Air Accidents Investigation Branch

AAIB Bulletin 3/2024

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AAIB Field Investigation Reports

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

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

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

Serious Incident

Aircraft Type and Registration:	Leonardo AW189, G-MCGT
No & Type of Engines:	2 General Electric Co CT7-2E1 turboshaft engines
Year of Manufacture:	2014 (Serial no: 92006)
Date & Time (UTC):	26 July 2021 at 1950 hrs
Location:	Ballintoy Harbour, County Antrim
Type of Flight:	Emergency Services Operations
Persons on Board:	Crew – 4 Passengers – None
Injuries:	Crew – None Passengers – N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	5,100 hours (of which 1,100 were on type) Last 90 days – 101 hours Last 28 days – 30 hours
Information Source:	AAIB Field Investigation

Synopsis

The Search and Rescue helicopter was on its third approach, in poor visibility, to collect a casualty from a site adjacent to high ground. The Pilot Flying (PF) selected a mode of the Automatic Flight Control System (AFCS) which would bring the helicopter to a hover. As he did so, the helicopter unexpectedly yawed towards the high ground. When a further selection was made on the AFCS to effect a go-around, the helicopter accelerated towards the terrain while maintaining height. The Helicopter Terrain Awareness Warning System (HTAWS) triggered a visual and aural CAUTION TERRAIN alert. The crew immediately made a climbing turn onto their planned escape heading during which a WARNING TERRAIN alert triggered. The helicopter recovered to a safe height and returned to its home base.

The unexpected yaw was caused by a mismatch between the previously selected AFCS heading reference and the heading flown by the PF. While the helicopter and the flight control system were found to be serviceable and performed as designed, the crew did not have a complete understanding of the functionality of all the AFCS modes. Other factors included:

- Overriding the engaged modes by manually flying the helicopter.
- A lack of clarity between the role of PF and Pilot Monitoring (PM).
- Ineffective communication and co-ordination between the pilots.
- Imprecise application of Standard Operating Procedures (SOPs).

The operator took a number of safety actions to raise awareness of the event, improve knowledge of the autopilot modes and include the event as part of their initial and recurrent training.

History of the flight

The Search and Rescue (SAR) helicopter, which was based at Prestwick Airport, had a crew of four consisting of two pilots, and two technical crew members situated in the cabin. On the event flight, the commander was in the right seat acting as PM, while the co-pilot, who was PF, was in the left seat.

At 2002 hrs the crew received a call from the Aeronautical Rescue and Co-ordination Centre with a task to collect a casualty from a beach at Ballintoy Harbour, Northern Ireland. The casualty was reported to be undergoing resuscitation and the helicopter landing site would be in a local car park. The crew briefing included the possibility of the task being cancelled before the helicopter arrived owing to the condition of the casualty and the transit time.

The helicopter departed Prestwick on a VFR clearance at 2011 hrs and flew west towards Ballintoy (Figure 1).

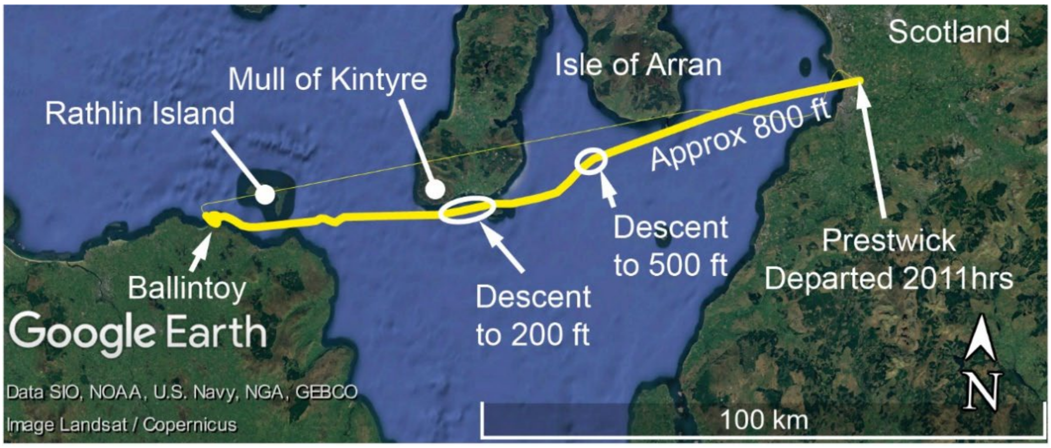

Figure 1
Overview of flight

The pilots noted that the cloud base outside the Prestwick zone was around 1,000 to 1,200 ft. The high ground on the Isle of Arran was in cloud, with some fog over the southern end of the island and the surrounding sea. As the flight progressed, the pilots observed that the cloud base was lowering, and as they travelled towards the southern end of the Mull of Kintyre the PF elected to descend to 500 ft; the PM remarked that it was getting dark and "claggy" up ahead.

The emergency services informed the technical crew member by radio that the weather at the landing site was "ok." As the helicopter transited south of the Mull of Kintyre, the PF descended to 200 ft to remain below cloud. The pilots could not see the lighthouse on Rathlin Island, which they would normally expect to see in clear weather and encountered fog and low cloud during this phase of the flight.

First approach

Given the poor visibility, the PM recognised that a Radar / Forward Looking Infrared Approach (RFA) might be needed and set up a route on the Flight Management System (FMS) that ran south of Rathlin Island, converging on the coast east of Ballintoy Harbour (Figure 2). As the helicopter approached Rathlin Island, the pilots commented that the visibility was improving. The PM briefed the let down and approach with an escape heading of 300° which would take them to a clear area over the sea. However, they momentarily entered cloud, and surface radar contacts ahead of the helicopter required the PM to adjust the waypoints to avoid them.

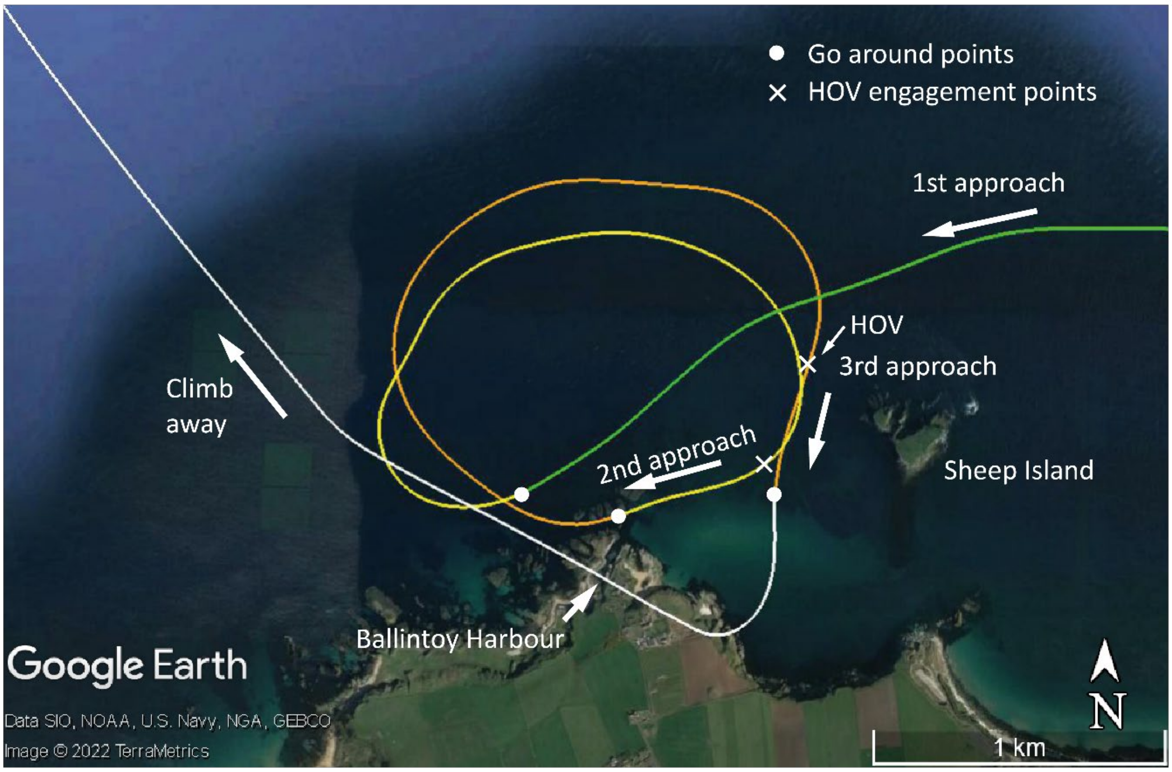

Figure 2

Flight paths during the three approaches to Ballintoy Harbour

Prior to turning to route north of Sheep Island, the PM commented that they had about 0.5 km visibility ahead, the weather to the north-west was better and he was happy to continue. Shortly afterwards, he advised that once they got closer they would bring the speed back and then he would ask the PF to select hover mode. The PM later reported that he could see that the north and west was clear of fog, but that it was partially foggy in the vicinity of the landing site.

While the PM completed the pre-landing checks, the PF off-set the helicopter heading into wind (to the right) to maintain a west-south-westerly track. The CVR recorded the PF saying that he could see the island, the coastline, and blue lights of the emergency vehicles. He subsequently informed the investigation that the blue lights were about 2 km away and he expected the final stage of the approach to be visual even though at the time he could not identify the exact location of the landing site. The PM was not able to see the island or the coastline from his position in the right seat.

The helicopter approached the landing site on a heading of between 230° and 240° on a converging track with the coastline. The PM suggested that the PF should select AFCS hover[1] (HOV) mode as the helicopter was abeam Ballintoy Harbour. However, as the PF was unable to visually identify the landing site, he informed the PM that he would reposition for another approach. The PM recalled looking up and seeing that the helicopter had entered a fog bank.

Second approach

Following the first approach the PF repositioned by turning right onto the briefed escape heading of 300º. The PM set up a waypoint on the FMS just to the north of Sheep Island. Although the AFCS had been captured on each of the four axes (collective, pitch, roll and yaw) for more than two minutes, the PF overrode the AFCS heading hold (HDG) mode captured on the roll channel by manually flying the helicopter. As the helicopter turned, a technical crew member reported that he was visual with land; this was in the direction of the landing site and indicated that visibility was approximately 1 km.

During the approach the helicopter maintained a heading of around 240° and converged with the coastline and cliffs, which were on the left side of the helicopter. At about 600 m from the harbour, the PF selected HOV mode. The PF controlled the rate of deceleration by manually flying the helicopter. At this stage the PF could see the blue flashing lights of the emergency vehicles at the landing site, whereas the PM who was sat on the other side of the cockpit could not. A few seconds after the PF selected HOV mode, the PM, perceiving that the approach was too fast, instructed him to go-around. The PF, who was still visual with the landing site, initially did not act on the PM's instructions. Therefore, the PM repeated the instruction, and the PF manoeuvred the helicopter into a right turn onto their pre-briefed escape heading.

Third approach

The PM outlined his plan for the next approach, which was to come to a hover over the sea to the north of the harbour then descend to 50 ft and hover taxi in. The PM created a waypoint 2 nm from the harbour to the north-east of Sheep Island. He then selected the AFCS to navigate directly to this waypoint. The pilots observed that it was getting darker and the approach would become more difficult. They considered using their night vision goggles (NVG), but thought it would not offer any significant benefit.

Footnote

1 Hover (HOV) mode in the history of flight refers to the selection of Position Hold using the fifth position of the cyclic beep trim (Figure 8).

Before the helicopter reached the waypoint, with the landing site just in sight, the PM selected HDG on the AFCS for the PF; the heading the AFCS was to capture was the current helicopter heading of 087°. Shortly after the PF asked if he should turn right. The PM instructed him to turn right and reduce speed to 50 kt and to select HOV once the helicopter was established on a heading of 200°. The PF flew the helicopter to the right, inside and to the west of Sheep Island, and once established on the heading selected HOV mode when about 900 m from the harbour. Instantly, the helicopter began to yaw left by approximately 35° onto a southerly track. The helicopter was now flying east of the harbour at 200 ft above the sea, at a groundspeed of 52 kt, on a heading taking them directly towards cliffs that were between 100 ft and 160 ft high, with the ground rising to 700 ft amsl about 1 km inland.

Go-around from the third approach

The pilots expressed surprise at the unexpected yaw. One of the technical crew asked if they were going around, which the PM confirmed they were. The PF selected Transition-Up (TU) mode and the helicopter began a level acceleration towards 80 KIAS. The PM called "*ROUTING TOWARDS LAND TURN RIGHT TURN RIGHT*" which the PF acknowledged. The PM repeated his instruction to turn right. This was coincidental with the annunciation of the CAUTION TERRAIN visual and aural alert generated by the HTAWS. At the same time one of the technical crew, seeing the helicopter transiting over land, urged the pilots to climb. This prompted the PM to take control and disengaged the upper modes. Shortly after this the WARNING TERRAIN alert sounded. The PM, now the PF, flew a climbing right turn onto the escape heading.

With the helicopter safely over the sea, the crew discussed what had happened and, given the medical assets on scene and the weather conditions, decided to return to Prestwick. The helicopter landed at 2122 hrs.

Location of casualty

Ballintoy Harbour is located on the north coast of Northern Ireland. The small harbour is accessed via a steep road, with a car park, located between the beaches and harbour walls. The car park, which had been used on previous occasions by the operator with the same helicopter type, had been cleared to allow the helicopter to land.

The ground rises to 700 ft amsl about 1 km inland. A church is approximately 450 m south of the landing site at an elevation of 165 ft amsl (Figure 3). There are 100 ft high cliffs either side of the harbour, which to the east rise to 160 ft (Figure 4). The casualty was being treated on the beach to the west of the car park. Coast guard vehicles with flashing blue lights were parked on the road near the casualty and at the church.

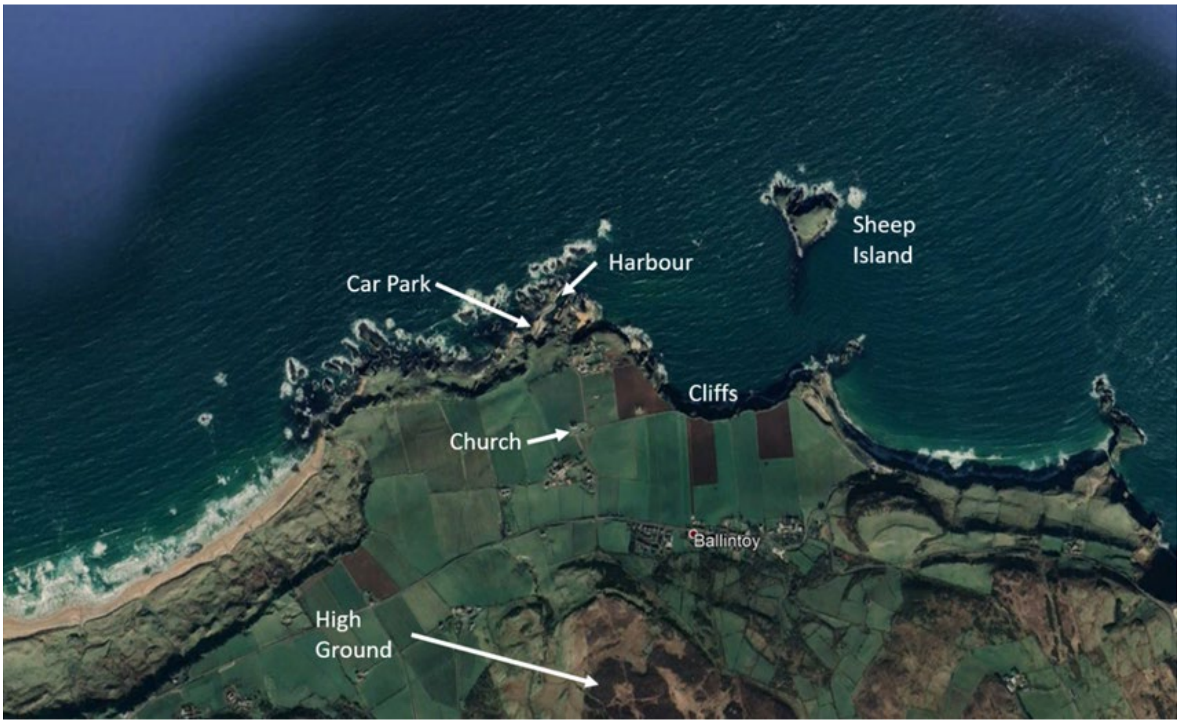

Figure 3

Ballintoy Harbour local area © 2021 Google, Image © TerraMetrics

Figure 4

Cliffs at Ballintoy Harbour
© 2021 Google, Image © TerraMetrics

Meteorology

The forecast indicated that the conditions for Prestwick would provide good visibility with a main cloud base between 2,000 and 4,000 ft. Isolated patches of mist and sea fog were expected along the windward coasts, which would reduce visibility to 3,000 m in mist with a cloud base of 400 to 600 ft; in fog the visibility was forecast to be 300 m.

The main cloud base in the area surrounding Ballintoy was forecast to be 1,000 ft, but areas of mist were expected along windward coasts with visibility of 3,000 m and cloud base of 400 to 800 ft. The wind was forecast to be light north-westerly.

The commander stated that the weather briefed during the shift handover earlier in the day set the expectation of a cloud base no worse than 800 ft overnight. This would allow for a VFR transit and approach for the task.

Sunset at Ballintoy was at 2041 hrs. A Met Office aftercast indicated that the light levels were not low enough to allow the use of NVG before 2100 hrs.

Helicopter examination

No system faults were identified on the helicopter prior to or during the flight. A pre-flight test of the AFCS carried out the day after the event identified no faults and the helicopter was assessed as airworthy.

Aircraft information

The AgustaWestland AW189 SAR helicopter (Figure 5) is a derivative of the commercial air transport version, which is equipped with specialist role equipment and a modified AFCS providing additional functionality for the SAR role.

Figure 5
An AgustaWestland AW189 (Used with permission)

Flight control system

The flight controls allow the crew to control the flight attitude, altitude, and direction of the helicopter. Control is transmitted to the main rotor swash plate and tail rotor pitch change mechanism through mechanical linkages connected to the cyclic stick, collective lever, and yaw pedals. The mechanical control is augmented by electric actuators mounted in series (linear) and parallel (trim) in each of the control systems (Figure 6).

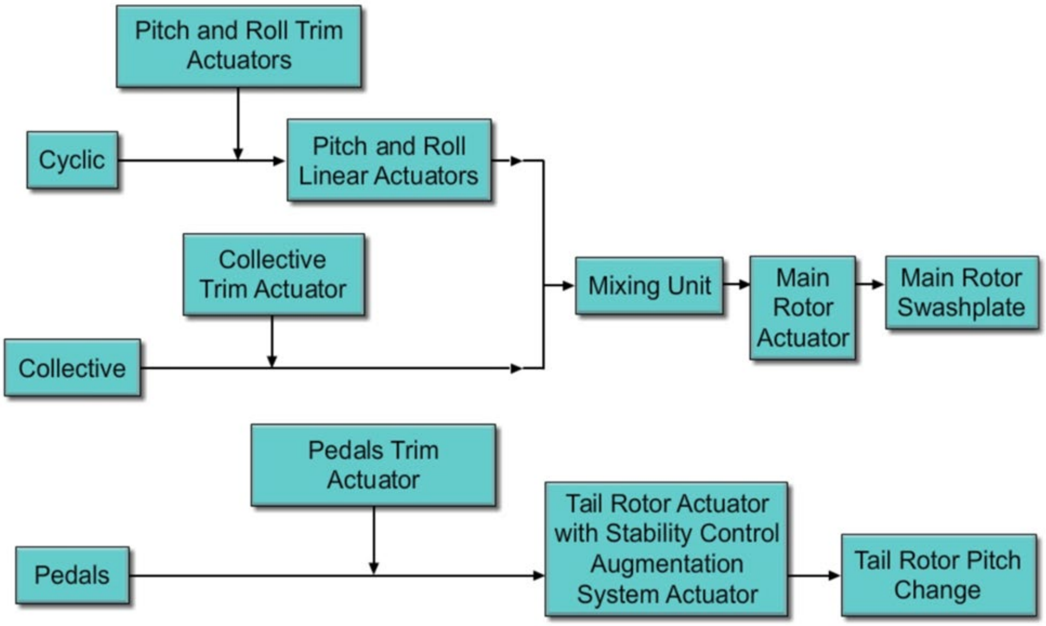

Figure 6

Flight control system (©Leonardo Helicopters)

Automatic Flight Control System

The four-axes AFCS assists aircraft handling and reduces pilot workload using the linear and trim actuators. The linear actuators have limited authority on the flying controls and counter short term external disturbances from a trimmed attitude. The trim actuators can move the flight controls through the full range of movement.

The AFCS performs a number of functions which are divided into two groups; Primary AFCS and AFCS upper modes. The Primary functions include turn co-ordination, stability command augmentation and autotrim. The AFCS upper modes can control the helicopter in four axes: longitudinally in the pitch axis; laterally in both the roll and yaw axes; and vertically in the collective axis. A more detailed description of the AFCS is provided at Appendix A.

Force Trim Release

The Force Trim Release (FTR) for the pitch and roll axes is located on the cyclic, and on the collective for the collective axis. The yaw pedals have microswitches which act as the FTR for the yaw axis. When AFCS upper modes are engaged, depression of the FTR suspends the upper modes for that axis, and the reference datum will track the changes in the relevant parameter. On release of the FTR, the current parameter will be captured as the new reference datum.

Flying-through AFCS modes

Each trim actuator includes a microswitch called a detent-switch which is activated when the flight control is moved by the pilot. When the detent-switch is activated the pilot is described as flying out-of-detent, or flying-through. This design allows the pilot to override captured AFCS modes at any time by flying-through, to direct the flight path of the helicopter. While doing so, the captured upper mode temporarily ceases to be in control of its axis. When a pilot is flying-through on any one axis, the reference datum for that axis is not changed, unless the pilot makes a separate input to change the datum.

There are no visual or aural cues to inform the pilots when an upper mode is not actively in control of its axis due to the pilot either flying-through or depressing the FTR.

AFCS mode status display

Autopilot upper modes are engaged by selecting the relevant mode button on the Autopilot Control Panel (APCP) which is located on the centre console. The button will illuminate green when the mode has been selected.

The Flight Mode Annunciator (FMA) located at the top of the Primary Flight Display (PFD) provides a visual display to the pilots of the modes which have been armed, captured, or are degraded (Figure 7). Captured modes are green, indicating the mode is in use, and is outlined by a green box which flashes for five seconds when first captured. Armed modes, which indicate that the mode has been selected but the parameters are not within range, are white and displayed next to the captured modes. A single aural tone sounds when a mode is engaged or disengaged.

The flight director select indication is a green triangle (Figure 7), which is displayed on the FMA on both PFDs and indicates the 'in-command' Flight Director (FD). It is selected by pressing the FD SEL button on the Display Control Panel. The PFD/multi-function display on the side with the 'in-command' FD supplies reference data to the AFCS. When power is first provided to the AFCS, the in-command FD defaults to the right. The operator's SOPs required that the in-command FD corresponded to the pilot acting as PF.

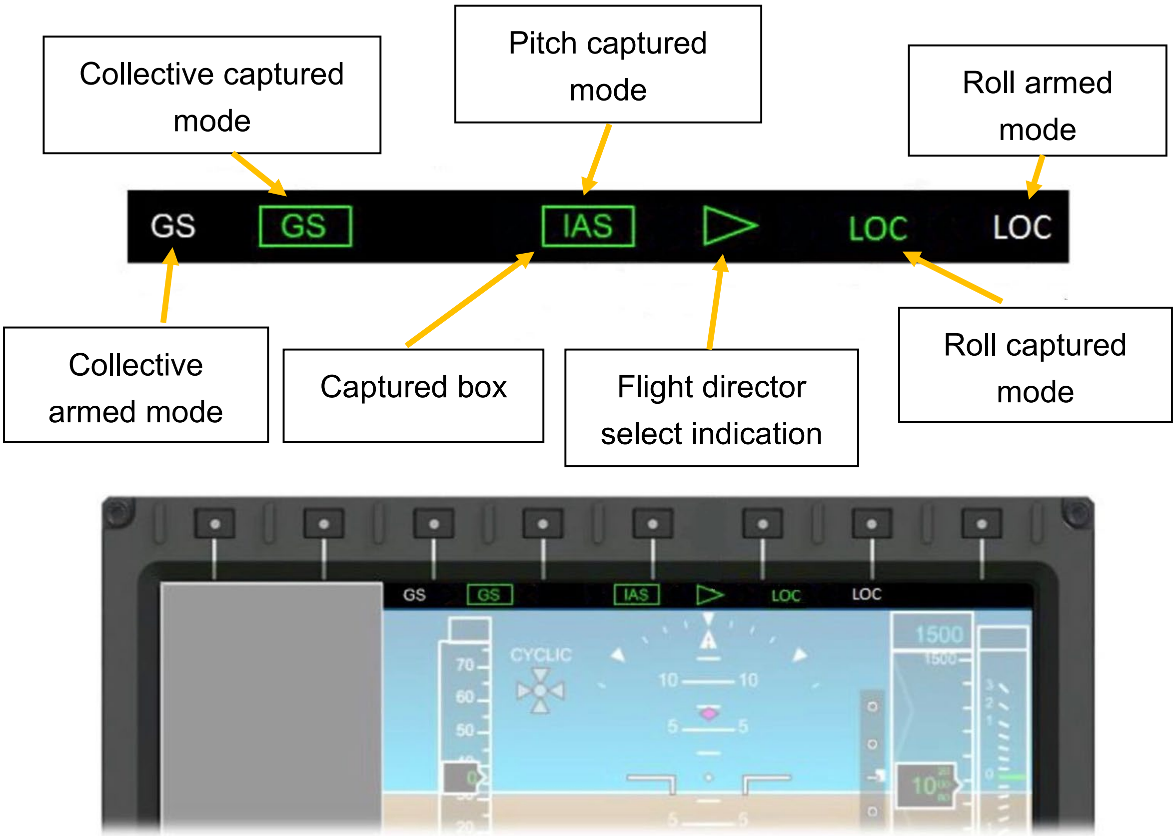

Figure 7
FMA located at the top of the PFD (©Leonardo Helicopters)

AFCS upper modes

The relevant modes for this investigation are:

- Radar Height Hold (RHT), captures and maintains a radio altimeter height.
- Heading Hold (HDG), captures and maintains a magnetic heading.
- Indicated Airspeed Hold (IAS), captures and maintains an indicated airspeed.
- Altitude Hold (ALT), captures and maintains a barometric altitude and is the default mode when the autopilot channels are engaged and the pilot is flying manually without any AFCS upper modes captured.
- Hover (HOV), establishes the helicopter in a velocity or position-hover.
- Transition down to the hover (TD/H), decelerates and descends the helicopter when operating at low level.
- Transition-Up (TU), accelerates and climbs the helicopter to 80 kt and 200 ft agl and automatically engages HDG on the present helicopter heading.

AFCS Heading hold (HDG) mode

The HDG mode provides the capability to capture and hold a magnetic heading. It operates on the roll and yaw axis during most phases of flight but below 40 KIAS, or if any other mode such as HOV is controlling the roll axis, it only operates on the yaw axis. The heading reference is either the heading pre-set by the pilot, or if the pilot has not pre-set a heading, the magnetic heading of the helicopter when the mode is selected.

The magnetic heading reference is displayed on the Horizontal Situation Indication (HSI) compass rose by a magenta bug (Figure 8).

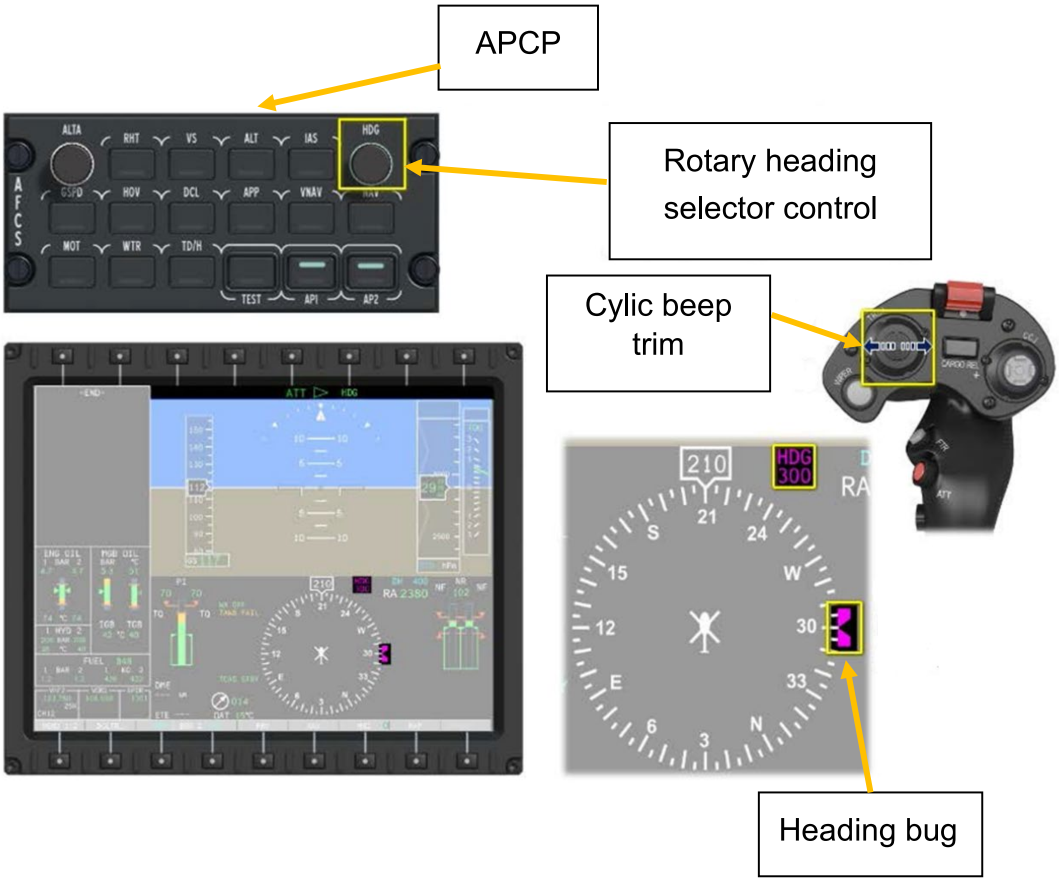

Figure 8

HDG mode controls and display (©Leonardo Helicopters)

The pilot can change the heading reference using the cyclic beep trim switch or the rotary heading selector control on the APCP. Below 40 KIAS, the heading reference is set using the collective/yaw beep trim. The heading reference can also be set when the HDG mode is not selected, by using the rotary heading selector control on the APCP; the heading reference is then displayed as a cyan bug.

When the pilot flies-through on the cyclic roll channel without pressing the cyclic FTR, the HDG bug will remain at its current heading as the helicopter turns. When the pilot releases the input on the cyclic, the detent-switch deactivates and the AFCS will regain control and turn the helicopter onto the previously set HDG bug reference.

AFCS Hover (HOV) mode

HOV mode performs one of two functions dependent on the method used by the pilot to select the mode (Table 1). These are either Velocity Hold or Position Hold.

Function	Action	Longitudinal and lateral groundspeed references
Velocity Hold	Captures current longitudinal and lateral groundspeed velocity	AFCS sets the references to the current values
Position Hold	Decelerates to a hover condition but not to a pre-determined geographical position	AFCS sets the references to zero to achieve zero kt groundspeed

Table 1

Functionality of HOV modes

The relevant mode function during the serious incident was Position Hold. While this mode brings the helicopter into a hover, it does not bring it to a pre-determined geographical position as the final position is dependent on the helicopter's weight and environmental conditions. There is no guidance from the manufacturer or operator on the time and/or distance to decelerate to the hover.

On capture of HOV mode, HOV is indicated on the FMA on both the pitch and the roll/yaw axes. The height reference used is radio height if a valid signal is received from the radio altimeter, otherwise the barometric altitude reference is used. The pilot also has the option to select either radio (RHT) or barometric height (ALT) reference in the collective channel.

The heading reference used when HOV mode is engaged is dependent on whether the HDG mode is captured. If HDG is captured, then the heading reference used is defined by the magenta bug on the HSI compass rose. If HDG is not captured, then the heading reference used is either the current magnetic heading of the helicopter, or the heading pre-set by the pilot and displayed on the compass rose as the cyan bug.

On selection of HOV mode, the HSI display changes to the hover mode symbology format (Figure 9). This symbology is overlaid on the compass rose and shows the current groundspeed and a velocity vector in green; the target groundspeed is indicated by the selected ground speed bug in magenta.

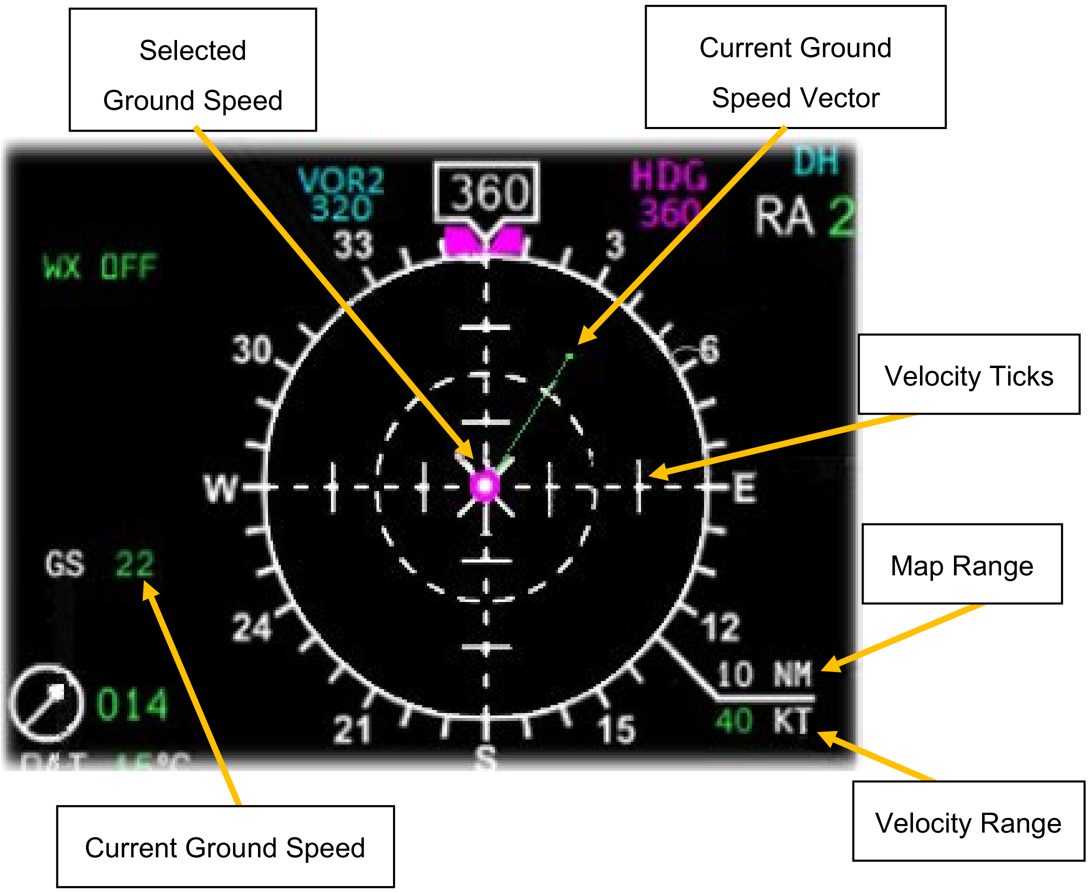

Figure 9
HSI Hover Speed mode symbology[2] (©Leonardo Helicopters)

Operator guidance on the use of automation

The helicopter operator uses the term ‘coupled’ and the helicopter manufacturer ‘captured’ to describe the active mode used by the AFCS.

Three axis coupling is pitch, roll and yaw; four axis coupling is pitch, roll, yaw and collective. The operator’s guidance in their operations manual on the use of automation states:

> *‘It is strongly recommended however, that at all times below 500 ft, amsl/agl, and especially in poor visual reference conditions, or at night, the aircraft should be coupled 3 or 4 axis.’*

Footnote

2 The figure shows all the symbology that may be shown on the HSI when HOV mode is captured, though not all the symbology can be shown at the same time.

The operator's SOP for engagement of automation followed the *'select, engaged, captured'* procedure. The PF will select or call for the PM to select an AFCS mode. The following guidance was provided to crews for operating at low altitude or in poor conditions:

> *'When operating below 500ft amsl/agl and in conditions of poor visual reference the pilot monitoring (PM) will normally make all AUTOPILOT (AP) Upper Mode selections. During times of high cockpit workload, the pilot flying (PF) may also make AP Upper Mode selections, provided that the PM is informed of any selections made at the earliest convenient moment. The pilot flying (PF) may dis-engage certain modes using the cyclic and collective buttons but this, and all other selections, will be carried out as a challenge and response action.'*

The operator emphasised the importance of the crew understanding which modes were engaged at all times.

Mixed mode flying

The operator defined mixed mode flying as when:

> *'the autopilot is only controlling some of the axis and the pilot is controlling the remainder.'*

The operator's procedures stated that mixed mode flying should be avoided except as allowed within the Operating Manual (OM) and stated that:

> *'Loss of situational awareness and loss of control can quickly occur as a result of mixed mode flight, especially during high workload and critical phases.'*

With regard to SAR operations, the operator explained that the use of mixed mode flying was sometimes required when a more rapid rate of turn was required than was available in HDG mode.

Crew's understanding of operation of the AFCS heading reference datum

The pilots' understanding was that on selection of HOV mode, the heading reference datum would capture the current magnetic heading of the helicopter. This was consistent with the manufacturer's type rating ground course notes for the Position Hold function which stated:

> *'…the AFCS maintains the current Radar Height and Heading (Low speed heading hold).'*

However, this is a partial explanation of the operation of the HOV function. Following this event, the manufacturer clarified that on selection of HOV mode, the heading reference datum is dependent on whether the HDG mode is already captured (Table 2). The heading reference datum is displayed on the compass rose as either a magenta or cyan bug.

HDG mode captured	HDG mode not captured
The heading reference datum will be the existing reference datum displayed as a magenta bug.	The heading reference data will either be: • The current magnetic heading of the helicopter, or • The pre-set heading reference datum input by the pilot and displayed as a cyan bug.

Table 2

HDG reference datum used on selection of HOV mode

Flight Mode Annunciator - AFCS upper mode indications

Throughout the flight, the active Flight Director of the AFCS was selected to the right, the side of the PM. While the roll axis was flown out-of-detent by the PF for most of the time during the three approaches, the FMA indicated that the AFCS was controlling the roll axis throughout.

During the second approach, about eight seconds after HOV was engaged, the PM commented that "IT'S NOT STOPPING." During those eight seconds, either the cyclic pitch, roll, or both, were out-of-detent, thereby suspending the HOV function. The PF was slowing the helicopter by flying-through, but not at the rate the PM was expecting from the engaged, but suspended, HOV mode. There was no indication on either the FMA or Flight Director that would have informed the PM that the PF was manually controlling the helicopter.

Other helicopter types from other manufacturers do indicate to pilots when a pilot is overriding an engaged AFCS mode through manual control inputs.

RFA Approach

The operator did provide a SOP for a RFA, which allowed the helicopter to make an approach to a hover close to terrain at night or in poor visibility using radar guidance and TD/H mode of the AFCS. If the PF could achieve visual references for the hover, the helicopter could then be manoeuvred visually to the required position.

Helicopter Terrain Awareness Warning System (HTAWS)

The helicopter was equipped with HTAWS to enhance the pilot's awareness of the flight path in relation to threats from terrain and obstacles. HTAWS has two alerting functions:

- Forward Looking Terrain and Obstacle Avoidance (FLTA).
- Ground Proximity Warning System (GPWS).

The FLTA alerting area is shown in Figure 10. It uses the aircraft position and the altitude data from the GPS combined with vertical speed to compute a predicted aircraft flight path which it compares to the terrain and obstacle databases. Alerts are generated if there is a potential conflict. For terrain the alert is either CAUTION TERRAIN or WARNING TERRAIN.

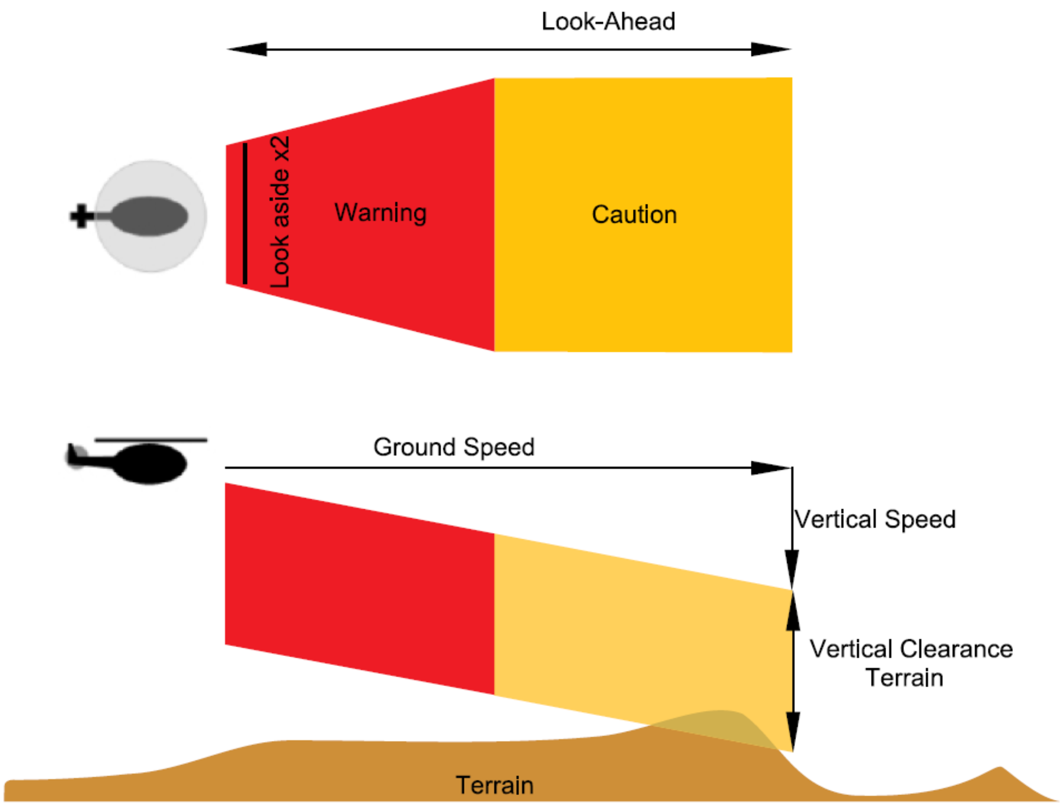

Figure 10

FLTA alerting envelope (©Leonardo Helicopters)

The pilot can select OFF AIRPORT mode to suppress alerts when landing at locations which are not in the database as designated airports. With OFF AIRPORT mode selected, the FLTA alerting envelopes are reduced when operating below 75 kt groundspeed and a height of 350 ft.

The pilot can also select one of three FLTA alert sensitivity modes: NORMAL, LOW ALT, TAC ALT. The LOW ALT mode reduces the alerting distance and, therefore, the time before a caution or warning is provided.

During the event, OFF AIRPORT mode and LOW ALT sensitivity had been selected which was consistent with the advice in the operator's SOPs. Table 3 shows the alert times at NORMAL and LOW ALT sensitivity using the speed and height the aircraft was flying when the HTAWS alerted CAUTION TERRAIN.

	Normal sensitivity (Caution / Warning)	Low Alt sensitivity (Caution / Warning)
Time to threat	21 s / 10 s	14 s / 7 s
Distance to threat	750 m / 375 m	550 m / 250 m

Table 3

FLTA alert time in OFF AIRPORT mode at 72 kt and 200 ft agl

On the third approach, prior to the selection of HOV mode, both the PF and the PM had the HTAWS overlayed on the compass rose of the PFD. However, on selection of HOV mode, this overlay was replaced by the hover speed mode symbology. Whilst either pilot could then have selected the HTAWS display either on their PFD or the MFD, neither did so. Consequently, while HTAWS remained active, neither pilot had HTAWS displayed on their screens.

Vision imaging system

The aircraft was equipped with a Forward Looking Infrared imaging system, and each pilot was equipped with a set of NVG. The PM had his NVG fitted to his helmet and the PF's were stored in the cockpit. The NVGs were not used during the flight.

Recorded information

Sources of data

The helicopter was fitted with a flight recorder which combined the FDR, CVR and Airborne Image Recorder (AIR) functions in one unit. It recorded more than 65 hours of data, 30 hours of audio and 3 hours of cockpit images.

Audio was captured from the three crew channels and the cockpit area microphone.

The cockpit imagery recording captured a snapshot of the general cockpit area four times a second, which provided context to the activity captured by the audio and data recordings - an overview of the use of AIR in this investigation is at Appendix B. The imagery also provided evidence of some of the activity not captured by the data or audio recordings and included:

- The pilot focus on the FMS. The resolution was not sufficient, and nor was it required to be, to read the information on the displays.
- The position of the pilots' hands and whether they were on the controls, pointing at waypoints on the displays, or referencing check lists or the content on tablets.
- Assessing the external conditions. Occasionally the terrain was visible in the top right and top left of the image frame, which when coupled with the terrain and helicopter locations allowed an estimate of the visibility.

Third approach and go-around

The initial part of the circuit was flown mainly with the RHT mode on the collective axis set at a reference height of 198 ft, and the IAS mode on the pitch axis set at a reference airspeed of 60 KIAS. The NAV mode was engaged on the roll axis but flown with the cyclic roll control out-of-detent. The AFCS had full control for about 18 seconds of the circuit, until the PM declared that he was selecting HDG mode. At this point the heading reference updated to the current heading of 087°. The turn rate as the PF manoeuvred onto the approach heading exceeded the rate-one turn capability of the engaged HDG mode, indicating that the PF was applying a manual input to the cyclic control and the cyclic roll was out-of-detent.

The later stage of the third approach is shown at Figure 11 (recorded data) and Figure 12 (flight path). The following significant events occurred during this stage of flight, some of which are annotated on Figure 11 and 12 using the numbers in brackets as the reference points:

- The heading diverged from the HDG bug datum of 087° (1) with HDG mode captured (2) and the cyclic roll control out-of-detent (3).
- The PM stated that he wanted the PF to select HOV once on a heading of 200°.
- The PF engaged HOV mode using the cyclic beep trim (4).
- The heading reference datum remained at 087° and the AFCS used the yaw axis to yaw the helicopter left from its heading of 200° to acquire the heading reference datum of 087°. This action generated an increasing drift angle to the left (5).
- Ten seconds after capturing HOV mode, the PF put his feet on the pedals and said, "LET'S GO" (6). The drift reached a maximum of 35° and then started to reduce, with a change in direction of the yaw rate to the right.

- The heading datum updated to 163° and started following the helicopter heading (7).
- At this point the helicopter was flying towards the cliffs about 700 m ahead, at 52 KCAS at an altitude higher than the cliffs, but with rising ground further inland.
- The helicopter pitched nose-down (8) and accelerated, maintaining a radio height of about 200 ft. The helicopter yawed slightly right, then started yawing back to the left (9).
- TU/HDG modes were engaged, which increased the speed datum to 80 KIAS and marked the end of the HDG datum being updated.
- The PF was flying-through in roll (10) and pitch almost continuously at this point.
- The heading trend returned to the right and the helicopter continued to accelerate and maintain a radio height of between 190 and 200 ft.
- A HTAWS CAUTION TERRAIN alert was triggered (11) at a speed of about 72 KCAS.
- Between two and three seconds later, the PM stated, "I HAVE CONTROL" and the helicopter AFCS modes changed to ATT; no collective mode was selected. The helicopter started to pitch up and the roll increased further to the right (12).
- Two seconds later, just after the helicopter started to climb, a HTAWS WARNING TERRAIN (13) briefly triggered. The climb rate reached a peak of 2,000 ft/min and the bank angle peaked at approximately 43° to the right.
- The lowest recorded radio height over terrain was 380 ft (14).
- The helicopter headed out to sea climbing, and returned to Prestwick.

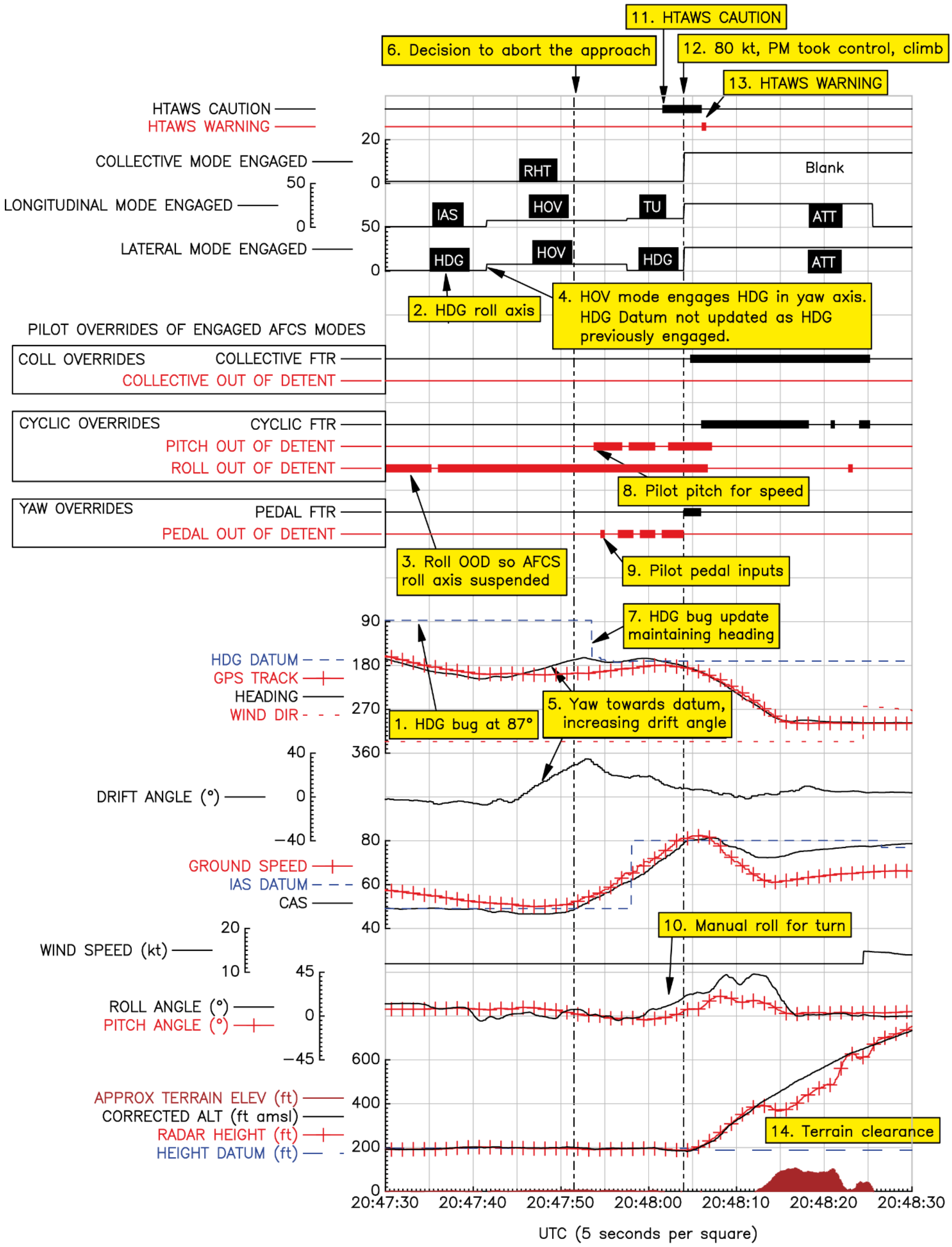

Figure 11

Recorded data for the later stage of the third approach and HTAWS alert

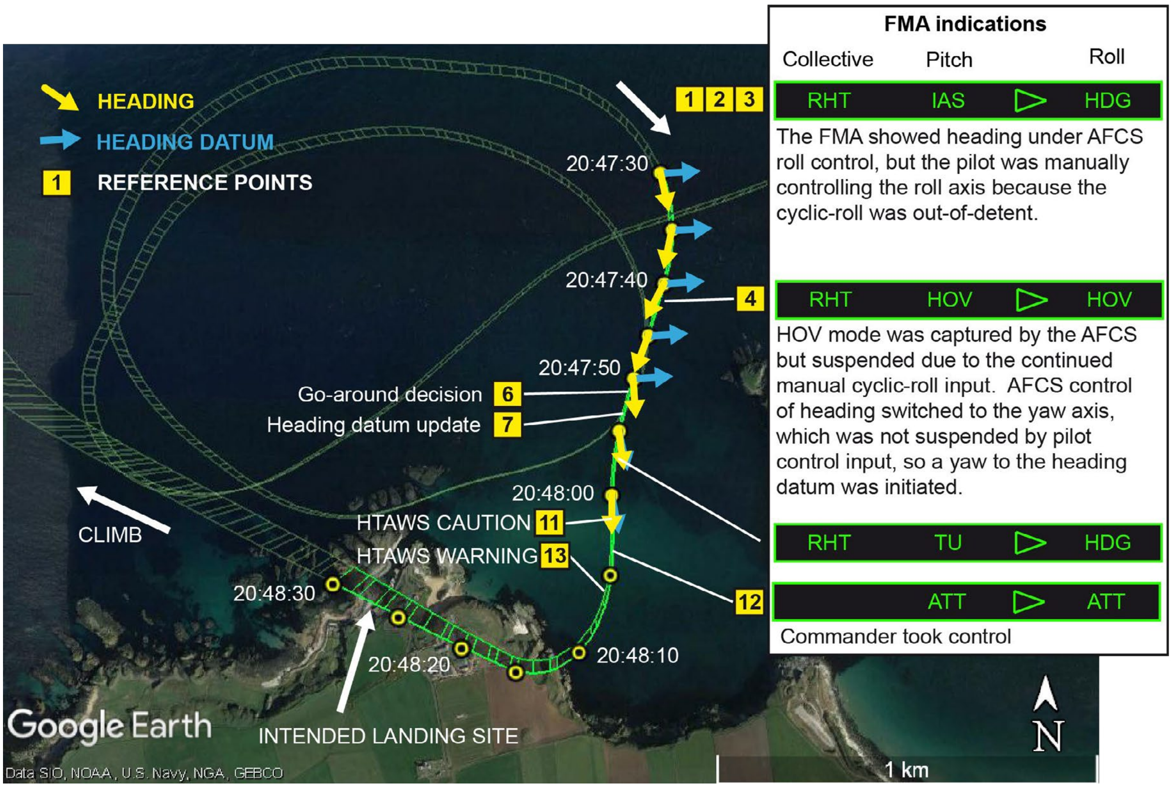

Figure 12

Overhead view of third approach showing FMA indications
(Reference points relate to Figure 11 and the report text)

HDG mode – use of reference datum

AFCS HDG mode was captured as the helicopter passed Rathlin Island and remained until HOV mode was captured during the second approach. Throughout this period the heading reference datum did not change and apart from a few brief periods, roll was controlled by the PF flying-through on the cyclic roll channel.

After the second approach was abandoned, NAV mode was captured followed by the HDG mode once the helicopter was flying in an easterly direction when the heading reference datum updated to 087°. The heading reference remained at 087° until after the third approach was abandoned. The data recorder did not capture any yaw pedal FTR activity at the time of the heading reference update.

HTAWS alerts

During the three circuits, the HTAWS was in OFF AIRPORT and LOW ALT sensitivity mode. The timing of the alerts during the third circuit indicates that these were triggered by the presence of the cliff. The approach altitude leading up to the HTAWS alerts was above the elevation of the cliffs, but level with terrain approximately 0.5 km further inland (Figure 13). At the point of transitioning to flying over land, the helicopter was at about 380 ft amsl and climbing. The highest terrain overflown was at an elevation of approximately 130 ft. The lowest radio height recorded while overflying the terrain was 380 ft.

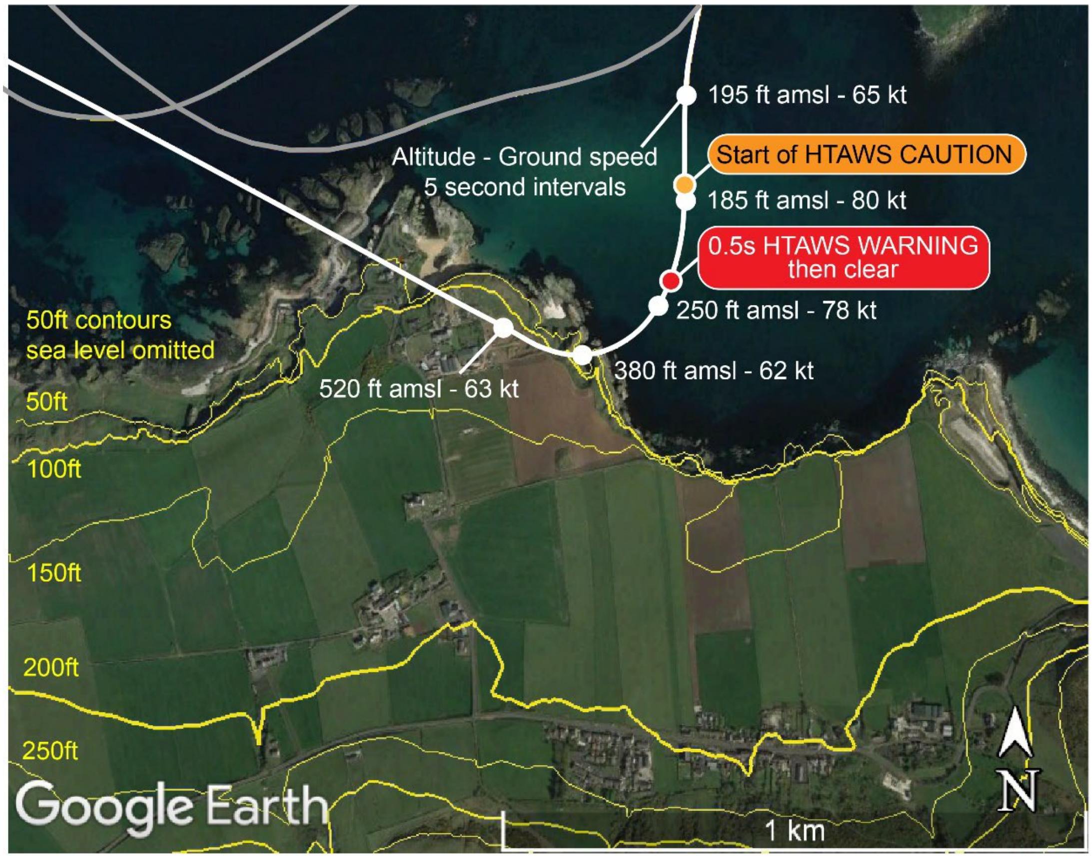

Figure 13

Flight path and speeds relative to terrain with associated HTAWS alerts
(The go-around decision was made while just north of the area shown)

Manufacturer assessment of recorded data

The manufacturer confirmed that for the third approach, as HDG mode was already engaged prior to the selection of HOV mode, HDG mode operated in the yaw axis alone and the heading datum reference was not updated. The manufacturer also confirmed that there is no display indication to the crew when a pilot is flying-through and the trim actuator is out-of-detent.

Personnel

Prior experience

Both pilots were qualified SAR commanders who had previously served as a SAR commander in the military flying Sea King helicopters. They both joined the operator approximately five years previously, when the operator began SAR operations, flying the Sikorsky S92 helicopter before converting to the AW189. The pilots undertook the type and operator role conversion training on the AW189 with the operator's own training organisation. Following the conversion training, each pilot underwent an operator proficiency check every six months and a licence proficiency check every 12 months in the simulator. Both pilots had over 1,000 hours on type; the PF was a type rating examiner for the operator.

Crew rostering

During the period of the COVID-19 restrictions, the operator implemented consolidated crewing as one of the measures to manage the health risk. As a result, the two pilots had been crewed together for six months during the previous year.

The shifts operated on a 24-hour pattern, with handover occurring at 1300 hrs. The duty crew were on 15 minutes notice to move until 2200 hrs and then 45 mins until 0800 hrs the following day. At the end of the shift, crew members had the next 24 hours off as a duty rest period. This pattern could be repeated up to four times in a row.

The commander and co-pilot had been crewed together for their previous shift. On the day of the event, the commander was on his second shift of two following three days off. He had operated for five shifts that calendar month and flown 19 tasks. The co-pilot was on his second of three shifts, and it was his eighth shift that month.

Both pilots reported that the month had been very busy month and their previous shift had included six taskings. The PM spoke of "mental tiredness rather than physical tiredness" following the level of tasking experienced on the previous shift, 48 hours before. The crew had met all the requirements of the flight time limitations, and both pilots spoke of having gained what they described as proper rest from the night before.

Although the effects of any fatigue on the performance of the crew cannot be ruled out, there was no observable evidence on the CVR or AIR.

Division of crew responsibilities

The operator's OM defined the duties of the PF as:

> *'The pilot flying a particular sector is to assume the responsibilities and duties of the Captain. These will include making decisions affecting the routine operation of the aircraft and its systems.'*

Degraded Visual Environment

A Degraded Visual Environment (DVE) encompasses environmental conditions such as rain, fog or low light levels that degrade the effectiveness of visual cues. This can decrease the ability of the pilot to maintain situational awareness and aircraft control.

During a previous AAIB investigation[3] in which a helicopter flew unintentionally to within 28 ft of rising terrain while operating in a DVE, the AAIB made the following Safety Recommendation to the CAA on 11 June 2021:

Safety Recommendation 2021-028

It is recommended that the Civil Aviation Authority revise its guidance on helicopter flight in degraded visual conditions to include further information on managing the associated risks.

The CAA responded by highlighting that there already exists significant research material, associated papers and guidance documents relating to operating in a DVE. To ensure that the existence of this material is widely known, the CAA issued SkyWise Notification[4] SW2022/133 on 20 June 2022, which recommended that organisations include this guidance in their training programmes and future safety meetings.

EASA guidance on automation and flight path management

In 2015 the EASA European Helicopter Safety Team (EHEST) issued guidance[5] on best practice in the use of automation and flight path management. The guidance identified a number of operational and human factors which are often seen in accidents and incidents when the use of automation is considered a factor. These factors include:

> '· *Insufficient understanding of mode transitions and mode reversions (i.e., mode confusion, automation surprise)*
>
> · *Untimely override action interfering with automation*
>
> · *Inadequate task sharing and/or CRM* [Cockpit Resource Management] *practices preventing the PF from monitoring the flight path and airspeed (e.g., both pilots being engaged in the management of automation or in solving an unanticipated situation or abnormal condition)'*

The EHEST suggested that to mitigate the risk when using automation to control the flight path, crews should always be aware of who is flying the helicopter whether it is the PF or the AFCS, and to announce call changes using standard calls as defined by the operator's SOPs.

Footnote

3 AAIB-26196 G-LAWX *'Near controlled flight into terrain, private landing site near Shipston-on-Stour, Warwickshire, 14 October 2019'*, https://www.gov.uk/aaib-reports/aaib-investigation-to-sikorsky-s-92a-g-lawx. [Accessed December 2023].

4 Skywise - Alert: Helicopter flight in degraded visual conditions (caa.co.uk) [accessed December 2023].

5 EASA, September 2015 '*EHEST HE 9 Training Leaflet – Automation and Flight Path Management'* Available at https://www.easa.europa.eu/en/document-library/general-publications/ehest-leaflet-he-9-automation-and-flight-path-management [accessed December 2023].

Analysis

The event

Having made two unsuccessful attempts to land at Ballintoy Harbour to retrieve a casualty, the crew of G-MCGT set up for a third approach. The plan for this approach was to fly a converging track with the coastline that would keep the helicopter clear of the cliffs and high ground. At a suitable point, the AFCS HOV mode would be engaged to bring the helicopter to a hover, the crew would then descend over the sea to the north of the harbour and hover taxi south to the landing site in the car park.

On the third approach the heading of around 200° was now 30° to 50° to the left of that previously used. Consequently, rather than flying on a converging approach with the coast, the helicopter was flying towards the cliffs.

The helicopter was at a height of 200 ft amsl and airspeed of 52 KIAS when HOV mode was selected approximately 900 m from the cliffs. The helicopter immediately yawed to the left, which despite a cyclic right roll applied by the pilot, resulted in a significant drift to the left. The crew decided to abort the approach and the PF moved the cyclic stick and yaw pedals out-of-detent on three occasions during which the drift to the left decreased. During this period the TU mode was selected by the PF, which caused the helicopter to accelerate to 80 KIAS while still continuing to fly at a height of approximately 200 ft amsl towards the cliffs and rising ground; a HTAWS caution and warning alerted.

Once the decision had been made to go-around, the delayed response by the PF in climbing and turning onto the escape heading contributed to the reduced terrain separation with the ground. This resulted in the PM taking control at about the same time as the HTAWS caution alerted.

HTAWS was set to OFF AIRPORT and LOW ALT for all the approaches at Ballintoy. This meant that the warning time for terrain available to the crew was reduced. It is unlikely that this was a factor in this serious incident as the crew had already commenced a go-around when the caution and warning were triggered. The crew were also aware of the high ground and were on their third approach to the landing site.

Cause of the unexpected yaw

Prior to manoeuvring onto the approach heading of 200°, the PM selected HDG mode which captured the helicopter's current heading of 087° as the reference heading. This reference heading would have been displayed on the compass rose as a magenta bug. As the PF turned onto and maintained a heading of 200° the cyclic roll was out-of-detent, indicating he was flying the roll axis manually. Neither pilot updated the reference heading.

When the PF then engaged HOV mode to automatically bring the helicopter to a hover, the AFCS, as designed, commanded a left yaw to acquire the reference heading that was still set at 087°. About 10 seconds later the PF decided to abort the approach and moved the yaw pedals to counter this yaw which opened the detent-switch on the pedal trim actuator, updating the reference heading to the helicopter's current heading of 180°.

The sudden yawing of the helicopter was unexpected by the pilots as they believed that the heading reference datum would align with the helicopter heading when HOV mode was captured. This understanding was consistent with the description of the HOV Position Hold mode in the manufacturer's type rating course notes which stated:

> *'…the AFCS maintains the current Radar Height and Heading (Low speed heading hold).'*

During this investigation, the manufacturer clarified that on selection of HOV mode, the heading reference used is dependent on whether HDG mode is already engaged. The heading reference on selection of HOV mode will either be the current magnetic heading of the helicopter, or the heading pre-set by the pilots, or the heading reference if HDG mode is captured. The manufacturer confirmed that the AFCS operated as designed and there were no faults found with the helicopter or software.

The operator took the following safety action to ensure that their crews are aware of this serious incident and the expected behaviour of the AFCS in HOV mode:

> The operator briefed all crews on the behaviour of the AFCS reference datum on selection of HOV mode and reinforced it during recurrent simulator training.

The manufacturer also plans to revise the type rating ground course to be clear on the operation of the HOV mode.

Human performance

The review of the AIR / CVR revealed a lack of clarity between the pilots on their roles during the flight, which consequently influenced their ability to work as an effective team.

The operator's OM defined the PF as the pilot that acts as '*captain*' directing the flight path of the helicopter. However, throughout the flight, the PM took the lead in directing the flight path through the FMS, mostly unprompted by the PF. This ambiguity of roles and leadership was reflected in the communication between the two pilots. The PF exhibited a reserved manner during the flight, which contrasted with the commander's style as PM who frequently updated the PF about waypoints input into the FMS and the intended flight path to be flown. At times the PM selected AFCS modes unprompted by the PF. However, the PM's actions did not always appear to be actively acknowledged or acted upon by the PF. It also ran counter to automation management SOPs which required the PF to call for, or action and announce, AFCS upper mode selection, and thereby contributed to both the imprecise application of SOPs and inconsistent use of automation.

There was little discussion between the pilots evaluating and reviewing the plan of how to make the approach to the site of the casualty. Both pilots assumed they would fly visual approaches, based on the expectation that conditions would allow this; this assumption took the place of a shared operating intent. While the PF did voice at times what he could see, this was not augmented by an expression of his intent, nor did the PM share what he himself could see. It is, therefore, likely that there was not a shared understanding between the pilots of what each could see.

There was a lack of explicit recognition as a crew that they were in DVE and that further visual approaches might not be the most appropriate way to manoeuvre the helicopter after the first attempt. The conditions did not appear to prompt the crew to review their course of action and consider using an alternative procedure available to them such as an RFA.

As a result of this serious incident the operator took the following safety action.

- Issued further guidance to their crews on managing the threat of a DVE.
- Added additional guidance in the OM including:

  'If DVE conditions are likely to occur, SAR crews should consider planning for an Instrument Flying profile, i.e., Instrument Let Down, RFA. Even if the route is visually flown the overlay of an RFA type approach will aid planning and allow a rapid conversion to IF techniques.

  Increased communications within the crew are vital to determine the actual environmental conditions, it is likely that one side of the aircraft could have significantly better visibility than the other, particularly in the mountains or coastal environment. In this case, communications within the crew are vital to provide a shared mental model of the situation and the best way to proceed.'

The diminished visual acuity probably degraded the effectiveness of the pilots' visual cues while the differing visual cues that each pilot could see also contributed to the differing mental models that each developed. The differing mental models may explain why the PF did not immediately respond to the instruction to go-around on the second approach as he felt he retained sufficient visual references.

The CVR recorded the use of colloquial or ambiguous language and a breakdown in SOP protocol for the selection and confirmation of AFCS modes, which occurred during periods of higher workload. This relaxation of SOP discipline may have arisen, in part, from familiarity of flying with each other for extended periods.

Additionally, while the PM instructed the PF more than once to turn right following the decision to go-around on the third approach, the absence of a clear instruction by the PM, emphasising the escape heading to be flown, probably compromised the effectiveness of the response by the PF. This resulted in the PM taking control, at a time of confusion caused by the 'unexpected yaw' and high workload.

Operation of the AFCS and flying-through

By flying-through, the PF had disconnected the captured AFCS upper modes from the actual aircraft path. The heading bug remained at its value of 087° despite the actual heading of the helicopter being around 200°. This difference in headings represented a latent threat, which set up the conditions that resulted in the unexpected yaw.

It may be appropriate at times to fly-through on an axis while an upper mode is captured, particularly on SAR operations where there may be terrain or obstacle constraints; however, it is essential for pilots to recognise the threats that flying in this manner may present and to manage them accordingly.

As a result of this serious incident the operator took the following safety action:

Amended their OM to:

- Clarify when mixed mode flying might be appropriate.
- Emphasise the importance of good communications and CRM within the whole crew in the use of automation.

The FMA is the core tool to provide awareness to crews on the state of automation. On this helicopter type, the FMA provided no indication that the PF was flying-through on an axis when an upper mode was captured. This resulted in a degradation of the awareness of the PM as to who or what was controlling the flight path of the helicopter – the AFCS or the PF.

With the more widespread use of advanced digital automation, awareness of whose inputs are controlling the flightpath of the helicopter - the AFCS or the pilot – is essential to ensure that threats are not introduced that cannot be recognised by crews.

Conclusion

The HTAWS activated during the third approach to the hover after the helicopter unexpectedly yawed and flew towards high ground after the PF selected Position HOV mode. The investigation established that the AFCS was serviceable and operated as designed.

The unexpected yaw occurred as a result of flying out-of-detent and the pilots' incomplete understanding of the heading reference used by the AFCS when HOV mode was selected. When the PF engaged HOV he was flying out-of-detent, thereby overriding the engaged HDG mode. Consequently, the reference heading used by the AFCS did not capture the helicopter's current heading, but instead remained at the heading selected when HDG was last engaged. When the PF stopped flying out-of-detent, the AFCS yawed the helicopter towards the previously captured reference heading which resulted in the aircraft tracking towards high ground.

In mixed mode flying it is important that both pilots have a clear understanding as to which axis the AFCS and pilot are controlling, and the effect this might have on parameters such as the heading reference. However, SOPs on the selection of automation were not always followed and communication between the pilots, and lack of annunciation on the FMA, meant that it might not have been obvious to the PM when the PF was flying out-of-detent.

The flight took place in weather conditions that can be described as DVE, which meant the visual cues available to the crew were diminished. On the second approach the PF did not immediately respond to the PM's instruction to go-around. During the go-around on the third approach, to avoid the high ground, the PM took control because he believed that the PF's response to the threat was not sufficient. A lack of effective communication and co-ordination between the pilots resulted in them forming different mental models of the situation.

Safety actions

During this investigation the operator took the following safety action:

- The operator has briefed all crews on the behaviour of the AFCS reference datum on selection of HOV mode and reinforced it during recurrent simulator training.
- Issued further guidance to their crews on managing the threat of a DVE
- Added additional guidance in the OM including:

  If DVE conditions are likely to occur, SAR crews should consider planning for an Instrument Flying profile, i.e., Instrument Let Down, RFA. Even if the route is visually flown the overlay of an RFA type approach will aid planning and allow a rapid conversion to IF techniques.

  Increased communications within the crew are vital to determine the actual environmental conditions, it is likely that one side of the aircraft could have significantly better visibility than the other, particularly in the mountains or coastal environment. In this case, communications within the crew are vital to provide a shared mental model of the situation and the best way to proceed.'
- Amended their OM to:
  - Clarify when mixed mode flying might be appropriate.
  - Emphasise the importance of good communications and CRM within the whole crew in the use of automation.

Appendix A

Use of Airborne Image Recorders in accident investigation

Cockpit Airborne Image Recorders (AIRs) became a requirement for UK State helicopters following Safety Recommendations made by the AAIB to the CAA during an investigation into a fatal police helicopter accident, G-SPAO[6], in 2013. G-SPAO was not required to be fitted with any kind of accident recorder. Consequently, key evidence on the information displayed to the crew, and use of switches in the cockpit was not captured.

AIR provides investigators with a source of evidence that might otherwise not be available, even with a conventional FDR and CVR fitted. This might include capturing data that cannot practically be captured by a data recorder, or as was the case for G-MCGT, capturing a general view of the cockpit area. This appendix briefly highlights some of the strengths and limitations found with the AIR recording analysed for this investigation that may be relevant to other investigations where an AIR is fitted, or when considering certification requirements for future installations.

The installed camera had a resolution of 2,000 by 1,520 pixels. While the wide-angle lens on the camera captured a significant proportion of the cockpit controls (Figure A-1), activity associated with the overhead panel and the left collective lever was not captured. Evidence the AIR provided included:

- Who operated the controls.
- The pilots' general focus on activities in the cockpit, albeit not including where they were specifically looking
- The pilots' use of reference material.
- Non-verbal communication between the pilots; though some head movements and facial expressions were not captured.
- Ground references, when in view through the small section of the cockpit windows.

The use of cockpit images also allows investigators to gain a rapid appreciation of the information presented to the pilots, that would otherwise take time to build from other data. Examples include display settings, modes and availability, system status, use of controls etc. While the images do not provide the level of detail available from data recorders, they are useful in helping to quickly identify where the initial recovery and analysis of data might be focused.

Footnote

[6] https://www.gov.uk/aaib-reports/aircraft-accident-report-aar-3-2015-g-spao-29-november-2013 Report on the accident to Eurocopter (Deutschland) EC135 T2+ (G-SPAO), Glasgow City Centre, Scotland, on 29 November 2013. Safety Recommendations 2015-032, 2015-033 and 2015-034 [accessed December 2023].

Appendix A (cont)

Figure A-1

Image from the cockpit camera.

Figure A-2 shows a zoomed-in view of the PFD. A combination of the AIR resolution and the use of a wide-angle lens meant that the displays were not readable, but there was no requirement for this. It is not known to what extent, if any, image compression affected the readability of the display images; however, there was still sufficient resolution to identify key features and the type of information displayed to the crew.

Figure A-2

Cropped image of the left PFD showing the benefits and limitations of the camera's resolution.

Appendix A (cont)

While the general light levels across most of the image were relatively dark, the map display had a light background which meant that it appeared mostly white on the recordings, thereby losing the information that was displayed. This can be seen in Figure A-3 where the detail on the map displayed on the Multi Functional Display (MFD) on the right side of the cockpit is 'washed out' compared with the MFD on the left side of the cockpit.

Figure A-3

Image showing crew communication and focus (pointing), NVG's fitted to the helmet, detail displayed on the MFDs and the effect of the limitation of the dynamic range of the video recording system.

In the G-MCGT investigation, the loss of detail on some of the displays due to the limitations of the dynamic range of the camera did not affect the investigation. A similar dynamic range limitation associated with an AIR recording from a different AAIB investigation resulted in the loss of information displayed on the PFD. It is not clear how the dynamic limitations of AIR recordings can be overcome with current technology, but developments to improve the dynamic range of cockpit cameras would greatly benefit safety investigations.

Appendix B

Automatic Flight Control System modes

Introduction

The appendix provides additional information on some of the functions of the AFCS modes and how they are selected.

AFCS modes

Attitude Hold (ATT) is the default mode of the system in normal operation when the AP channels are engaged, and the pilot is flying manually without any AFCS upper modes captured. It provides the capability to acquire and hold an attitude reference in the pitch, roll and yaw axes independently. Stability command augmentation functions any time a pilot is 'flying-through' any of the AFCS upper modes and prevents the AFCS counteracting attitude changes induced by the pilot on the pitch and roll axes.

RHT mode captures a radio altimeter height through the collective axis.

ALT mode captures a selected barometric altitude through the collective axis.

IAS mode captures a pilot selectable reference airspeed through the pitch axis.

NAV mode provides AFCS coupling to roll steering provided by the FMS. This operates through the roll axis with roll co-ordination achieved through the yaw axis.

TD/H mode provides a fully automated descent down to 50 ft agl (or current height if lower) and 0 kt groundspeed. On reaching those parameters, RHT and HOV modes are captured. This mode requires the height to be between 30 ft and 210 ft and below 85 KIAS.

TU mode provides a fully automated climb to the reference height of 200 ft agl on the radio altimeter while accelerating to 80 KIAS. On reaching 200 ft, the AFCS will capture RHT; at 40 KIAS, HDG mode captures on the roll axis and on reaching 80 KIAS, the AFCS captures IAS mode on the pitch axis. It may be selected from either collective GA/TU pushbutton. TU mode captures when the relevant conditions are met which include airspeed between 40 KIAS and 80 KIAS with groundspeed greater than 30 kt with one of the specific SAR modes, including HOV, is captured.

The reference height can be modified by the collective beep switch and the airspeed by the cyclic beep switch. The TU mode can be cancelled by selecting another upper mode or selecting the collective/cyclic FTR buttons.

AFCS controls

The control panel for the AFCS, referred to as the APCP, provides controls for the arming or engagement of a mode and display of its associated status. It is also used for pre-flight testing. The APCP is in the centre of the inter-seat console between the pilots. It has 16 push buttons and two rotary/push knobs. Each button or rotary knob has its function annotated above it (Figure B-1).

Appendix B (cont)

Figure B-1
Autopilot Control Panel

The cyclic and collective grips have several controls for the AFCS (Figure B-2). While most modes are selected and deselected using the APCP, control of the AFCS datums and some specific modes can be selected on the cyclic or collective grips.

The cyclic beep trim switch is a 5-position rocker switch which allows small attitude adjustments in pitch or roll axes when the helicopter is in ATT mode by pressing it forward/aft/left/right. If an AFCS upper mode is captured the beep trim can be used to amend the reference datum for the relevant axis. For example, the IAS reference datum when IAS mode is captured, and the heading reference datum when HDG mode is captured and above 40 KIAS. When HOV mode is selected, the trim in pitch and roll is used to adjust and select the overall groundspeed vector reference on the HSI. A fifth position, by depressing the cyclic beep trim, is used to select the position-hover function of HOV mode.

The collective/yaw beep trim is a 4-way position rocker switch. Pressing the switch fore/aft adjusts the reference datums of the upper modes on the collective axis while pressing left/right adjust yaw trim when in ATT mode. Below 40 KIAS, or when HOV mode is captured, low speed heading hold is active, and the heading reference datum can be adjusted by pressing the switch left/right.

The cyclic FTR button suspends attitude hold in the pitch and roll axes when it is depressed and should be used for any large stick movements used to adjust the attitude of the helicopter. On release, attitude hold is restored. The collective FTR button suspends the mode captured on the collective axis. A yaw trim clutch mechanism on the pedals can be de-activated by depression of microswitches on the pedals.

The reference datums of the upper modes will synchronise the helicopter's actual datums with the movement of the controls when the FTR is depressed; the new datum is set on release of the FTR button.

Appendix B (cont)

The ATT button is used to deselect all the upper modes and engages ATT mode in all axes.

GA/TU switch is used to select the GA /TU mode, depending upon the helicopter parameters at the time.

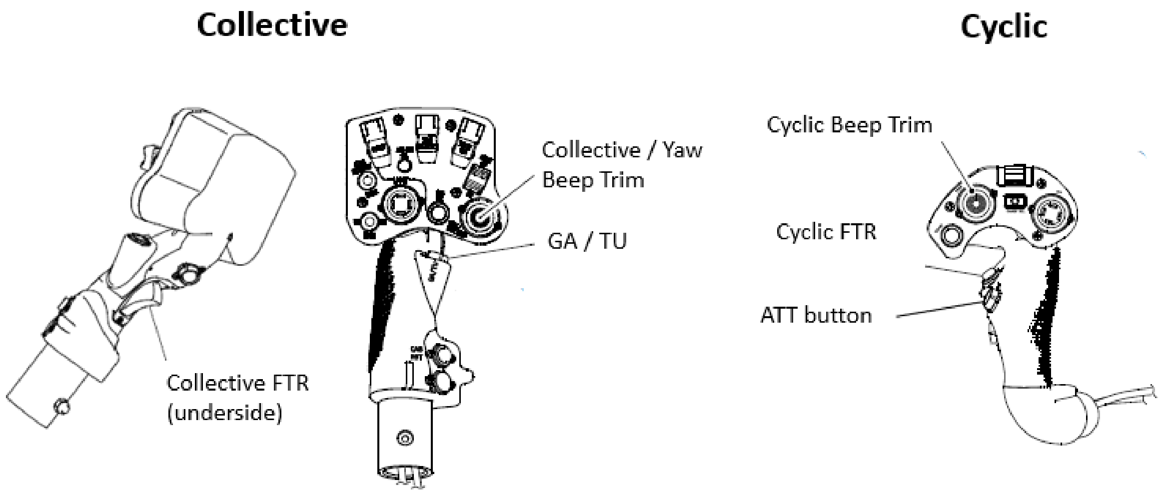

Figure B-2
Collective and Cyclic AFCS Controls

Published: 15 February 2024.

Accident

Aircraft Type and Registration:	Piper PA-28-180, G-AXSG
No & Type of Engines:	1 Lycoming O-360-A4A piston engine
Year of Manufacture:	1970 (Serial no: 28-5605)
Date & Time (UTC):	7 April 2023 at 0827 hrs
Location:	St Mary's Airport, Isles of Scilly
Type of Flight:	Private
Persons on Board:	Crew – 1 Passengers – 2
Injuries:	Crew – None Passengers – None
Nature of Damage:	Left main landing gear cylinder and torque link lugs fractured, damage to underside of flap and wing
Commander's Licence:	Private Pilot's Licence
Commander's Age:	79 years
Commander's Flying Experience:	1,400 hours (of which 500 were on type) Last 90 days – 31 hours Last 28 days – 7 hours
Information Source:	AAIB Field Investigation

Synopsis

On touchdown the left main landing gear collapsed. The cause of the collapse was failure of both upper torque link attachment lugs on the landing gear cylinder due to fatigue cracking. There is a known history of fatigue cracking on cast landing gear cylinders and a manufacturer's Service Bulletin exists to regularly inspect the area around the attachment lugs. There is currently no Airworthiness Directive to mandate the Service Bulletin.

One Safety Recommendation is made to the CAA to ensure that the level of safety of cast main landing gear cylinders fitted to PA-28 and PA-32 aircraft is acceptable.

History of the flight

As the pilot applied the brakes after touching down, the aircraft veered to the left onto the grass where the left main landing gear leg collapsed. The remaining portion of the landing gear dug into the grass, turning the aircraft through 180° before it came to a stop (Figure 1). The pilot and passengers were uninjured.

Figure 1
G-AXSG following the landing

Aircraft information

The Piper PA-28 has a fixed, tricycle landing gear. Each main landing gear leg comprises a cylinder attached to the main wing spar; an oleo leg with a wheel and brake assembly; and upper and lower torque links. The torque links retain the oleo leg within the cylinder and prevent it from rotating. The upper torque link is connected to the man landing gear cylinder via two torque link attachment lugs (Figure 2). The same cylinder is fitted to some models of the PA-32 aircraft.

The main landing gear cylinder is aluminium alloy and can be manufactured either as a cast or a forged part. Casting requires the aluminium alloy to be heated until it becomes liquid, when it is then poured into a mould to form the component. The forging process heats the aluminium alloy to a plastic state where it is then shaped into the component using compressive forces. Forging typically results in a stronger component which is not as susceptible to fatigue cracking as the equivalent cast part.

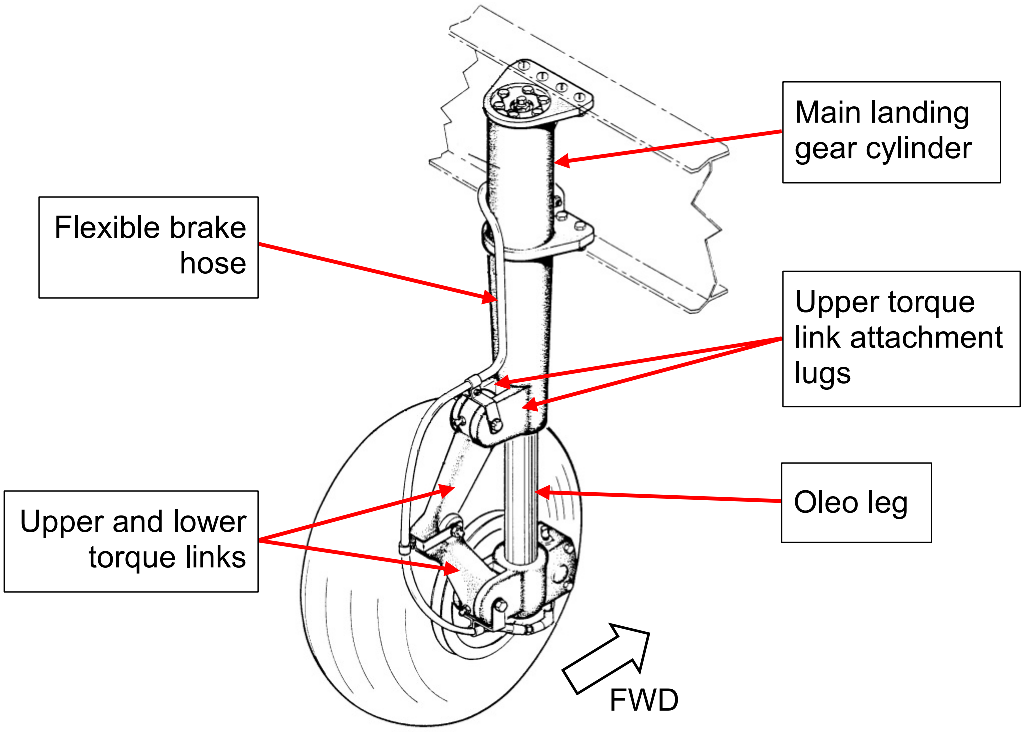

Figure 2
Left main landing gear leg assembly

Aircraft examination

The following damage was found on the aircraft:

- The left landing gear wheel, torque link and oleo strut assembly had detached from the landing gear cylinder but remained attached to the aircraft by the brake hose.
- The torque link attachment lugs had broken from the main landing gear cylinder and remained attached to the upper torque link (Figure 3).
- The base of the main landing gear cylinder had fractured into several smaller pieces near to the upper torque link attachment lugs (Figure 4).
- There was damage to the left flap and wing surface sustained from the oleo leg and wheel assembly during the accident sequence.
- The left wheel brake disc surface was corroded and did not show witness marks from the brake pad rubbing against the disc.

Figure 3

Detached torque link lugs and wheel assembly

Figure 4

Fractured lower left main landing gear cylinder fragments

Maintenance history

G-AXSG had a valid Airworthiness Review Certificate issued on 18 July 2022 at 8,044 hours. The last recorded annual inspection was conducted at the same time.

Following a report of the left main landing gear brake binding in February 2023, new piston seals were fitted and the brakes operated satisfactorily when tested.

Applicable Service Bulletins and Airworthiness Directives

Background

Fatigue cracking of the torque link attachment lugs is known to occur on the cast main landing gear cylinders fitted to PA-28 and PA-32 aircraft manufactured between 1961 and 1977. Aircraft manufactured since 1977 were fitted with a forged cylinder which can be used as a replacement for the cast cylinders.

Service Bulletins and Airworthiness Directives

Fatigue cracking of the torque link attachment lugs has been addressed within the UK and EU by a series of Airworthiness Directives (AD) and manufacturer's Service Bulletins[1] (SB) specifying inspections every 100 flight hours. Neither the SBs or ADs specified a calendar life or the maximum number of landings between inspection intervals.

The AAIB investigated a failure of a cast cylinder on a PA-28 (G-BRBA) on 4 September 2021 and the report contains the background to the SB and AD. In summary, CAA AD 002-06-99 was issued in 1999, followed by SB1131 in 2003 and updated by SB1131A in 2016. EASA AD 2005-0035, which mandated both SBs, was cancelled in 2020 by EASA due to the perceived low number of cast cylinders in service and the level of risk of failure. Currently, there is no AD to mandate SB1131A.

Inspection method

SB1131A called for a visual inspection before and after applying a liquid penetrant dye to the landing gear cylinder. However, the porosity of the aluminium alloy casting can produce a degree of background fluorescence when the dye is applied, making it difficult to differentiate small cracks from the porosity. With the cylinder fitted to the aircraft, access to the undersides of the upper torque link attachment lugs can be difficult and the effectiveness of visually identifying cracks is dependent on the level of lighting.

Compliance

SB1131A was last carried out on G-AXSG on 24 October 2019 at 7,948 hours with no record of any cracks having been detected. At the time of the accident the aircraft had flown a further 141 hours and completed 299 landings.

Footnote

1 CAA Airworthiness Directive AD 002-06-99 (iss. 1999), Piper SB1131 (iss. 2003), EASA AD 2005-0035 (iss. 2005), and Piper SB1131A (iss. 2016).

Fracture surface examination

The fracture surfaces on the left main landing gear cylinder removed from G-AXSG were examined using a stereomicroscope and scanning electron microscopy.

The landing gear cylinder fractures were assessed to have occurred due to overload. They happened after the failure of the torque link lugs and detachment of the oleo leg and wheel assembly.

Both torque link attachment lug fracture surfaces showed an area of stable, progressive fatigue crack growth with faint striations[2] present. The fractures had initiated at the inner lower radii of each lug (Figure 5). The cracks reached a maximum depth of 2 mm on the inboard lug and 3 mm on the outboard lug before instantaneous fracture occurred. There was no evidence of pre-existing material or mechanical defects associated with the fatigue crack initiation.

Following the period of stable fatigue crack growth, the inboard lug showed evidence of having fractured in two stages. The first fracture (stage 1) extended to approximately three quarters of the lug's surface area, identified by slight oxidation of the fracture surface. Subsequent final separation of both the inboard and outboard lugs due to the secondary fracture (stage 2) are as assessed as having occurred at the same time.

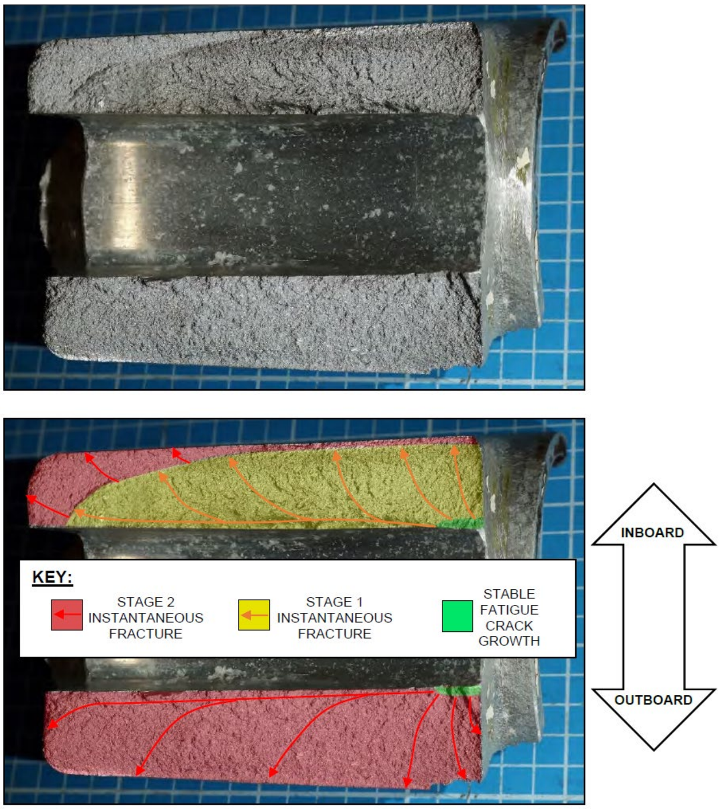

Figure 5

Torque link attachment lug fracture surface analysis

Footnote

2 Marks on a fracture surface that indicate the incremental growth of a fatigue crack.

Brake function

The left main landing gear brake calliper was tested using an off-aircraft rig and found to operate normally. The brake pads showed evidence of light binding with the brake disc surface, but not to a level that would significantly affect rotation.

Assessment of unsafe condition

Within the UK, an aircraft component, part or system must initially demonstrate an acceptable level of safety in accordance with the requirements of UK Regulation (EU) No 748/2012. If subsequently, failures or defect reports indicate that this is no longer being achieved, an assessment can be made in accordance with Annex I Part 21.A.3 of the Regulation, to determine if an unsafe condition exists.

Analysis

The left landing gear torque link lugs failed on landing, resulting in the landing gear oleo, torque links and wheel assembly detaching from the main landing gear cylinder.

The fatigue cracks formed and grew from the inner lower radii of each lug, followed by instantaneous failure. Fine fatigue striations were present in the areas of stable crack growth on both lugs, but it was not possible to correlate them with the numbers of landings. It was also not possible to determine how long the inboard lug's first fracture had been present, prior to final fracture occurring. It is possible that the fatigue cracks were present at the last inspection, which was carried out while the leg was fitted to the aircraft, but were not detected using the dye penetrant inspection technique.

The last recorded compliance with SB1131A on G-AXSG was 141 flying hours prior to the accident, which was 41 hours beyond the recommended interval in SB1131A. The growth of fatigue cracks on the lugs is a function of the number of landings rather than flying hours and G-AXSG had completed 299 landings since the last inspection.

While SB1131A is still current, the EASA AD mandating it was cancelled in 2020 as EASA determined that an acceptable level of safety existed. Cast main landing gear cylinders are still fitted to aircraft and fatigue cracking of the lugs continues to occur. To ensure that an acceptable level of safety still exists for the cast cylinders fitted to PA-28 and PA-32 aircraft, and to provide appropriate guidance on inspecting the cylinders, the following Safety Recommendation is made to the CAA:

Safety Recommendation 2024-001

It is recommended that the Civil Aviation Authority undertakes an unsafe condition assessment, in accordance with the requirements of UK Regulation (EU) No 748/2012 Annex I Part 21.A.3, for the cast main landing gear cylinder cracking affecting PA-28 and PA-32 aircraft, and take appropriate action based on the outcome of the assessment.

Conclusion

The left main landing gear torque link attachment lugs failed due to fatigue cracking, causing the wheel assembly and oleo to come out of the landing gear cylinder on landing. While a SB exists to inspect the landing gear for fatigue cracking, the EASA AD mandating the inspection was cancelled in 2020 due to the perceived low number of cast aluminium cylinders in service and the level of risk of failure.

The SB was carried out on G-AXSG, with the landing leg still fitted to the aircraft. It is possible that the fatigue cracks were present but were not detected using the dye penetrant inspection technique.

Published: 1 February 2024.

Accident

Aircraft Type and Registration:	EV-97 teamEurostar UK, G-IFLE
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2004 (Serial no: 2113)
Date & Time (UTC):	4 June 2023 at 1257 hrs
Location:	Otherton Airfield, Staffordshire
Type of Flight:	Private
Persons on Board:	Crew – 1 Passengers – 1
Injuries:	Crew – 1 (Fatal) Passengers – 1 (Fatal)
Nature of Damage:	Destroyed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	134 hours (of which 134 were on type) Last 90 days – 3 hours Last 28 days – 2 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot intended to fly to another airfield 37 nm south of Otherton Airfield where the aircraft was based. The aircraft was climbing into the overhead while flying along the downwind leg. When at a height of about 740 ft agl, it started to descend and appeared to be returning to land. The base leg was flown relatively close to the airfield and during the turn onto the final approach the aircraft entered a spin from which it did not recover before striking the ground. The investigation was unable to establish why the aircraft descended and appeared to return to the airfield. However, the relatively high bank angle, decaying speed and retracted flaps would have provided the conditions for an entry to the spin. Guidance for pilots on stall and spin awareness can be found in CAA Safety Sense Leaflet 30[1].

History of the flight

At 1120 hrs the pilot and passenger taxied from outside the hangar where G-IFLE was kept to the clubhouse (Figure 1), where they had breakfast and spoke to a witness. The pilot and passenger both appeared to be fine and told the witness that they were going to fly to Croft Farm. About an hour later the pilot taxied back to the hangar and approximately 20 minutes after that taxied back to the clubhouse where the engine was shut down. The pilot entered the clubhouse and booked out, while the passenger remained seated in the aircraft. The airfield movement log shows that he booked out at 1345 hrs (1245 hrs UTC)

Footnote

[1] CAA Safety Sence Leaflet 30, Loss of Control, Stall & Spin Awareness. CAA8230_SafetySense_30-LossOfControl_V10.pdf [accessed 23 November 2023].

with one passenger for a flight to Croft Farm, which is approximately 37 nm south and located near Defford, Worcester.

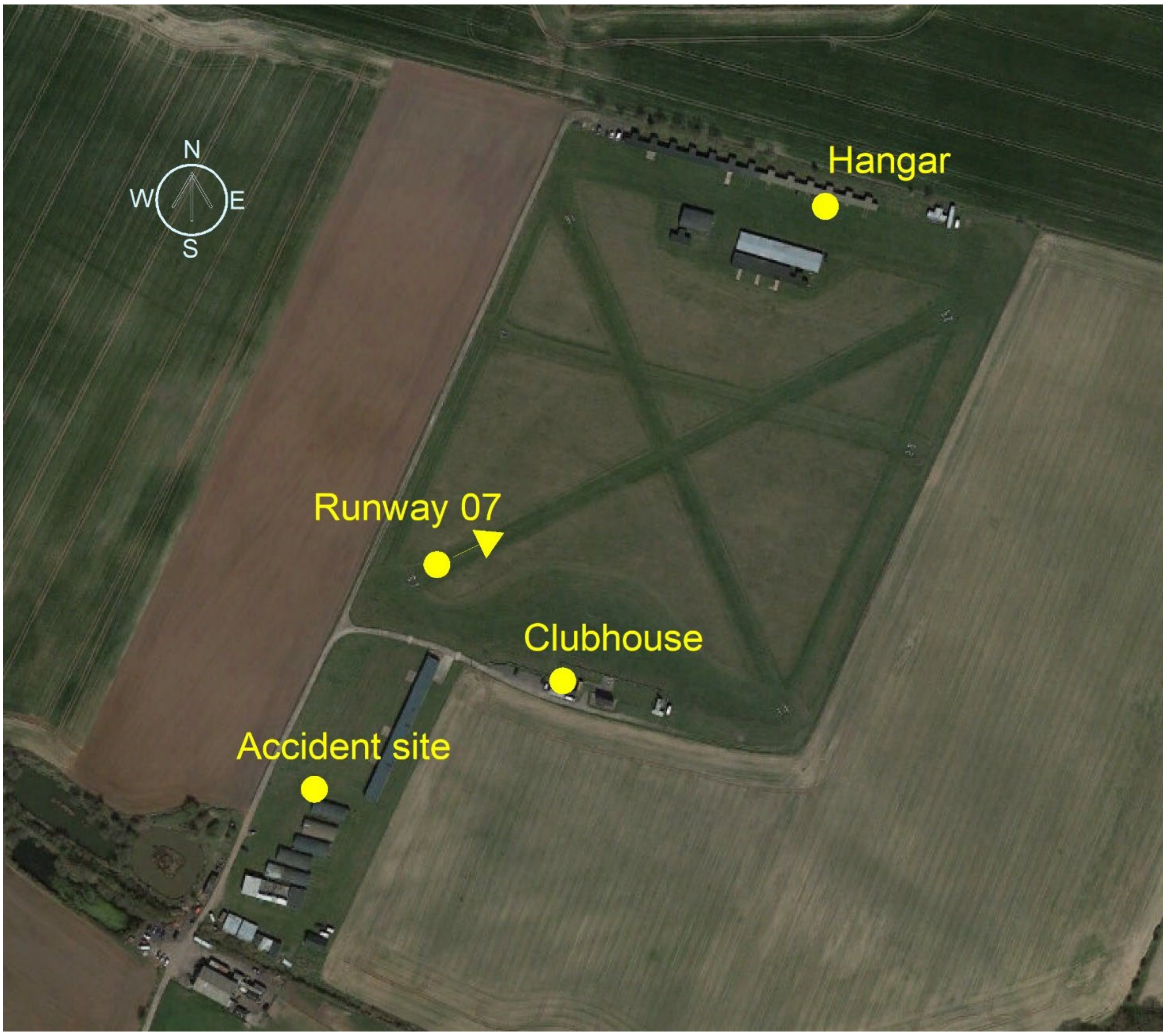

Figure 1

Otherton Airfield - location of G-IFLE's hangar, clubhouse and accident site
(© 2023 Google, Image © Maxar Technologies)

Approximately six minutes later, the pilot started the engine and taxied to Runway 07. The aircraft stopped short of the runway for about 30 seconds and then at 1256 hrs lined up and commenced the takeoff run.

The takeoff run and climb appeared to be normal and a witness reported that the engine sounded as if it was at full power. The aircraft continued to climb and at around 360 ft agl, started a right turn which brought it onto a heading of 240°, aligned with the downwind leg for Runway 07. When the aircraft was abeam Runway 34, at a height of about 740 ft agl, it commenced a right turn onto a heading parallel with the base leg and began to descend.

At approximately 500 m from the threshold of Runway 07, at a height of approximately 550 ft agl, the aircraft entered a right turn towards the runway. Shortly afterwards, it descended in a steep nose-down attitude in a clockwise rotation and struck a metal shipping container adjacent to one of the hangars on the south side of the airfield. The aircraft immediately caught fire. The pilot and passenger were fatally injured, and the aircraft was destroyed.

There were no reports of any radio calls having been made from G-IFLE during the short flight.

Aerodrome information

Otherton Airfield has three grass runways and the circuit height is 500 ft agl[2] (Figure 2). The airfield elevation is 340 ft amsl. An Air/Ground radio service is available and if it is unmanned, pilots are asked to make "Blind Calls".

The airfield plate[3] states:

> *'**Remarks.**…NO FLY ZONE to north and south of airfield…*
>
> ***Departures**. Climb in the overhead to minimum 1,200ft agl. Depart East or West, maintain heading until 2nm from the airfield before turning onto course'*

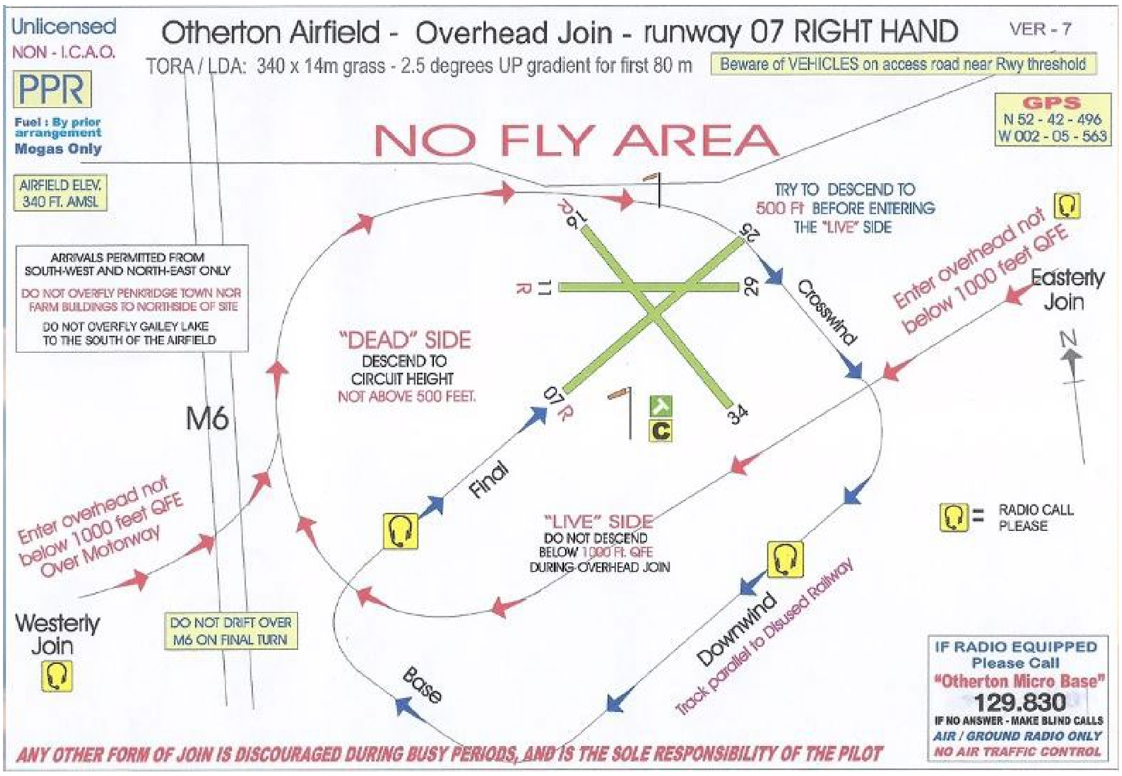

Figure 2

Airfield information
(Used with permission)

Footnote

[2] QFE and agl are used interchangeably in this report; they both refer to height above the ground.
[3] Pooleys Flight Guide 2023.

Meteorology

An Aftercast provided by the Met Office reported:

> *'…at the time of the incident there was no cloud below 5000FT reported in the area and visibility was greater than 10Km with light east to north-easterly winds.'*

The Aftercast was consistent with CCTV footage from the airfield taken at the time of the accident. From the recorded images of the windsock located near the clubhouse it was estimated that the wind was from 030° at 8 kt.

Accident site

The accident site was approximately 140 m from the threshold of Runway 07 and adjacent to one of the hangars on the south side of the airfield (Figure 3).

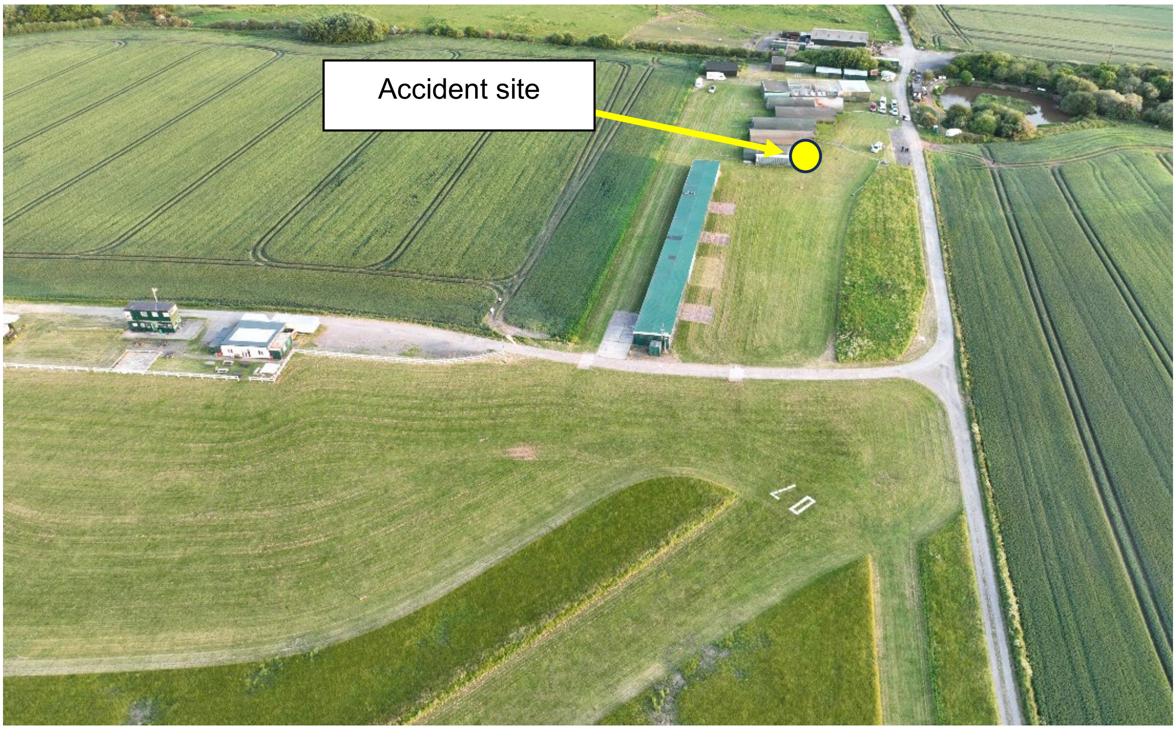

Figure 3

Aerial view showing the location of the accident site relative to the Runway 07 threshold

The left-wing had struck the top of a metal shipping container and separated from the rest of the aircraft, which came to rest alongside. The fuel tank was split open and there had been a post-crash fire that consumed parts of the aircraft; no fuel remained in the tank.

Witness marks in the ground and damage on the wings indicated that the aircraft was in a steep nose-down attitude when the accident happened. From a review of the CCTV footage and examination of the wreckage the aircraft appeared to be intact when it struck the container.

Aircraft information

The EV-97, also known as the Eurostar, is a two-seat microlight aircraft (Figure 4). G-IFLE was an EV-97 teamEurostar UK, meaning that it was assembled in the UK by a CAA approved organisation. The aircraft was built in 2004 and its Permit to Fly was valid until 18 September 2023. The aircraft was kept in a hangar at the airfield.

G-IFLE was fitted with a three-bladed composite propeller. The aircraft can be equipped with an optional stall warner, but G-IFLE did not have a stall warner fitted.

The POH[4] provides the following operating information:

- Stall speed with the engine at idle: flaps fully extended is 40 mph (CAS) and with flaps retracted is 48 mph (CAS).
- Best glide speed is 68 mph with flaps retracted, for landing select flaps as required.
- Intentional spins are prohibited.

Figure 4

Image of teamEurostar UK, G-IFLE
(Image used with permission)

Local practice

The local practice which the pilot had been taught when flying the EV-97 at Otherton was:

- The initial climb in the EV-97 would normally be flown at 75 mph and on turning onto the downwind leg slow to 65 mph and select full flap.
- The turn from base leg onto the final approach would normally be at a height of around 300 to 400 ft agl.

Footnote

4 Light Sport Aviation, Pilot's Operating Handbook, EV-97 teamEurostar UK, POH/EUR/01 Issue 4.

- Engine failures were not practised at Otherton as the circuit was tight and the runways short.
- Glide approaches would be conducted from the final approach at around 400 ft agl.
- When leaving the circuit, climb on the downwind leg to above 1,000 ft agl.
- For a flight to Croft Farm, the aircraft would leave the circuit to the west.
- The pilot's normal practice was to fly one or two full stop landings before leaving the circuit to land at another airfield.

Recorded information

Recorded data

Data for the accident flight was available from a ground receiver system[5] that had recorded transmissions from a Pilot Aware Rosetta[6] electronic conspicuity device fitted to the aircraft. This provided GNSS derived position, groundspeed and the altitude of the aircraft at recorded rates of between once a second and once every four seconds. This data ended shortly before the aircraft struck the ground.

CCTV footage of the aircraft was captured by several co-located cameras on the airfield and a camera located at a private property which was about 0.5 nm south-east of the airfield. The footage included the period when the aircraft taxied to the runway and took off, and then as it subsequently descended and struck the ground.

Accident flight

The takeoff roll and liftoff appeared normal with the aircraft climbing at an average rate of 660 ft/min at an estimated airspeed of about 70 mph; this was based on a wind from 030° at 8 kt.

The following sections of the flight are shown on Figure 5 and 6:

- As the aircraft climbed through 260 ft agl (600 ft amsl) it started a right turn onto a downwind heading and at 600 ft agl (940 ft amsl) the rate of turn was reduced with the aircraft rolling out onto a track of about 240° (Figure 5 and Figure 6 Point A).
- The climb rate then reduced to about 340 ft/min and the airspeed gradually increased to an estimated 85 mph (Figure 5 and Figure 6 Point B).
- At a height of about 740 ft agl (1,080 ft amsl) (Figure 5 and Figure 6 Point C) the aircraft started to descend and its airspeed increased to an estimated 100 mph; the aircraft was laterally positioned about 550 m from the threshold of Runway 07 at this time. As the aircraft descended it turned to the right,

Footnote

5 PilotAware Air Traffic Observation and Management (ATOM) grid.
6 Rosetta (pilotaware.com) [accessed 13 November 2023].

back towards the airfield, with the estimated bank angle increasing to approximately 30° right wing down.

- As the aircraft descended to about 550 ft agl (880 ft amsl) (Figure 5 and Figure 6 Point D) its rate of descent reduced from about 1,800 ft/min to an average of 360 ft/min. As the aircraft gradually descended its airspeed also reduced.
- After about 10 seconds the estimated airspeed of the aircraft had reached about 60 mph at which point the data indicates that the rate of turn had also increased quickly with the estimated bank reaching more than 45°.
- At a lateral distance of about 200 m from the threshold of Runway 07, the aircraft then entered a rapid descent from a height of about 480 ft agl (Figure 5 and Figure 6 Point E). The first CCTV image of the aircraft as it descended was captured shortly after.

Comparison of the ground track of the accident flight with a previous flight recording of G-IFLE landing on Runway 07 showed that the downwind leg of the previous flight had extended much closer to the M6 motorway (Figure 2) before the aircraft turned onto base leg.

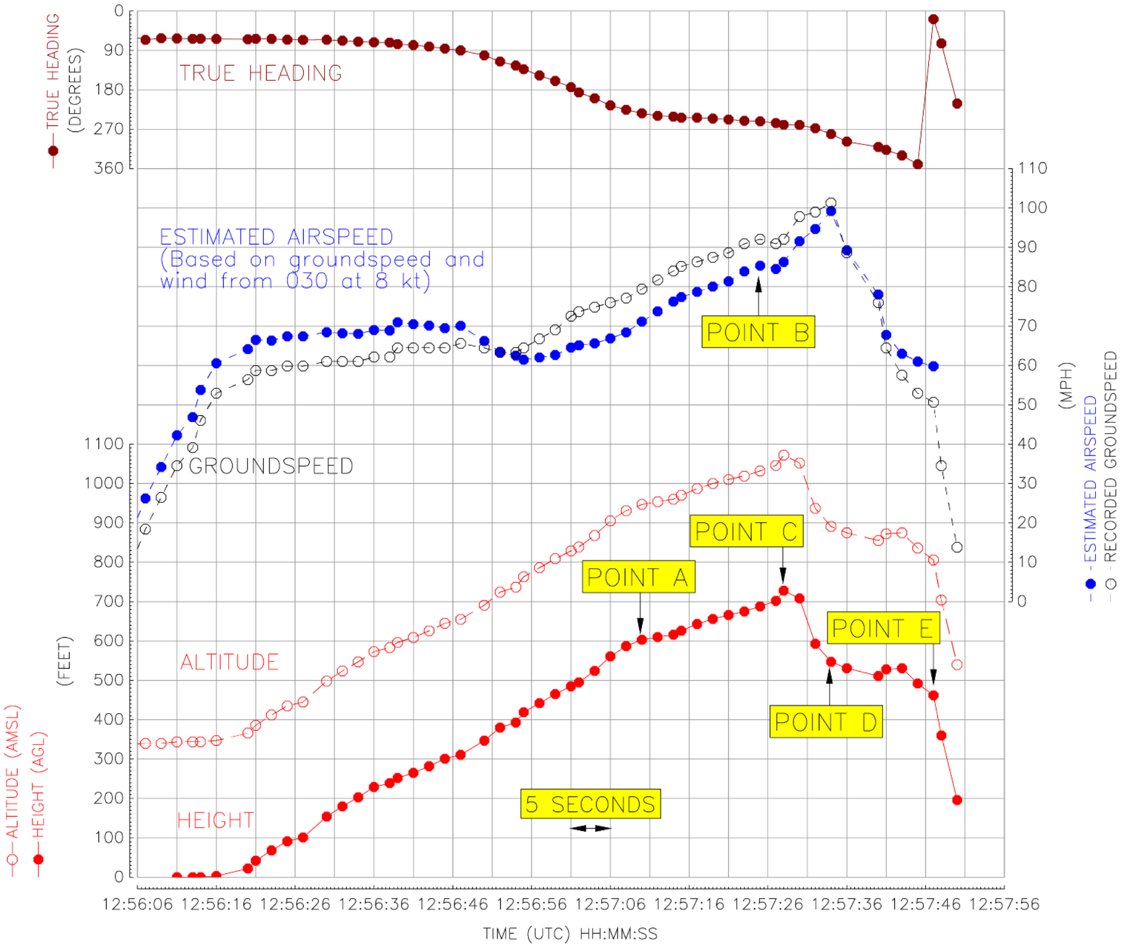

Figure 5

Data plot of accident flight

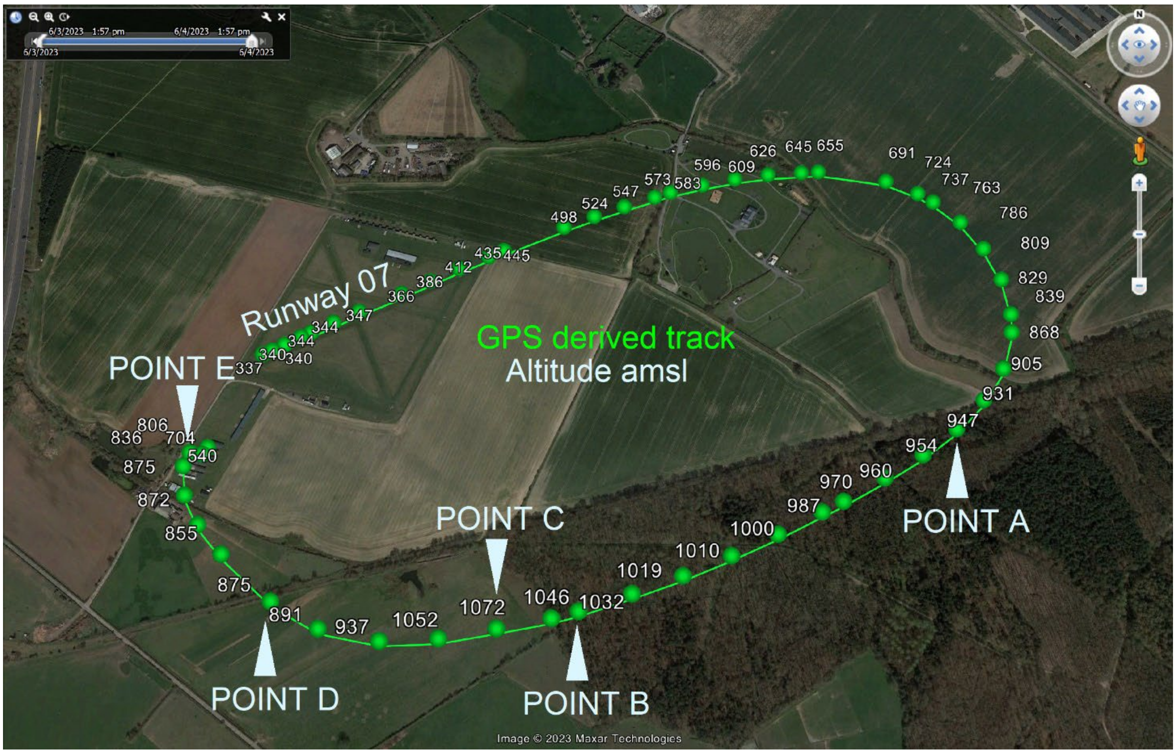

Figure 6

GPS derived track and altitude
(© 2023 Google, Image © Maxar Technologies)

The descent

A composite image of the descent footage is provided in Figure 7; each image of the aircraft is 0.5 second apart.

At the beginning of the CCTV footage the aircraft's pitch attitude was at about 35° nose-down and the bank angle was about 80° right wing down. The aircraft turned to the right as it descended, and its nose-down attitude increased to about 70°. The average descent rate was about 5,000 fpm (57 mph) with one complete rotation of the aircraft taking about 4.5 seconds. The aircraft remained in a steep nose-down attitude until it struck the ground, which was captured by CCTV at the airfield.

The time from the aircraft departing from controlled flight to crashing was approximately six seconds during which it made around 1.5 rotations. There was no evidence of the aircraft starting to recover from the spin.

Figure 7
Composite CCTV image of the descent

Aircraft examination

The aircraft was badly damaged in the accident and fire, which prevented a full assessment of its condition prior to the impact being carried out. The investigation established the following:

Structure

There was no evidence of a structural failure.

Flying controls

- There was no evidence of a control failure.
- The flaps were retracted.

Fuel

- The fuel tank had cracked in the impact and was empty.
- The fuel pump had broken off the engine, but its internal condition was good. It contained a small amount of fuel.
- The fuel shut-off valve was open.
- The main fuel jets in the carburettors were clear, and the throttle plates were both close to the idle position.

Engine

- The visual appearance of the spark plugs was normal.
- The cylinders and pistons were intact and of a normal appearance.
- The oil filter was clear of debris and the oil pump was in good condition.
- The engine ignition switches were ON, which is the normal position for flight.

Propeller

Witness marks in the reduction gearbox indicated that the propeller was rotating when the aircraft crashed. The speed of rotation is unknown.

Recent engine maintenance

The engine was manufactured in 2008 and last underwent maintenance in April 2023 after reports of a rough running engine. The spark plugs were replaced and the carburettors adjusted. The flight log recorded that the aircraft had flown 13 times since this maintenance, including a three-hour flight the day before the accident. There were no reports of any engine problems following this maintenance.

Weight and Balance

G-IFLE, which is classed as a microlight, has a Maximum Take-off Weight (MTOW) of 450 kg. The Aerotechnik EV-97A Eurostar, which is classed as a Single Engine Piston aeroplane has a MTOW of 480 kg. Both aircraft are structurally the same and have the same flying characteristics.

The website for Croft Farm Airfield states that fuel is not available; therefore, the pilot would have had to take sufficient fuel for the return journey plus a reserve. It was not possible to establish the actual fuel load at the start of the flight.

An instructor familiar with the aircraft said he would expect to plan for 30 litres of fuel. For the occupants he would have allowed for a weight of between 152 and 160 kg. This would have given an estimated minimum weight at the start of the flight of 472 kg, which would have placed the CG at 23% inside the allowable limit.

With a full fuel tank, the estimated maximum weight would have been 485 kg with the CG at 18% inside the allowable limit.

Estimation of stall speed

The British Microlight Aircraft Association (BMAA) calculated the stall speed of G-IFLE during the final turn assuming ISA conditions, level flight in a 45° bank, flaps retracted, and a weight of between 472 kg and 485 kg, and estimated it to be around 59 mph.

Medical

The pathologist found that the pilot and passenger both died from injuries sustained during the accident. There was no evidence of medical impairment or incapacitation of the pilot before the aircraft struck the ground. Carboxyhaemoglobin analysis was carried out on a sample of the pilot's blood and was not found to be indicative of carbon monoxide poisoning.

Pilot and passenger information

Pilot

The pilot was issued with a UK National Private Pilot's Licence Aeroplanes (NPPL(A)) on 26 July 2019, and held a microlight aeroplane rating, which was issued on 10 August 2021 and valid until 31 August 2023.

The pilot's logbook shows that he started his flying training in May 2016 and had flown around 134 hours of which around 30 hours were recorded as Pilot in Command (P1). All the flights were undertaken in an EV-97 and since 12 May 2021 were flown in G-IFLE.

In 2023 the pilot flew seven flights totalling 4 hours 30 minutes and in 2022 flew four flights totalling 3 hours 25 minutes. His last flight with an instructor was on 6 September 2021 and the logbook entry records '*P/APP Glide App Side Slips Ex 12 +13*'. The BMAA Microlight Instructor and Examiner Guide[7] describes Exercise 12 and 13 as *'Take-off, Climb to Downwind, The Circuit, Final Approach and Landing'.*

Passenger

The passenger also held a NPPL(A) and completed his General Skills Test (GST) on 20 June 2022. His microlight rating had expired and he was flying under the supervision of an instructor as he prepared to take his GST to renew his rating. He last flew as PIC on 22 May 2023 and the remarks columns in his logbook for this flight recorded *'Ex 17B[8]'*. His total hours were 143 hours 10 minutes of which 24 hours 50 minutes were recorded as P1. All the flights were in an EV-97.

Footnote

7 BMAA Instructor & Examiner Guide. Edition 5. May 2013 (Amended December 2016).
8 BMAA Instructor & Examiner Guide. Edition 5. May 2013 (Amended December 2016). Exercise 17b Solo circuit, local area, and general flying consolidation to GST for microlight NPPL.

Spin awareness training

Training for a NPPL is conducted in accordance with a syllabus approved by the CAA; the BMAA syllabus which the pilot followed during his training is approved by the CAA. Section 4 of the BMAA Instructor & Examiner Guide, provides guidance to instructors and details the exercises that a student must complete in order to pass the GST. Exercise 11 covers spin awareness.

Spinning is not permitted in microlight aircraft and, therefore, students and pilots only receive spin awareness training. The guidance for Exercise 11 states:

> *'4.12.1 It is not possible to provide flying training for recovery at the incipient stage of the spin in the current generation of microlight aircraft, as none are cleared for spinning…Instructors should cover the spin awareness exercise as a discussion item. Individual aircraft may have different recovery procedures; always refer to the Pilot Operator's Manual.*
>
> *4.12.4 It should be appreciated that in any unplanned spin entry situation the element of surprise is likely to limit the ability of the student to respond promptly and correctly. The time available to effect a recovery at the incipient stage of the spin is limited.*
>
> *4.12.6 It should be noted that many aircraft will increase their spin rotation rate if the incipient recovery is used whilst the aircraft is in a fully developed spin.'*

The actions to take to recover the EV-97 from an incipient and developed spin are listed in Table 1.

Order of actions	Incipient spin	Developed spin
1	Control column forward	Reduce throttle to idle
2	Power as required	Ailerons neutralised
3	Rudder to prevent further yaw	Apply full opposite rudder
4	Level wings and regain balanced flight	Control column forward as required to stop spin
5		Immediately after rotation stops, neutralise rudder.
6		Recover from dive

Table 1

Actions to be taken to recover from an incipient and developed spin

CAA guidance on stall and spin awareness

CAA Safety Sense Leaflet[9] 30 provides guidance to pilots on stall and spin awareness. It states that *'Loss of control through stalling or entering a spin remains one of the leading causes of General Aviation accidents'* and that at low level it may be impossible to recover from a spin. When considering why loss of control might happen during the different stages of flight, it discusses the importance of pilot's being constantly aware of the aircraft's attitude and airspeed.

Analysis

The pilot's intention was to fly to Croft Farm, which is approximately 37 nm south of the departure airfield. His normal practice before flying to another airfield was to first make one or two full stop landings at Otherton before climbing above 1,000 ft agl and fly out to the west avoiding the No-Fly Zone to the south.

The takeoff appeared normal, and the aircraft turned onto the downwind leg and continued climbing to 740 ft agl. The airspeed and height then started to reduce, and the aircraft turned onto a track roughly parallel to the base leg, but much closer to the airfield. When the aircraft was about 200 m from the runway threshold, at a height of about 480 ft agl, it entered a 70° nose-down attitude, with a clockwise (right) rotation. There was no evidence that the aircraft had started to recover from this attitude before it struck the ground about six seconds later. There were no reports of any radio calls having been made from G-IFLE during the short flight.

There was no evidence of a structural failure of the aircraft, or disconnection of the flying controls prior to the impact. While the estimated weight of G-IFLE at the start of the flight was between 22 and 35 kg above the maximum permitted weight, after accounting for the amount of fuel used it was probably within the permitted weight of the EV-97A, which has the same flying characteristics. Therefore, the weight and CG of G-IFLE were not considered to be factors in this accident.

Medical incapacitation seems unlikely as the pathologist concluded that the pilot and passenger were fatally injured in the crash and there was no evidence of carbon monoxide poisoning. Whilst the passenger probably had sufficient experience to fly the aircraft if the pilot was incapacitated, success would rely on recognising a need to take control.

If the pilot intended to land, then it would be normal to fly the downwind leg at 500 ft agl with the flaps extended. Continuing to climb to 740 ft agl with the flaps retracted might indicate that he intended to climb and leave the circuit, or that he had become distracted.

The possibility that the pilot climbed to practise an engine failure and glide was considered, but engine failures were not practised at the airfield and glide approaches were normally entered from the final approach. It was also unlikely that his first landing of the day would be a glide approach.

Footnote

[9] CAA Safety Sence Leaflet 30, *'Loss of Control, Stall & Spin Awareness.'* CAA8230_SafetySense_30-LossOfControl_V10.pdf [accessed 23 November 2023].

There may have been a technical problem, but with a glide range of at least 0.8 nm, from when the downwind descent started, the aircraft would have been able to glide to one of the runways; the estimated speed of the aircraft in the circuit indicates that the glide speed of 68 mph was never maintained. The pilot's logbook recorded that he had last flown a glide approach with an instructor on 6 September 2021.

Consideration was given to the possibility that there had been an engine failure or loss of power. The fuel shut-off valve and engine ignition switches were found in the normal operating positions for flight and the intensity of the fire is evidence that there was fuel onboard the aircraft. Examination of the engine concluded that it was probably operating at a low power setting and the propeller was rotating when the aircraft struck the ground.

The low power setting could be due to the pilot closing the throttle when attempting to recover following the loss of control, or a fault in the engine. However, the damage to the engine and aircraft meant that it was not possible to establish if there had been a fault. Maintenance had previously been carried out on the engine following reports of rough running, but it had since flown 13 flights with no further reports.

The profile of the final manoeuvre was consistent with the aircraft entering a spin from which it did not recover. G-IFLE was not fitted with the optional stall warner and during the final turn the flaps were retracted, and the speed had reduced to around 60 mph; with a bank angle of 45°, the estimated stall speed would have been around 59 mph. The aircraft would have been high on the approach for a landing on Runway 07. Microlight aircraft such as G-IFLE have relatively low inertia and will quickly slow down following a reduction or loss of engine power if the pilot does not immediately lower the nose of the aircraft. The relatively high bank angle, decaying speed and retracted flaps would have provided the conditions for an entry to the spin.

It took around six seconds from the start of the final manoeuvre to the aircraft striking the ground, during which it made approximately 1.5 rotations. The pilot was relatively inexperienced and suddenly entering a spin would have startled him and possibly limited his ability to respond promptly and correctly.

Conclusion

While turning onto the final approach during a return to the airfield the aircraft entered a spin. The pilot was unable to recover the aircraft before it struck the ground and caught fire. The accident was not survivable.

Published: 1 February 2024.

AAIB Correspondence Reports

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

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

The accuracy of the information provided cannot be assured.

Serious Incident

Aircraft Type and Registration:	ATR 72-212A-600, EI-HDK	
No & Type of Engines:	2 Pratt & Whitney Canada PW127M turboprop engines	
Year of Manufacture:	2016 (Serial no: 1334)	
Date & Time (UTC):	14 August 2023 at 1327 hrs	
Location:	Liverpool Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew – 5	Passengers – 66
Injuries:	Crew – None	Passengers – None
Nature of Damage:	Main landing gear changed due to hard landing	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	43 years	
Commander's Flying Experience:	3,160 hours (of which 2,927 were on type) Last 90 days – 82 hours Last 28 days – 28 hours	
Information Source:	Aircraft Accident Report Form submitted by the commander and further enquiries by the AAIB	

Synopsis

The aircraft was making an approach to Runway 09 at Liverpool Airport. As it crossed the runway threshold it entered heavy rain and the visibility reduced to near zero. The airspeed reduced and the rate of descent was maintained which resulted in a hard landing. The commander took control and executed a missed approach, landing without further incident.

Analysis of FDR recordings and meteorological reports suggests that the aircraft probably encountered an increasing tailwind as it crossed the runway threshold, whilst flying through heavy rain.

History of the flight

The crew were scheduled to operate a passenger service from Dublin to Liverpool Airport. After the first takeoff they returned to Dublin due to a pitot heat failure. The crew changed aircraft to EI-HDK and took off a second time bound for Liverpool, approximately 90 minutes behind schedule. The co-pilot was pilot flying. During the cruise the commander listened to the ATIS for Liverpool which indicated Runway 09 was in use with surface condition 5/5/5[1], wind from 150° at 12 kt gusting 22 kt and varying from 110° to 170°, visibility 10 km with 7 km to the south-east, temperature 20°C, rain showers in the vicinity and QNH 1003 hPa.

Footnote

[1] The runway surface was condition code '5' in all thirds of the runway. Condition code 5 on this day meant the runway surface was covered by visible dampness or water up to and including 3 mm depth.

The crew briefed that, due to the gusts, the commander might need to perform the landing if the weather did not improve.

When speaking to Liverpool Approach the commander obtained a wind report, indicating from 150° at 7 kt, so the crew agreed the co-pilot would fly the landing. The crew noticed some red radar returns on the weather radar close to the airport, which they thought were rain. The tower controller reported that there was a shower to the south. The aircraft was stable on the approach by 1,000 ft aal and when cleared for landing, the surface wind was reported as from 220° at 5 kt. The commander commented that it was now a tailwind and advised the co-pilot to "keep an eye on the power if the wind changes." As the aircraft continued the approach it encountered some rain but the crew maintained sight of the runway and approach lights. On short final the rain became increasingly heavy and the commander switched the windscreen wipers to FAST for both screens. He asked the co-pilot "do you want me to take it?" but the co-pilot confirmed he was content to continue. The commander recalled they were still visual with the runway as the aircraft passed over the runway threshold but, passing 50 ft, the rain intensity increased and the visibility rapidly deteriorated. The co-pilot recalled the flight deck "going dark, like someone had pulled the curtains". The commander recalled the aircraft seemed to suddenly and firmly touchdown as the visibility reduced to near zero. He immediately took control and executed a missed approach.

When the aircraft had climbed away the tower controller reported that the rain was now clearing and the surface wind was now from 220° at 7 kt, offering an approach to Runway 27. The crew accepted and started to position for a second approach, but the controller then advised that an inspection was required due to the amount of water on the runway, so they discontinued. The controller subsequently advised that the runway was wet with standing water on the shoulders and that taxiway E, F and G were flooded, so the aircraft would need to vacate on taxiway D or C. The aircraft was then vectored to the south to avoid the weather which was now tracking to the north. The commander made an approach to Runway 27 and an uneventful landing.

Once parked on stand the crew checked the aircraft g-meter, which had recorded a 2.8 g during the first landing.

After the incident the commander commented that the approach had been stable to 50 ft with very little fluctuation in speed. He considered that the aircraft encountered a downdraught in the heavy rain shower and commented that the near zero visibility would have required a go-around regardless of the hard landing.

Recorded information

Both the CVR and FDR captured the full duration of the incident flight.

Cockpit Voice Recorder

The cockpit voice recordings corroborated the pilots' recollection of the incident. The sound of rain against the windshield was faintly audible on the pilot microphones and became slightly more audible as the aircraft approached the runway.

The CVR captured the sound of the aircraft's radio height callouts from 50 ft to 10 ft. The time between these callouts was short and indicated that the vertical speed was not reducing before the heavy landing.

The CVR recorded the sound generated by the heavy landing. The commander's call to go-around was recorded approximately 4 seconds later.

Flight Data Recorder

Figure 1 shows pertinent FDR parameters recorded from 1,000 ft agl until the go-around after the hard landing.

It indicates that EI-HDK was in a stable descent with no significant airspeed or engine torque changes until the aircraft descended through 50 ft agl at point A. FDR parameters recorded a small and gradually increasing pitch-up input on the control column from this point. The flare was initiated at point B, where the aircraft reached 30 ft agl at an airspeed of 109 kt.

The FDR recorded vertical acceleration data eight times per second. It recorded a vertical acceleration of 2.8 g when the aircraft touched down (point C). The recordings indicate that the vertical speed was around –670 fpm and the airspeed reduced to 95 kt at this point. Increasing engine torque and pitch attitude are shown at point D, consistent with the commander's call to go-around recorded on the CVR. Point E, approximately 5 seconds after the hard landing, shows a positive vertical speed as the aircraft climbed away from the runway.

The wind speed and direction are calculated by the Flight Management System (FMS) based on ground speed, estimated ground track, heading and true airspeed. The outputs of these calculations are displayed on the pilots' Navigation Displays and were recorded to EI-HDK's FDR once per second.

The recordings indicate that the aircraft was flying with a crosswind from the right, which changed direction between points B and F to give an increasing tailwind component. After point F, the recordings indicate that the wind returned to a crosswind from the aircraft's right. There was no significant change in the aircraft's heading during this time.

Wind speed and direction changes are reflected in FMS calculations following changes to the parameters used to calculate it. The FMS uses an algorithm which smooths the input measurements over a time lag, to avoid large instantaneous changes being displayed to the pilots. This means that the wind changes displayed to the crew, and recorded to the FDR, may lag real-time winds conditions experienced by the aircraft.

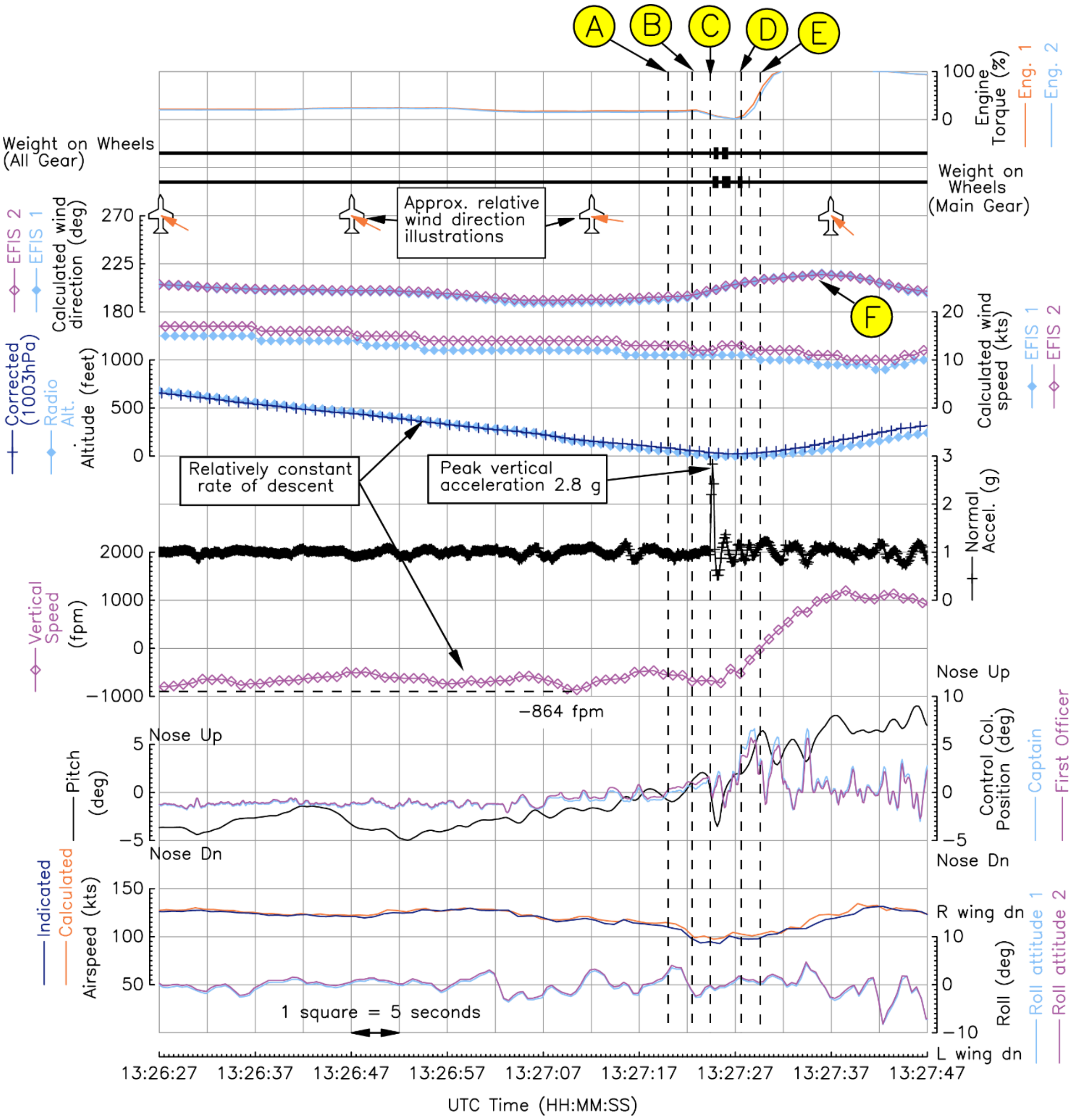

Figure 1

Pertinent parameters recorded by the FDR.

Aircraft examination

There was no obvious damage to the aircraft, but following analysis of the flight data the manufacturer advised the operator to change both main landing gear assemblies. The assemblies were sent to the manufacturer for further mechanical analysis and overhaul.

The aircraft returned to service on 30 August 2023.

Meteorology

Forecast conditions

The TAF issued for Liverpool at 1059 hrs stated that temporarily between 1200 hrs and 1700 hrs the visibility would be 7,000 m in rain showers and rain, and the cloud would be broken at 800 ft. It gave a 30% probability of temporary visibility of 3,000 m in heavy rain showers between 1200 hrs and 1600 hrs, and from 1400 hrs until 1700 hrs a 30% probability that temporarily the wind would be from 290° at 15 kt gusting to 25 kt with cloud broken at 400 ft.

This was updated at 1337 hrs to contain temporary visibility of 3,000 m in heavy rain showers and hail between 1300 hrs and 1700 hrs. A further update was issued at 1349 hrs which included a 40% chance that temporarily the wind would be from 290° at 15 kt gusting to 25 kt, visibility would be 2,000 m in heavy thunderstorms and hail, with cloud broken at 300 ft.

Actual weather conditions

The METAR issued just prior to the incident at 1320 hrs gave a surface wind from 160° at 10 kt, visibility greater than 10 km, showers in the vicinity, few clouds at 900 ft, scattered cloud at 1,700 ft, broken cloud at 2,600 ft, temperature 19°C, dew point 18°C and a QNH of 1003 hPa.

The METAR issued just after the incident at 1350 hrs gave a surface wind from 200° at 9 kt, visibility greater than 7 km but 2 km to the south-east, light rain, few clouds at 100 ft, scattered cloud at 1,500 ft, broken cloud at 3,300 ft, temperature 17°C, dew point 17°C, QNH 1003 hPa and recent rain.

Flight crew

The commander had a total of 3,160 flying hours of which 2,927 was on the ATR 42/72. He had 1,135 hours in command.

The co-pilot had a total of 1,290 flying hours. He had 172 hours on the ATR 42/72 having recently started his first airline flying job.

Analysis

As the aircraft crossed the runway threshold it entered heavy rain, and visibility reduced to near zero. The airspeed decayed at this point, with no corresponding increase in engine thrust. As the co-pilot increased pitch in the flare the vertical speed did not reduce before the main landing gear touched down on the runway. This resulted in a hard landing at a vertical speed of about –670 fpm. The commander took control and executed a missed approach.

The pilots recalled the visibility rapidly deteriorating as the aircraft crossed the threshold. It is likely the reduced visibility made it difficult to detect visually that the rate of descent was not reducing. A probability of heavy rain was included in the forecast but the view from the flight deck, the reports from the tower controller, and the indications on the flight deck did not give advance warning of the severity of the weather that the aircraft encountered. After the incident, the forecast was updated to include a probability of thunderstorms, hail and lower visibility.

The recorded windspeed and direction suggests that the tailwind component increased at the time of the hard landing. The gradual variation around point F in Figure 1 is typical of instantaneous wind direction changes, appearing as a "smooth curve" in the recording due to the wind calculation algorithm. The start of the change coincides with a reduction in airspeed after point A in Figure 1, suggesting that the airspeed reduction as EI-HDK crossed the runway threshold may have been due to an increased tailwind.

The FDR recorded the vertical acceleration reaching 2.8g when the hard landing occurred. There is no evidence that the maximum vertical acceleration significantly exceeded the recorded value, though the investigation did not rule out that the peak vertical acceleration may have been reached between the times its measurement was sampled by the recording system.

Conclusion

It is likely the aircraft encountered an increase in tailwind in heavy rain as it crossed the runway threshold, which resulted in a hard landing. The commander executed a go-around and made a second landing attempt which was uneventful.

Inspection of the aircraft identified no physical defects but following a review of the vertical acceleration experienced during the landing, the main landing gear assemblies were replaced. The aircraft returned to service on 30 August 2023.

Serious Incident

Aircraft Type and Registration:	BN2T Islander, G-BSWR
No & Type of Engines:	2 Allison 250-B17C turboprop engines
Year of Manufacture:	1991 (Serial no: 2245)
Date & Time (UTC):	16 August 2023 at 0955 hrs
Location:	Private airstrip, Tandragee, County Armagh
Type of Flight:	Emergency Services Operations
Persons on Board:	Crew – 1 Passengers – 2
Injuries:	Crew – None Passengers – None
Nature of Damage:	Rudder trim tab disconnected, minor damage to rudder skin and trim tab attachment structure.
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	7,992 hours (of which 3,618 were on type) Last 90 days – 55 hours Last 28 days – 13 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft made an uneventful landing after the rudder trim tab separated from its control rod. The missing bolt was not recovered so the investigation could not ascertain a definitive cause.

History of the flight

The pilot was flying VFR at approximately 1,500 ft when the aircraft and rudder pedals started shaking violently. He said he had been airborne approximately 1.5 hours and whilst yaw control was difficult, the aircraft was still controllable. The shaking continued irrespective of the force he applied to the rudder pedals, and it became worse when the speed was reduced. A rear-seat observer looked out of his 'bubble' window and estimated that the top of the vertical stabiliser was moving side-to-side approximately 30 to 40 cm.

The pilot was unsure about the aircraft's structural integrity, so he declared an emergency and diverted to a known private airstrip about 5 nm away. The landing was uneventful, but the aircraft was described to be 'severely shaking'.

Aircraft examination

Visual examination found that the rudder trim tab was not connected to its control rod (Figure 1). The two items are normally connected using a bolt, nut and split pin, but none of these components were recovered. The bearing in the control rod eye-end was reported to be free to rotate, and it was deemed to be acceptable for further flight.

Figure 1

Photographs taken after the aircraft landed showing the rudder trim tab bolt missing

Minor damage was found on the rudder skin and trim tab attachment structure, and this was assessed by the aircraft manufacturer before the aircraft flew to the operator's maintenance facility at Aldergrove. The aircraft was subsequently repaired in accordance with a manufacturer's bespoke repair scheme.

Other information

The aircraft manufacturer said that they did not believe that loss of the bolt could cause a catastrophic failure. They were not aware of any previous occurrences.

The operator reported that the bolt was last installed in May 2023 when an independent check confirmed that the split pin was fitted.

Analysis

There are two scenarios that could explain the missing bolt:

1. The bolt failed in flight and the broken parts were lost.
2. The split pin was not fitted, failed, or fell out. This allowed the nut to work loose.

The aircraft operator reported that the eye-end bearing was found to be free to rotate so it is unclear where sufficient loads could originate to cause the bolt to fail in flight.

The operator said that the bolt was last disturbed in May 2023, approximately 54 flying hours before the serious incident. They said the bolted joint was subject to an independent visual check to ensure correct assembly and no anomalies were apparent.

Conclusion

The aircraft and rudder pedals started to shake violently. The pilot completed a successful landing and the bolt that normally joins the trim tab to its operating rod was found to be missing. The missing components were not recovered so the investigation could not provide a definitive explanation as to the root cause.

Accident

Aircraft Type and Registration:	Piper PA-28-181, G-CCAV
No & Type of Engines:	1 Lycoming O-360-A4M piston engine
Year of Manufacture:	1980 (Serial no: 28-8090353)
Date & Time (UTC):	3 May 2023 at 1120 hrs
Location:	London Biggin Hill Airport
Type of Flight:	Private
Persons on Board:	Crew – 1 Passengers – 1
Injuries:	Crew – None Passengers – None
Nature of Damage:	Damage to nose landing gear and propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	355 hours (of which 355 were on type) Last 90 days – 38 hours Last 28 days – 16 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquires by the AAIB.

Synopsis

The nose landing gear wheel fork fractured during taxiing causing the nosewheel to detach and the propeller to strike the runway. The cause of the fracture was multiple fatigue cracks from corroded bolt holes in the fork assembly. The CAA has taken safety action to issue a Safety Notice to inspect the fork assembly for corrosion and cracking.

History of the flight

While taxiing, following a normal landing, part of the nose landing gear failed (Figure 1) and the propeller struck the runway surface, stopping the engine.

Aircraft information

G-CCAV is a PA-28-181 built in 1980 and until 2003 was operated as a training aircraft. In 2003 the aircraft suffered a landing accident[1] and incurred significant damage, particularly to the nose landing gear and associated structure. The aircraft was rebuilt but no records of the work were kept.

Footnote

[1] AAIB Report G-CCAV 13 June 2003 [accessed September 2023].

Figure 1

G-CCAV after nose landing gear failure

The nose landing gear of the PA-28 consists of a wheel, fork and strut assembly (Figure 2). The aluminium fork is attached to an attachment block by four $^{5}/_{16}$ inch diameter steel bolts and the strut is retained to the attachment block by a single ¼ inch diameter steel bolt.

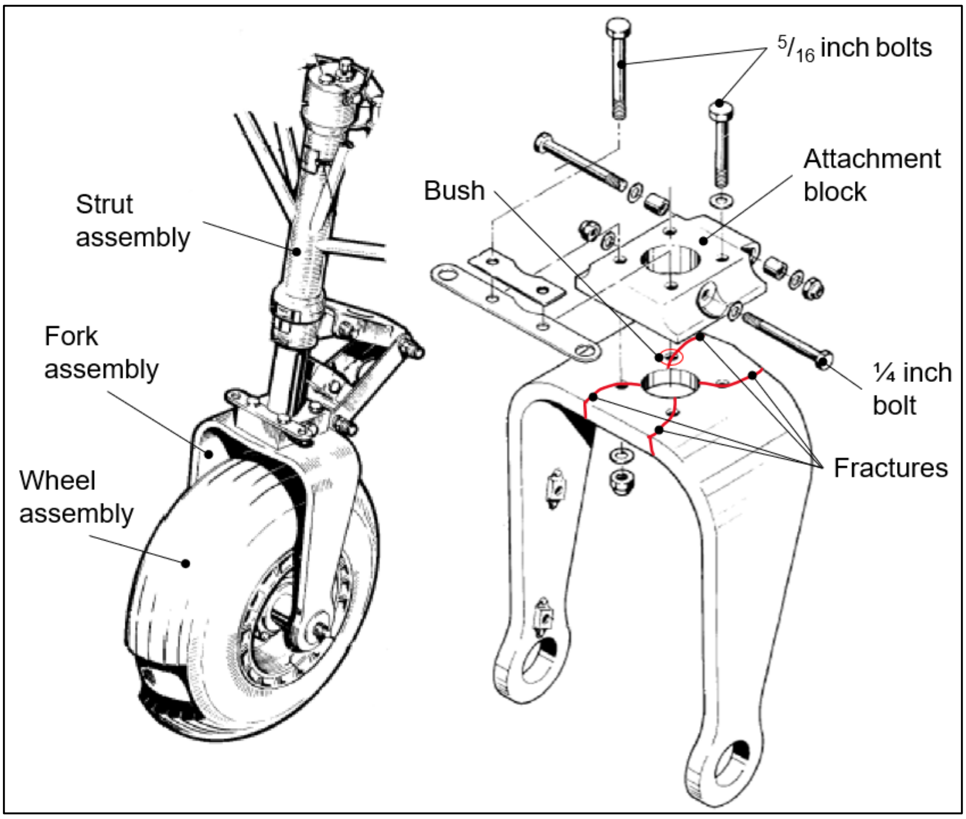

Figure 2

PA-28 Nose landing gear

The aircraft had always been fitted with aerodynamic wheel spats and was predominantly parked on a hard standing, although there was evidence that it had also been parked on grass.

In March 2022 the aircraft underwent its annual inspection and it was recorded on the work sheet: '*Nosewheel Removed Heavy corrosion cleaned and fork re-protected. Nosewheel Hub corrosion rectified and repainted*'. The fork assembly was not removed from the strut assembly to perform these tasks.

Landing gear examination

The fork and strut assembly were inspected and it was determined that the fork assembly had fractured through all four of the attachment block bolt holes (Figure 2). Two pieces of the fork and all the bolts remained attached to the strut assembly and showed evidence of heavy abrasion from the runway surface. There was wear and paint loss on the upper surface of the fork where it was in contact with the attachment block.

The four pieces of the fork were examined using a Scanning Electron Microscope. While most of the surface detail of the fracture faces had been damaged by corrosion, it was possible to observe fatigue striations characteristic of fatigue crack growth. Corrosion pits and additional cracks were observed (Figure 3) in all the bolt holes.

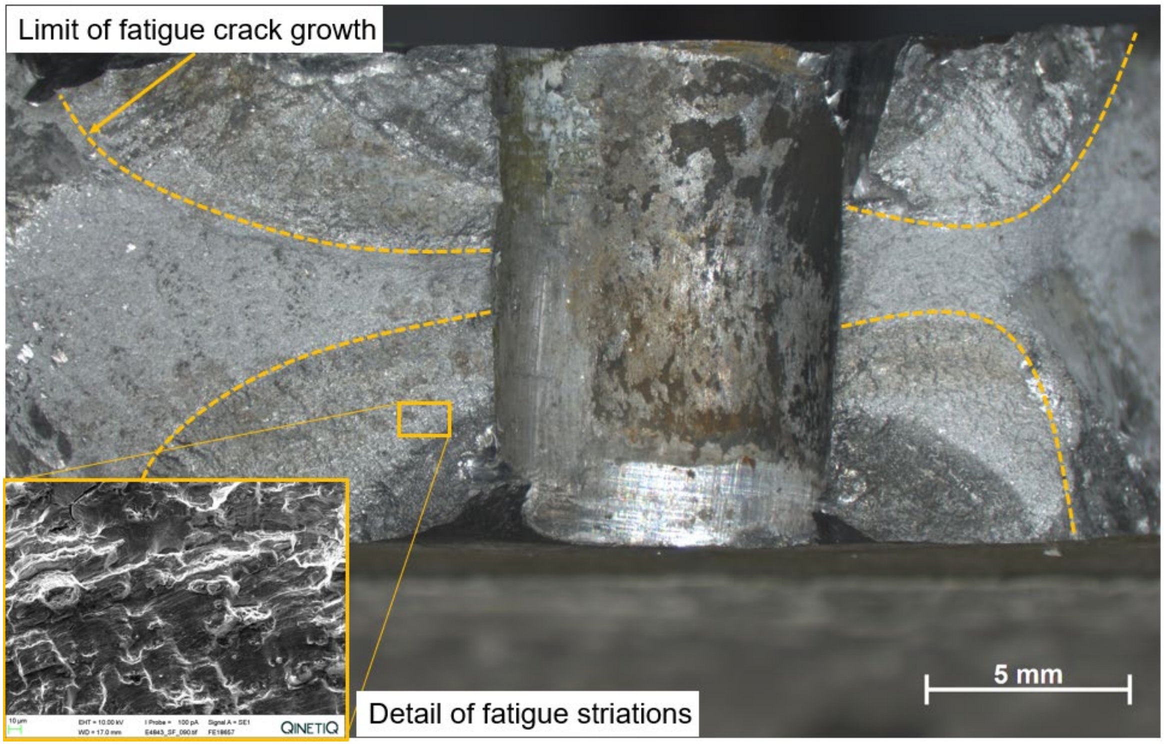

Figure 3

Detail of typical bolt hole showing limits of fatigue crack growth

Right aft bolt hole

In the aft right hole, there was a steel bush which had corroded (Figure 4); there was no visible evidence of a corrosion protective coating on the bush.

Figure 4
Steel bush

The upper part of this hole exhibited a delaminated structure characteristic of exfoliation corrosion, and it is possible that galvanic corrosion between the aluminium fork and the steel bush may have caused the exfoliation corrosion (Figure 5). The investigation could not find any documentation regarding the installation of this bush.

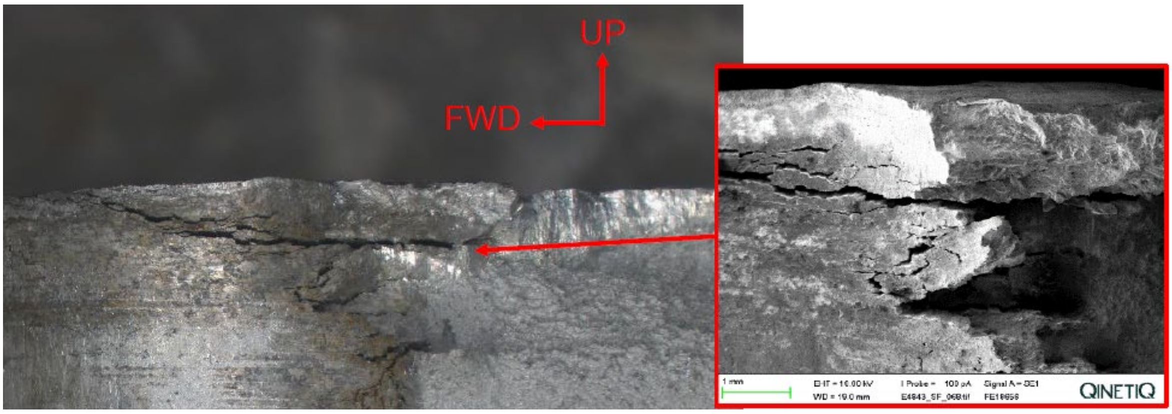

Figure 5
Detail view of right side, aft hole

The hole in the attachment block for the strut assembly was examined and extensive corrosion pitting, cracking around the lower edge and some areas of intergranular corrosive attack were seen.

Airworthiness Bulletin

The Australian Civil Aviation Safety Authority (CASA) published Airworthiness Bulletin 32-019[2] in April 2009 after a series of nose landing failures and recommended operators periodically inspect the interface between the fork and the attachment block. Findings included loose bolts, cracking and corrosion. No similar instructions for continued airworthiness were issued by the FAA, CAA or EASA.

A review of the manufacturer's maintenance manuals for the PA-28-181 aircraft showed that the only corrosion inspection published for the landing gear assembly was a 200-hour interval Special Inspection for aircraft operating in high humidity or salty environments.

Analysis

The failure of the nose landing gear of G-CCAV was caused by fatigue cracks propagating simultaneously from the four attachment bolt holes in the aluminium wheel fork. It was not possible to identify the initiation points for the fatigue cracks due to the level of corrosion on the fracture faces, but there was sufficient evidence to suggest that they would all have started from corrosion damage. The justification for a steel bush could not be determined but it was suspected that it was fitted in 2009 following the heavy landing accident. The lack of protective coating on the bush is likely to have caused galvanic corrosion between the dissimilar metals and exfoliation corrosion of the fork. It was deemed unlikely that this bush would have been a factor in the initiation of fatigue cracks in the other holes.

During maintenance in March 2022 the fork was retreated and corrosion removed from the nosewheel but no disassembly or inspection of the interface with the fork and the attachment block was undertaken. There was a lack of paint and wear was present between the fork and the attachment block, so it is possible that the four attachment bolts were under-torqued. The insufficient clamping might have resulted in relative movement between the two and resulted in rubbing and wear, further reducing the preload. It is known that under-torqued bolts can be the cause of fatigue initiation at the edges of fastener holes.

The aircraft was always fitted with aerodynamic wheel spats which may have contributed to the level of corrosion. Moisture may have become trapped, especially during times when the aircraft was parked on grass and the enclosed space of the spat would have delayed it drying, increasing the risk of corrosion.

A search of the maintenance instructions from the manufacturer revealed that the only specific corrosion inspection of the landing gear is every 200 hours for aircraft operating in salty or high humidity environments. To bring this issue to the attention of operators and maintenance organisations in the UK, the CAA has taken the following Safety Action that will require disassembly of the fork assembly:

Footnote

[2] CASA Airworthiness Bulletin 32-019 [accessed September 2023].

The CAA intend to issue a Safety Notice to advise operators and maintenance organisations on the inspection of the fork assembly at the interface between the fork and attachment block as part of their routine maintenance programme. The visual inspection is to find corrosion or cracking in the fork and report any findings to the CAA.

Conclusion

The nose landing gear fork of G-CCAV failed because of fatigue cracks from the four attachment bolt holes which had initiated from corrosion damage. There are no mandated corrosion inspections of the landing gear other than if the aircraft is operated in salty or high humidity environments.

Serious Incident

Aircraft Type and Registration:	Piper PA-34-220T, G-ZZOT
No & Type of Engines:	2 Teledyne Continental TSIO-360-RB1B piston engines
Year of Manufacture:	1998 (Serial no: 3449108)
Date & Time (UTC):	15 August 2023 at 1045 hrs
Location:	Liverpool Airport
Type of Flight:	Training
Persons on Board:	Crew – 2 Passengers – None
Injuries:	Crew – None Passengers – N/A
Nature of Damage:	Impact damage to both propellers and shock loading to both engines and propeller drivetrains. Minor damage to under surface of fuselage.
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	2,695 hours (of which 842 were on type) Last 90 days – 62 hours Last 28 days – 25 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft's propellers struck the runway during a go-around from a simulated one engine inoperative (OEI) approach at Liverpool Airport that was inadvertently flown with the landing gear up.

While the aircraft was fitted with an unsafe landing gear position warning system, the instructor had disabled it by pulling its circuit breaker (CB) due to nuisance warnings after a previous approach and go-around. His intention was to re-enable the warning system when downwind to land but cited distraction as a contributory factor for him omitting to reset the CB and not positively confirming the gear was down for the landing.

The operator intended issuing formal guidance to its pilots that CBs should only be pulled if specifically required when following an approved abnormal procedure checklist.

History of the flight

The serious incident occurred on a training flight being undertaken as part of a multi-engine instrument rating course. After successfully completing a simulated OEI ILS approach and go-around to Runway 27 at Liverpool the aircraft was turned downwind to join the visual circuit for a simulated OEI landing. The instructor reported that, during the go-around, the aircraft's unsafe landing gear warning alarm was sounding "well above" the normal engine manifold pressure (MAP) alert level. The alarm sound was significantly interfering with communication between him and his student, so he elected to pull the "landing [CB] to silence the alarm." He initially left his finger on the CB as a reminder to reset it when downwind to land.

On the downwind leg the pilots were asked by ATC to orbit before turning finals due to an ahead aircraft on the ILS for Runway 27. As a result of the orbit, when it intercepted the centreline, G-ZZOT was further from the runway than would be normal for a visual circuit and it was decided to delay lowering the landing gear until assured of reaching the runway. The student's workload was high during the approach, thereby increasing the monitoring workload for the instructor. As a result, neither pilot completed their prescribed pre-landing checks, the landing gear remained up and the associated warning system remained inhibited due to the pulled CB.

When in the pre-touchdown flare the instructor "became aware of abnormal [propeller] contact with the runway" and "reacted instinctively" by selecting full power and attempting a go-around, which was successful. When the landing gear was selected down during the subsequent visual circuit it travelled normally and after "three greens" had been confirmed, the aircraft was landed safely from a normal approach.

Aircraft information

As described in the Pilot's Operating Handbook, the PA34's throttle levers are mounted in a control quadrant on the lower centre of the instrument panel. They are used to control the engines' MAP. On some PA34 aircraft, including G-ZZOT, the throttle quadrant also houses microswitches linked to a '*gear up warning'* system. The microswitches are designed to be activated by either or both throttle levers during the *'lower portion of throttle lever travel, (approximately 14 in Hg* [inches of mercury] *MAP and below).*' When the microswitches are activated the warning horn will sound if the landing gear is not down and locked. The PA34 Maintenance Manual gives a '*normal'* microswitch activation MAP tolerance range of 14 ± 2 in Hg.

The operator reported that G-ZZOT had undergone maintenance action approximately eight months prior to this incident due to a fault with the MAP trigger level, but that the warning system had been operating at the expected power settings thereafter. The instructor on the incident flight reported the warning horn sounding when power was reduced to approximately 16 in Hg.

Organisational information

While not explicitly stated in their operations manual, the operator reported its expectation was that pilots would only pull CBs when specifically required as part of an approved abnormal procedure checklist.

Analysis

The aircraft's landing gear warning system appeared to have been operating normally during the go-around from the ILS approach, albeit triggering at the top end of its tolerance range. To the instructor this was at a higher MAP setting than he expected and it made effective communication with the student pilot challenging. He pulled the CB because he considered the risk from communication difficulties outweighed the immediate risk from silencing the alert. He initially kept his finger on the CB as a tactile reminder, but at some stage unconsciously removed it. He considered that the distraction caused by the orbit and change from normal sequencing for lowering the landing gear "most likely diverted [him] from resetting the CB." He further considered that workload and distraction were factors in the student not completing the pre-landing checklists and procedures and him not detecting that the action had been missed.

The company operations manual (OM) did not contain a policy for the pulling of CBs outwith published abnormal procedure checklists. Following this incident, the operator declared an intention to amend the OM to include guidance on the issue.

Conclusion

The aircraft's propellers struck the runway after an inadvertent landing gear-up approach.

While the aircraft was fitted with an unsafe landing gear warning system, the instructor had disabled it by pulling its CB during a go-around because the warning horn was causing intra-cockpit communication difficulties. His intention was to re-enable the warning system when downwind to land, but he cited distraction as a contributory cause for him omitting to reset the CB and not positively confirming the gear was down for the landing. Had the warning system not been inhibited, it would have been more likely that the unintentional gear-up approach would have been detected and prevented by one or both of the pilots.

The operator intended issuing formal guidance to its pilots that CBs should only be pulled if specifically required when following an approved abnormal procedure checklist.

Accident

Aircraft Type and Registration:	Pegasus Quik, G-CDCF	
No & Type of Engines:	1 Rotax 912-UL piston engine	
Year of Manufacture:	2004 (Serial no: 8076)	
Date & Time (UTC):	30 September 2023 at 0703 hrs	
Location:	Northrepps Airfield, Norfolk	
Type of Flight:	Training	
Persons on Board:	Crew – 2	Passengers – None
Injuries:	Crew – 1 (Serious) 1 (None)	Passengers – N/A
Nature of Damage:	Substantial damage to the airframe and engine shock loaded.	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	65 years	
Commander's Flying Experience:	2,083 hours (of which 1,840 were on type) Last 90 days – 22 hours Last 28 days – 5 hours	
Information Source:	Aircraft Accident Report Forms submitted by the pilot and student	

Synopsis

During the takeoff roll on a training flight, G-CDCF departed the runway's edge and overturned, despite steering corrections made by both the student and instructor. The instructor believes that the student had inadvertently applied the brake pedal whilst countering the pressure he was applying on the foot throttle, whereas the student believed that his feet were clear of the brake pedal. The absence of further information precluded the reconciliation of these differences and the identification of the cause of the runway excursion.

History of the flight

The student pilot, who was undertaking his 6th hour of training, and his instructor completed separate pre-flight checks of the aircraft and taxied to Runway 15 for departure. The weather was CAVOK, with little wind, although the grass runway was wet. The student checked G-CDCF's brakes and applied takeoff power, using the throttle operated with his right foot. At approximately 45 mph the trike, which had initially tracked straight along the runway, began to turn to the right. Using his foot-operated steering bar, the student attempted to correct this deviation, as the instructor in the rear seat remarked "what are you doing?" and applied a correction on his own, linked steering bar. The rear seating position does not have throttle or brake controls. Despite steering corrections being applied by both occupants, they appeared to have no effect. Shortly afterwards, G-CDCF reached the runway's edge and the instructor recalls seeing both main wheels skidding on the wet grass as the student released the foot throttle. G-CDCF then skidded into longer grass, the left undercarriage collapsed, and the aircraft toppled onto its left side and came to rest. After making the aircraft safe, the student was able to vacate the aircraft and render assistance to the instructor who had broken a wrist.

The instructor believes that the student inadvertently applied the brake pedal, situated at the top of the left side of his steering bar, at some point during the takeoff whilst countering the pressure he was applying with his right foot on the throttle. However, the student believes that during the takeoff his foot was clear of the brake pedal. In the absence of any further information, it was not possible to reconcile the differences between these two accounts.

The student noted that, following the advice given in a recent BMAA safety promotion[1], both occupants used their front seat shoulder straps, and he believed that this had prevented more serious injuries.

Footnote

1 https://www.bmaa.org/information-library/belt-up-safety-campaign [accessed December 2023].

Accident

Aircraft Type and Registration:	X'Air Jabiru(1), G-HITM
No & Type of Engines:	1 Jabiru 2200 piston engine
Year of Manufacture:	2000 (Serial no: BMAA/HB/112)
Date & Time (UTC):	13 June 2023 at 1858 hrs
Location:	Private strip, Welshpool
Type of Flight:	Private
Persons on Board:	Crew – 1 Passengers – 1
Injuries:	Crew – Serious Passengers – Serious
Nature of Damage:	Substantial
Commander's Licence:	Private Pilot's Licence
Commander's Age:	68 years
Commander's Flying Experience:	Not provided
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Shortly after takeoff, the engine lost power and the aircraft struck the ground. The cause of the power loss was not determined. The AAIB noted that the aircraft's Permit To Fly was not valid at the time of the accident.

History of the flight

The pilot reported that the accident occurred shortly after takeoff from a private grass airstrip, described as firm and dry. Weather conditions were reported as CAVOK with scattered clouds and a temperature of 20°C. Weather recordings in the area indicated temperatures at that time of approximately 24°C with a dew point of 8°C and a north-easterly wind of about 3 kt gusting 10 kt.

The pilot stated that external and power checks were satisfactory prior to the flight. However, the engine lost power at an estimated height of 50 ft agl after takeoff and the aircraft struck the ground. The attending emergency services advised that the aircraft came to rest on the driveway to a farm. Both the pilot and passenger, who were wearing full harnesses, suffered serious injuries.

The pilot did not provide further information as to a possible cause of the loss of engine power. The AAIB noted that the aircraft's Permit To Fly was not valid at the time of the accident and had expired in May 2022.

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: December 2023 - January 2024

10 Sep 2023 **UAS DJI Mavic 2 Pro** Near Cowes Harbour, Isle of Wight

The remote pilot was operating the 907g UA from a ship anchored approximately 2 km to the nearest land. The UA was about 100 m from the ship when the remote pilot noticed a sailboat was approaching toward it. Believing that the UA was in the path of the sailboat, the remote pilot moved the UA an additional 20 m away from the ship. Video footage from the UA, however, shows the top of the sailboat mast colliding with the UA and the UA tumbling down the main sail onto the deck below.

15 Oct 2023 **UAS DJI Mavic 3** Holyhead, Isle of Anglesey

The UA was at approximately 17 ft agl, circling a building with the video recording, when a red message appeared on the control screen saying ‘preparing for takeoff’. The screen turned white, then black, and the UA fell to the ground. The UA had been flying with a fully charged battery for approximately 50 seconds with no prior warning of a malfunction or loss of link. The cause of the failure is not known.

Miscellaneous

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

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

Bulletin Addition

Aircraft Type and Registration:	MBB-BK 117 C-2, G-MPSB
Date & Time (UTC):	12 March 2021 at 1150 hrs
Location:	North Weald Airfield, Essex
Information Source:	AAIB Field Investigation

AAIB Bulletin No 03/2022, page 34 - 57 refers

On 12 March 2021, G-MPSB, an MBB-BK 117 C-2 helicopter suffered a firm landing during the demonstration of a Category A (Cat A) Clear Heliport takeoff procedure with a simulated engine failure after takeoff decision point. The landing did not meet the manufacturer's definition of a 'hard' landing, but resulted in damage to the aircraft's skid assembly.

The engine failure was simulated by the commander reducing Engine No 1's throttle to IDLE. Shortly afterwards the commander increased the throttle setting, but Engine No 1 did not respond. During attempts to resolve the problem, the throttle setting for Engine No 2 was inadvertently reduced, resulting in insufficient power being available for continued safe flight. The investigation found that Engine No 1 probably did not respond because the rotor rpm droop compensation had been inadvertently trimmed in the wrong direction.

An alternative means of demonstrating the procedure was possible using a manufacturer's one engine inoperative (OEI) training device that employs collars to restrict throttle movement. The manufacturer explicitly required use of the device for Cat A OEI training when at maximum training gross mass (MTGM). It was prohibited for use by the operator due to previous overtorque events when using it.

The investigation report was published in February 2022 and can be accessed at: https://www.gov.uk/aaib-reports/aaib-investigation-to-mbb-bk-117-c-2-g-mpsb.

Safety recommendation

The investigation found that the event might have been avoided by using a different throttle handling technique when simulating the engine failure, and the helicopter manufacturer stated that it intended to take two safety actions:

1. To develop formal guidance to pilots delivering simulated OEI training in the helicopter using the one engine at IDLE technique.
2. Review the appropriateness and scope of the rotorcraft flight manual (RFM) limitation requiring the use of the manufacturer's training device when conducting OEI training at MTGM.

The helicopter manufacturer has not taken the intended safety action. Accordingly, the following two Safety Recommendations are made.

Safety Recommendation 2024-002

It is recommended that Airbus Helicopters Deutschland GmbH develop formal guidance to pilots delivering simulated one engine inoperative training in MBB-BK 117 helicopters using the one engine at IDLE technique.

Safety Recommendation 2024-003

It is recommended that Airbus Helicopters Deutschland GmbH review the appropriateness and scope of the MBB-BK 117 rotorcraft flight manual limitation requiring the use of the manufacturer's training device when conducting one engine inoperative training at maximum training gross mass.

Aircraft Accident Report Correction

Aircraft Type and Registration:	Boeing 777-236, G-YMML
Date & Time (UTC):	28 June 2023 at 1240 hrs
Location:	Beijing Daxing International Airport
Information Source:	Aircraft Accident Report Form submitted by the commander

AAIB Bulletin No 01/2024, page 86 refers

The information in the bulletin header stated incorrectly that there was one crew member on board and no passengers.

This information has been corrected to state that were 13 crew members on board and 239 passengers.

The online version of this report was corrected when published on 8 February 2024.

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

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

Published November 2018.

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

Published March 2020.

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

Published May 2021.

1/2023 Leonardo AW169, G-VSKP
King Power Stadium, Leicester
on 27 October 2018.

Published September 2023.

2/2023 Sikorsky S-92A, G-MCGY
Derriford Hospital, Plymouth, Devon
on 4 March 2022.

Published November 2023.

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

Air Accidents Investigation Branch