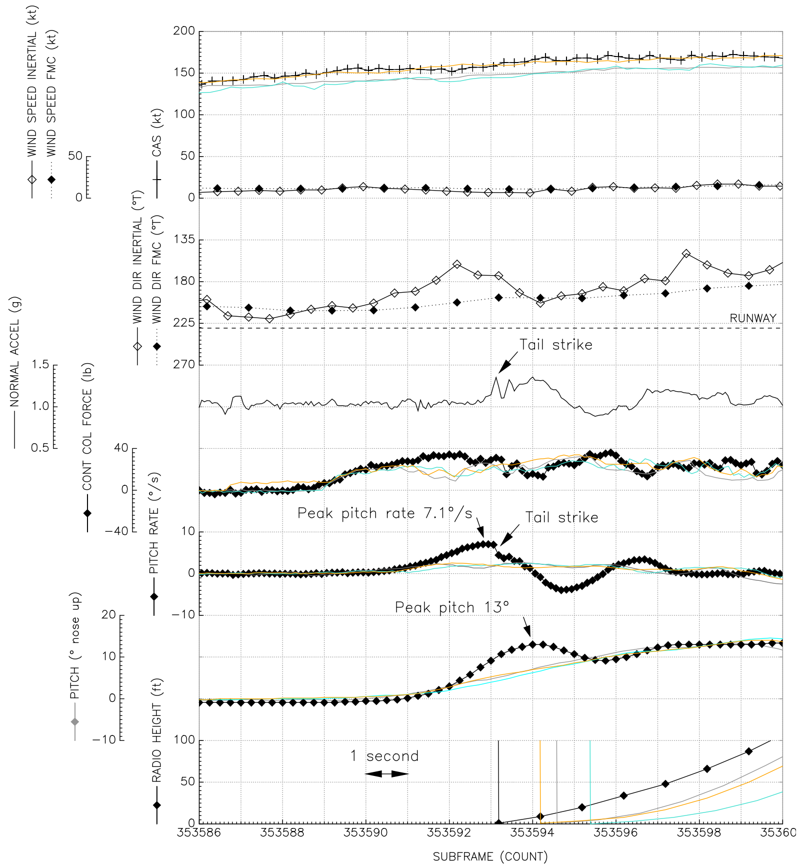

**Figure 1**

Takeoff plot for the incident flight (black)
and the aircraft's three previous flights (grey, orange, and blue)
(vertical lines on the radio height scale indicate the lift-off point)

## Operator's comments

The operator commented that the training the co-pilot received was compliant with its training policy which, due to the pandemic, required a bespoke training package which was assessed and managed by a training manager. As well as additional simulator time, the co-pilot's training included flying the first ten sectors with a line training captain qualified to a Zero Flight Time (ZFT) standard[6].

The operator recognised that the delays during his training had not been ideal, but this had been considered when assessing his training need. It is possible that recency was a contributory factor, but the co-pilot had flown two days prior to the incident and his last takeoff and landing prior to the event was at the minimum company standard expected for someone at his stage of training and with his experience. The policy to continue

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**Footnote**

[6] A Zero Flight Time (ZFT) type rating course allows trainees who meet specified minimum experience requirements to commence line flying without first being required to fly the aircraft without passenger (known as base training). Training captains need additional training to be authorised to supervise the first few line sectors of a pilot undertaking a ZFT course. The co-pilot involved in this incident was not undertaking a ZFT course, as he did not meet the minimum experience standard, and had completed base training.

flight training with an experienced training captain from a long runway was deemed appropriate.

The operator is aware that training pilots in a long body aircraft like the B737-800 poses a tail strike risk and has this risk on its risk register. It provides additional intervention training to training captains. It has also re-emphasised to its training captains the need for caution when conditions are not suitable for low experienced trainees to operate as pilot flying during the takeoff and landing, even if this results in the training objectives for that flight not being achieved. However, the operator noted that the reported wind for this departure was suitable at the time the takeoff run was commenced. It has also taken action to ensure better training continuity.

Average rotation rates are monitored monthly as part of the operator's Safety Management System and there is currently no concern on the overall rotation rates data on the 737 fleet.

## Analysis and conclusion

On takeoff, during a line training flight, the trainee co-pilot rotated the aircraft too rapidly causing the aircraft's tail to strike the runway. The trainee had experienced disjointed training due to public health restrictions, which is likely to have made it harder to learn and retain the correct takeoff technique. During his first few sectors on the aircraft, it had been noted that his rotation rate was slightly slow, and he was allowing the rotation to stagnate. It is likely that trying to correct these issues contributed to the rapid rotation rate. The crosswind on the takeoff might have further added to co-pilot's workload.

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## Bulletin Correction

The following sections of the report have been amended post-publication:

Operator's comments (first paragraph, last sentence)

Original text:

> The operator considered this was more than required by the regulations.

The sentence is deleted.

Operator's comments (third paragraph, first sentence)

Original text:

> The operator is aware that training low experience pilots in a long body aircraft like the B737-800 poses a tail strike risk and has this risk on its risk register.

Corrected text:

> The operator is aware that training pilots in a long body aircraft like the B737-800 poses a tail strike risk and has this risk on its risk register.

The online version of this report was corrected when published on 11 August 2022 and a correction was also published in the October Bulletin.

## ACCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Aeronca 65C, G-BTRG | |
| **No & Type of Engines:** | 1 Verner Scarlett 7Hi piston engine | |
| **Year of Manufacture:** | 1939 (Serial no: C4149) | |
| **Date & Time (UTC):** | 21 October 2021 at 1435 hrs | |
| **Location:** | Birchwood Airfield, North Yorkshire | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - 1 |
| **Injuries:** | Crew - None | Passengers - None |
| **Nature of Damage:** | Aircraft extensively damaged and missing propeller | |
| **Commander's Licence:** | Private Pilot's Licence | |
| **Commander's Age:** | 58 years | |
| **Commander's Flying Experience:** | 568 hours (of which 387 were on type)<br>Last 90 days - 4 hours<br>Last 28 days - 4 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot | |

### Synopsis

Shortly after takeoff the propeller departed the aircraft and then the engine over sped. All six propeller bolts failed in fatigue due to a lack of pre-load. It is possible that a misinterpretation of an engine manufacturer's requirement resulted in the incorrect bolt length being chosen. When the bolts were tightened to the correct torque they shanked, no pre-load was applied and failed due to normal propeller loads in fatigue. The aircraft was extensively damaged and the propeller was not recovered.

### History of the flight

The aircraft, with the pilot and one passenger, took off from Runway 26 at Birchwood private airstrip for a short flight. It was the first flight after completion of a Permit-to-Fly renewal flight following annual maintenance. The aircraft climbed through 450 ft and as the pilot went to reduce the engine power, it suddenly over sped. The pilot does not recall any abnormal indications such as noises or vibration prior to the engine over speeding. The pilot immediately closed the throttle and flew the aircraft to maintain its best gliding speed of 65 to 70 mph. He evaluated possible landing sites ahead but chose to return to the airfield as he felt his options were limited. He lined up on Runway (RWY) 03 and slide slipped to lose height as he was closer than he had anticipated. The pilot felt that the aircraft was going too fast to stop on RWY 03, so realigned to RWY 08 and landed on the main wheels. Despite the use of braking, the aircraft went through a hedge at the far end of the runway (Figure 1). The pilot turned the fuel and electrical master off and vacated through the left door with the passenger. It was then that they noticed that the propeller was missing. The propeller has not been recovered.

**Figure 1**

Accident site with close-up of propeller flange
(Photographs used with permission)

## Aircraft information

The Aeronca Chief is a family of American high-winged light touring aircraft, designed and built from the late 1930s by Aeronca Aircraft. G-BTRG was a 65C model made in 1939 and was originally fitted with a Continental A-65 engine. The A-65 is a horizontally opposed four-cylinder 65 hp engine. The aircraft was restored in 2017 and the A-65 was replaced with Verner Motor Scarlett 7-cylinder radial 124 hp engine. The conversion was accomplished under the CAA E-conditions and the aircraft was operated under an LAA Permit-to-Fly.

## Propeller information

G-BTRG was fitted with a 76” wooden propeller (Figure 2 left) and was attached to the engine propeller flange with six M8 x 110 mm, 8.8 steel bolts. The heads were drilled, wire locked in pairs and the threaded part had been shortened. Under the head of each bolt was a plain washer and a 8 mm thick recessed crush plate (Figure 2 centre and right). The bolts thread into inserts which are press fitted into the attachment flange. The full thread started approximately 1 mm inside the insert from the propeller side.

Prior to the Permit-to-Fly renewal flight the propeller had been removed and returned to manufacturer as there was evidence of cracks and disbonding of the surface lacquer finish. The propeller was refurbished by stripping it back to bare wood and the moisture content checked. No additional drying was required so the propeller was re-lacquered, balanced and returned. The newly refurbished propeller was re-fitted for the renewal flight and was to be torque checked after 25 flight hours. The propeller manufacturer recommended a torque check after the first flight, after 25 hours and every 50 hours thereafter.

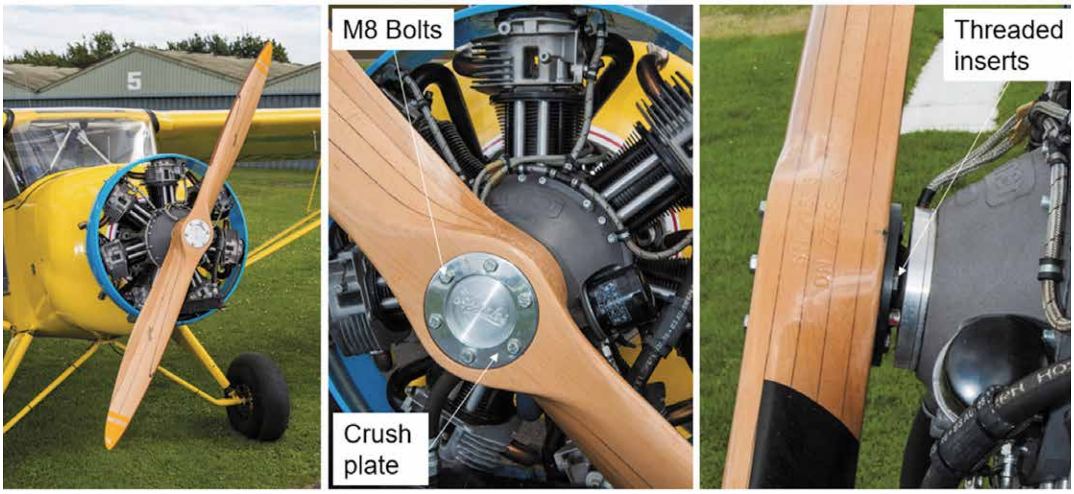

**Figure 2**

G-BTRG with Hercules propeller (left), detail of the attachment (centre and right)
(Photograph credit: FLYER - Ed Hicks)

### Propeller flange examination

The propeller attachment flange was removed from the aircraft (Figure 3 left) and sent to AAIB where the threaded inserts were removed and sent for metallurgical examination (Figure 3 centre and right).

**Figure 3**

Attachment flange (left), example threaded insert removed (centre),
remaining bolt thread in the insert (right)
(Photographs used with permission)

After an initial optical examination at magnifications up to x 45 the threaded inserts were cut to remove the remaining threaded part of the bolt. The rust deposits were removed from the fracture surfaces and then examined using a Scanning Electron Microscope at magnifications up to x 5,000.

Examination of the fracture faces showed that all the bolts had similar characteristics of failure. Multiple fatigue cracks had propagated inwards from initiation sites around the circumference of the bolt, coalescing to form two major cracks (Figure 4). This is consistent with reverse-bending fatigue and the fine spacing of the crack growth indicated loading under high frequency vibration. No pre-existing mechanical or material defects could be found at the initiation sites. Sample bolts were strength tested and they conformed to all specification requirements.

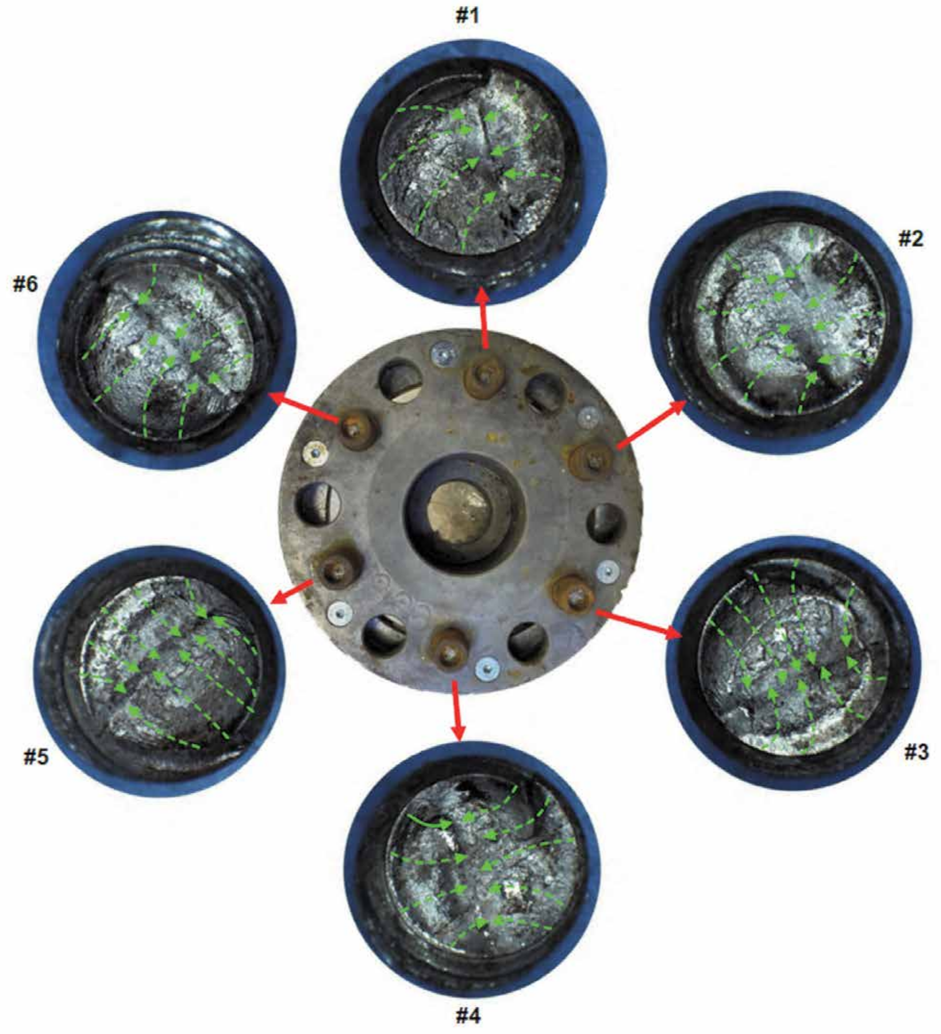

**Figure 4**

Fracture faces of all bolts showing propagation direction.
(Photograph used with permission)

The tail of all the bolts showed evidence of grinding marks consistent with the bolts being shortened and chamfered (Figure 5). The bolt standard states the full thread length of the bolt is 22 mm minimum and the average length of full thread documented on the batch certificate of conformance was 23.2 mm. The thread transition was approximately 1 mm. The part of the bolt removed from the threaded insert was 18 mm and as the thread transition was visible, approximately 5 mm had been removed from the bolt tail.

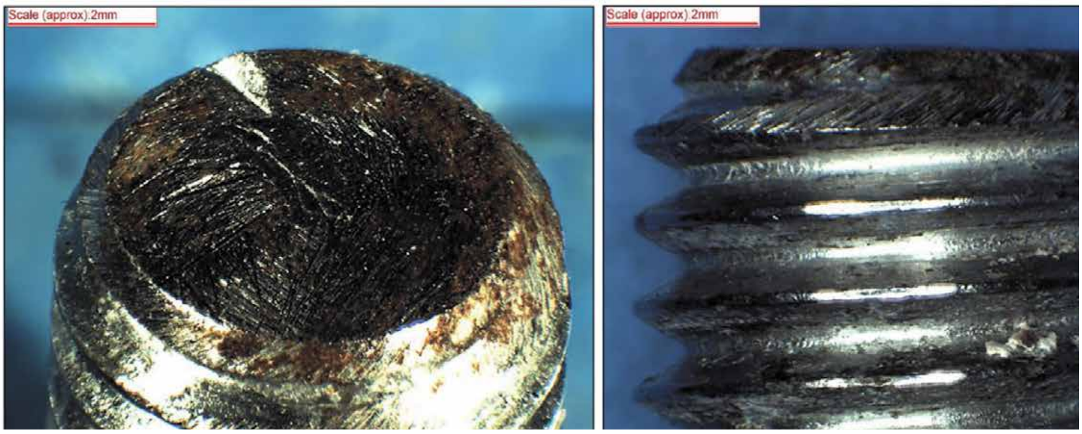

**Figure 5**

Detail of the bolt tail showing grinding marks and chamfering.
(Photographs used with permission)

There was evidence on two of the threaded inserts of a circular imprint and helical machining marks on the surface on the non-flanged end, ie the end adjacent to the propeller (Figure 6). It was considered possible that these imprints were a result of the shank of the bolt having been pressed into the insert. This situation is called 'shanking', where the bolt is tightened to the specified torque but the pre-load tension in the bolt is lower than specified. Insufficient pre-load is a common cause of fatigue failure of threaded fasteners.

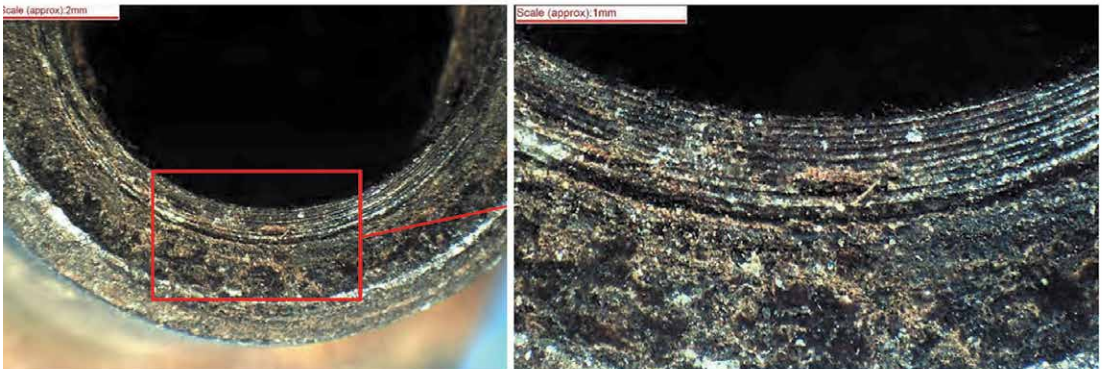

**Figure 6**

Detail of the circular imprint and helical machining marks on a threaded insert.
(Photographs used with permission)

## Bolt length

The cross section shown in Figure 7 shows the propeller, flange and threaded insert arrangement. The recessed crush plate and the washer under the head of the bolt are also included. The M8 x 110 mm bolt has a shank length of 86.6 mm (110 – 23.2 = 86.6 mm). It was assumed that the full thread would start 2 mm inside the insert due to the overlapping thread transitions and this was supported by the fracture faces being approximately 2 mm inside the insert (Figure 3 right).

The stack of components in the joint is 82.6 mm (2 - 20 + 9 + 91 + 1.6 = 83.6 mm) thereby leaving a gap of 3 mm. The installed bolt would have shanked before pre-load had been applied. The engineer stated that when the propeller was installed the crush plate "was proud by 2 to 3 millimetres" which he accepted as correct.

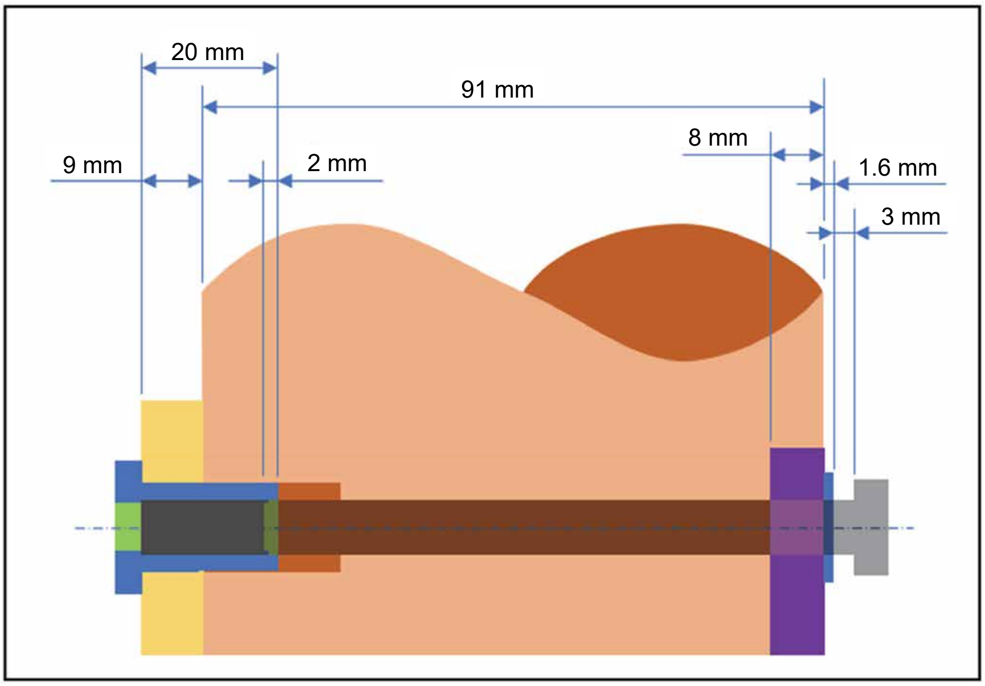

**Figure 7**

Cross section of the propeller to flange bolted joint

In the engine manufacturer's installation documentation, there is a requirement that no more than 10 mm of bolt is to protrude through the propeller to ensure clearance of the alternator windings which are located just behind the propeller flange (Figure 8).

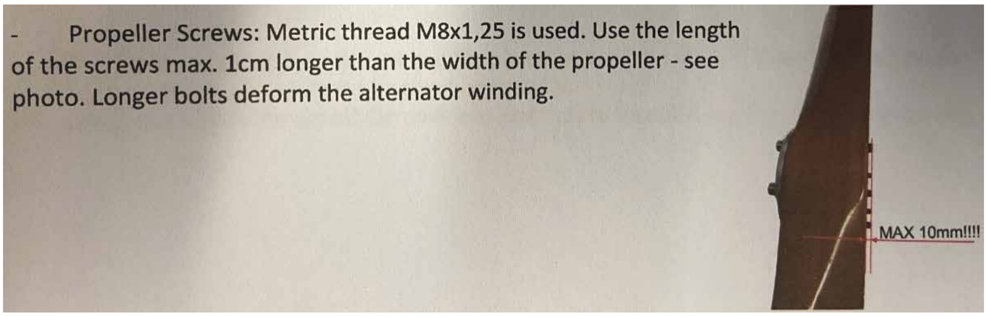
- Propeller Screws: Metric thread M8x1,25 is used. Use the length of the screws max. 1cm longer than the width of the propeller - see photo. Longer bolts deform the alternator winding.

**Figure 8**

Engine manufacturer's installation documentation regarding propeller bolting

The engineer responsible for the installation of the propeller stated that an M8 x 100 mm bolt was too short and that a 110 mm was required. The propeller, crush plate (3 mm proud) and washer had a combined stack of 96 mm (91 + 1.6 + 3 = 95.6 mm) and a 100 mm bolt would have had 4 mm of thread protruding through the rear face of the propeller whereas a 110 mm bolt would have had 14 mm. The length of thread remaining in the threaded insert after the accident was 18 mm which equates to a standard thread length with 5 mm removed thereby leaving just less than 10 mm protruding through the propeller. The engineer stated he had cut “less than 10 mm” from the tail of the bolts before installing them to ensure the clearance to the alternator windings as per the installation documentation.

## Analysis

Shortly after takeoff all six propeller bolts failed, resulting in the propeller departing the aircraft. There were no indications prior to the failure and the first symptom was the engine over speeding. The pilot closed the throttle and made a forced landing which resulted in the aircraft being extensively damaged.

Examination of the failed bolts revealed that they had failed from high cycle, reverse-bending fatigue. This failure is consistent with normal loads applied by the propeller to bolts which have insufficient pre-load. This loss of pre-load was possibly due to the bolts having shanked. On installation the correct torque was applied however as the bolt shank was too long no axial pre-load was applied to the bolt.

It is possible that the length of bolt was chosen based upon a misinterpretation of the installation document from the engine manufacturer. A bolt length was chosen which protruded more than 10 mm and was then shortened so that just less than 10 mm protruded. This resulted in a shank length which was too long for the stack by approximately 3 mm. A 100 mm bolt would have had full thread engagement without shanking and protruded approximately 4 mm from the rear face of the propeller.

When the propeller was installed, it is possible that no gaps where visible after the bolts were fully torqued due to the crush plate not fully seating into the rebate as new surface lacquer had just been applied. The propeller manufacturer recommended a re-check after the first flight which was not done.

As a result of this accident the engine manufacturer has taken safety action to revise the information in the installation document to include a drawing to aid the correct length of bolt to be selected.

## Conclusion

Lack of pre-load in the propeller bolts resulted in their failure by reverse-bending fatigue shortly after takeoff. The bolts had shanked but were correctly torqued without applying a pre-load. It is possible that the incorrect bolt length was chosen due to a misinterpretation of the engine manufacturer’s installation document.

The engine manufacturer has taken the following safety action:

> To revise the propeller installation document to include a drawing to aid the correct length of propeller bolt to be selected.

## ACCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | CAP 231, G-IIHZ | |
| **No & Type of Engines:** | 1 Lycoming AEIO-540-L1B5D piston engine | |
| **Year of Manufacture:** | 1988 (Serial no: 8) | |
| **Date & Time (UTC):** | 9 January 2022 at 1515 hrs | |
| **Location:** | Mundesley, Norfolk | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - None |
| **Injuries:** | Crew - None | Passengers - N/A |
| **Nature of Damage:** | Control arm mount detached from rudder, fin stern post dis-bonded from fin structure | |
| **Commander's Licence:** | Private Pilot's Licence | |
| **Commander's Age:** | 51 years | |
| **Commander's Flying Experience:** | 359 hours (of which 200 were on type)<br>Last 90 days - 11 hours<br>Last 28 days - 5 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB | |

### Synopsis

The pilot had taken off from Northrepps Airfield in Norfolk to carry out an aerobatic display sequence practice. During one of the manoeuvres, he felt a "jolt" through the airframe and the aircraft departed into an inverted spin. He was able to regain control of the aircraft and land back on the airfield. Examination of the aircraft found that the plywood mounting structures of the lower hinge assembly of the rudder and fin had failed. The exact cause and sequence of the failure of the various structures could not be determined.

### History of the flight

The pilot had taken off from Northrepps Airfield in Norfolk to carry out an aerobatic display sequence practice towards the North Norfolk coast. The pilot had completed several high energy manoeuvres, and as he neared the end of the display sequence and was conducting a vertical left roll, he felt a "jolt" through the aircraft, which immediately departed into an inverted spin. He closed the throttle and realising that there was something odd about the yaw control, he gently recovered the aircraft to level flight using the ailerons. He was able to retain control of the aircraft and carried out an extended long final approach to land back at the airfield. The landing was uneventful.

Examination of the aircraft immediately after the flight found that the rudder control horn had partially broken away from the rudder structure on its left side. There was also dis-bonding damage towards the bottom of the fin ‘stern post’. The small aluminium alloy fairing which forms the leading edge at the bottom of the rudder was also trapped and deformed.

## Structural examination

### *Rudder*

The rudder is of wooden construction consisting of a lightweight three ply 2.5 mm thick plywood skin bonded to plywood ribs. The surfaces of the rudder are fabric covered with an epoxy coating. There are three metal pivot hinges attached to plywood re-enforced blocks within a box section plywood main spar. The rudder control horn was attached to the back of the lower hinge plywood re-enforcing block. An aluminium fairing was fitted around the bottom leading edge of the rudder and encloses the hinge area around the control horn. It was held in place by small (No 6 x ½ inch) countersunk wood screws.

The fairing was partially attached but appears to have been trapped and crushed between the rudder fin skin edges where they overlap the stern post (Figure 1).

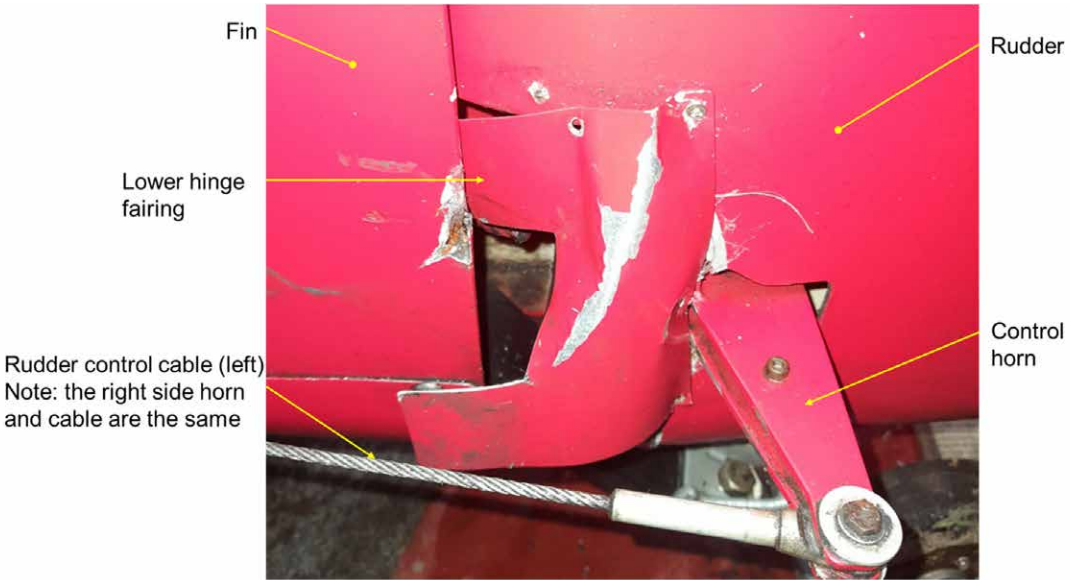

**Figure 1**

Rudder lower hinge fairing damage

The upper and lower rudder hinge pivot brackets and surrounding structure was undamaged as were the left and right faces of the rudder. The lower hinge and control horn were correctly attached to the re-enforcing block, but this was partially detached from the rudder structure. It had broken away from the box section main spar within the rudder structure (Figure 2).

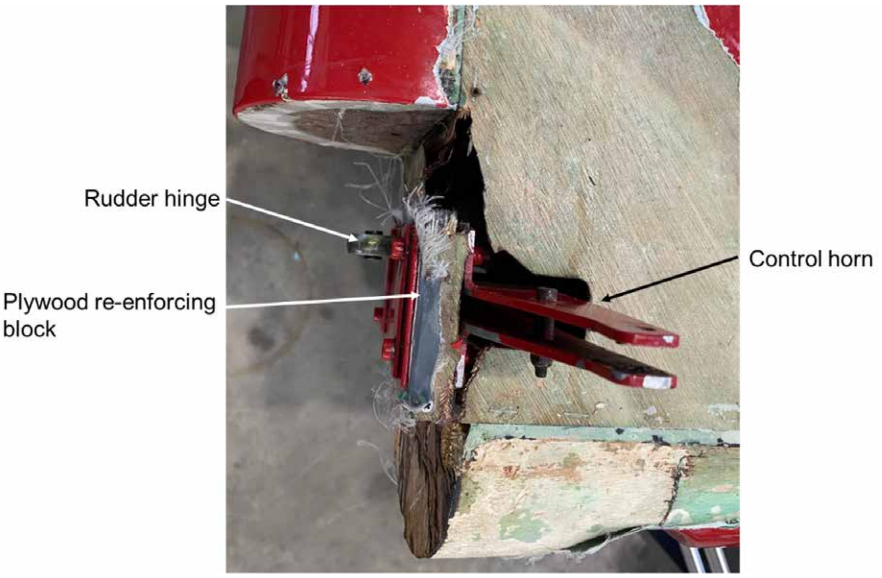

**Figure 2**

Damage to the rudder spar and lower hinge and horn mounting block
(Fabric covering removed from the surrounding area for examination)

*Fin*

The fin is of similar construction to the rudder. Three hinge pivot brackets are mounted on the rear spar of the fin, described as the stern post. The bottom hinge bracket is fitted with adjustable rudder travel stops. The lower portion of the stern post near the lower hinge bracket, whilst still in its correct position, had dis-bonded from the fin skin structure and lost its rigidity. Evidence of distress on the centre and lower hinge between the stern post and skin overlap is shown in Figures 3 and 4.

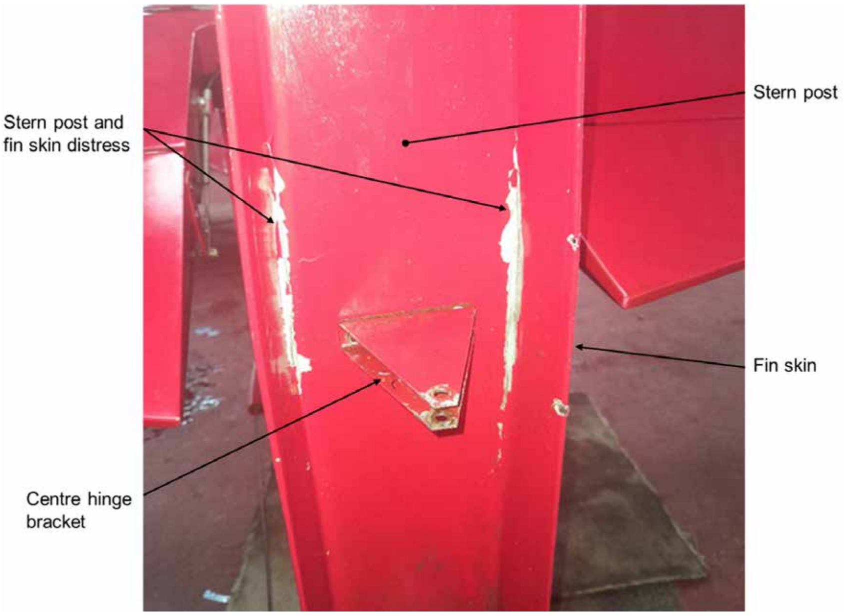

**Figure 3**

Distress between the fin skin and stern post both sides of the centre hinge

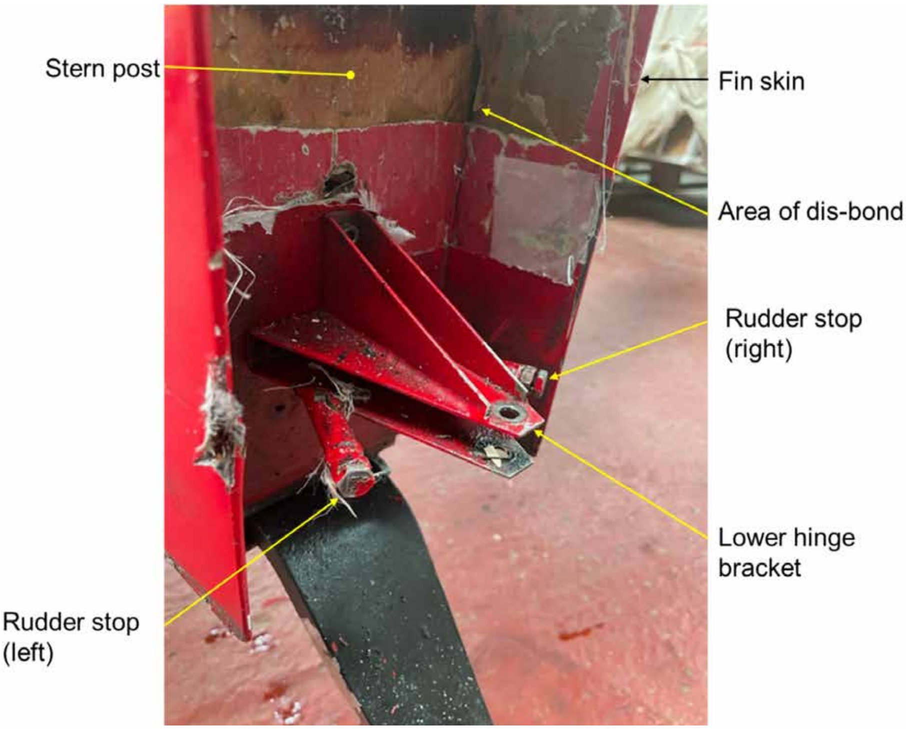

**Figure 4**

Lower hinge bracket and integrated stops showing the dis-bond.
(Fabric covering removed in the surrounding area for examination)

Examination of the stern post attachment to the fin skins showed evidence that a repair had been carried out in the past and that the right side glued edge had parted. It was also apparent that the bond along this edge seemed to have been assembled with only a small bead of glue.

## Discussion

*Failure sequence*

The nature of the damage to the fin, rudder and fairing made it difficult to ascertain the initiating event. If the rudder horn on its re-enforcing block had partially detached first, it is plausible that it could lead to the fairing damage which in turn led to the stern post damage.

Similarly, the same conclusion could be drawn if the fairing had detached during rudder movement and become jammed between the rudder and stern post. This would result in damage to the bottom hinge and horn block and a transference of more load on to the centre hinge leading to the fin dis-bond.

It is also possible that the stern post had dis-bonded first, which would have led to a loss of rigidity in the lower hinge bracket. This would have put abnormal loads into the centre hinge bracket hence the distress apparent where the skin meets the stern post on both sides. Additionally, this mis-location or loss of rigidity would have led to abnormal loads in the bottom hinge rudder and control horn.

*Potential cause*

The aircraft was designed to undertake high energy aerobatic flight. A vertical left roll manoeuvre was being flown when the aircraft departed into the inverted spin. This is not considered to have put abnormal loads on the rudder. The pilot was experienced in the manoeuvres he was flying and had done the same routine many times before. Notwithstanding, an overly vigorous input into the rudder control system earlier in the flight, shock loading the control horn or it ‘slamming’ onto the right control stop, has to be considered. However, discussions with the pilot and his description of his regularly flown routine, suggest that whilst rudder control inputs must be positive, rapid and use the full range of movement, they are not to the extent the stops are constantly being hit excessively hard by the rudder.

The possibility of the rudder being forced onto its stops by mishandling on the ground, in the hangar or due to gusty conditions whilst the aircraft is parked, was considered. However, discussions with the pilot, who is the sole owner of the aircraft, suggest that these potential risks to the rudder are highly unlikely and therefore can be ruled out.

## Conclusions

The rudder and fin components failed during part of an aerobatic sequence which had been regularly flown and practiced by the pilot. Until the jolt leading to the inverted spin, the pilot does not consider anything unusual to have occurred, or that any abnormal loads were applied to the rudder.

There appears to be three distinct failure features identified in the rudder and fin components. There is partial detachment and severe distortion to the lower hinge fairing, the horn and lower hinge mounting block has partially broken away and the glued joint between the stern post and fin skin, which was part of a previous repair, had failed. It is plausible that either one of these failures could lead to the others. However, it could not be positively determined which one was the initiating failure.

## ACCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Casa 1-131E Series 1000, G-BUCK | |
| **No & Type of Engines:** | 1 ENMA Tigre G-IV-A2 piston engine | |
| **Year of Manufacture:** | 1951 (Serial no: 1113) | |
| **Date & Time (UTC):** | 13 June 2022 at 1650 hrs | |
| **Location:** | Turweston Aerodrome, Buckinghamshire | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - None |
| **Injuries:** | Crew - None | Passengers - N/A |
| **Nature of Damage:** | Landing gear collapsed, shock-loaded engine, lower wing and propeller damaged | |
| **Commander's Licence:** | Airline Transport Pilot's Licence | |
| **Commander's Age:** | 65 years | |
| **Commander's Flying Experience:** | 21,552 hours (of which 44 were on type)<br>Last 90 days - 39 hours<br>Last 28 days - 20 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot | |

On its third flight of the day, following an extensive restoration, the aircraft landed on grass Runway 27 at Turweston. The wind was approximately from 290° at 5 kt.

The view forward from this aircraft type is restricted on the ground and the pilot was looking over the left side of the engine to keep clear of the left runway edge markers. At a speed of about 30 kt he became aware of tall grass to his right. Realising that the aircraft was drifting towards the right edge of the runway, he applied left rudder but almost immediately heard a bang. The landing gear collapsed and the aircraft stopped upright, sustaining damage to its propeller and right lower wing.

The uninjured pilot found that the right mainwheel had struck a stack of four traffic cones at the northern edge of the grass runway, beyond which was tall grass separating it from the adjacent asphalt runway.

The pilot considered that the accident would not have occurred had he planned beforehand to remain no more than one wingspan away from the left runway edge. It is likely he would not have found this difficult in the prevailing conditions, as he reported his recent experience included several flights in similarly configured Tiger Moth aircraft.

Information published by the aerodrome operator on its website instructs pilots to remain within the marked manoeuvring area, indicating that it may be hazardous to operate outside the marked manoeuvring areas even in the absence of the cones.

## ACCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Cessna 120, G-OVFM | |
| **No & Type of Engines:** | 1 Continental Motors Corp O-200-A piston engine | |
| **Year of Manufacture:** | 1948 (Serial no: 14720) | |
| **Date & Time (UTC):** | 06 December 2021 at 1530 hrs | |
| **Location:** | South Cave (Mount Airy) Airfield, Hull, East Riding of Yorkshire | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - 1 |
| **Injuries:** | Crew - None | Passengers - None |
| **Nature of Damage:** | Right main gear leg displaced, fuselage buckled, engine cowlings and propeller damaged | |
| **Commander's Licence:** | Private Pilot's Licence | |
| **Commander's Age:** | 20 years | |
| **Commander's Flying Experience:** | 192 hours (of which 35 were on type)<br>Last 90 days - 24 hours<br>Last 28 days - 10 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot and examination of the aircraft by the AAIB | |

### Synopsis

The aircraft landed long and fast onto a downhill wet grass runway and failed to stop, striking a hedge beyond the end of the runway. The pilot did not report the accident; however, it was subsequently reported by a third party. The circumstances surrounding this event serve as a reminder to all pilots of their obligation to report accidents and serious incidents and to ensure flight planning is conducted however familiar the pilot is with the aircraft they fly and the airfields they fly into.

### History of the flight

The pilot, accompanied by a passenger, was returning to the airfield having flown to Sherburn-in-Elmet for a private flight earlier that day. As they arrived the pilot overflew the runway to view the windsock. This indicated that the downhill[1] Runway 25 was most favourable. The pilot positioned for the runway and commenced his final approach. The approach was quick and resulted in touching down further along the runway than normal. As the pilot applied the brakes, the wheels, which were equipped with slick tundra tyres, skidded. At this point the pilot realised he was unlikely to stop on the runway. He made an

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**Footnote**

[1] South Cave Runway 25 has a downhill gradient of 2.3%

assessment that there was insufficient distance to get airborne and clear trees beyond the end of the runway so elected to continue with the landing. As expected, he was unable to stop the aircraft before colliding with a hedge at the end of the runway. Both the occupants were uninjured.

The pilot believes that between the time that he departed from South Cave (Mount Airy) and his subsequent return to the airfield rain showers, which were forecast, had wetted the grass runway, and made it slippery, increasing the landing distance of the aircraft. In addition, the pilot was accustomed to flying G-OVFM solo and was not used to flying with a passenger which had brought the aircraft close to maximum takeoff mass. The pilot stated that he was also used to flying a Cessna 172, which slowed more rapidly with the use of flaps, a control that the Cessna 120 is not fitted with.

## Aircraft examination

The damaged aircraft was recovered to a hangar and its wings and engine removed in preparation for repair. Subsequent inspection by the AAIB identified the right main landing gear leg was deflected rearwards. This resulted in buckling and twisting of the floor pan and fuselage to the rear of the landing gear mount (Figure 1). The fuselage to the rear of the left seat had buckled (Figure 2) and the right wing root had cracked (Figure 3). The engine cowls were damaged, as was the propeller.

**Figure 1**

G-OVFM showing movement of right main gear leg and damage to fuselage rear of its mounting location

**Figure 2**

G-OVFM fuselage buckling

**Figure 3**

G-OVFM cracking of right wing root

## AAIB comment

*Reporting*

The accident was not reported to the AAIB by the pilot or aircraft owner. It was only when a third party contacted the AAIB, enquiring whether the event was being investigated, that the AAIB became aware of the accident.

Non-reporting of an accident is an offence and breach of The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018, Part 2, Regulation 20[2]. This occurrence serves as a reminder to all pilots of their obligation, as a licence holder, to report accidents or serious incidents, even if they consider the event not to have been reportable.

### *Flight preparation*

The pilot was familiar with the airfield and was flying an aircraft he had flown many times before. With this, he may have been lulled into a false sense of security and may not have planned the flight as diligently as if her were flying to a new location. The changing weather conditions, increased aircraft weight and fast and deep approach combined with the adverse gradient on the landing runway to increase the stopping distance and reduced the brake effectiveness resulting in the runway overrun. If the pilot had considered these factors in advance of the flight and accounted for threat and error management he may have gone around earlier, or accepted a slight tailwind, but uphill landing. CAA publications, such as CAP1535S, '*The Skyway Code*'[3], and the newly published, Safety Sense leaflet, SS12 on Strip Flying[4] (this had not been published at the time of the accident) are helpful resources to all pilots as reminders and prompts to aid planning and decision making associated with GA flying.

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**Footnote**

[2] https://www.legislation.gov.uk/uksi/2018/321/regulation/20/made (accessed May 2022)

[3] https://www.caa.co.uk/general-aviation/safety-publications-and-information/the-skyway-code/ (accessed May 2022)

[4] https://www.caa.co.uk/media/cwjom2ph/safetysense_12-strip-flying.pdf (accessed May 2022)

## SERIOUS INCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Grob G115B, G-BYDB | |
| **No & Type of Engines:** | 1 Lycoming O-320-D3G piston engine | |
| **Year of Manufacture:** | 1988 (Serial no: 8025) | |
| **Date & Time (UTC):** | 17 April 2022 at 1450 hrs | |
| **Location:** | Clacton Airfield, Essex | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - None |
| **Injuries:** | Crew - None | Passengers - N/A |
| **Nature of Damage:** | Damage to the leading edge of the wing and shock loading of the engine | |
| **Commander's Licence:** | Private Pilot's Licence | |
| **Commander's Age:** | 52 years | |
| **Commander's Flying Experience:** | 189 hours (of which 10 were on type)<br>Last 90 days - 4 hours<br>Last 28 days - 2 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot | |

### Synopsis

The pilot judged he was high on the approach and increased the aircraft's rate of descent to compensate, which probably also increased its airspeed. The aircraft touched down but, despite the use of maximum braking, overran the runway and came to an abrupt halt in the airfield's boundary hedge.

The pilot considered that it might have been better to go around when he realised he was high on the approach, especially given the short landing distance (505 m).

### History of the flight

This serious incident occurred on a cross-country flight from Fowlmere Airfield to Clacton Airfield (Clacton) in Essex. On the day of the incident, Clacton was using Runway 18 (Figure 1), which the pilot had previously landed on in a Cessna 172. On that earlier occasion he was advised, "if you do not land before the footpath, perform a go-around".

When he arrived in the Clacton overhead on the incident flight, the pilot saw from the windsock that the surface wind was calm and he positioned for Runway 18. On final the pilot judged that he was "a little high" and increased the rate of descent to compensate, achieving a touchdown "just" before the footpath. Despite applying full braking, he was unable to stop the aircraft in the remaining distance. G-BYDB overran the runway before coming to an abrupt halt in the airfield's boundary hedge (Figure 2). Uninjured, the pilot unfastened his harness and exited the aircraft without external assistance.

The aircraft suffered damage to the wing leading edge and shock loading of the engine. During a pre-takeoff test at Fowlmere Airfield G-BYDB's brakes had worked normally, and a post-incident technical investigation found the brakes to be "fully functioning".

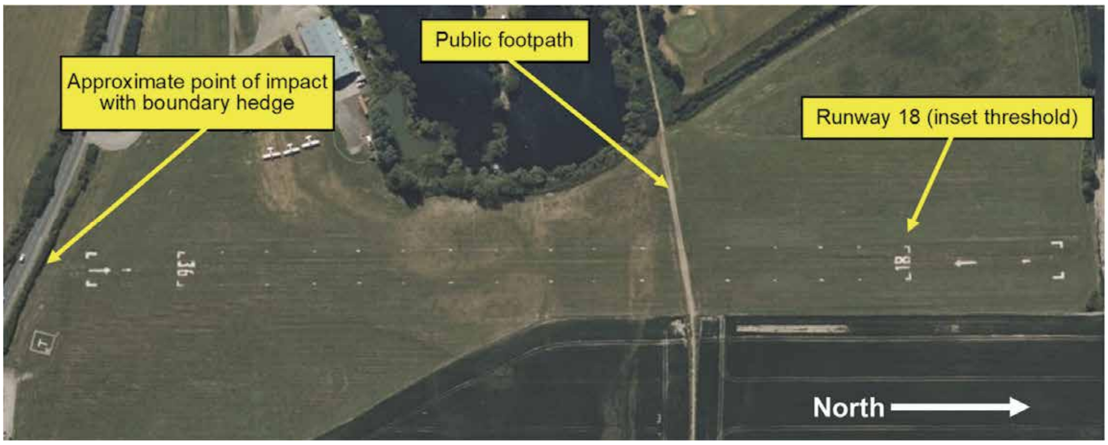

**Figure 1**

Overview of Runway 18/36 at Clacton Airport
(Imagery ©2022 Bluesky.CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky.Landsat / Copernicus, Maxar Technologies, Map data 2022)

**Figure 2**

G-BYDB in the boundary hedge after the runway overrun

### Pilot's observations

The pilot reported that, having previously landed at Clacton in a Cessna 172, he had assumed that the, smaller, Grob 115 would "comfortably have enough runway to land safely." Under this assumption he did not check landing performance against the Pilots Operating Handbook or speak with one of the operator's instructors beforehand to "determine the suitability of flying into Clacton in the Grob".

While managing to touch down before the footpath, the pilot surmised that increasing the rate of descent to achieve it resulted in a higher-than-normal touchdown speed, making a runway overrun more likely. He reflected that a wiser course of action would have been to perform a go-around rather than continuing with a high approach, especially given the relatively short maximum landing distance available (505 m) and lack of appreciable headwind.

### AAIB comment

While previous experience is generally beneficial, making assumptions based on it can engender risk. On-the-day factors, such as aircraft performance, local weather conditions and achieved flight parameters, are key considerations in any pilot's decision-making process, both before and during flight.

## SERIOUS INCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | DJI Air 2S | |
| **No & Type of Engines:** | 4 electric engines | |
| **Year of Manufacture:** | 2021 (Serial no: 3TYDJ23 003L96S) | |
| **Date & Time (UTC):** | 16 April 2022 at 1630 hrs | |
| **Location:** | Welfare Park, Huthwaite, Nottinghamshire | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - N/A | Passengers - N/A |
| **Injuries:** | Crew - N/A | Passengers - N/A<br>Other - 1 (Minor) |
| **Nature of Damage:** | Nil | |
| **Commander's Licence:** | Other | |
| **Commander's Age:** | 45 years | |
| **Commander's Flying Experience:** | 15 hours (of which 15 were on type)<br>Last 90 days - 1 hour<br>Last 28 days - 1 hour | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot | |

### Synopsis

While a DJI Air 2S (Air2S) unmanned aircraft (UA) was being flown in a low hover over a group of children one of them attempted to grab it and their hand touched the rotor blades. The aircraft became destabilised, briefly lost height and injured the child. The pilot reflected that he should not have been flying his aircraft so close to the children.

### History of the flight

The incident pilot was flying his Air2S in Welfare Park, Huthwaite (Figure 1) when some children who were in the area "took an interest" in it. The pilot began flying the aircraft "a few feet above their heads" and they started to chase it. He then brought the UA to a GPS-stabilised hover, at which point a 3-year-old child "jumped up" and tried to catch it. The child managed to reach up and touch the rotor blades which destabilised the aircraft. The UA briefly lost height and its blades struck the child, making two significant cuts on their face as well as smaller cuts to their nose, chin and fingers. The facial cuts required hospital attention. After striking the child, the UA automatically re-established its hover and the pilot flew it away from the children. The child's injuries were assessed as minor.

## Incident site

Welfare Park is a public recreation space within a residential area of Huthwaite, Sutton-in-Ashfield. At the time of the incident, the UA was being flown over open ground toward the northern end of the park (Figure 1). The closest dwellings were approximately 75 m from the incident site.

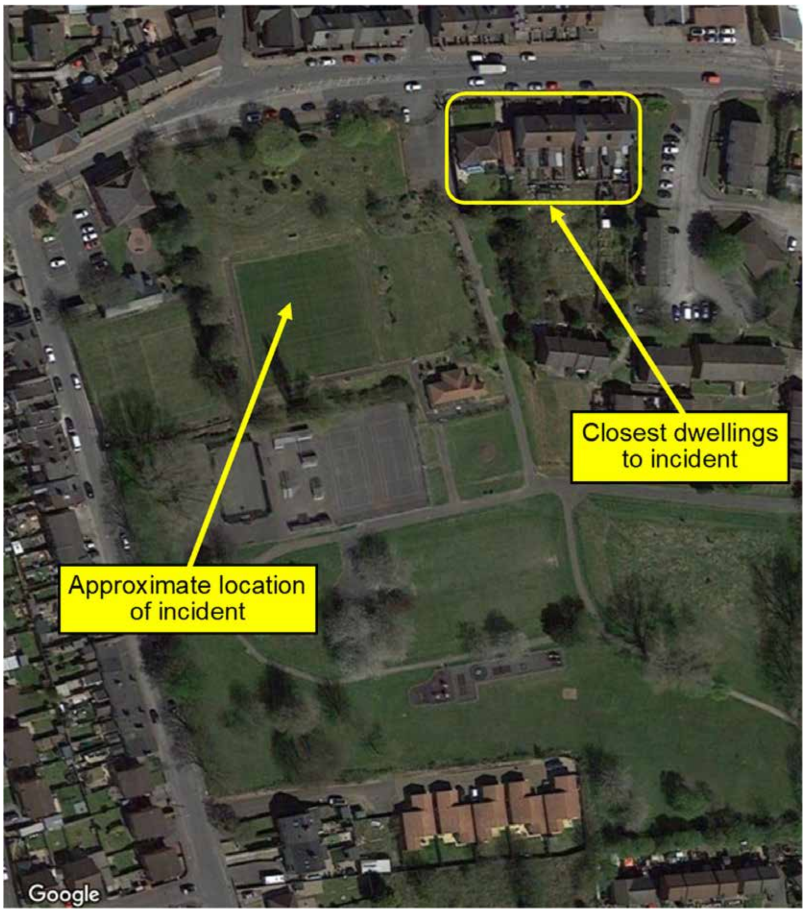

**Figure 1**

Welfare Park, Huthwaite, Sutton-in-Ashfield

(Satellite image ©2020 Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, Map Data ©2022)

## Regulations for UA operations

### *Basic regulation*

Specific EU regulations covering unmanned aircraft system (UAS) operations were published in 2019 and transferred into UK law at the end of the EU exit transition period. This 'UAS Regulation Package' consisted of two separate, but interlinked regulations:

- '*Commission Implementing Regulation (IR) (EU) 2019/947 on the procedures and rules for the operation of unmanned aircraft*,' and,
- '*Commission Delegated Regulation (DR) (EU) 2019/945 on unmanned aircraft and on third country operators of unmanned aircraft systems*.'

As a result of the UK's exit from the European Union, both regulations have been amended and consolidated versions of each are published by the CAA as CAP1789A (IR) and CAP1789B (DR).

*UK Air Navigation Order 2016*

The Air Navigation Order 2016 (ANO) is described as regulating *'matters such as aviation safety standards and aircraft navigation'* and being '*wide-ranging, covering aircraft, air crew, passengers, cargo, air traffic services and aerodromes.*' Article 241 of the ANO requires that '*a person must not recklessly or negligently cause or permit an aircraft to endanger any person or property.'*

*UK guidance for UAS operations*

Detailed guidance for operating UASs in UK airspace is contained within the CAP722 document series which references the basic regulations and is published by the CAA. CAP722 is the lead document and CAPs 722A-E cover wider topics such as risk assessment methodology, training policy and a glossary of terms relating to UAS operations. The CAA's '*Drone and Model Aircraft Code*' website[1] contains further guidance for pilots and operators of UASs to help them '*fly safely and legally*.'

CAP722D definitions relevant to this incident were:

- Aircraft: '*any machine that can derive support in the atmosphere from the reactions of the air other than reactions of the air against the earth's surface*.'
- UA: '*any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board*.'
- UAS: '*a UA and the equipment to control it remotely*.'
    - ◊ A UAS comprises individual system elements consisting of the UA and any other elements necessary to enable flight, such as a Command Unit (CU), communication link and launch and recovery element. There may be multiple UAs, CUs or launch and recovery elements within a UAS.
- Remote pilot: 'a *natural person responsible for safely conducting the flight of* [a UA] *by operating its flight controls, either manually or, when the* [UA] *flies automatically, by monitoring its course and remaining able to intervene and change the course at any time*.'
    - ◊ Before flying any UA covered by the regulations, a remote pilot must obtain a 'flyer ID'[2] by passing the CAA's official theory test. The theory test includes questions on the regulations for UAS flying in the UK.

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**Footnote**

[1] The Drone and Model Aircraft Code | UK Civil Aviation Authority (caa.co.uk) (accessed 19 May 2022).

[2] Getting what you need to fly | UK Civil Aviation Authority (caa.co.uk) (accessed 4 May 2022).

  - ◊ The remote pilot is responsible for the safe and legal operation of any UA that they are flying.
- UAS operator: '*any legal or natural person operating or intending to operate one or more UAS*.' *The UAS operator is responsible for the overall operation of the UAS, and most specifically the safety of that operation. This includes the conduct of any safety risk analysis of the intended operations*.'
  - ◊ The operator of a UAS must register with the CAA to obtain an 'operator ID' number which must be displayed on their aircraft.
  - ◊ The operator is responsible for ensuring that anyone who flies their UA has a flyer ID.
  - ◊ Provided they hold the correct CAA-issued IDs, an individual can act as both remote pilot and operator for the UA they are flying.
- Uninvolved persons: '*persons who are not participating in the UAS operation or who are not aware of the instructions and safety precautions given by the UAS operator*.'

*UAS operational categories*

UAS operations in the UK are regulated according to the perceived level of risk that the intended operation presents. Operations are deemed to fall within one of the following three broad categories:

- Open: operations presenting a low risk to third parties.
- Specific: operations requiring a CAA-issued operational authorisation because they present a greater risk than those in the Open category.
- Certified: operations that present an equivalent risk to that of manned aviation.

The remote pilot was operating under the auspices of the Open category at the time of the incident.

*Open category*

Flights in the Open category are restricted to Visual Line of Sight[3] operations of UA below 25 kg maximum takeoff mass. The category is divided into three operational subcategories, primarily based on the permitted proximity of a UA to uninvolved persons while in flight:

- A1 ('*fly over people*'): operations limited to UA posing a '*very low risk of harm*' due to their weight or construction.

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**Footnote**

[3] Normally limited to a maximum distance of 400 ft (120 m) from the closest point of the surface of the earth and at a maximum range that allows to pilot to maintain visual contact and monitor the aircraft's flight path and manoeuvre it clear of anything that it might collide with.

- A2 (‘*fly close to people*’): remote pilots are required to gain an A2 Certificate of Competency (A2 CofC) to operate under the A2 subcategory regulations and must not fly their aircraft closer than 30 m horizontally[4] from uninvolved persons.
  - ◊ The A2 CofC qualification is primarily intended to assure an appropriate knowledge of the technical and operational mitigations for the risk of a person being struck by a UA.
- A3 (‘*fly far from people’*): separation from any uninvolved person must not be reduced below 50 m horizontally at any time and the UA must not be flown within 150 m horizontally of areas used for residential, commercial, industrial or recreational purposes.

## Aircraft information

The Air2S was a commercially available UAS comprising a UA, with a nominal takeoff weight of 595 g, and a handheld remote control module. The system was required to be operated in accordance with UK regulations for UAS operations.

The Air2S aircraft was too heavy for the A1 Open subcategory but, subject to a remote pilot’s qualifications, could be flown in either the A2 or A3 Open subcategory.

## Personnel

The incident pilot was also the operator of the UAS and was in possession of valid ‘flyer’ and ‘operator’ IDs issued by the CAA. He had not gained an A2 CofC qualification.

The children were not participating in the UAS operation and had not received any safety instructions from the incident pilot. The pilot reported being surprised when the child jumped up and reflected that, in hindsight, he should not have been flying his UA in the area.

## Analysis

The Air2S UAS was covered by, and its operator responsible for compliance with, the UK regulations for UAS operations. The incident UAS’s operator was also acting as the remote pilot and was responsible for the safe operation of the aircraft, including compliance with the ANO, while it was in flight. As defined in CAP722D, in relation to the operation of the incident UAS, the injured child was an uninvolved person.

The incident pilot held the appropriate authorisations to fly the Air2S under the A3 Open category, which required a minimum horizontal separation of 50 m from uninvolved persons and 150 m from areas used for residential, commercial, industrial or recreational purposes. These required separation minima were not maintained.

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**Footnote**

[4] 5 m if the UA is in the system’s ‘low-speed’ mode.

## Conclusion

This incident occurred when a UA operated in the A3 Open category was flown closer to uninvolved persons than allowed for under the applicable regulations. Had the regulated horizontal separation minima been observed, the incident could not have occurred.

## SERIOUS INCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | DJI Phantom 4 Pro | |
| **No & Type of Engines:** | 4 electric motors | |
| **Year of Manufacture:** | 2018 (Serial no: OAXDDAB 0A20205) | |
| **Date & Time (UTC):** | 25 November 2021 at 1018 hrs | |
| **Location:** | Railway Terrace, Rugby, Warwickshire | |
| **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:** | None | |
| **Commander's Licence:** | Other | |
| **Commander's Age:** | 58 years | |
| **Commander's Flying Experience:** | 40 hours (of which 40 were on type)<br>Last 90 days - 8 hours<br>Last 28 days - 3 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot | |

### Synopsis

The pilot, without a separate observer, was conducting a flight to document a construction site. Shortly after takeoff, the pilot's attention was diverted to two messages displayed on his controller. After reading them he was unable to regain visual contact with the aircraft. One message advised that the aircraft had lost its heading reference due to magnetic interference and prompted the pilot to resume manual flying, the second advised of reduced propulsion due to battery health. The lack of heading reference prevented the aircraft from responding to the pilot's command for it to return to home and a subsequent message identified that the command link signal was too weak and that the connection had been lost.

The aircraft, out of the pilot's control, drifted over a congested area and subsequently landed in a tree.

### History of the flight

The pilot was using the aircraft to document progress on a construction site. He was not assisted by an observer. The site is in a congested area, amongst housing and close to a railway line. Two automated flights had been flown, with some deviation during the end of the second flight necessitating the pilot to take manual control to return it. The third flight was flown manually and the wind at the time was from 330° at 13 kt.

The pilot reported that two messages were displayed almost immediately after takeoff. One stated PROPULSION OUTPUT HAS BEEN LIMITED TO ENSURE BATTERY HEALTH and the second advised MAGNETIC FIELD INTERFERENCE. EXIT P-GPS MODE. The pilot stated that on looking back up from reading the messages he could not regain visual contact with the aircraft. His response was to trigger the return-to-home function, but this did not work. The next message displayed to the pilot advised that the signal was too weak, and the connection had failed.

Given a loss of connection, the pilot stated that he would have expected the aircraft to have returned to home. However, the MAGNETIC FIELD INTERFERENCE. EXIT P-GPS MODE message meant that the aircraft was unsure of its heading and so was unable to hold a fixed position as it did not have sufficient information to correct a deviation from that position. This also means it cannot return home.

The EXIT P-GPS MODE is the prompt to resume manual flying which requires the pilot to be able to see the aircraft clearly in order to control it. A video link was still active, but the information displayed was insufficient for him to regain visual contact. He continued to attempt to regain control but was unsuccessful. Finally, a LANDING message was displayed.

The aircraft, out of the pilot's control, drifted 630 m over a congested area, before landing in a tree. The aircraft was located using the 'Find My Drone' feature on the pilot's controller.

The PROPULSION OUTPUT HAS BEEN LIMITED TO ENSURE BATTERY HEALTH message means that the ability of the aircraft to counter wind was reduced. The wind at the time was about 13 kt, but the aircraft manufacturer did not provide any information regarding what the effective wind limit is reduced to under these circumstances. Although it was not determined whether wind limits were a factor in this incident, it does highlight the potential risk associated with reduced power when flying adjacent to congested areas in windy conditions.

The pilot stated that having an observer during the operation would have been helpful to avoid loss of visual contact when the messages on his controller diverted his attention. He also advised that the sun was low at the time of flight, which hampered his ability to see the aircraft.

## Conclusion

The aircraft, having been subject to magnetic interference, was unable to hold its position or return home. It drifted, out of the pilot's control, for a considerable distance over a congested area thus posing a risk to uninvolved persons and property.

This incident highlights the importance of understanding the implications of any messages displayed to a pilot and also shows the benefits of having an additional observer to maintain visual contact.

# 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: May - June 2022

**31 Dec 2021** **Aeronca 7AC** **G-BVCS** Leicester Airport

The pilot was taking part in an authorised flour bombing event during which he inexplicably “lost vision momentarily” during an approach towards the target on the ground. Airfield CCTV footage showed the aircraft descend to the ground with no sign of a pull up. Just before the aircraft hit the ground to the right of the target, the flour bomb (released manually from the pilot’s window) was seen ‘exploding’ on the ground. The aircraft was extensively damaged.

**25 Feb 2022** **Laser Z200 (Modified)** **G-BWKT** Solent Airport, Hampshire

During a bounced landing the tailwheel attachment bolt failed causing the tailwheel to detach from its spring leg. It was not possible to determine if the bolt failure was caused by a pre-existing defect as one of the failure surfaces was worn away by ground contact and the other part of the bolt was not found.

**9 Mar 2022** **Socata TB9** **G-BIXB** Shobdon Airfield, Herefordshire

The aircraft encountered turbulent, down-drafting conditions at approximately 50 ft agl on short final. The pilot was unable to correct the induced rate of descent, the aircraft struck a fence and then landed approximately 30 m short of the runway threshold.

**15 Mar 2022** **Renegade 912** **G-BWPE** Ashcroft Airfield, Cheshire

The pilot had collected the new Renegade from Kent and was returning to land at his home field of Ashcroft. Because of unfamiliarity with the Type, having previously flown a Pioneer 200, the aircraft did not continue flaring as he expected, and he landed heavily on the grass runway causing extensive damage to the aircraft.

**3 Apr 2022** **Pegasus Quik** **G-CDGD** Yatesbury Airfield, Wiltshire

During the takeoff roll, the flexwing microlight drifted right and the trike rolled onto its left side.

**18 Apr 2022** **Vans RV-12** **G-CLMA** Weybourne, Norfolk

While climbing following a go-around the pilot encountered control problems. Following an uncommanded roll on flap retraction, he diverted to Norwich Airport where emergency support was available and made an uneventful landing. Subsequent inspection revealed that the outermost rib of the left flaperon was buckled, probably from an undetected impact.

## Record-only investigations reviewed: May - June 2022 cont

**21 Apr 2022** **Guimbal Cabri G2** **G-SHRU** Wolverhampton Halfpenny Green Airport, Staffordshire

On the fourth touchdown of an Engine Off Landing exercise, the aircraft touched down more nose up than previously. As the aircraft pitched forward onto its skids, the main rotor blades struck the tailboom damaging one rotor blade and the tail rotor drive shaft.

**28 Apr 2022** **Grob G115E** **G-BYVE** Wittering, Cambridgeshire

The student pilot was on their first solo flight. As the aircraft came into land, the pilot flared the aircraft late which resulted in a hard landing during which the aircraft bounced twice and the nosewheel axle bolt failed in overload. The pilot, who was unaware that the nosewheel had detached from the aircraft, flew a go around. During the subsequent landing the lower section of the nose leg collapsed, and the aircraft came to rest on the runway.

**3 May 2022** **Ikarus C42 FB100** **G-FLYC** Durley, Hampshire

The pilot attempted a precautionary landing due to high engine temperatures, but touched down too far down the runway so went around. The engine failed during the go-around and, during the subsequent forced landing in a field, the pilot was unable to prevent the aircraft from striking a hedge before coming to rest on an adjacent minor road.

**8 May 2022** **Rans S6S-116 Super Six** **G-XALZ** Yearby Airstrip, Redcar, North Yorkshire

The aircraft encountered turbulence on short finals which led to the left wheel entering the long grass beside the runway after touchdown. Despite the efforts of the pilot to steer back to the runway, the aircraft suffered significant damage when it then struck the boundary hedge.

**14 May 2022** **Mooney M20J** **G-OEAC** Skegness Airfield, Lincolnshire

Shortly after takeoff at around 150 ft agl, the aircraft veered to the left which the pilot was unable to correct. The aircraft descended rapidly and came to rest in a large ditch. The aircraft was substantially damaged.

**15 May 2022** **X'Air Falcon 912(2)** **G-CCNF** Wickenby Aerodrome, Lincolnshire

Following two abortive approaches due to turbulent conditions at low level, the pilot decided to make a third approach because their low fuel state precluded diversion. During the flare, the left landing gear struck the ground heavily and the mainwheel broke off.

## Record-only investigations reviewed: May - June 2022 cont

**17 May 2022** **Rans S6-ES** **G-CCTV** Chilbolton Airfield, Hampshire

The aircraft's engine lost power at low altitude during takeoff. The pilot stated that a landing straight ahead was not possible due to a road and a hedge, so he turned back towards the runway. The pilot lost control of the aircraft over the runway whilst in a left turn, resulting in moderate damage to the aircraft.

**20 May 2022** **Staaken Z-21 Flitzer** **G-ERMN** Perth Airport, Perth and Kinross

The pilot intended to carry out a touch and go but immediately after the aircraft landed it veered to the left and nosed over on the runway.

**22 May 2022** **Aeroprakt A32 Vixxen** **G-DREW** Compton Abbas Airfield, Dorset

After a normal initial touchdown the nose landing gear collapsed during the landing roll.

**28 May 2022** **EC120 B** **G-TIMO** Denton, Oxfordshire

The pilot reported that this was the first time he had taken off with rear seat passengers onboard. There was a 9 kt wind from the left and the helicopter yawed to the left when it became light on the skids. He continued to pull up on the collective lever and, with the forward part of the right skid still in contact with the ground, the helicopter dynamically rolled onto its right side.

**29 May 2022** **DH82A Tiger Moth** **G-ALWW** Bidford Airfield, Warwickshire

Prior to engine start, whilst the pilot was rotating the propeller by hand, the engine fired on one cylinder and a blade hit and fractured the his hand. It was later established that there was an intermittent connection of the 'p' lead to the impulse (right magneto) in the contact breaker cap.

**1 Jun 2022** **Jodel D117** **G-BHEL** Deenethorpe Airfield, Northamptonshire

After a 'fast' landing, the aircraft ground looped and the right gear caught the edge of the runway area and suffered damage.

**1 Jun 2022** **Easy Raider J2.2(2)** **G-CBXF** Gerpin's Farm Airfield, Upminster, Greater London

Whilst flying a circuit the engine speed started to fluctuate. The pilot flew a slightly tighter circuit, maintaining extra height and speed to give a margin in case the engine failed. At 10-15 ft the aircraft developed a high rate of descent and landed firmly, damaging the landing gear. The pilot considered he may have flared too high or lost airspeed after crossing the threshold.

**Record-only investigations reviewed: May - June 2022 cont**

**7 Jun 2022** **Beagle Auster A.61** **G-ARNO** Fowlmere Airfield, Hertfordshire

The aircraft sank quickly as the pilot flared for landing. The pilot stated that he was slow to apply power to cushion the landing. The aircraft bounced, pitched forward, and nosed over. The pilot attributed the pitching forward to the control column not being held fully back. He was wearing a flying helmet which he felt prevented a serious head injury.

**7 Jun 2022** **Zenair CH 601XL** **G-CDGP** Barton Ash, Winchester, Hampshire

On final approach to land, the aircraft was caught by a gust of wind which pushed it close to some trees. The pilot attempted to recover but the aircraft's right wing contacted the ground, and the aircraft came to a halt after hitting a hedge, wire fence and a tree.

**9 Jun 2022** **Sling 4** **G-SLIV** City Airport (Barton), Manchester

On landing the aircraft struck an area of uneven ground on the runway, which pitched the aircraft nose down. The nose landing gear passed over a raised area of ground, which caused it to fail leading to damage to the fuselage and two propeller blades.

**12 Jun 2022** **Rotorsport UK MT-03** **G-CFKA** Revesby, East Lindsey, Lincolnshire,

The engine lost power during the approach to land so the pilot made a forced landing in a crop field. The tail, rudder and horizontal stabiliser were damaged during the landing.

**15 Jun 2022** **Flight Design CT2K** **G-TOMJ** Sackville Farm Airfield, Risely, Bedfordshire

The student pilot made an approach that was fast. He flared for the landing but, after touchdown, the aircraft bounced three times. Then, from a height of about 5 ft, the student pushed the nose down and the aircraft landed heavily on the nosewheel which suffered damage as a consequence.

**18 Jun 2022** **Jabiru J400** **G-CDJL** Near Penrith, Cumbria

After 20 miles of flight the engine lost power and cut out due to fuel starvation. The main landing gear was damaged during the subsequent forced landing in a field.

**19 Jun 2022** **Ikarus C42 FB100 VLA (M)** **G-CCPS** Ballymeanoch, Argyll & Bute

The pilot encountered an unexpected gust during landing. The wing and landing gear were damaged in the subsequent hard landing.

**Record-only investigations reviewed: May - June 2022 cont**

**19 Jun 2022** **Pegasus Quik** **G-CCOK** Fairleigh Farm, Pontefract, West Yorkshire

During the landing at a farm strip, a gust of wind caused the aircraft to drift left into a standing wheat crop. The wing caught the crop and the aircraft ended up on its side.

**19 Jun 2022** **Jabiru SP-470** **G-IPAT** Perth Airport, Perth and Kinross

The pilot described making ‘a rough’ landing during which the nosewheel collapsed.

# Miscellaneous

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

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

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

| | |
|---|---|
| 1/2015 | Airbus A319-131, G-EUOE<br>London Heathrow Airport<br>on 24 May 2013.<br>Published July 2015. |
| 2/2015 | Boeing B787-8, ET-AOP<br>London Heathrow Airport<br>on 12 July 2013.<br>Published August 2015. |
| 3/2015 | Eurocopter (Deutschland)<br>EC135 T2+, G-SPAO<br>Glasgow City Centre, Scotland<br>on 29 November 2013.<br>Published October 2015. |
| 1/2016 | AS332 L2 Super Puma, G-WNSB<br>on approach to Sumburgh Airport<br>on 23 August 2013.<br>Published March 2016. |
| 2/2016 | Saab 2000, G-LGNO<br>approximately 7 nm east of<br>Sumburgh Airport, Shetland<br>on 15 December 2014.<br>Published September 2016. |
| 1/2017 | Hawker Hunter T7, G-BXFI<br>near Shoreham Airport<br>on 22 August 2015.<br>Published March 2017. |
| 1/2018 | Sikorsky S-92A, G-WNSR<br>West Franklin wellhead platform,<br>North Sea<br>on 28 December 2016.<br>Published March 2018. |
| 2/2018 | Boeing 737-86J, C-FWGH<br>Belfast International Airport<br>on 21 July 2017.<br>Published November 2018. |
| 1/2020 | Piper PA-46-310P Malibu, N264DB<br>22 nm north-north-west of Guernsey<br>on 21 January 2019.<br>Published March 2020. |
| 1/2021 | Airbus A321-211, G-POWN<br>London Gatwick Airport<br>on 26 February 2020.<br>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 |
| 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) |
| FDR | Flight Data Recorder |
| FIR | Flight Information Region |
| FL | Flight Level |
| ft | feet |
| ft/min | feet per minute |
| g | acceleration due to Earth’s gravity |
| GNSS | Global Navigation Satellite System |
| 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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