Air Accidents Investigation Branch

AAIB Bulletin 7/2023

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(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Field Investigation Reports

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

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

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

ACCIDENT

Aircraft Type and Registration:	Piper PA-32-300, G-KNOW
No & Type of Engines:	1 Lycoming IO-540-K1G5 piston engine
Year of Manufacture:	1978 (Serial no: 32-7840111)
Date & Time (UTC):	11 February 2022 at 1300 hrs
Location:	Steyning Valley, South Downs Way, East Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - 1 (Serious)
Nature of Damage:	Significant damage to fuselage, wings, engine and propeller. Beyond economic repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	698 hours (of which 180 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

While the aircraft had sufficient fuel on board for the flight, the fuel tank being used – which was one of four, separate, manually selected tanks – ran out of useable fuel, causing the engine to stop over a hilly area. Relevant emergency checklists were not carried out. The aircraft struck the ground heavily causing serious injuries to both occupants.

The report considers fuel management guidance. It discusses threat and error management techniques in relation to managing significant aircraft characteristics, raising situation awareness and regularly self-briefing emergency procedures.

In response to this accident, the CAA intends to include fuel management awareness in its current safety promotional activities.

History of the flight

Background information

On the day of the accident the pilot and a passenger set out to fly from Lydd Airport to Lee-on-Solent Airport, and back. The accident occurred during the return flight (Figure 1).

Outbound flight

G-KNOW took off from Lydd at 1005 hrs, routing south-west along the coast. It flew south of the Isle of Wight and around its west coast, landing at Lee-on-Solent at 1106 hrs.

Figure 1

Route flown on the day of the accident

Accident flight

G-KNOW took off from Lee-on-Solent at 1239 hrs and followed the coast eastbound, before routing inland (Figure 1). The passenger, who could not fully recall the accident, reported believing they went inland to see a landmark.

Recorded data indicated that at 1258 hrs the aircraft was heading east approaching Steyning on the northern border of the South Downs National Park, at 2,100 ft amsl and 136 KTAS. The passenger recalled the pilot saying they had "a problem" and the aircraft lost engine power. The pilot turned the aircraft right onto a south-westerly heading. Although he could not recall the accident, he believed this was to face into wind and avoid a built-up area ahead. He transmitted a MAYDAY call to Brighton City Airport[1], which was approximately 4 nm to the south-east.

The passenger, who was not a pilot, heard the pilot talking through his actions though could not recall what he said. He recalled the pilot trying to restart the engine around 2 or 3 times and operating the engine control levers[2], especially the mixture control lever (Figure 7). A number of witnesses reported hearing the engine "revving" and "spluttering", before it stopped.

The aircraft glided towards Steyning Valley then at around 950 ft amsl turned left, descending south along its western ridge line, reaching a minimum height above it of around 160 ft (Figure 3). The aircraft turned left towards the rising ground on the opposite side of the valley, already below its ridge line. The passenger described that turn, "Ahead to the right

Footnote

[1] Commonly referred to as Shoreham Airport.
[2] Engine controls: three levers for throttle, propeller, and mixture control.

were trees and ahead to the left was hilly grass. There were a few bad options, it was trying to decide which was least bad, the trees, or where we ended up on the hill".

The aircraft's TAS reduced throughout the descent to 67 kt, with a corresponding rate of descent of around 650 ft/min. The passenger indicated the ground was possibly steeper than it looked, and the aircraft struck it "hard", seriously injuring both occupants.

A helicopter emergency medical services (HEMS) crew heard the emergency on Brighton City's radio frequency and routed to the accident site. The HEMS crew and some witnesses helped the passenger exit the aircraft and extricated the pilot, who was unconscious. Both occupants were airlifted to hospital.

Weather and landscape information

Aftercast information showed there was little or no cloud near the aircraft route. The wind at 2,000 ft amsl when the engine stopped was approximately 4 kt from 230°, with temperature 1°C. Brighton City's surface wind was reported at 1250 hrs as 6 kt from 180°, with temperature 8°C.

Satellite imagery along the aircraft's flight path indicated that when the engine stopped there were three built-up areas ahead of the aircraft. Fields to the left of the aircraft appeared smaller than those to the right.

Recorded information

GPS navigation unit

The aircraft was equipped with a GPS navigation unit that logged the aircraft's height and position - the ground track of the flight from Lydd to Lee-on-Solent and accident flight is show in Figure 1.

For the flight from Lydd to Lee-on-Solent, the aircraft was airborne for 61 minutes, cruising at a height of about 3,000 ft amsl before descending to 1,500 ft amsl around the Isle of Wight. The aircraft's calculated airspeed[3] for the flight varied around 135 KIAS. The GPS was powered up 14 minutes before takeoff and powered down 3 minutes after landing.

For the accident flight, the aircraft was airborne for 21 minutes, and the GPS was powered up 13 minutes before takeoff. Figure 2 shows that the aircraft's cruise height varied around 2,000 ft amsl and an average calculated airspeed of 130 KIAS.

Footnote

[3] The indicated airspeed (IAS) was calculated from calibrated airspeed (CAS) using the airspeed calibration data in the PA-32-300 pilot's operating handbook. CAS was calculated from the true airspeed (TAS) by subtracting 1 kt per 1,000 ft of altitude. TAS was calculated using the groundspeed (derived from GPS position) and the wind aftercast information.

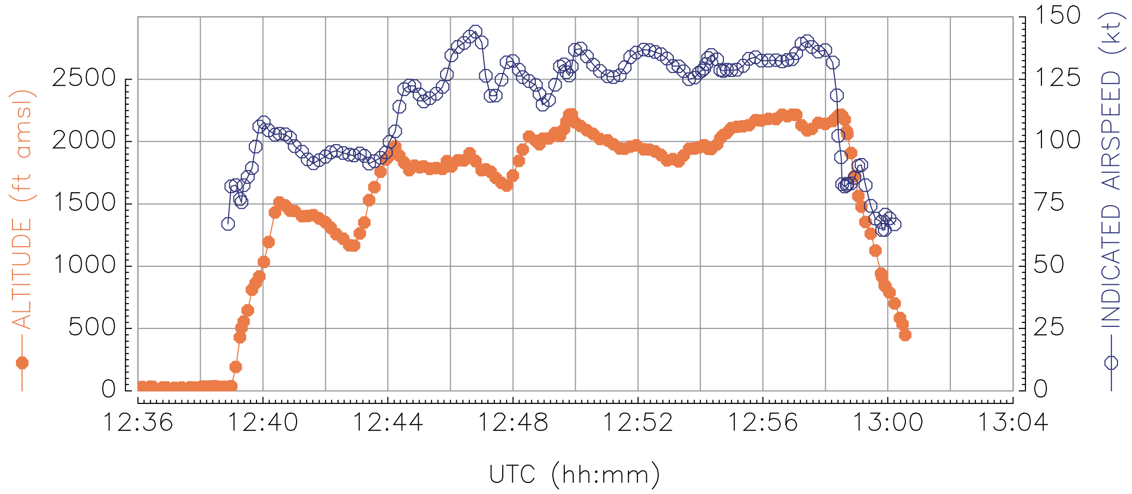

Figure 2

Accident flight GPS altitude and calculated IAS

Figure 3 details the GPS altitude and GPS derived data, and Figure 4 the ground track, for the last three minutes of the flight. The figures start at 1257:30 hrs just before the Mode A squawk[4] changed from 7011 (Southampton listening squawk) to 7000, with the aircraft tracking parallel to the northern border of the South Downs National Park, at approximately 2,100 ft amsl and about 136 KIAS. Points highlighted in the figures are:

UTC (hh:mm:ss)	Description
12:58:00	Altitude remained between 2,100 and 2,200 ft amsl while IAS started to decrease from 137 kt [1].
12:58:22	Start of turn towards southwest [2].
12:58:32	IAS reached about 83 kt and aircraft started to descend [3]. The descent rate peaked at 1,400 ft/min 17 seconds later [4] before reducing to about 850 ft/min.
12:59:04	Aircraft descended through 1,500 ft amsl and IAS increased to 91 kt as the pilot transmitted a MAYDAY call [5].
12:59:47	At about 950 ft amsl the aircraft turned left turn over high ground (240 ft below the aircraft) towards Steyning Valley, and then descended along its western ridgeline at rate of around 600 ft/min and airspeed of about 70 KIAS and slowing [6].
13:00:23	At about 160 ft agl, and near the end of the valley, the aircraft turned left towards the rising ground on the opposite side of the valley [7].

Footnote

[4] From Secondary Surveillance Radar recordings.

The ground-track distance from point [1] to the accident site was about 3.65 nm. From point [3], when the aircraft's speed reduced to 83 KIAS, the distance was 2.54 nm, with a corresponding height loss of about 1,760 ft.

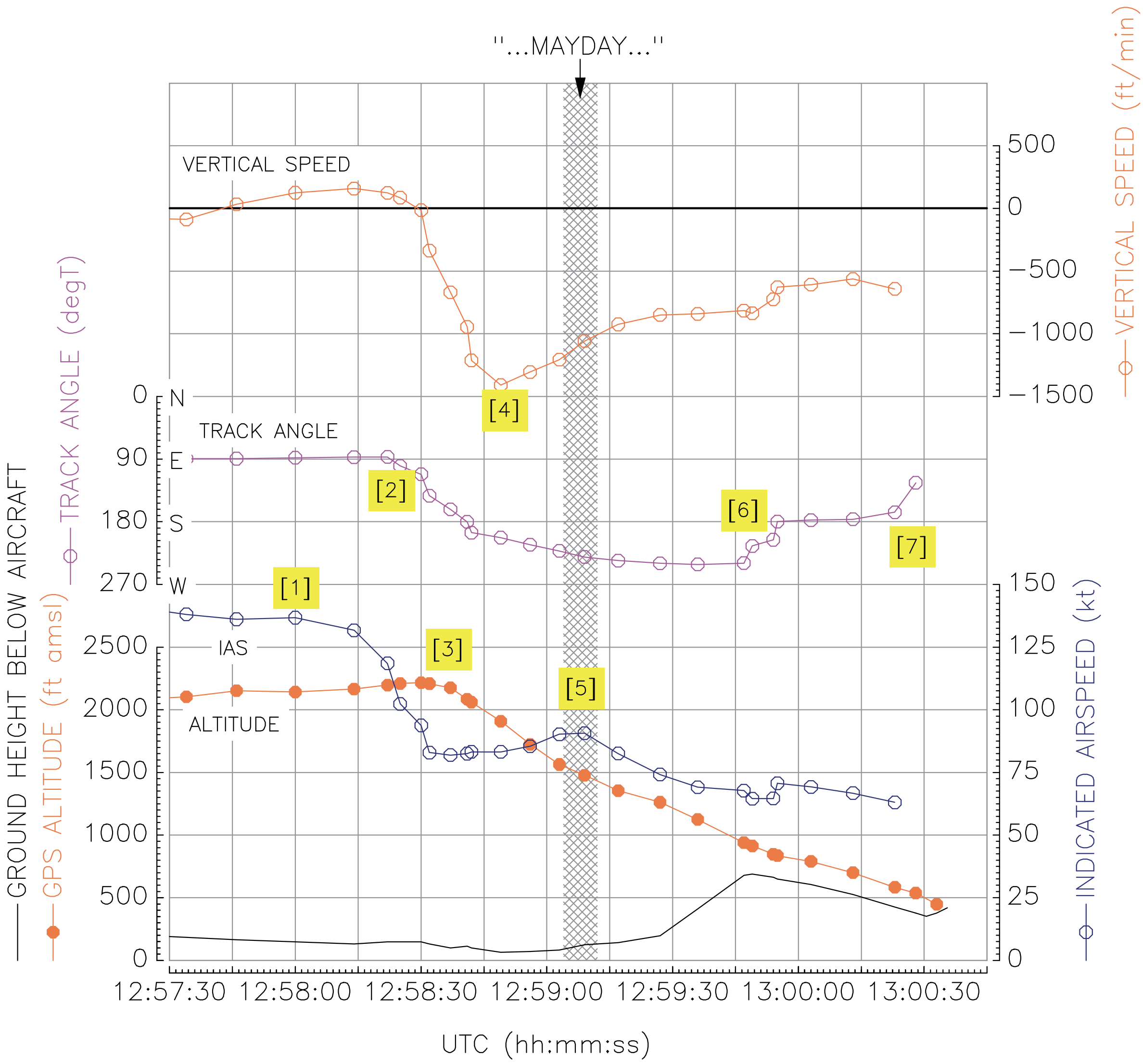

Figure 3

GPS altitude and derived data for last 3 minutes of the accident flight

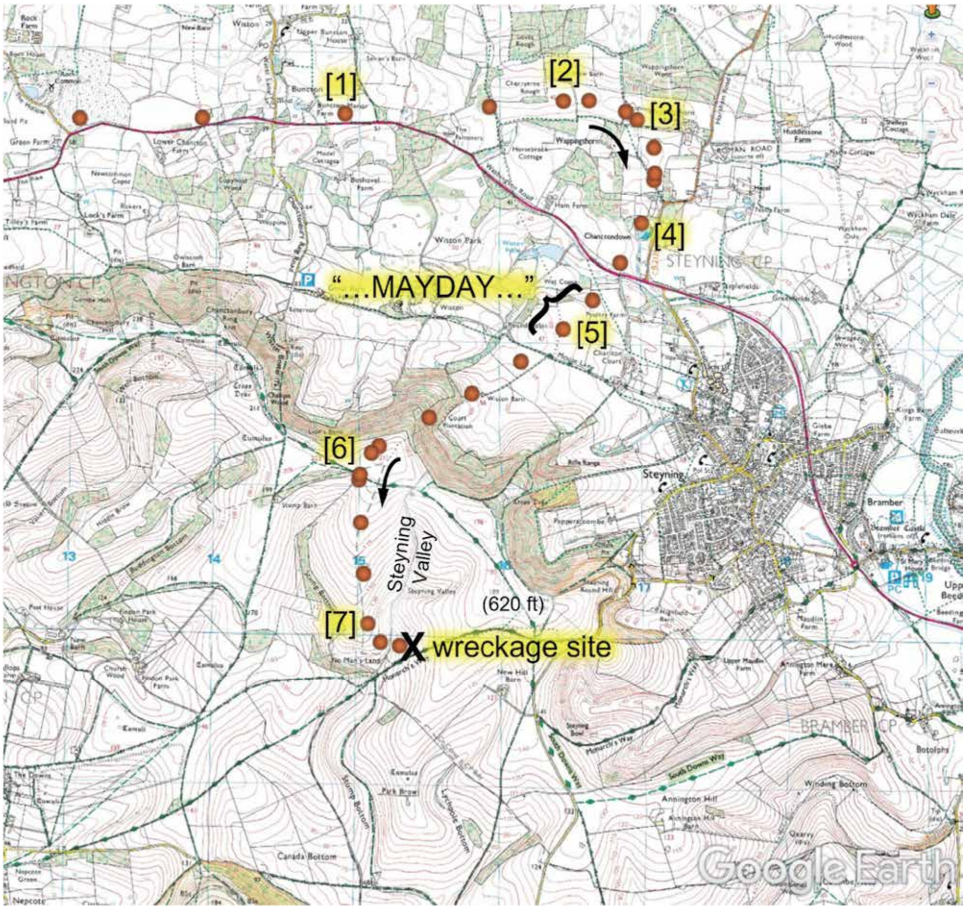

Figure 4

Ground track for last 3 minutes of the accident flight

'Switch fuel tanks' alarm

A switch fuel tanks alarm (fuel alarm) feature of the GPS unit was active and setup to display a 'Switch fuel tanks' message on the unit's screen every 15 minutes (Figure 5). The message could be cancelled by touching it and would be displayed again 15 minutes after it was last displayed (ie if a message was left on for 10 minutes before being cancelled it would display again after another 5 minutes). The GPS unit also allowed an audio alert – a single beep – which would sound at the same time the message was displayed; however, this option had been selected off.

Engine monitoring unit

Installed in the instrument panel was a JP Instruments EDM-730 engine monitoring unit (EMU) capable of displaying and recording engine and fuel parameters such as cylinder head and exhaust gas temperature, turbine inlet temperature and fuel flow. The unit's firmware, which had not been updated since the unit's manufacture in 2013, was such that once the internal memory was full it stopped logging new data. After downloading the memory, it was found that it had stopped logging new data in August 2017, so data for the accident flight had not been recorded. (A subsequent firmware update included a change to the recording function such that it would have overwritten the oldest data with new data.)

Figure 5

GPS unit's 'Switch fuel tanks' alarm message

Additional information about the accident

The pilot

A family member of the pilot reported that in hospital after the accident he said "…running rough… battery dead… engine stopped". Otherwise, the pilot could not remember the day of the accident.

Eye witnesses

The passenger recalled the pilot had inspected the fuel tank quantities, both visually and on the gauges, and checking fuel samples, before both flights. The pilot performed engine ground checks[5] without any apparent abnormalities.

The passenger said the pilot explained some technical aspects to him prior to the outbound flight, including using the fuel selector lever to switch between tanks regularly. He recalled the pilot operating that lever during the flights but could not recall when. He did not remember noticing any fuel alarms which may have occurred.

The passenger described that after the engine stopped, the pilot "was occupied with re-starting the engine, then the MAYDAY call, then the heading we were given, then figuring out if we could make it, and then when we realised we wouldn't, where best to set the aircraft down".

A number of eye witnesses indicated that after the accident there was a strong smell of fuel near the aircraft, and it was trickling from a wing tip.

The HEMS pilot

The HEMS pilot reported that before helping G-KNOW's occupants out he turned the fuel selector "two positions, fully left, to the OFF position". He turned the magneto and starter

Footnote

5 Checking engine functionality at a high power setting prior to takeoff.

switch from BOTH to OFF. Referring to the electrical switch panel[6], he recalled believing the master switch and fuel pump were already OFF, and that he turned the anti-collision light, landing light, and pitot heat OFF.

Accident site

The aircraft force landed on an eastern face of Steyning Valley, on rising ground that varied from approximately 15° gradient, at the first point of impact, to 11°; where the aircraft came to rest. The initial ground impact marks show the left-wing tip hit the ground first. The impact on the left-wing tip was followed by the left main landing gear (MLG) striking the ground causing it to break free and bounce forward and right of the aircraft heading. The aircraft then rolled right resulting in an impact on the right MLG, which struck with such force that it resulted in a downward bend of the right wing at approximately 50% span. The aircraft's lower left front fuselage then struck the ground with sufficient impetus to drive the engine upwards, bend the nose landing gear aft and cause the tail structure to fail and partially separate just aft of the rear cockpit. Damage to the aircraft was consistent with a high sink rate on impact. After the fuselage impact, the aircraft bounced, shedding various pieces of structure including the left tip tank and right MLG. The aircraft came to rest at a fence line, (Figure 6), where the right-wing tip struck a fence post, disrupting the fuel tank.

Figure 6

Ground impact marks, wreckage trail and damaged aircraft

Footnote

6 A set of switches located to the left of the pilot's seat.

Aircraft information

G-KNOW was a PA-32 Cherokee ‘Six’ which is a stretched version of the four seat Piper PA-28 family of single engine monoplanes. Featuring six seats, a fixed tricycle landing gear and all metal construction, the aircraft was powered by a six-cylinder, fuel injected, 300 hp Lycoming IO-540 piston engine. Constructed in 1978, the aircraft had flown 3,297 hours since new. The Airworthiness Review Certificate was due to expire on 28 March 2022.

Aircraft fuel system

G-KNOW’s fuel system layout comprised of two metal main fuel tanks (main tanks), one in each wing, and two resin-impregnated fibreglass wing tip tanks (tip tanks). The fuel tanks were manually selected by moving a fuel selector lever located below the centre console to one of five positions. The lever could be positioned to OFF, left tip tank (LEFT TIP), left main tank (LEFT MAIN), right main tank (RIGHT MAIN) and right tip tank (RIGHT TIP). The lever was connected via a rod to a fuel selector valve located below the floor underneath the two forward passenger seats in the rear cockpit. The valve had five detents, each one corresponding to one of the fuel tank selections. The valve also had a fuel strainer and drain lever to allow fuel to be drained from each of the tanks and connecting pipes depending on tank selection.

Fuel was supplied from the tanks to the fuel injection system via an engine driven fuel pump. There was also a separate electric auxiliary booster pump providing a backup to the engine driven pump and boosting fuel pressure during periods of high fuel demand such as takeoff. The electric pump was operated from a single switch in the cockpit and had independent circuit protection.

The RSA type fuel injector system used a flow divider to proportion a constant stream of metered fuel to injection nozzles at the intake manifold port of each cylinder (Figure 7). The system used a combination of differential air pressure and differential fuel pressure to regulate and meter the fuel flow. The fuel required for the engine was metered via a venturi measuring device. This provided proportional changes to the amount of fuel according to the flow rate of air through the venturi. The fuel was then divided evenly by the flow divider and delivered to the respective intake manifolds. Fuel was sprayed onto the back of the intake valves and the resulting fuel-air mixture pulled into the cylinder when the intake valve opened.

Fuel quantity gauges for each of the four tanks were fitted to the cockpit engine instrument cluster on the lower left side of the instrument panel together with a fuel pressure gauge and a fuel flow indicator (Figure 11).

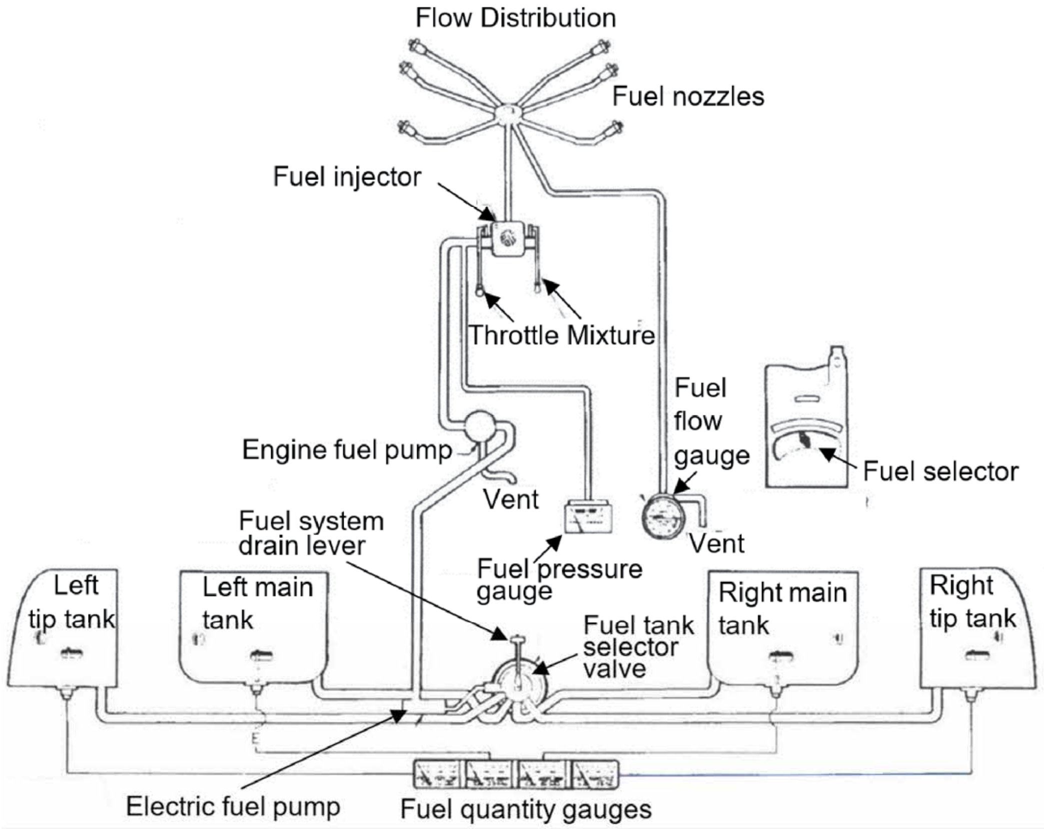

Figure 7

Fuel system diagram for G-KNOW

Information from the aircraft's Pilot Operating Handbook

Fuel system

The aircraft's *'Pilot Operating Handbook'*[7] (POH) specified the total fuel capacity as 84.0 gal US[8], including an unusable amount of 0.1 gal US[9] per tank. Each wing tip tank (tip tank) holds 17 gal US. Each main tank holds 25 gal US, or 18 gal US if fuelled to the *'FILLER NECK INDICATOR'*, also known as 'tabs'.

The *'FUEL SYSTEM'* section explained *'…fuel should be distributed equally between each side. The tip tanks should always be filled first, and fuel from the main tanks should be used first.'*

G-KNOW had *'Fuel quantity gauges for each of the four tanks'* and a *'fuel pressure indicator'* (Figure 9). It had an *'electric fuel pump… for use in case of failure of the engine driven pump'*.

Footnote

[7] *'CHEROKEE SIX 300 INFORMATION MANUAL'*, Handbook part no. 761 632, issued 19 August 1976; therein referred to as the *'Pilot's Operating Handbook'.*

[8] Different fuel capacities were specified for some aircraft with other serial numbers.

[9] Around 400 ml.

Performance

Cruise performance tables gave an approximate fuel flow of 16 to 18 US gallons per hour (GPH)[10,11], when using 75% rated power setting[12]. They indicated the endurance for an aircraft fuelled to tip tanks full and main tanks 'tabs', in conditions similar to the day of the accident, could be 3 hours and 53 minutes to 4 hours and 10 minutes[13,14].

Normal procedures

The *'AIRSPEEDS FOR SAFE OPERATIONS'* section specifies the *'Landing Final Approach Speed (Flaps 40°)'* as 80 KIAS. There was no corresponding airspeed for landing with flaps up.

Emergency procedures

The *'ENGINE POWER LOSS IN FLIGHT'* emergency checklist[15] stated:

ENGINE POWER LOSS IN FLIGHT

Fuel selector . . . . switch to tank containing fuel
Electric fuel pump . . . . .ON
Mixture . . . . RICH
Alternate air . . . . OPEN
Engine gauges . . . . check for indication of cause of power loss
If no fuel pressure is indicated, check tank selector position to be sure it is on a tank containing fuel.

When power is restored:
Alternate air . . . . CLOSED
Electric fuel pump . . . . .OFF
If power is not restored prepare for power off landing.
Trim for 87 KIAS

The corresponding amplified procedure additionally stated:

> *'Complete engine power loss is usually caused by fuel flow interruption and power will be restored shortly after fuel flow is restored. If power loss occurs at a low altitude, the first step is to prepare for an emergency landing…*

Footnote

10 Depending on use of best economy or best power settings.
11 Mixture leaned per Lycoming instructions; maximum gross weight; 2,400 rpm.
12 A power setting table provides manifold pressure values for operating at 55%, 65% or 75% rated power, using 2,100 to 2,400 rpm.
13 Depending on use of best economy or best power settings.
14 Mixture leaned per Lycoming instructions; no planned reserve; endurance includes time to climb and descend.
15 'Emergency checklist' – abbreviated in nature, containing an action sequence for critical situations. Expanded on in the corresponding 'Amplified emergency procedure'.

If time permits, turn the ignition switch to "L" then "R" then back to "BOTH." Move the throttle and mixture control levers to different settings. This may restore the power if the problem is too rich or too lean[16] *a mixture or if there is a partial fuel system restriction. Try other fuel tanks. Water in the fuel could take some time to be used up, and allowing the engine to windmill may restore power. If power loss is due to water, fuel pressure indications will be normal.*

If engine failure was caused by fuel exhaustion power will not be restored after switching fuel tanks until the empty fuel lines are filled. This may require up to ten seconds.

If power is not regained, proceed with the Power Off Landing procedure…'

The *'POWER OFF LANDING'* emergency checklist stated:

POWER OFF LANDING

Locate suitable field.
Establish spiral pattern.
1000 ft. above field at downwind position for normal landing approach.
When field can easily be reached slow to 80 KIAS for shortest landing.

Touchdowns should normally be made at lowest possible airspeed with full flaps.

When committed to landing:

Ignition	OFF
Master switch	OFF
Fuel selector	OFF
Mixture	idle cut-off
Seat belt and harness	tight

The corresponding amplified procedure additionally stated:

'If loss of power occurs at altitude, trim the aircraft for best gliding angle (87 KIAS, Air Cond. off) and look for a suitable field. If measures taken to restore power are not effective, and if time permits, check your charts for airports in the immediate vicinity; it may be possible to land at one if you have sufficient altitude. At best gliding angle, with the engine windmilling, and the propeller control in full "DECREASE rpm," the aircraft will travel approximately 1.5 miles for each thousand feet of altitude…

When you have located a suitable field, establish a spiral pattern around this field. Try to be at 1000 feet above the field at the downwind position, to make a normal landing approach. When the field can easily be reached, slow to

Footnote

16 A pilot uses the mixture control lever fuel to adjust the air to fuel ratio, resulting in the mixture being 'rich' (relatively more fuel) or 'lean' (relatively less fuel).

80 KIAS with flaps down for the shortest landing. Excess altitude may be lost by widening your pattern, using flaps or slipping, or a combination of these.'

Aircraft examination

Examination of the cockpit at the accident site revealed the fuel selector lever was positioned between LEFT TIP (left-wing tip fuel tank), and LEFT MAIN (left main fuel tank), (Figure 8). Force was needed to move the lever to OFF, but it would not stay in position and sprang back between LEFT TIP and LEFT MAIN. From this position, moving the lever two 'clicks' to the right selected the RIGHT MAIN fuel tank and the lever remained in position. The switches on the main switch panel to the left of the cockpit and the ignition switches were set to OFF. The flap lever between the front seats was positioned in the first notch of the selection mechanism, indicating 10° flap was selected[17]. Although the flaps were selected to 10°, the flap control surfaces were in the up position (0° flap). On the engine control quadrant, the throttle lever was set just above IDLE and was bent and jammed in this position. The throttle housing was also deformed and torn. The fuel mixture lever was positioned just below RICH and the propeller lever was pushed fully forward to INCR (increase). To the right of the quadrant, the Alternate Air (Alt. Air) lever was in the CLOSED position.

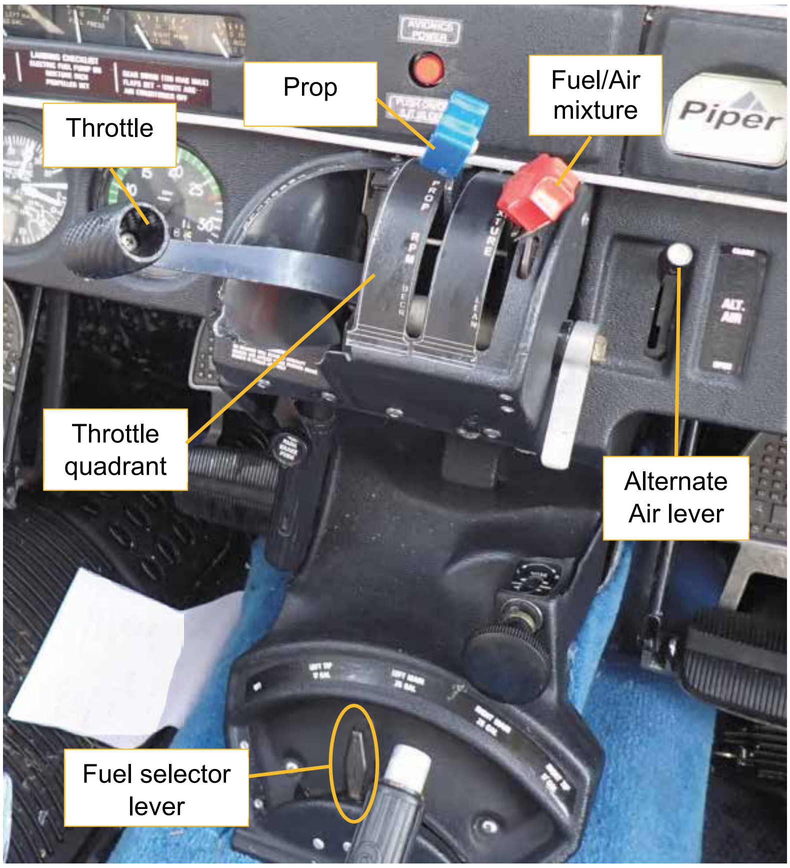

Figure 8

Fuel selector lever position, throttle quadrant and Alt. Air lever

Footnote

17 The flap mechanism has three extended positions - 10°, 25° and 40°.

The front left seat was resting on the cockpit floor because the seat's lower frame assembly had collapsed during the impact. The right seat's frame was deformed, but not to the same extent as the left, and was still fixed in place. Both front seat shoulder straps inertia reels were locked with the straps almost fully extended.

Whilst both wing tip tanks were disrupted and contained no fuel, the main fuel tanks were undamaged. Approximately 8 gal US of fuel was recovered from the left main tank but only about 0.12 of a US gallon[18] was recovered from the right tank.

The damage to the propeller blades was consistent with an engine not under power when the aircraft hit the ground. The underside of the spinner was lightly scored longitudinally rather than radially, also indicating that the propeller had not been turning under power when it scraped along the ground.

Fuel System

Examination of both main fuel tanks did not reveal any signs of damage or leakage from the tanks or the connecting pipework. Examination and operation of the electric fuel pump showed that it was still functioning correctly. The engine driven fuel pump was removed, and bench tested, it also operated without fault. The engine's flow divider spring loaded valve showed no signs of obstructions or debris and the valve slid out of its housing with little resistance. Both the fuel injector servo and flow divider were sent to a certified maintenance facility for bench testing. Other than some minor calibration issues with the servo, both devices were functioning correctly. There were no signs of leakage from any of the fuel pipes between the aircraft's fuel tanks and the engine.

On accessing the fuel selector valve, a light touch of the selector rod connecting the valve to the fuel selector lever resulted in a slight displacement of the rod. The fuel selector lever operated normally afterwards, with all five selectable positions producing positive detents and the lever remaining in position when released. Subsequent examination of the fuel selector valve showed no sign of damage or obstructions and correct operation at each detent location. It is likely that the selector lever connecting rod was displaced during the accident sequence as there were no reports of fuel selection issues prior to the accident. Fuel samples from the remaining main tanks were clear, bright and showed no sign of contamination from water or debris.

Engine

Whist there were some minor faults found during the engine examination, none would have caused the engine to fail in flight or prevent the engine from restarting.

Flight control surfaces

Control surface connections were checked on site and continuity to their respective controls confirmed. The controls responded correctly to inputs from the control yoke.

Footnote

[18] Approximately 473 ml

Battery

Whilst the external surfaces of the aircraft battery showed some superficial damage, there was sufficient charge remaining to power the fuel booster pump at the site. A later recharge attempt was successful with the battery charge increased by 20%, although no further attempts were made due to the potential risk of internal damage. The battery was functioning correctly when examined.

Survivability

Injuries

The passenger sustained serious injuries to his chest, spine and skull. The pilot sustained serious and, in some cases, life changing injuries to his head, neck, spine, chest and hips.

Damage to the front seats

The front left seat's frame lower assembly had deformed and completely collapsed during the accident leaving the upper section of the seat frame resting on the cockpit floor. The lower section of the structure had broken away from the frame assembly and, although still attached to the cockpit floor, was only attached to the seat by the cables for the height adjustment mechanism (Figure 9). The assembly had failed in overload due to the vertical impact force resulting from the aircraft's high sink rate as it struck the ground.

Figure 9

Front left seat showing disrupted frame assembly

By comparison, the right seat's frame assembly although deformed, remained attached to the cockpit floor on three out of the four floor brackets (Figure 10). The seat was still elevated above the floor by the brackets but, due to the deformation of the frame assembly, not to its full extent.

Figure 10

Front right seat showing compressed and partially disrupted frame assembly

Inertia reel, three-point harnesses

Both front seat three-point inertia reel harnesses were locked in place. Once the belts were slackened and pushed back into the reel, they unlocked and rewound slightly back onto their reels. Visual inspection of the shoulder harness webbing connected to their respective release buckles revealed signs of stretching and damage to the stitching commensurate with the effect of the impact forces on the occupants. Post-accident inspection of both shoulder harnesses revealed similar lengths of the belts were extended from their reels to the belt buckle and similar damage to their stitched ends fitted to the belt buckles.

Arrangements for using the aircraft

The aircraft's owner kept G-KNOW at Lydd and allowed a small number of other pilots to fly it, including the accident pilot. The other pilots would inform the owner, then arrange to use the aircraft directly with the airport. Each pilot would refuel it afterwards, to tip tanks full and main tanks tabs.

G-KNOW was last flown prior to the day of the accident on 1 February 2022 by the accident pilot. He performed three touch and go's, and a landing, and refuelled the aircraft according to the normal agreement.

Personnel

The pilot started flying in 1995 and had owned a number of aircraft. That included a PA-32R-301T Saratoga on which he had logged 140 hours. His logbook showed he had regularly flown with passengers, often landing away at other airfields.

The pilot's logbook and G-KNOW's technical log indicated he first flew that aircraft in August 2020. Almost all his logged flights since then were in G-KNOW, totalling around 40 hours. These were mainly single flights out of Lydd of 0.5 to 2.0 hours. Three return trips to other airfields – Goodwood, Lee-on-Solent and Duxford – were recorded, and the pilot said he had flown the accident route before. On the Lee-on-Solent and Goodwood trips, the pilot had logged the outbound flight, but not the return.

The passenger described himself as an aviation enthusiast. He did not hold a pilot's licence.

One of the other pilots who flew G-KNOW worked as a contract pilot and flight instructor – herein he is referred to as 'Pilot B'. He reported having around 60 to 70 hours in G-KNOW and had instructed the aircraft owner and accident pilot in that, and other, aircraft.

Additional aircraft operating information

Information relating to the pilot

The pilot indicated, for trips like the accident one, he would depart with the aircraft fuelled to "tabs"[19], so he could fly there and back with generous reserves. He would select the fullest tank for takeoff[20] and switch tanks in response to the fuel alarm. He said he normally used a 75% rated cruise power setting and would begin leaning the mixture in stages when approaching cruise altitude.

The Saratoga aircraft the pilot previously owned had two interconnected fuel tanks in each wing. The fuel selector had three positions, one corresponding to each inboard wing tank and an OFF position.

Information from other G-KNOW pilots

Pilot B considered the Cherokee Six to consume comparatively more fuel than other aircraft he flew, and the mixture should be leaned effectively. He described the fuel alarm audio alert as "intrusive". He said he used the EMU's fuel information with caution because he could not be sure of its accuracy. Its quantity reading relied on being updated by pilots. Both the aircraft owner and Pilot B reported expecting a fuel flow of around 17 GPH[21] when operating G-KNOW, which could normally be leaned to around 16 GPH. The aircraft owner indicated he would identify where on a route he anticipated switching to tip tanks.

Pilot B commented the aircraft's glide performance was less than other types he flew and could be noticeably improved by setting the propeller control to 'full decrease'[22,23].

Footnote

19 Main fuel tanks filled to tabs and wing tip tanks full.
20 The POH's *'BEFORE TAKEOFF'* checklist included moving the *'Fuel selector'* to the *'proper tank'*.
21 The owner said he would expect 18 GPH fuel flow for cruise altitudes at or below 1,500 ft.
22 The propeller control lever is used to adjust propeller RPM to high ('INCR') to low ('DECR').
23 POH glide performance tables assume the use of 'full decrease'.

Cockpit fuel information

Figure 11

G-KNOW analogue fuel information[24]

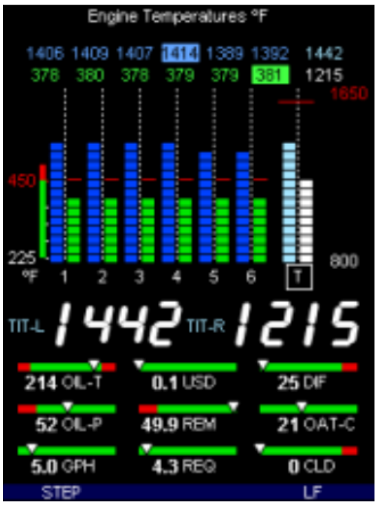

Figure 12

Typical display configuration of the EMU[25]

Fuel planning guidance

The CAA's *'Safety Sense Leaflet 1E Good Airmanship'*[26] contains the following guidance:

'13 <u>FUEL PLANNING</u>

a) Always plan to land by the time the tanks are down to the greater of ¼ tank or 45 minutes' cruise flight, but don't rely solely on gauge(s) which may be unreliable. Remember, head-winds may be stronger than forecast and frequent use of carb heat will reduce range.

b) Understand the operation and limitations of the fuel system, gauges, pumps, mixture control, unusable fuel etc. and remember to lean the mixture if it is permitted.

Footnote

[24] Photograph taken some weeks after the accident.
[25] From the unit's *'Pilot's Guide'*.
[26] SafetySense Leaflet 01 (caa.co.uk) [accessed 16 August 2022].

c) *Don't assume you can achieve the Handbook/Manual fuel consumption. As a rule of thumb, due to service and wear, expect to use 20% more fuel than the 'book' figures.'*

The CAA's *'Skyway Code'*[27] stated *'You must ensure sufficient fuel, oil, coolant or ballast (depending on the type of aircraft) is carried for the intended flight and a safe margin for contingencies…'*. The minimum day time VFR fuel reserve for an aircraft like G-KNOW[28] is 30 minutes.

It advised:

'You should have a good working knowledge of your aircraft's fuel burn at different power settings. Leaning is also an important element of engine and fuel management. You should be familiar with the procedure for your aircraft's engine.

- *Fuel burn and range figures can be found in the AFM*[29]
- *The amount of fuel reserve carried should be proportionate to the nature of the intended flight...*
- *On a longer flight or if fuel reserves may be marginal, you should pay much more attention…*[30]
- *Fuel gauges in most GA aircraft are not sufficiently reliable for the purposes of flight planning or pre-flight checking… However in flight, low fuel gauge readings should never be ignored.'*

The Aircraft Owners and Pilots Association (AOPA) produced a *'Safety spotlight'* article on *'Fuel Management'*[31]. It included the following advice:

'Know the fuel system of the airplane you fly. Some systems are quite simple, while others may be complex and include auxiliary and aftermarket tip tanks with electrical boost and transfer pumps. Pilots have made forced landings with fuel still available because they did not understand the system or operate it properly…

To maintain lateral balance in airplanes that cannot simultaneously feed fuel from both wings, try to keep tanks as equal as possible (within reason)… Many pilots mount a timer in plain view to remind them to switch tanks…

Determine available fuel in hours and minutes instead of gallons and pounds…

Recalculate range and endurance hourly to maintain adequate fuel reserves.'

Footnote

27 CAP1535S Skyway Code Version 3.pdf (caa.co.uk) [accessed 16 August 2022].
28 Part-21 under Part-NCO.
29 Aircraft flight manual.
30 Listed factors relating to fuel burn, cruise altitude and TAS, winds and diversion options.
31 Fuel Management - AOPA [accessed 16 August 2022].

Startle

A SKYbrary article on *'Startle effect'*[32] stated:

'Startle has been found to impair information processing performance on mundane tasks, such as continuous solving of basic arithmetic problems, for 30 to 60 seconds after the event occurrence. The duration of the performance degradation increases as the task becomes more complex. Thus, the startle effect disrupts cognitive processing and can negatively influence an individual's decision making and problem solving abilities.'

CAP 737 stated the following in its section on *'Surprise and startle'*:

'…the fight or flight[33] response is accompanied by an urge to be engaged in the active solution… the brain wants to quickly establish a very basic mental model then drop any assessment process in order to concentrate all attention to the response. But if resources are not given to assessment and problem solving then the person cannot decide the best response… This situation would be best described as a vicious circle… the brain favours sources of information that require the minimum of processing. This means simple 'real-world' cues or conditioned cues and responses.

…reduced fear of situations can happen… for example becoming more confident in one's ability to cope with emergencies, more familiar with an aircraft type or more familiar with unusual situations or upsets.'

Analysis

Engine and fuel system

During aircraft examination there was no evidence of pre-existing faults with the engine and fuel system which would have caused the engine to stop in flight.

Fuel selection

There was no evidence of fuel leakage from the right main fuel tank. As only 0.12 US gallons of fuel was recovered from the right main fuel tank, and it had an unusable fuel volume of 0.1 US gallons, the tank was effectively empty when examined. There was sufficient fuel in the left main tank to continue powered flight and there was anecdotal evidence from the rescue services at the accident site that both tip tanks contained fuel prior to the impact. The most probable cause of the loss of engine power was fuel starvation as a result of continued use of fuel from the right main fuel tank.

Accident dynamics

The ground impact on the front left nose of the aircraft was sufficient to bend the nose and engine upwards and overload the left pilot's seat's support structure. The aircraft's impact

Footnote

[32] Startle Effect | SKYbrary Aviation Safety [accessed 10 February 2023].
[33] Innate, 'alarm' reaction to a threat – often coincides with startle effect.

dynamics show that it had a high sink rate and left-wing low attitude when it struck the ground creating vertical forces on the left seat that were much greater than the right seat. This is why the pilot received more significant injuries than the passenger.

Fuel planning and management

General information

The pilot mainly could not recall the day of the accident. The HEMS pilot's description of moving the fuel selector lever after the accident suggested the right main tank, which was empty of useable fuel, was selected when the engine stopped.

The evidence suggested the pilot followed the normal procedure of using fuel from the main tanks first. Assuming the tip tanks were full when the engine stopped, the resulting main tank quantities and recorded data indicate 28 gal US was consumed, at a rate of 15.1 GPH, during both flights. That rate, being slightly lower than that suggested by other pilots and relevant performance tables, indicated the pilot was leaning the mixture effectively.

Endurance

Consistent with advice to consider fuel in 'time' as well as quantity, relevant performance tables suggested G-KNOW's outbound departure fuel equated to around four hours' endurance, with thirty minutes of that constituting the required daytime minimum reserve. Recorded data indicated the aircraft's engine had been running for 1 hour and 51 minutes across the two flights when it stopped, with more than half its initial departure fuel still on board.

The pilot indicated he tended to fly familiar routes, well within the range of the aircraft fuelled to 'tabs'. The investigation did not establish what, if any, additional pre-flight fuel planning he undertook. Estimating an engine running time of around 2 hours and 30 minutes for both flights, sufficient total fuel was onboard to complete them while preserving a substantial margin over, not just the required reserve, but also the *'45 minutes' cruise flight'* suggested in CAA guidance.

The estimated fuel burn of 15.1 GPH indicated G-KNOW's actual endurance was around 40 minutes higher than the planning figure. Though CAA guidance recommends expecting to use 20% more than POH figures.

In-flight fuel management

The POH and other guidance recommended keeping the fuel as equal as possible between sides. Recorded data and fuel quantities found in G-KNOW's main tanks after the accident indicated there was a fuel imbalance equating to around 32 minutes flying time when the engine stopped, theoretically enough time for two fuel alarms. While the passenger described the pilot inspecting G-KNOW's fuel and operating the fuel selector lever, the investigation did not establish how the pilot managed fuel across the flights and how that imbalance developed.

The pilot said he normally switched fuel tanks in response to the fuel alarm, the audio for which was found after the accident to be OFF. While the screen message would still have presented, the absence of that "intrusive" sound indicates why the otherwise observant passenger did not notice any alarms, and probably reduced the pilot's fuel awareness. The engine stopped around 19 minutes into the return flight. Given the pilot normally took off using the fuller fuel tank, he possibly switched to the emptier one shortly before the engine stopped, in response to the first fuel screen message.

The investigation did not establish whether the pilot updated the EMU fuel quantity, and consequently how accurate it was. That total quantity does not account for separate tanks. Therefore, while cockpit gauges can be imprecise, they pictorially represent individual tank quantities and should be continuously observed, particularly when switching tanks and when fuel becomes low in a tank.

Under the same circumstances, an aircraft with two fuel feeds like the Saratoga could probably have completed both flights, even with the right side selected for the remainder of the return leg. The Cherokee's fuel system – having four, independent, manually selected fuel tanks – may require particular understanding and disciplined management, for example, in relation to fuel burn awareness and balancing. Endurance and reserves could be considered for each tank, as well as overall, perhaps applying the CAA's minimum quarter tank landing fuel guidance. EMU information and GPS fuel alarms are useful back-up tools which can be checked against fuel gauges, and inflight endurance calculations using timers mounted in plain view.

Events after the engine stopped

<u>Track</u>

Recorded data and weather reports were consistent with the pilot's suggestion that he turned the aircraft right to face into wind, and to avoid a built-up area. While there were hills on the right, the fields may have appeared more suitable than those on the left. It is possible the undulation of the terrain was not immediately obvious at the height the aircraft was flying.

The passenger's description of the pilot's actions, and the aircraft's final turn representing a decision between "bad options", indicate – to the extent the terrain would have allowed – a pattern was not established around a chosen field.

<u>Descent and airspeed</u>

Relevant emergency procedures specified trimming for the best gliding angle speed of 87 KIAS and preparing for an emergency landing. G-KNOW's airspeed initially reduced to around 83 KIAS. It fluctuated and continued reducing to a minimum of 67 KIAS, around 30 seconds before it struck the ground. Notwithstanding the effects of the wind, which was light, flying at speeds other than 87 KIAS meant G-KNOW travelled 0.1 nm less than that suggested by the POH. Selecting the propeller lever to FULL DECREASE improves glide performance.

The power off landing procedure specified a landing speed of 80 KIAS, with flaps down. Therefore, G-KNOW's landing speed of 67 KIAS, with flaps up, was substantially slower than what would be the relevant speed. The resulting 650 ft/min descent rate combined with rising ground contributed to the "hard" nature of the touchdown.

Emergency checklists

Notwithstanding any unrecorded cockpit selections which may have occurred immediately after the accident, the positions of the fuel selector lever, electric fuel pump switch, mixture control lever, alternate air control, and ignition switch, indicated the engine power loss in flight and power off landing checklists were not performed. However, consistent with the power off landing procedure, the master switch appeared to have been switched off.

Startle

Relevant emergency procedures recommended first attempting to restore fuel flow – which can take 10 seconds – and or preparing for an emergency landing. The passenger's description of the pilot focussing on a 'real-world' active solution of re-starting the engine, suggested the pilot was experiencing 'fight or flight'. No faults were found supporting the pilot's recollection of a battery problem.

Regularly self-briefing emergency procedures reduces the mental processing required by them, allowing the actions to become *'conditioned'* responses. The act of performing a learned procedure can help a startled pilot rebuild situation awareness.

Threat and error management

Threat and error management (TEM) involves pilots thinking ahead to identify threats and specifying actions to prevent or deal with any resulting errors – thus raising situation awareness and reducing the potential effects of startle. Examples in the context of this accident could include identifying significant characteristics of a new aircraft type; considering the ramifications of four separate fuel tanks; regularly self-briefing engine failure procedures; and managing potential distractions related to carrying passengers and locating landmarks.

A pilot more used to flying the outbound leg of a trip might identify fuel management on the return leg as a 'threat' – when tank quantities may be lower. That might involve determining where, geographically, they expect to switch to tip tanks.

Safety promotion

In response to this accident, the CAA said it intends to include fuel management awareness in its general aviation safety promotional activities before summer 2023.

Conclusion

The aircraft's engine stopped because the fuel tank being used ran out of useable fuel. There was sufficient fuel in the remaining three tanks to complete the flight. Relevant emergency checklists were not carried out and the aircraft struck hilly ground.

Proper fuel management, especially on aircraft with multiple fuel tanks, and regularly self-briefing emergency procedures in a threat and error management context could reduce the risk of, or consequences of, engine stoppage due to fuel starvation.

In response to this accident, the CAA intends to include fuel management awareness in its current safety promotional activities.

Published: 1 June 2023.

ACCIDENT

Aircraft Type and Registration:	Pitts S-1C (Modified), G-BTOO
No & Type of Engines:	1 Superior XP-IO-320-A3AD3 piston engine
Year of Manufacture:	1966
Date & Time (UTC):	27 March 2022 at 1600 hrs
Location:	Popham Airfield, Hampshire
Type of Flight:	Test Flight
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Substantial
Commander's Licence:	FAA Private Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	339 hours (of which 188 were on type) Last 90 days - 1 hour 20 minutes Last 28 days - 1 hour 20 minutes
Information Source:	AAIB Field Investigation

Synopsis

Whilst on a test flight, after an extensive rebuild, the pilot became aware the elevator was no longer connected to the control column. He was able to maintain control, but during the final stages of approach, the aircraft pitched nose down and landed heavily on the forward fuselage; it came to rest inverted. The pilot received a severe laceration to the head and was assisted from the aircraft before being taken to hospital.

The investigation identified that a pivot joint at the end of an elevator pushrod had become disconnected, most probably due to the lack of a split pin to prevent the securing bolt's castle nut from loosening.

Although not directly linked to this accident, discrepancies were found regarding adherence to LAA guidance for recording work. Inconsistencies were identified within LAA Technical Leaflets regarding who can sign for duplicate inspections. It was also noted that the extent to which the 51% rule for amateur built aircraft needs to be applied in relation to overhaul, repair, and restoration of amateur built aircraft was not clear in regulatory material. The Civil Aviation Authority (CAA) has stated it will be taking two Safety Actions, and the Light Aircraft Association (LAA) has stated it will be taking two Safety Actions to address these issues.

History of the flight

The pilot was conducting a test flight as part of the process for regaining G-BTOO's permit to fly following an extensive rebuild. Prior to takeoff, the pilot stated that he had completed extended ground running of the engine and control checks to ensure all were operating normally. This was followed by an extended period for another 20 minutes of fast taxiing to determine the handling characteristics he was likely to encounter on landing. After departure on Runway 03 at Popham, the pilot then conducted a series of flight manoeuvres for about 15 minutes during which no handling issues were highlighted.

The pilot then joined in formation with another Pitts Special about 4 nautical miles from the airfield and began to route back. He stated that G-BTOO was trimmed in straight and level flight at 2,500 ft amsl with 140 mph indicated airspeed; at this point, he felt that he had some play on the stick in the pitch axis. He determined that he was able to move the control column fully forwards and backwards without any effect on the pitch attitude of the aircraft. Concerned that the elevator may have detached completely, he asked the pilot of the other Pitts to undertake a visual check of the elevator, who reported that it all looked normal.

The pilot then declared a MAYDAY on the Popham radio frequency stating that he had lost all elevator authority and was returning to the airfield. He assessed that the trim control had no tangible effect and understood that the effects of the propeller would affect the pitch attitude of the aircraft when turning. He commenced an unbalanced turn to the left and completed 3 - 4 turns which allowed him to set up on the inbound heading for Runway 03. He then made a flat approach ½ nm from the threshold at 140 mph. The pilot assessed that the aircraft would touch down about ¼ of the way down the runway from the threshold. As the aircraft passed over trees in the undershoot of Runway 03, the pilot reported that he felt the aircraft was affected by turbulence which resulted in a steep nose-down attitude of the aircraft. In response the pilot closed the throttle, before the aircraft struck the ground, flipped over, and came to a stop inverted.

The pilot sustained a severe laceration to the head and was taken to hospital.

Accident site

The aircraft came to rest on Runway 03 at Popham. Figure 1 shows some of the ground markings and the aircraft's final resting position. The AAIB did not attend the site initially and airfield staff recovered the aircraft to its hangar, using a trailer.

Aircraft information

The Pitts Special S-1 aircraft is a small single seat biplane of mixed construction and is capable of aerobatics. The fuselage and tail surfaces are constructed from welded steel tube, and the wings from wood; all are covered with fabric.

Figure 1

View along Runway 03 at Popham
Image used with permission

History of the aircraft

G-BTOO was amateur built[1] and was originally constructed in the United States of America in 1966. It was a S-1C version and was imported into the United Kingdom in 1991. The aircraft had been constructed with an additional bellcrank in the elevator control run, located in the rear fuselage. This non-standard arrangement was approved by the Light Aircraft Association (LAA) during the process to issue the aircraft with its initial UK Permit to Fly.

The aircraft was registered to the current owner in 2011 and underwent an extensive rebuild which was completed in 2014.

In 2018, the owner contracted an individual, who had a business maintaining and rebuilding Permit to Fly aircraft, to rebuild and modify the aircraft. The individual had extensive experience in the maintenance of this type of aircraft and was an LAA approved inspector. The commercial business did not hold any CAA approvals and the business owner held no formal aircraft maintenance qualifications, and they were not required to.

The aircraft was dismantled and taken to a workshop for an extensive rebuild and modification. This modification, which was in the process of being approved by the LAA, entailed fitting a different set of wings which incorporated four ailerons, one on each lower wing, and two on the upper wing, instead of the original configuration of just two ailerons, one on each lower wing. The completed wings were acquired by the owner and were

Footnote

1 Amateur built – 'aircraft of which at least 51% is built by an amateur, or a non-profit association of amateurs, for their own purposes and without any commercial objective' CAA CAP659, paragraph 3.1.

inspected as part of the rebuild, there was no information provided on their provenance. Modifications were also required to the fuselage structure to accept the replacement wings.

The work was completed in 2021 and the completed work pack for the rebuild was submitted to the LAA. This included an unconventional, but generally comprehensive, narrative of the work that had been undertaken rather than worksheets detailing the work in stages. More conventional documentation was provided for completion and certification of the welding work and the flying control and airframe duplicate inspections. The individual who undertook the work reportedly took photographs of the work, but none were with the work pack or could be located.

The first part of the duplicate inspections was signed by the individual who had completed the work and then acting in their LAA Inspector role, issued the Permit Maintenance Release (PMR). The second part of the duplicate inspections was signed by another person, who did not have any link to the aircraft. This independent person was a licensed pilot and a member of the LAA and had experience in aircraft inspection and met the requirements stated on the aircraft duplicate inspection record they signed.

All the documentation describing the work had been signed on 6 August 2021.

Sadly, the person who had completed the rebuild work, the permit maintenance release and one part of the duplicate inspections passed away after a sudden and unexpected medical event.

The LAA then briefed another inspector, who was taking over supervision of the project, on the details and progress of the modification approval process.

The LAA issued a Certificate of Clearance on 4 November 2021, and it was valid until 3 February 2022. It was duly signed by the owner/pilot and the LAA inspector who had taken over supervision, as required to confirm the aircraft was ready for flight, on 5 November 2021.

A 30-minute flight was conducted without incident on 11 November 2021 and the date and duration was recorded in the aircraft log books. There are no details of the content of this test flight or the functioning of the aircraft.

The airfield log records that G-BTOO departed on 3 December 2021 and again on 5 January 2022. The duration of these flights was not recorded by the airfield. There are no flights recorded in the aircraft log books for these dates. The owner did not recall the exact details of the departures but suggested they may have been high speed taxi tests using the runway.

During March 2022, the owner applied for a new Certificate of Clearance as the previous one had expired. The LAA re-issued it on 24 March 2022, and it was valid until 23 June 2022. It was duly signed by the owner/pilot and an LAA inspector as required on 26 March 2022 confirming the aircraft was ready for flight.

The aircraft was flown for 20 minutes on the 26 March 2022 before the accident flight on 27 March 2022.

Aircraft examination

The aircraft was initially examined in the hangar to which it had been recovered, where it was stored inverted on a trailer. It was later transported to the AAIB facilities for a more detailed examination.

Elevator control system

There were no access panels close to a bellcrank in the elevator control linkage, but it could be seen through a hole in the lower fuselage fabric, created during the accident (Figure 2). One of the push rods was no longer connected to the bellcrank which resulted in the loss of elevator control.

Figure 2

Showing bellcrank and disconnected pivot joint after recovery to the hangar, view looking towards top of fuselage, cockpit is to the left
Image used with permission

The disconnected bolt for the pushrod to the elevator was found in the bellcrank hole furthest from the pivot point. It could not be confirmed whether this was the hole it was in at the time of the accident, as damage to the paint around both bolt holes indicated a bolt had been fitted in both positions. The bolt showed signs of a nut having been fitted. Neither the nut nor a split pin was found, but the fuselage is open at the rear. The other push rod connected to the bellcrank was connected to the control column. Its bolt and the bell crank mounting bolt were secured with a nut and split pin as was the central pivot bolt.

Photographs taken after the previous rebuild, completed in 2014, show at this time the aircraft had access panels next to the bellcrank and that the bellcrank was fitted in the other orientation. The pivot bolt for the control column pushrod was fitted to the inner hole (Figure 3).

No other anomalies were identified with the control systems.

Figure 3

Bellcrank arrangement after previous rebuild
Image orientated to be similar to Figure 2 to show different orientation
Image used with permission

Survivability

Seat harness

The pilot was restrained by a five-point harness. The harness, its attachments and the seat remained intact. The AAIB were informed the harness was new and it appeared to be so. The narrative work pack indicated the person performing the re-build had cleaned and refitted the original harness. There is no record of the harness being replaced.

Cockpit safety

The material of the fuselage skin that formed the coaming above the instrument panel was manufactured from flat sheet. Design drawings for the aircraft specify the resulting sharp edge, in front of the pilot's head, to be thickened with a tube riveted to the panel and then covered with padding. This is to minimise injury to the pilot should they be thrown forward on to it (Figure 4). This had not been installed on G-BTOO.

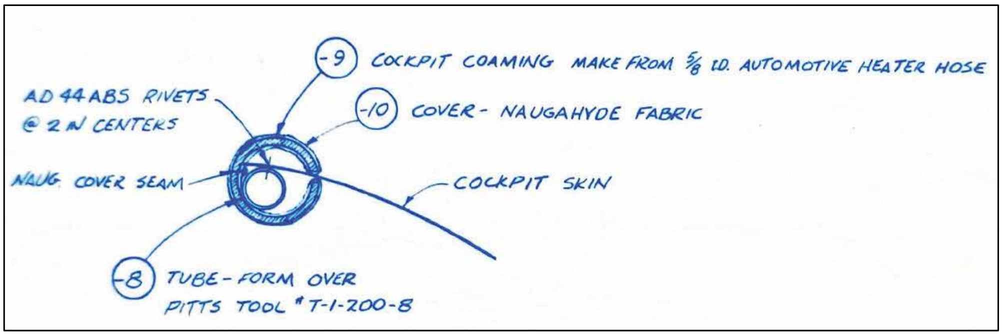

Figure 4

Drawing of padding arrangement for cockpit skin forming instrument panel coaming

Although the pilot was restrained by the seat and harness, the flex in his body and the proximity of the coaming meant his head struck the unprotected edge of the cockpit skin, or coaming, causing a deep cut to his forehead and scalp.

Head protection

The pilot was not wearing any head protection.

Effects of power and the propeller

Pilot's understanding

The pilot stated that he was concerned about the effect of using rudder on a 'floating' elevator and that with:

> *'yaw [from the application of rudder], the gyroscopic effect will come into play which means if I turn right with my rudder the 'P factor of the propeller will put my aircraft in a nose down attitude… I have ailerons, if I turn left just with my ailerons, the P factor of my propeller coming down to the right and up to the left will hold my nose up above the horizon.'*

Effects of power

The secondary effects of power are on the pitch, yaw and roll trim of the aircraft about the axes (Figure 5). Any change in power alters the thrust which, in turn, affects the longitudinal trim of the aircraft about the lateral axis, primarily through the effect of the slipstream on the tailplane – more power – nose up, less power – nose down. Thrust also affects the strength of the slipstream over the fin and rudder changing the yaw trim of the aircraft about the normal axis. Further, as power changes, the torque reaction on the propeller will tend to roll the aircraft in the opposite direction to the rotation of the propeller.

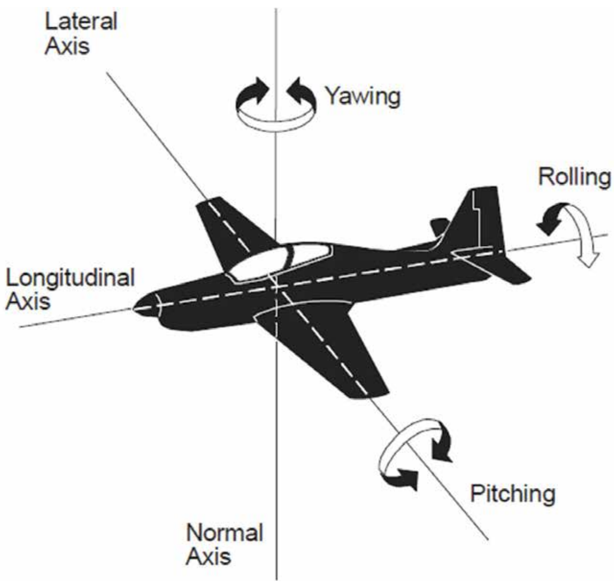

Figure 5

Axes and trim of the aircraft

Gyroscopic effects of the propeller

The effect of precession means that any force which is applied to a rotating object acts at a point 90ºs in the direction of rotation from the point that any force is applied. Thus, for a clockwise rotating propeller, as seen from behind, the application of yaw right will result in a pitch down, while yaw left will result in a pitch up.

Asymmetric blade effect

As an aircraft slows down, the nose of the aircraft is required to pitch up to maintain straight and level flight and the plane of rotation of the propeller becomes less perpendicular to the direction of flight and the airflow. This results in what is known as Asymmetric Blade Effect, also known as the 'P' factor or Asymmetric Loading, owing to the differences in the angle of attack, and hence thrust, between the down-going blade and the up-going blade.

As the nose attitude increases and the plane of rotation of the propeller becomes less perpendicular to the direction of flight, the down-going blade is advancing faster into the airflow than the up-going blade. Consequently, the angle of attack on the down-going blade is greater than the angle of attack on the up-going blade, with the consequent effect on thrust provided by each blade.

This difference in thrust moves the centre of thrust outwards from the centre along the chord of the down-going blade, resulting in asymmetric loading of the propeller, and a consequent yawing moment. For a clockwise rotating propeller, as seen from behind, the resultant yaw from slowing down would be to the left. The effect on yaw trim has no effect on pitch attitude and can be controlled through the rudder pedals.

Meteorology

The pilot reported that the wind was 15 mph from the north. The actual weather at RAF Odiham, approximately 15 miles away, recorded a wind of 8 kt from the northeast.

Popham Airfield

Popham Airfield has two grass strips, Runway 03/21 and Runway 08/26 (Figure 6). There are trees to south of the A303 on the undershoot of the approach to Runway 03; this runway has a marked downslope of 1.3%.

Pilot licencing

Articles 137, 138 and 150 of the UK Air Navigation Order (ANO) 2016 permit a pilot to fly an aircraft with a 'permit to fly' on the privileges of a pilot's licence issued by an ICAO compliant third country.

The pilot held a valid FAA private pilot's licence with a current single engine land airplane rating and a valid FAA third class medical.

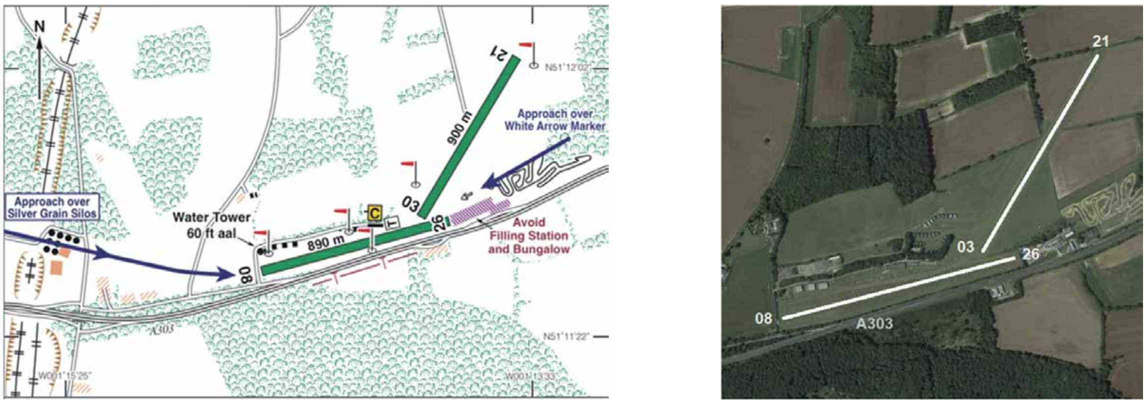

Figure 6

Popham Airfield (Source: Pooleys and Google Earth)

Amateur built aircraft

General legislation

An amateur built aircraft cannot qualify for the issue of a Certificate of Airworthiness as it has not been designed and constructed by an appropriately qualified organisation. Instead, a Permit to Fly may be issued if the requirements of British Civil Airworthiness Requirements (BCAR), Chapter A3-7, '*Permit to Fly Aircraft – Initial and continuing airworthiness*', have been met.

Civil Aviation Publication (CAP) 659, '*Amateur Built Aircraft*', provides guidance to amateur constructors on how to comply with BCAR A3-7 and associated regulations for an amateur built aircraft.

Section 1.8, '*Who This CAP Affects*', states:

> *'1.8.1 This CAP applies to anyone who seeks a Permit to Fly for an amateur built aircraft*
>
> *1.8.2 This CAP is equally applicable to anyone who is restoring an aircraft (which is not eligible for a Certificate of Airworthiness) and seeks a Permit to Fly for it, be it an existing amateur constructed aircraft, or an historic aircraft……'*

When building an aircraft CAP 659 notes:

> *'Anybody is free to construct an amateur built aircraft. But in order for the constructor to maintain amateur status and for the aircraft to subsequently qualify for approval as amateur built, the following criteria will have to be met:'*

These include:

> *'We* [The CAA] *will need to be satisfied that both the building and operation of the aircraft will be solely for the education and recreation of the amateur builder. This means that he would not be permitted to commission someone else to build his aircraft or even, subject to the provisions of the 51% rule, significant parts of it, with the exception of the engine(s), propellers, and helicopter or gyro plane transmissions, rotor heads or rotor blades. Stage inspections made at suitable intervals along with a final inspection of the aircraft and its records will verify these conditions are being met.'*

The LAA and its approved inspectors

The LAA are approved by the CAA, as a BCAR A8-26 organisation[2], to undertake many of the approval activities on the CAA's behalf and they have a network of approved inspectors to undertake inspection activities. The LAA '*Inspector approval scheme document*, *LAA/IAS/17*', explains the scheme along with the responsibilities and limitations of an inspector. Each approved inspector is approved to undertake a certain range of tasks, depending on their skills, knowledge, and experience. These are set out on an LAA Inspector Approval Card individually issued to each approved inspector.

Note 4 of LAA/IAS/17 sets out an approved inspector's limitations for '*Signing Own Work or Aircraft'*.

> *'There is no restriction on LAA inspectors signing off their own work, as long as the work is within the scope of their approval, except for the following. LAA policy is that whilst any suitably approved inspector, even if the owner, may carry out and sign off 'between-permit' work and sign off worksheets and Section 2 of the Permit Renewal application form, only inspectors who do not own or part own the aircraft may sign the Inspector's Declaration (Section 3) of the Permit Renewal application form, unless the inspector is also a licensed engineer. No inspector is permitted to sign off the build stages of any project that they own, or part own.'*

The LAA provide on their website a range of Technical Leaflets (TL's) which explain the various aspects of owning and operating a Permit to fly aircraft.

Owner's responsibilities

Leaflet TL 2.01, '*A guide to LAA aircraft ownership*', provides a summary of the responsibilities of owning and operating an LAA Permit to Fly aircraft. Section 2, '*Maintain your aircraft in an airworthy condition*', includes the following statements.

> *'LAA encourages owners to engage themselves fully with the maintenance of the aircraft, but alternatively this can be carried out on a commercial basis*

Footnote

[2] BCAR A8-26 – Organisations Supporting Recreational Aviation.

> *either using paid individuals or a maintenance organisation. Either way, by their very nature, Permit to Fly aircraft are somewhat unique and less well supported in airworthiness terms than their C of A cousins and need a greater degree of owner engagement, technical appreciation and vigilance to achieve an equivalent safety level.*
>
> *Note that if an inspector carries out maintenance on behalf of an owner, he or she can do so but whether renumerated or not, this is not carried out under a LAA inspector's remit. The inspector's remit only covers the inspection and certification role.'*

Building an LAA aircraft

Leaflet TL 1.02, '*Building your aircraft with the LAA*', describes the process behind building an LAA aircraft and includes details of the build inspection schedule and the inspection stages required. It also draws attention to the 51% rule.

> *'The build inspection schedule specifies each of the main inspection stages required for the project. There may be anything from, say, ten to thirty stages depending on the complexity of the aircraft type concerned but this does not mean that ten stages means ten visits from your inspector.*
>
> *A major hurdle passes with the signing off by the inspector of each main component (fin, tailplane, wing, etc) in the project Inspection Record, indicating that the inspector is entirely satisfied that the part is fit to go on to the next stage. The inspector will want to sign up each stage as it is completed, so keep the build Inspection Record to hand for each visit.*
>
> *Another function of the inspector is to verify that the aircraft has actually been built by the person claiming to have built it. The rule is that at least 51% of the build must be completed by the amateur builder(s). The amateur-building rules do not allow commercial construction on a commissioned basis, or building an aircraft expressly for the purpose of sale on completion. Were this to happen the finished aircraft would not be able to be issued with a Permit to Fly.*
>
> *Should you decide to pay someone else to build parts of the aircraft for you, the inspector will warn you that whilst it is acceptable for some specialist work to be farmed out (eg welding, covering, etc) the majority of the work must be done on an amateur basis by the owner.'*

Rebuilding an LAA aircraft

Leaflet TL 2.21, '*Rebuilding an aircraft under the LAA system*', sets out in the detail the process and procedures to be followed for an aircraft rebuild. This includes the following extracts.

> *'LAA procedures require a rebuild project to be inspected throughout the rebuild process at stages agreed between you and your inspector. As the process reaches completion there will be a particularly intensive period of inspection,*

leading up to the aircraft being ready to be cleared for flight. This applies to all aircraft rebuilt within the LAA system and whilst owners of rebuild projects remain wholly responsible for the quality and conformity of the finished aircraft, these inspections are aimed at helping the owner ensure the aircraft meets accepted standards of build quality, conforms to the approved design and complies with various legal requirements.

Between you and your inspector, you will need to write up worksheets describing the rebuild, to be signed up by your inspector as you go along. A copy of the worksheets are to be submitted on completion of the rebuild. It's a good plan to make a photographic record of the work as it is being undertaken, and submit that along with the worksheets.'

It refers to the obligation in the Air Navigation Order to provide a record of work undertaken and goes on to explain over three pages what should be included and why, and offers a workshop template that can be downloaded.

It gives an example for what would be typically expected for a bi-plane of similar complexity:

'In the case of a major rebuild of a Tiger Moth, for example, it might well be that there'd be a page or two of worksheet devoted to each of the four wings, one for each of the tail surfaces, two for the fuselage and another couple for the rigging and final checks, so that by the time the worksheets have been stapled together along with the logbook certificates relating to such things as engine rebuilds, a 'form 1' for a new propeller, certificates of conformity for flying wires, calibration certificates for the instruments and engine ground run results, it all makes up to quite a substantial 'work pack'.'

Duplicate inspections

Leaflet TL 2.01, '*A guide to LAA aircraft ownership*', contains information about duplicate inspections.

'Duplicate inspections are required whenever engine or flying controls are disturbed. Each part of such inspections should be signed by a suitably approved LAA inspector. Where a second inspector is not available, an owner/pilot who is also a member of the LAA may carry out the second part of the duplicate inspection, and sign out the second part.'

Leaflet TL 2.03, '*Maintaining your own aircraft*', also contains information about duplicate inspections.

'Duplicate inspections are required whenever engine or flying controls are disturbed. Each part of such inspections should be signed by a suitably approved LAA inspector or suitably licensed CAA Engineer. Where there is no possibility of such a person being available, an owner/pilot who is also a member of the LAA may sign the second part of the duplicate inspection.'

Leaflet TL 2.05, '*Pilot authorised maintenance*', defines permitted pilot maintenance tasks including duplicate inspections.

> *'A duplicate inspection is required following reconnection or adjustment of any engine or flying control. For LAA aircraft, a licensed Pilot who is the owner of the aircraft and who is a member of the LAA is an acceptable signatory for one part of a duplicate inspection.'*

The '*Aircraft duplicate inspection record*', form LAA/IC-DUP,

> *'The first part of a duplicate inspection must be certified by an LAA inspector.*
>
> *The second part of the duplicate inspection may be certified by a second inspector or by a licensed pilot who is a current member of the LAA.'*

Analysis

Aircraft Handling

The event resulted in the pilot being faced with a high stress situation in an aircraft with a 'floating elevator' and no means to control the pitch attitude through the control column. At this stage, the aircraft was at 2,500 ft trimmed for straight and level flight at 140 mph. He retained full control in roll and yaw through the ailerons and rudder respectively, and was, therefore, able to maintain and adjust trim in these axes without restriction.

However, the pilot assessed that he had only very limited authority in pitch through the trimmer and could only control the pitch attitude by varying power. Therefore, he sought not to upset the trim of the aircraft but to establish the aircraft on the approach while maintaining the speed at which the aircraft was trimmed.

Landing at such high speed would have provided the pilot a significant challenge to slow the aircraft down after it had touched down. The condition of the 'floating' elevator, with which he was faced, is similar to a pilot having their hands off the control column. In the absence of any comments raised from previous flights with regards to the pitch trim, suggesting that it had been rigged correctly, it is reasonable to believe that the pilot should have had the trim authority to be able to trim the aircraft to a speed lower than 140 mph and significantly closer to normal approach speed. This would have enabled him to fly an approach profile similar to a normal approach.

The pilot's understanding of the effects of the propeller upon the pitch trim of the aircraft do not seem to have been entirely clear, as he associated the 'P' factor, or asymmetric blade effect, with an effect on the aircraft's pitch attitude. Asymmetric blade effect has no influence on pitch attitude.

The pilot elected to fly left turns, recognising that turns to the left would assist him to maintain his pitch attitude owing to the gyroscopic effects of the propeller while enabling him to lose height. As he remained uncertain about the effect of rudder, he elected to fly unbalanced turns. However, the use of rudder to fly balanced turns would have had no influence on the pitch attitude but would have reduced the rate of descent during the turn.

The pilot attributed the sudden nose down attitude that occurred in the very final stages of the approach as a result of turbulence. Any reduction in throttle would have also contributed to a pitch down of the nose. A means to counter a pitch down of the nose would have been to make a short sharp increase in throttle to give a burst of engine power by which to raise the pitch attitude. However, this was likely counter-intuitive owing to the proximity of the ground.

Survivability

Although the pilot was restrained by the seat and harness, he was not wearing any head protection. His unprotected head struck the sharp edge of the coaming, which had not been padded as required, causing a deep cut to his forehead and scalp.

Other accidents involving the forced landing of a high-performance aircraft, such as that involving G-INVN on 4 August 2020[3], have shown the benefit of wearing head protection to minimise injuries.

Although it may not always be practical to wear a full crash helmet, even leather helmets can afford a degree of protection to the head. Other measures, such as padding sharp edges in the cockpit, can also minimise injuries.

Engineering procedures

The aircraft had undergone an extensive rebuild lasting several years, this work was contracted to an individual who was also a LAA approved inspector. The work entailed disassembly of the aircraft, installation of an alternative set of wings and the associated structural changes required for their mounting. The accident flight was one of the first following the rebuild.

The LAA approved inspector submitted an unconventional, but generally comprehensive narrative summary of the work completed. It was not possible to determine when the various elements of the work had been carried out and when they had been inspected as the narrative summary had been signed once on completion of all the work. More conventional documentation was provided for the completion and certification of the welding work and the flying control and airframe duplicate inspections.

Following a fatal accident to Auster AOP.9, G-BXON, on 18 June 2017[4], the LAA undertook safety action to reinforce its existing processes and published guidance in areas relating to the Permit to Fly application process and documentation of aircraft maintenance. In October 2018, the LAA issued revised TL 2.21 *'Rebuilding an aircraft under the LAA system'* which now included additional guidance on the completion of worksheets, the expected level of detail to be recorded, and reiterated the respective responsibilities of owners and inspectors for the quality and conformity of rebuild projects. The TL also suggests taking photographs to support the worksheets. The documentation to support the rebuild of G-BTOO did not meet the guidance provided by TL 2.21.

Footnote

3 AAIB-26839, published in AAIB Bulletin 10/2021.
4 EW/C2017/06/01, published in AAIB Bulletin 3/2019.

Whilst the narrative nature of the documentation provided to support the approval of G-BTOO's rebuild broadly met the requirements of LAA Technical Leaflet TL 2.21, it was not sufficiently detailed or comprehensive to properly record the progress and details of the work completed over the three-year rebuild process. When received, the documentation was assessed as acceptable by the LAA. The LAA have stated they will be taking the following safety action.

> The Light Aircraft Association will be reviewing the guidance provided to LAA members and Inspectors regarding worksheets. TL 2.21 *'Rebuilding an aircraft under the LAA system'* and other documents will be reviewed and will result in a revised TL 2.21. This review will include.
>
> > Reviewing the minimum acceptable standard for worksheets.
> >
> > Expanding the recommendation that a photographic record of the work is kept, to include the recommendation for inspectors to make a photographic record of what they have inspected.
> >
> > Clarification of 'stage inspections' and when they should be made and how they should be recorded.
>
> Once complete the revision of TL 2.21 will be publicised to LAA members and Inspectors.
>
> A new LAA worksheet proforma specifically for larger projects such as rebuilds has been created. The intention that this proforma will guide the restorer towards presenting the worksheet in a format closer to the ideal. This has already been published on the LAA website.
>
> A short item on the importance of full and complete worksheets to properly record work undertaken is included in the 'Engineering matters' column of the December 2021 edition of their Light Aviation magazine.
>
> A briefing for inspectors covering the topic of filling in logbooks and worksheets was conducted on 27 February 2023, with a recording available for inspectors who were unable to attend.

The elevator control system had been signed off as part of the overall PMR by a LAA approved inspector. This was the same person who had completed the work. A duplicate inspection was then completed by two people with both confirming the elevator system was correctly assembled and locked. One was the LAA inspector who had completed the work. The second was not involved in the aircraft in any way but was a licensed pilot and a current member of the LAA. He signed the duplicate inspections as he met the requirements stated on the aircraft duplicate inspection record form used for recording the inspections. *'The first part of a duplicate inspection must be certified by an LAA inspector. The second part of the duplicate inspection may be certified by a second inspector or by a licensed pilot who is a current member of the LAA.'*

There is slightly different wording used in LAA Leaflet TL 2.05, '*Pilot authorised maintenance*', which defines permitted pilot maintenance tasks including duplicate inspections. '*For LAA aircraft, a licensed Pilot who is the owner of the aircraft and who is a member of the LAA is an acceptable signatory for one part of a duplicate inspection.'*

Leaflet TL 2.03, '*Maintaining your Own Aircraft*', contains the wording: '*Duplicate inspections are required whenever engine or flying controls are disturbed. Each part of such inspections should be signed by a suitably approved LAA inspector or suitably licensed CAA Engineer. Where there is no possibility of such a person being available, an owner/pilot who is also a member of the LAA may sign the second part of the duplicate inspection.*

It is not consistent within the TL's as to who can sign duplicate inspections. The Light aircraft Association are taking the following safety action.

> The Light Aircraft Association have amended their Technical Leaflets to ensure the information relating to who can sign a duplicate inspection is consistent.

For this rebuild project, taking several years, it seems unlikely that a suitably approved LAA inspector could not be found to complete the duplicate inspections in addition to the inspector who had completed the work.

The information supplied to the LAA indicates that the duplicate inspections were undertaken all together and after the aircraft was complete. This would have made some inspections more difficult, including the disconnected joint, but nevertheless it could be seen and inspected. Had the inspection been completed prior to fabric covering or had access panels next to the joint been refitted during the rebuild, the inspection would have been easier.

LAA TL 2.21, '*Rebuilding an aircraft under the LAA system*', describes the process for rebuilding an LAA aircraft. It is very much focussed on the owner conducting the rebuild with the support and guidance of an LAA approved inspector.

In this case, the work was contracted to an individual who was an LAA approved inspector. The LAA is clear in TL 2.01, '*A guide to LAA aircraft ownership*', that if an LAA approved inspector carries out maintenance on behalf of an owner, he or she can do so, but whether renumerated or not, this is not carried out under a LAA inspector's remit.

The work was carried out, on a commercial basis, by an individual who is not subject to any qualification or approval requirement, as the procedures allow. It is then up to an LAA approved inspector, who in this case was the same person, to inspect and issue a PMR for the work completed.

LAA TL 1.02, '*Building your aircraft with the LAA*', describes the process for building an aircraft. It is similar to TL 2.21 for rebuilding an aircraft, but for a new build, a pre-determined inspection schedule sets out the main inspection stages of the project and each needs to be signed off as the projects progresses.

With a rebuild project, the reliance is on worksheets to describe and record the work as it is completed and, like a new build, inspections are required as the project progresses.

For a new build aircraft over 51% of the build must be completed by the amateur builder(s). The amateur-building rules also do not allow commercial construction on a commissioned basis, other than for limited specialist tasks.

For the rebuild of G-BTOO, the complete aircraft was disassembled to its individual parts so it could be refurbished and modified to accept a new set of wings with additional ailerons. The parts were either inspected and re-used, overhauled or replaced.

All this work had been contracted-out by the owner, on a commercial basis, to an individual. There was no owner participation in the work. The new wing assemblies were supplied by the owner completely built, with only inspection and covering required. Their provenance is not known and no build records were included in the workpack to show when or where they were constructed, the source of the raw materials or who built them; they were not built by the owner. The inspector assessed them as being satisfactory.

A fundamental question that follows is, what is the difference between a build, a rebuild or restoration and maintenance? The LAA procedures as they stand, align a rebuild with maintenance, mainly in that it can be contracted out, whereas a build cannot, except for certain specialist work. For an amateur build aircraft, the 51% rule needs to be complied with although CAP 659 states its guidance applies equally to anyone who is restoring an amateur built aircraft to seek a Permit to Fly. It could be argued that due to the scope and extent of the work, a rebuild or restoration is more similar to a build than it is to maintenance.

The privileges of an LAA inspector allow them to sign-off their own work, as long as the work is within the scope of their approval with a few exceptions. One of these exceptions is, no inspector is permitted to sign-off the build stages of any project that they own, or part own. This limitation, the restriction on contracting out work, and the 51% rule effectively means that during a build project, an inspector can only sign-off work completed by someone else, apart from limited specialist work.

It is a different situation for a rebuild project. In this case, an LAA inspector was paid to commercially modify and rebuild someone else's project as an individual, and then once the work was complete, they took on the LAA inspector role and issued a PMR for the work.

A rebuild or restoration project, such as this one involving G-BTOO, is arguably like a build project in terms of the scope and complexity of work, and as such it would seem prudent to have the rebuilder's work inspected by an independent inspector as would be the case for a build project in which the inspector had a financial interest.

The CAA became aware of this event through its normal reporting channels. The AAIB have sought its clarification on the relevant regulatory framework relating to this investigation. The CAA has stated that it will be taking the following safety actions.

The Civil Aviation Authority will be reviewing the regulatory framework with respect to British Civil Airworthiness Requirements A8-26, '*Approval of organisations supporting recreational aviation*' and A3-7, '*Permit to Fly Aircraft – Initial and Continuing Airworthiness*', in conjunction with the approved organisations. The review will include an evaluation of the requirements relating to duplicate inspections.

The Civil Aviation Authority will engage separately with the approved organisations on the applicability of the '51% rule' in relation to overhaul, repair, and restoration of amateur built aircraft.

Engineering, the aircraft

One of the pushrods in the elevator control system was found disconnected, its attaching bolt was present, but its securing castellated nut and split pin were not found. The bolt showed signs of having had a nut fitted but it seems most likely that the nut had come undone due to no split pin being fitted to prevent the nut from undoing. Once the nut had loosened and detached, there was nothing to prevent the pushrod end fitting falling off the bolt and detaching from the bellcrank.

The bellcrank in the elevator control was found installed the other way up from how it was before the rebuild (Figures 2 and 3). In this orientation had a pushrod been installed on the inner hole as it was prior to the rebuild, the control feel, and response would have been different from how it was before the rebuild.

In the accident orientation, had the bellcrank been assembled with a pushrod connected to the inner hole, as it was before the rebuild, the control column would have needed to be moved further and with less force to get the same elevator deflection. As a result, the aircraft's elevator control would have felt lighter and less effective than it was prior to the rebuild.

Moving it to the outer hole, where the disconnected bolt was found by the AAIB, would have reduced this effect slightly, but it still would not give the same feel and more direct control response as the arrangement prior to the rebuild.

The firmest feel for the elevator and smallest movement of the control column to obtain an elevator deflection would be in the previous orientation of the bellcrank and position of the push rods.

Both holes on the side of the bellcrank with the disconnected joint showed signs of having had a bolt fitted, as the paint was damaged around both holes. It seems that at some time both the holes had been used for the push rod.

There is no record of which hole was used when the aircraft was rebuilt, and no record of any changes made to the pushrod position. Had the recommendation in LAA TL 2.21 section LAA worksheets, of 'make a photographic record of the work as it is being undertaken' been adopted, the condition and arrangement of these parts at the end of the rebuild would be clearer. Photographs were reportedly taken during the rebuild, but they did not form part of the workpack, and they were not located.

Conclusion

Aircraft handling

The aircraft was flying trimmed straight and level at 140 mph when the pilot discovered that he had lost his primary means to control the pitch attitude of the aircraft through the control column. He then assessed that he had very limited trim authority as a secondary means, leaving only the use of power to control the pitch of the aircraft. In a high stress situation, and not entirely clear of the effects of controls upon the pitch attitude of the aircraft, he elected to fly unbalanced left turns to descend the aircraft and set it up for a high speed approach to Runway 03 at Popham.

However, on the final stages of the approach, the pitch attitude of the aircraft dropped, which the pilot ascribed to turbulence. He closed the throttle in response and impacted the ground with a nose down heavy landing before coming to rest inverted.

Engineering

The loss of elevator control was caused by a bolted pivot joint in the elevator control system coming undone. This was most likely due to the lack of a split pin to secure the bolt's castellated nut.

At the completion of the rebuild, two separate people signed to say the split pin was fitted.

Both alternative holes in one side of the elevator bellcrank in the rear fuselage, to which the pushrod had been attached, had indications of being used and there is no record of if or when the pushrod position was changed.

It is therefore not possible to determine with any certainty when the split pin was omitted.

The pilot's seat and harness remained intact, but he sustained a significant injury when his unprotected head struck the coaming above the instrument panel. This sharp panel edge should have been thickened and padded to comply with the aircraft's design drawings.

The AAIB were informed that the seat harness was new, and it appeared to be so. This is different from the one described in the narrative of the rebuild. There is no record of its replacement.

Although not directly linked to this accident, discrepancies were found regarding adherence to LAA guidance for recording work. Inconsistencies were identified within LAA Technical Leaflets regarding who can sign for duplicate inspections. It was also noted that the extent to which the 51% rule for amateur built aircraft needs to be applied in relation to overhaul, repair, and restoration of amateur built aircraft was not clear in regulatory material. The Civil Aviation Authority (CAA) has stated it will be taking two Safety Actions, and the Light Aircraft Association (LAA) has stated it will be taking two safety actions.

Safety actions

The CAA has stated that it will be taking the following safety actions.

> The Civil Aviation Authority will be reviewing the regulatory framework with respect to British Civil Airworthiness Requirements A8-26, '*Approval of organisations supporting recreational aviation*' and A3-7, '*Permit to Fly Aircraft – Initial and Continuing Airworthiness*', in conjunction with the approved organisations. The review will include an evaluation of the requirements relating to duplicate inspections.
>
> The Civil Aviation Authority will engage separately with the approved organisations on the applicability of the '51% rule' in relation to overhaul, repair, and restoration of amateur built aircraft.

The LAA have stated they will be taking the following safety actions.

> The Light Aircraft Association will be reviewing the guidance provided to LAA members and Inspectors regarding worksheets. TL 2.21 *'Rebuilding an aircraft under the LAA system'* and other documents will be reviewed and will result in a revised TL 2.21. This review will include.
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>
> The Light Aircraft Association have stated they have amended their Technical Leaflets to ensure the information relating to who can sign a duplicate inspection is consistent.

Published: 22 June 2023.

ACCIDENT

Aircraft Type and Registration:	Guimbal Cabri G2, G-CJEK
No & Type of Engines:	1 Lycoming O-360-J2A piston engine
Year of Manufacture:	2016 (Serial no: 1151)
Date & Time (UTC):	20 June 2022 at 1059 hrs
Location:	Near Burton in Lonsdale, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Fatal)
Nature of Damage:	Helicopter destroyed
Commander's Licence:	Private Pilot's Licence (Helicopter)
Commander's Age:	66 years
Commander's Flying Experience:	Approximately 538 hours (of which approximately 258 were on type) Last 90 days – Not available Last 28 days – Not available
Information Source:	AAIB Field Investigation

Synopsis

The aircraft departed a private site with the intention of flying a local experience flight. As the helicopter returned to land at the departure point, it made a left turn away from the landing site and began a shallow climb. It began to yaw to the left, initially with a normal attitude before the nose dropped. The helicopter continued to yaw to the left, the nose dropped further and it rapidly descended into a tree. There was an intense post-crash fire. Both occupants were fatally injured. Due to the damage sustained and lack of available evidence, the investigation was not able to reach a definitive conclusion, but a number of possible causes have been identified.

History of the flight

The flight departed a private site at approximately 0930 hrs with the pilot, who owned the helicopter, and one passenger on board. The purpose of the flight was for the passenger to experience his first helicopter flight.

The helicopter departed initially on a westerly track then routed around the Lake District (Figure 1), before returning to the landing site approximately 1 hour and 20 minutes later. The pilot did not report any problems during his routine interactions with ATC throughout the flight.

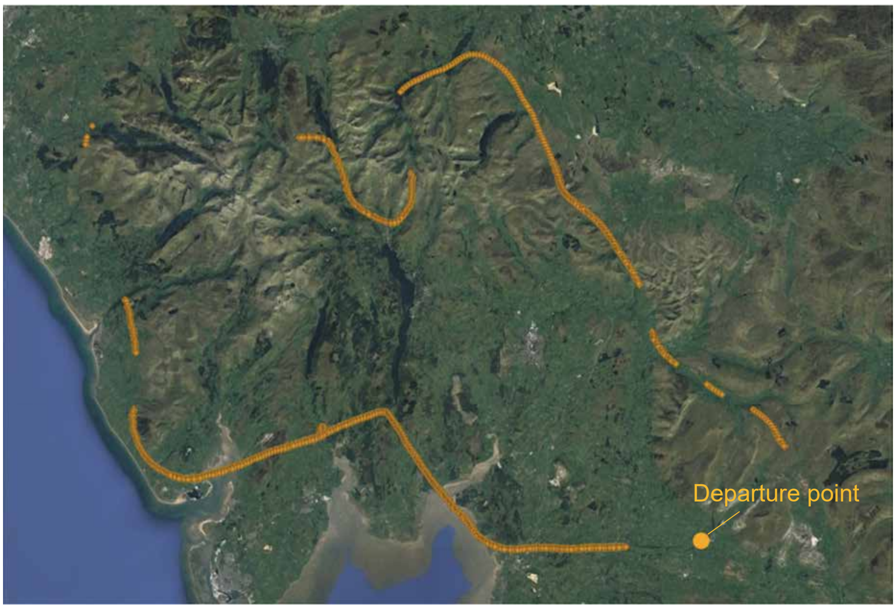

Figure 1
Radar track of route flown

Several witnesses saw the helicopter approaching the landing site and described it flying along the river Greta in a westerly direction. Some witnesses, who lived locally and were familiar with the helicopter landing nearby, stated that the initial approach appeared "normal" and similar to what they had observed on previous occasions.

There was limited closed-circuit television (CCTV) recorded from a nearby farmhouse which captured short periods of the helicopter's flight path prior to the accident. It showed the helicopter initially flying in a westerly direction (Figure 2) before it began what appeared to be a controlled left turn. The helicopter then continued heading approximately south, with decreasing groundspeed and climbed from an approximate height of 70 ft before the turn to about 130 ft when it went out of view of the CCTV.

Although not captured on the CCTV, the helicopter subsequently entered what was described by witnesses as an uncontrolled yaw to the left, initially maintaining altitude before the nose dropped. A witness working close to the accident site described hearing what sounded like a "bang or a pop", before looking up to see the helicopter in a nose-down attitude, descending toward the ground. The CCTV momentarily captured the helicopter descending in a nose-down attitude whilst rotating to the left, before it struck trees.

Witnesses heard the impact, and some attended the scene in an effort to assist the occupants, although they were unable to access the wreckage due to its location. They reported hearing the engine continue to run for approximately 5 minutes after the impact and, once the engine stopped running, the wreckage caught fire. The fire service attended the scene 39 minutes[1] after a call was made by a witness to the emergency services.

Footnote

[1] As recorded on the fire service Incident Report.

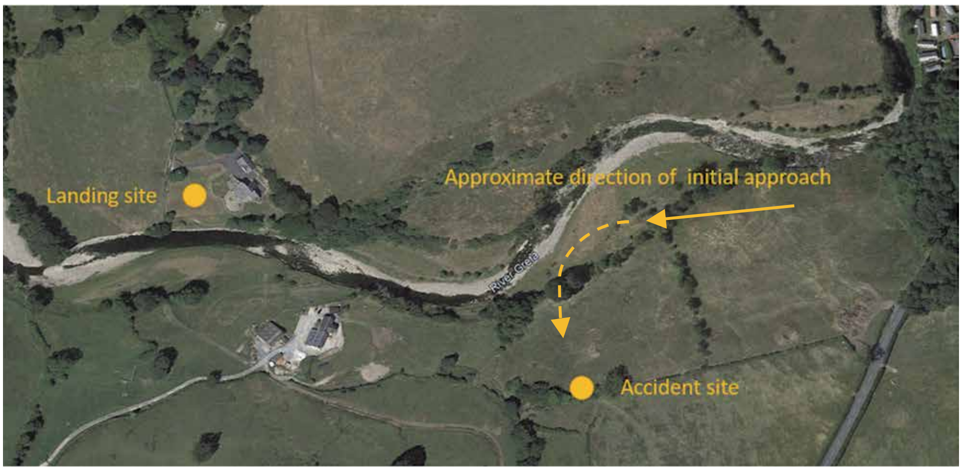

Figure 2
Approximate direction of initial approach

Accident site

The accident site was in a small tree-lined gully within a livestock field, approximately 100 m south of the river Greta and 250 m west of Bentham Road, near Ingleton, North Yorkshire. Witnesses who initially arrived at the scene recalled that the helicopter was suspended in a hawthorn tree, with the engine running. However, after a short period of time, a fire broke out and the helicopter then fell to the ground.

The helicopter fuselage had been destroyed by fire, but it was evident that it had come to rest with the helicopter's nose vertically downwards with the main rotor gearbox to the north, on top of the gully, and the helicopter landing gear to the south, at the bottom of the gully. The pilot's and passenger's bodies lay within the wreckage, underneath the engine. Both of their harness buckles were found to have been correctly fastened.

The main rotor blades all exhibited evidence of having struck the trees with some energy with their fragments surrounding the accident site, and some fragments up to 50 m from the main wreckage. Damage to the trees in the location of the main wreckage suggested that the helicopter entered the trees almost vertically.

The main rotor blades also remained on the top of the gully. Two of the blades and the root of the third blade had been completely consumed by fire, the remainder of the third blade was misshapen with evidence of entanglement with the trees. The main rotor gearbox casing had partially melted exposing its internal gears. These gears were intact and showed no evidence of distress. The blade pitch control links were destroyed by the fire.

The engine was positioned above the rest of the helicopter wreckage, with its front vertically downward and remained in its support frame. The engine output pulley, rotor system input drive pulley, the associated tensioning system and the drive belt had been destroyed in the fire.

The tail rotor had come to rest in the bottom of the gulley. An arc of approximately 180° of the tail rotor structure was fire-damaged. All the tail rotor blades were present and showed no sign of leading edge damage. Drive from the tail rotor drive shaft to the tail rotor, through the tail rotor gearbox, was confirmed. The tail rotor drive shaft had fractured adjacent to the rear firewall bearing and the forward section of the drive shaft was found in the wreckage.

Continuity of the tail rotor pitch control was confirmed from the forward end of the yaw push/pull control cable located in the cockpit to the blades but, due to the fire damage it was not possible to confirm whether the cable was attached to the yaw control pedals.

The helicopter was fitted with dual cockpit controls. The cyclic and collective levers were found within the wreckage, but the fire had melted the aluminium control rods and mixer unit that translate the pilots' control inputs into pitch changes on the main rotor blades, making it impossible to confirm control continuity.

Recorded information

CCTV recordings

CCTV recordings were available from a farmhouse, nearby to the accident site, and are referenced earlier in this report. Three cameras captured G-CJEK's approach – one on the eastern elevation of the farmhouse facing approximately north-east and two other cameras, which were situated on the same outbuilding, that looked towards the western elevation of the farmhouse. No audio was recorded, but some 12 seconds of continuous footage was captured before G-CJEK initially left the cameras' field of view. G-CJEK then briefly re-entered the view from the outbuilding and, approximately 10 seconds later, the same camera shows G-CJEK descending rapidly whilst rotating to the left. The impact with the tree is then captured by the other outbuilding camera.

Photogrammetry

The AAIB undertook a photogrammetry[2] analysis of the CCTV recordings using commercially available software. This established that G-CJEK approached the farmhouse and commenced a left turn, climbing as it turned from a height of approximately 70 ft agl to about 130 ft agl. It was not possible to reliably quantify G-CJEK's groundspeed due to visual artefacts associated with the file compression used on the CCTV recordings, and distortion at the extremities of the CCTV frames.

Flight recorders

G-CJEK was not fitted with a crash-protected flight recorder, nor was it required to be. Later Guimbal Cabri G2's, from serial number 1260[3] onwards, are equipped with a data logger that records, at up to 10 samples a second, time-stamped engine, rotor speed,

Footnote

[2] Photogrammetry is the science of gathering measurements and data about an object by analysing the change in position of the object across a series of recorded images.
[3] G-CJEK was serial number 1151 and was not equipped with a data logger.

pedal position, engine governor and GPS data, amongst other parameters. However, these loggers are not crash-protected and, in three out of four cases after an incident, when the manufacturer has attempted to download the logger, data recovery has not been possible.

Radar and RTF

Radar coverage was lost, due to terrain masking, nine miles to the north-east of the accident site, but was used to confirm the approximate duration of G-CJEK's flight and is shown in Figure 1. RTF recordings were made available to the AAIB, and all communications were routine.

Aircraft information

The Guimbal Cabri G2 is a light two-seat helicopter powered by a Lycoming O-360-J2A piston engine. The engine transmits the drive to the three-bladed main rotor via a belt and pulley mounted on the main gearbox input shaft. The input shaft couples with the tail rotor drive shaft, which in turn drives the shrouded seven-blade tail rotor.

The airframe is composed of three sections: main fuselage, engine section, and tail boom. The main fuselage is a carbon-fibre reinforced monocoque, constructed in five parts. In the cabin there are two side-by-side seats, with the pilot occupying the right position. G-CJEK was equipped with flying controls at both seats. The main fuselage also includes a central structure, baggage compartment and fuel tank. The engine section is isolated from the cabin by a firewall with the engine supported on a tubular steel frame. The composite tail boom incorporates a Fenestron tail rotor, vertical fin and a horizontal stabilizer.

The engine is mounted to the rear of the passenger compartment and drives a pulley at the front of the engine. A belt transmits the drive from the engine pulley to the main input drive of the rotor system via a pulley and freewheel coupling. A clutch mechanism is used to engage the drive from the engine to the rotor system. This is achieved by pivoting the engine about its rear mounts; an actuator lowers the front of the engine which tensions the belt, allowing drive to be transmitted to the rotor system. When the clutch is disengaged, the actuator retracts, lifting the output pulley and disengages the drive.

The main rotor rotates clockwise when looking from above. In the event of an engine failure, the helicopter would tend to yaw to the right. In the event of a loss of tail rotor drive, the helicopter would tend to yaw to the left.

G-CJEK was built in 2016 and had been owned by the pilot from new. It had been regularly maintained in accordance with the rotorcraft maintenance manual. The last recorded maintenance was a 15-hour airframe and a 50-hour / 4-month engine inspection in April 2022. At that time the helicopter and engine had accrued 222.8 hours. The helicopter and engine logbooks were held by the maintenance organisation, but the technical logs for the flights since the last maintenance had been carried in the helicopter at the time of the accident and were extensively damaged in the fire. As a result, accurate total hours for the airframe or engine could not be determined, nor whether there had been any technical issues noted in that period, but it was possible to identify that the helicopter had flown eight times since the last maintenance.

G-CJEK's Certificate of Registration and Airworthiness Review Certificate were valid at the time of the accident.

Aircraft examination

The wreckage was recovered to the AAIB facility in Farnborough for further examination.

The fractured tail rotor driveshaft was found to have failed in torsional overload in combination with bending. The fracture had occurred where it passed through the rear fire wall. The characteristics of the fracture indicated that, in combination with the tail boom deflecting, the forward end of the drive shaft had stopped whilst the rear was still rotating.

The engine's external components had been extensively fire-damaged, it was therefore not possible to determine the condition of the ignition, carburation or fuel supply systems. Internally, the engine components looked normal, with no indication that the engine was underperforming.

The extensive damage caused by the intense post-accident fire prevented any further assessment of the helicopter.

Weight and balance

It was not possible to establish with certainty what fuel load was on board the helicopter when it departed. However, the investigation considered two scenarios; a full fuel load and the minimum fuel required to fly for the helicopter's actual airborne time.

If the helicopter had departed with a full fuel tank, it is probable that it would have taken off above its maximum takeoff weight but with the centre of gravity within limits. In both scenarios, the helicopter would have arrived at the landing site within the flight manual's stated weight and balance limits.

Aircraft performance

Manufacturer Service Letters

The manufacturer describes a Service Letter's (SL) as documents published for helicopter operators specifically regarding the operation of the aircraft. There is no process to ensure operators have read or acknowledged the publication or contents of a SL.

By comparison, the manufacturer described a Service Bulletin (SB) as a document intended for the helicopter maintenance provider, usually to implement a modification or prescribe a verification. SB's are specific to the maintenance and continuous airworthiness of the aircraft and fall into 'optional', 'recommended' or 'mandatory' categories.

SL 12-001 - Yaw control in approach

This SL, published in 2012, aimed to address handling characteristics which are unique to helicopters with Fenestron-equipped tail rotors. It cites two incidents during which the pilots, who did not have previous experience flying a helicopter with a Fenestron tail rotor, lost control of the helicopter in yaw. Neither accident resulted in fatalities.

SL 12-001 states the Cabri G2 is immune to stall and to what is commonly referred to as 'loss of tail rotor effectiveness' (LTE). It highlights the need for pilots to use a much greater pedal input for a given tail rotor thrust than that which would be required in helicopters with a conventional tail rotor (Figure 3) and the need for pilots to react to uncommanded yaw without delay.

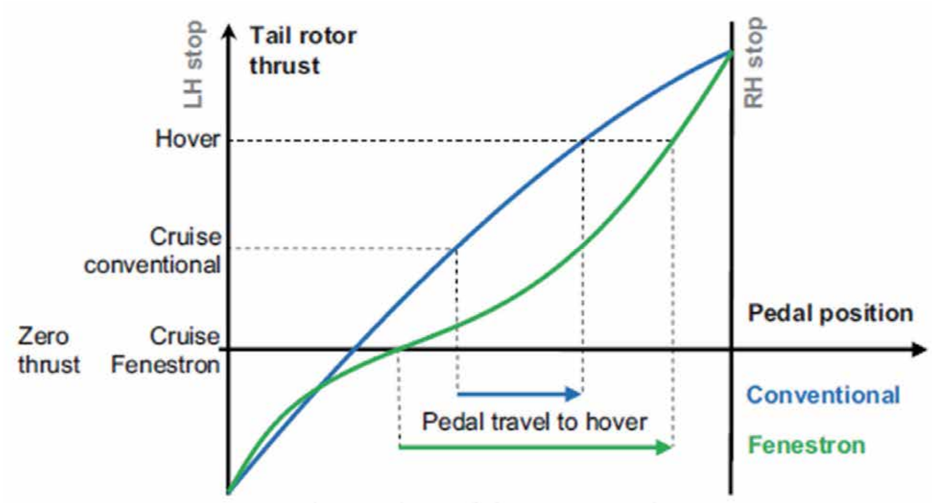

Figure 3

Comparison of thrust curves for
identical performance tail rotors Conventional/Fenestron

The SL states pilots with most experience on helicopters with anti-clockwise rotating rotors are a *'significant aggravating factor'* in loss of control in yaw events, as '*the pilot is used to apply [sic] left pedal rather than right, regardless how good his training was, thus accelerating yaw motion rather than stopping it*'.

The SL concludes with the following advice:

> '***Advice 1**: Never wait to correct a sideslip – and particularly to the left – when approaching for a standard landing (30 – 60 kt approach). Use adequate pedal without any hesitation. If there is a known cross wind, and particularly from the right hand, pay even more attention to keep the helicopter centreline aligned with the path and be prepared to large pedals input.*
>
> ***Advice 2: Never hesitate to apply full right pedal** to correct a yawing to the left before it gets faster. Keep the pedal to the stop, until the rotation stops completely.*

__Advice 3:__ When practicing spot-turns at low height above the ground, always do it __"on the power pedal"__– to the right in the Cabri G2 case. Then raising the collective in case of problem will stop the spin.

……..'

SL 19-002 – Controllability in yaw at low rotor speed

This SL was published in 2019 following an AAIB investigation[4]. It was published in order to:

'• clarify the tail rotor behaviour at low RPM,

• illustrate associated risks,

• provide recommendations to avoid such situations.'

It states that, although the main rotor is capable of producing lift below 450 rpm, below this figure full right pedal will not produce sufficient anti-torque thrust, and the helicopter will begin to spin uncontrollably to the left. Should this occur close to the ground, the pilot's instinct may be to raise the collective, which will lower the rotor speed more and thus increase the rate of left spin.

The SL summarises its content with the following recommendations:

'Low rotor speed situations can always be avoided by taking adequate precautionary measures.

Nonetheless, in case of a low rotor speed, if full right pedal is applied, or is close to being applied, the following recommendations must be used;

__Do not raise the collective__, it would aggravate the situation,

__Lower the collective as much as possible;__

- *If height is sufficient, increase airspeed using forward cyclic input,*
- *If height is low, manage the contact with the ground,*

__Do not try to increase the rotor speed by turning the twist grip,__ it can only aggravate the situation.

Overall, always consider that excessive right pedal input cannot hurt.'

Footnote

4 AAIB Accident Report G-PERH, available at Guimbai_Cabri_G2_G-PERH_Correction_09-21 [accessed on 22 March 2023].

Meteorology

The forecast for the area was for benign conditions with clear skies and a light north-westerly wind. An assessment of the reported conditions conducted by the Met Office for the AAIB investigation described the conditions as '*generally settled with good visibility and little or no significant cloud*.' The recorded wind at 1050 hrs at Blackpool Airport, located 29 nm from the accident site, was from 310° at 8 kt.

Personnel

The pilot held a valid licence and medical. The pilot first obtained his PPL (H) in 2001 and flew Robinson R22 and R44 helicopters until 2016, when he purchased the Cabri G2. His logbook was onboard the helicopter when the accident occurred and therefore his total hours could not be confirmed. However, his declared total time on an application form submitted to the regulator in May 2022 was 538 hours.

Post-mortem reports

The pilot's post-mortem report recorded the cause of death as '*unascertained*'. It identified evidence of risk factors, such as coronary disease, which may have caused the pilot to become incapacitated but there was no evidence of an acute medical event which would have certainly caused the pilot to be unable to control the helicopter. An aeromedical expert commented that, based on the evidence, it was possible that '*a complete or partial incapacitation could* [have] *occur*[ed] *suddenly'.*

The passenger's post-mortem report established the cause of death was blunt head injury resulting from the initial impact before the post-accident fire.

Analysis

Analysis of all the evidence available was inconclusive and so the investigation considered a number of scenarios which may have led to this accident. Mechanical failure, helicopter handling, inadvertent control input/restriction and pilot incapacitation are discussed further below.

Mechanical failure

At the time of the accident G-CJEK had a valid Airworthiness Review Certificate and was correctly registered. The helicopter was well maintained and had no outstanding technical issues at the time of its last service, nor reported defects during the flight. The helicopter was within weight and balance limits.

Except of fragments of the main rotor blades (which were located around the accident site), all the helicopter wreckage was in a confined area, indicating that the helicopter was intact when it struck the tree. The main rotor blade fragmentation showed that the main rotor had energy at that time. This is also corroborated by the fractured tail rotor drive shaft, which failed at the time the helicopter struck the trees and confirmed that the engine was providing power to the rotor system.

Witnesses observed that the helicopter departed from controlled flight whilst in a progressively tightening left turn. When considering technical issues that could induce a left turn, a tail rotor drive or pitch control issue were the most likely causes. Examination of the wreckage found no evidence of loss of tail rotor drive or discontinuity of the pitch control system before the accident. Due to the extensive fire which resulted in most of the aluminium components being destroyed, full continuity of the yaw control system could not be established, therefore the investigation could not completely rule out a mechanical issue.

Cabri G2 Handling characteristics

The manufacturer's SLs and previous events indicate a recurrent theme of a loss of controllability in yaw for Cabri G2 helicopters. In the absence of evidence to the contrary, pilot handling or undesirable environmental conditions leading to a loss of control, as described in the SLs, could not be ruled out.

The pilot could have found himself in conditions described in '*typical situations'* in SL 12-001 and that he did not react with either:

- sufficient right pedal or,
- a timely input or,
- maintain input for sufficient time.

However, the pilot did not fit the profile of those most likely to be unaware of the unique characteristics of a Fenestron tail rotor. He was not a student or low hours helicopter pilot, he had 20 years of experience, and he did not routinely fly another helicopter type with an anti-clockwise rotating main rotor. As a consequence, his instinctive pedal input would likely have been the correct one. Approximately half of his total flying experience was on the Cabri G2 and he was operating in a familiar environment.

Alternatively, in the scenario outlined in SL 19-002, it cannot be discounted that the helicopter may have made the approach with low rotor rpm, to which the pilot did not apply the appropriate response outlined in the SL and, as a consequence, the helicopter departed controlled flight.

Although these scenarios and risks identified in the manufacturer SLs 12-001 and 19-002 cannot be ruled out, the pilot's experience and the circumstances of the accident, reduce the likelihood.

Inadvertent control input/restriction

The left seat dual controls were found within the wreckage and confirmed to have been connected. Based on the available evidence, the possibility of an inadvertent passenger input on fitted dual controls could not be ruled out as a potential explanation for the departure of the helicopter from controlled flight.

Medical incapacitation

Based on the results of the pilot's post-mortem report, and in the absence of conclusive evidence which explains the loss of control of the helicopter, the investigation concluded that medical incapacitation of the pilot could not be ruled out.

Conclusion

The evidence recovered in this investigation was not sufficient to determine the cause of the accident. Based on the evidence available, the investigation concluded the cause was likely to be one or more of the following factors; a mechanical failure, an incorrect pilot response to unexpected environmental conditions, an inadvertent passenger input or restriction on the controls, or pilot partial or complete medical incapacitation.

Published: 1 June 2023.

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:	Sikorsky S-92A, EI- ICU
No & Type of Engines:	2 General Electric CT7-8A turboshaft engines
Year of Manufacture:	2006
Date & Time (UTC):	5 February 2023 at 1453 hrs
Location:	5 nm east-northeast of City of Derry Airport, Eglinton, Londonderry
Type of Flight:	Training
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage (possibly pre-existing) resulting in replacement of stabilizer strut, aft tail drive shaft bearing support and forward tail drive bearing support
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	8,080 hours (of which 2,400 were on type) Last 90 days - 45 hours Last 28 days - 13 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

A search and rescue training flight encountered turbulence without any visual indication which resulted in the helicopter exceeding its maximum speed. The flight subsequently diverted to the City of Derry Airport.

An overspeed inspection of the helicopter identified three items which were rectified by the replacement of components. The helicopter returned to service two days later. The manufacturer's representative believed the findings likely pre-existed the overspeed event.

Analysis of meteorological reports suggested that EI-ICU probably flew through mountain waves associated with the Sperrin Mountains, creating the turbulence which affected the helicopter. Moderate turbulence was forecast in the region and discussed in the pre-flight briefing, but analysis of subsequent meteorological information suggested that mountain wave activity was present at the time of the event.

History of the flight

The flight was part of a training exercise which departed from Sligo, Ireland, to rendezvous with a lifeboat near Portrush at approximately 1500 hrs. It was operated by two pilots and two rear crew members. The departure from Sligo was uneventful, and the helicopter cruised north-east toward its intended destination, at 2,000 ft amsl. The flight was operating under VMC. The weather forecast indicated occasional moderate turbulence up to 6,000 ft amsl, mainly along the north coast.

During the cruise, the helicopter encountered unexpected severe turbulence approximately 5 nm east-northeast of the City of Derry Airport. The pilot reported that the helicopter pitch increased slightly before reducing, and the helicopter began to accelerate. During this time the airspeed reached 175 KIAS, exceeding V_{NE} (165 kt), and an aural "AIRSPEED" warning sounded. The pilot raised the pitch attitude, reduced the collective and slowed the helicopter to around 100 KIAS. The pilot maintained this speed and subsequently climbed to 2,800 ft amsl.

The commander reported that all crew members felt a noticeable increase in airframe vibration after the overspeed event. The pilots discussed diverting to the City of Derry Airport then notified ATC of their intention. The aircraft diverted and landed without further incident.

Recorded information

The helicopter was fitted with a combined CVR and FDR which captured the full duration of the event flight. A Health Usage Monitoring System (HUMS) also recorded data. The FDR parameters included the helicopter's indicated airspeed, ground speed, altitude, and pilot control inputs (Figure 1).

Wind speed and direction are calculated by the Flight Management System (FMS) and can be displayed to the pilots on the Navigation Displays. The calculated wind data is a result of an algorithm in the FMS which smooths the data and introduces a time lag to avoid large instantaneous changes being displayed to the pilots which may not be reflective of the actual conditions. The recorded wind speed and direction are calculated using estimated ground speed, estimated ground track, heading and true air speed. Any wind changes will only be picked up when those data inputs begin to change. This means that the recorded wind changes may lag the environmental conditions being experienced by the helicopter. The time lag included in the algorithm also increases the delay in recorded wind changes in the FMS data. The FMS calculated windspeed and direction were recorded on the FDR, which indicated that there was a tailwind.

FDR data showed that at Point A in Figure 1, the aircraft experienced an oscillation in pitch over approximately eight seconds with the cyclic control moving in the opposite sense to the pitch. At the end of this period, at Point B, the airspeed began to increase sharply, and the pilot made a nose-up cyclic input (Point C), which increased the pitch attitude, and lowered the collective control (Point D). During the 10 seconds after the indicated airspeed began to increase, the wind speed dropped significantly (Point E) although there was no change in direction.

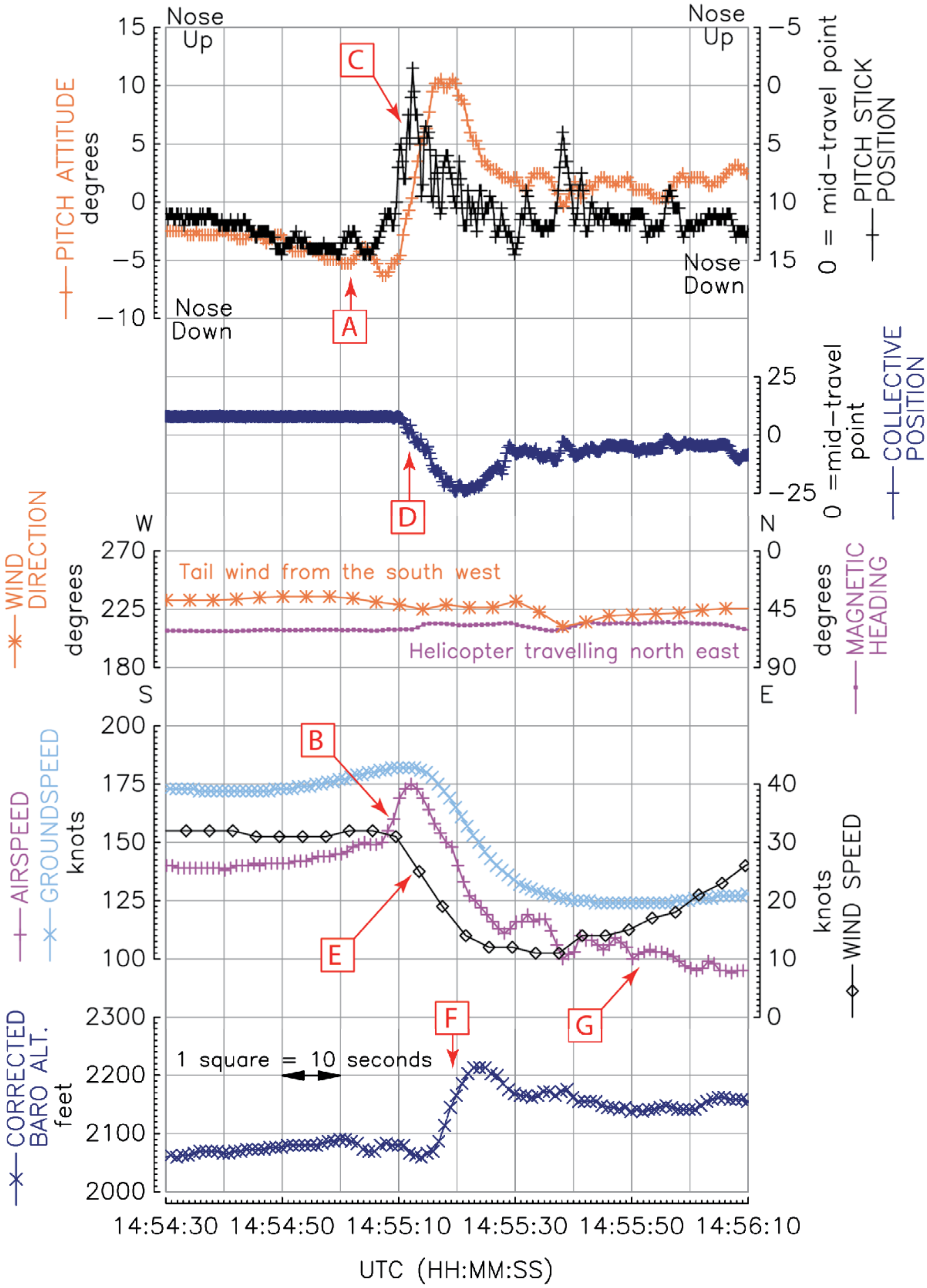

Figure 1

FDR data from EI-ICU at the time of the weather encounter

Approximately eight seconds after the speed began to increase the altitude began to increase, and the pilot responded by making a nose-down cyclic input while continuing to lower the collective. The airspeed peaked approximately 25 kt above its initial value, and the altitude increased by approximately 150 ft (Point F) as the pilot made these inputs.

The helicopter subsequently slowed to around 100 KIAS (Point G), which was maintained until the pilot later elected to climb to a higher altitude.

Engine torque, turbine rpm and rotor speed parameters were recorded and indicated normal behaviour throughout the flight.

Aircraft information

The Sikorsky S-92A is a twin gas turbine engine medium-lift transport and utility helicopter, used in both civil and military operations. The S-92A is widely used for Coastguard Search and Rescue operations.

Figure 2

EI-ICU at the City of Derry Airport. Image used with permission

Meteorology

The crew had reviewed the weather before the flight and the conditions were more than adequate for the planned sortie. The weather was clear and there were no signs of convective activity or low cloud.

On the day of the flight high pressure was centred over the UK and there was a decaying frontal system, which at the time of the event was situated around the west coast of Ireland. The frontal system was moving slowly to the east-southeast. The skies of Northern Ireland were largely clear with some high cirrus but no detected precipitation. The winds were south-westerly and forecast to increase during the day, with the strongest winds in the northwest of the region. The low-level significant weather chart provided to the crew contained a warning of occasional moderate turbulence up to 6,000 ft amsl in the north of the forecast region.

An aftercast was obtained which included further information on the possibility of turbulence and mountain wave activity. This suggested that in Northern Ireland there was the possibility of moderate mountain waves with the height of the strongest activity at 3,000 ft amsl, although there was no risk of rotor streaming. There was also a widespread elevated inversion which would have further promoted the formation of mountain wave activity.

At 2,000 ft amsl in the area where the turbulence encounter occurred, the crew were directly in the lee of the Sperrin Mountains, a range of hills to the east of Strabane. The highest point on these hills is around 2,200 ft amsl. At the height the helicopter was flying, the wind was approximately 210° at 40 kt. This meant that the wind was flowing almost perpendicular to the ridge of hills and the helicopter was approximately 8 nm downwind. The UK Met office concluded from a satellite image taken at 1530 hrs that there were areas of mountain wave activity over western Ireland with some weak activity in the area of the event.

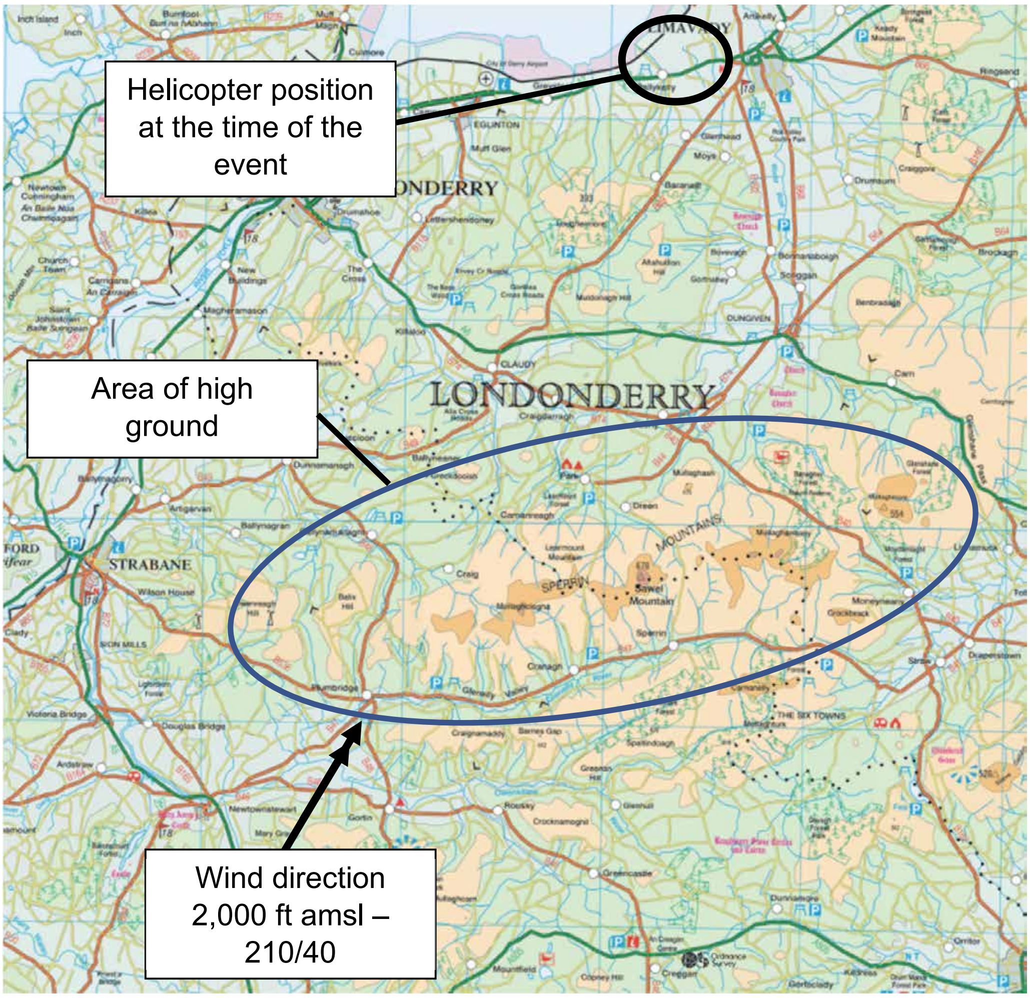

Figure 3

Helicopter position at the time of the event © Ordinance Survey

Mountain waves, although most often associated with much higher terrain, can occur downwind of any hills. They are oscillations as a result of the horizontal airflow being disturbed by the high ground.

An aircraft on approach into the City of Derry Airport had reported windshear on the approach and had conducted a go-around before making a further approach and landing. This had been approximately two hours before EI-ICU encountered turbulence. No other reports from aircraft in the area had been received by ATC.

Other information

Post-flight inspection

After the helicopter was shut down, the commander performed a visual inspection, but he saw no obvious damage to the helicopter. The overspeed event was reported to the operator and an overspeed inspection was conducted, which identified three findings. These were rectified via replacement of components, and the helicopter was returned to service two days after the event flight. The operator also checked the helicopter's HUMS, which monitors the vibration of rotor drive shaft bearings. The HUMS did not show any increase in vibration during the flight.

The operator's findings were shared with the helicopter manufacturer's Field Service Representative. The representative felt that the defects were probably pre-existing and not related to the V_{NE} exceedance.

Analysis

As the helicopter approached a point approximately 5 nm east-northeast of the City of Derry Airport it suddenly encountered severe turbulence. FDR parameters indicate that the pitch of the helicopter varied gradually until a sudden change in windspeed was experienced, when the pitch began to oscillate. The built-in time lag and the method of calculation used to generate the FMS wind speed means that although the FMS data indicates that the wind speed reduction occurred after the initial pitch oscillations (Points A and E in Figure 1), it is likely that this change in wind occurred close to or prior to the oscillations beginning.

The crew described the helicopter pitching up momentarily before pitching down and accelerating. The airspeed reached 175 KIAS which exceeded V_{NE}. The commander reduced the collective and increased the pitch attitude to reduce the speed, with the helicopter climbing 150 ft in this time. The relatively constant groundspeed recorded suggests that the change in airspeed was due to a sudden change in wind conditions.

The crew noted what they felt was an increase in vibration levels in the aircraft after the event and after a discussion decided to divert the City of Derry Airport. The approach and landing were uneventful. The helicopter was inspected by the operator and findings were rectified with the replacement of components. The helicopter was returned to service two days after the event.

It is likely that EI-ICU flew through an area of mountain wave activity associated with the Sperrin Mountains. Flying through this activity created the turbulence which affected the helicopter. There were no visual indications for the crew of the presence of mountain wave activity. Moderate turbulence was forecast for the north of the region in the crew briefing but subsequent analysis of forecasts not available to the crew would have suggested that mountain wave activity was a possibility in Northern Ireland. Observations by satellite taken near the time of the event did show weak activity in the area.

Conclusion

The helicopter encountered unexpected turbulence, probably mountain wave activity, which caused an exceedance of V_{NE}. The crew felt a change in vibration and decided to make a precautionary diversion to the City of Derry Airport.

Inspection of the helicopter after the event resulted in the identification of some defects which were rectified by the replacement of components. The helicopter returned to service two days after the event flight.

ACCIDENT

Aircraft Type and Registration:	Vans RV-9A, G-CCGU
No & Type of Engines:	1 Lycoming O-320-D1A piston engine
Year of Manufacture:	2003 (Serial no: PFA 320-13798)
Date & Time (UTC):	2 March 2023 at 1212 hrs
Location:	Henstridge Airfield, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Serious)
Nature of Damage:	Damage to both wings, rudder, engine propeller, engine cowling, engine mounting, and firewall. Canopy destroyed
Commander's Licence:	Light Aircraft Pilot's Licence
Commander's Age:	81 years
Commander's Flying Experience:	1,106 hours (of which 791 were on type) Last 90 days - 8 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Late in the final approach to Henstridge Airfield, which is unlicensed, the aircraft struck a heavy goods vehicle on a road which crossed the undershoot. The aircraft then struck the ground inverted, short of the runway. The pilot sustained only minor injuries, but the passenger was seriously injured.

The aircraft was on a standard 3° approach path when it struck the lorry. The airfield operator subsequently increased the distance by which the threshold is inset from the end of the runway so that aircraft on a standard approach would be higher when crossing the road.

History of the flight

The aircraft, a Vans RV-9A (Figure 1), had taken off at 1200 hrs to conduct a short local flight before a planned departure to Dunkeswell later in the afternoon.

On return from the local flight the pilot positioned to land on Runway 06 at Henstridge. The pilot recalled turning finals at approximately 500 ft agl and felt the approach was normal. He had operated from Henstridge since 2006 and was therefore aware of the road, which crosses the Runway 06 undershoot, but he did not observe any vehicle traffic as he began the approach.

Figure 1
Vans RV-9A

Just before touchdown the pilot saw a heavy goods vehicle (HGV) very close to the right of the aircraft, and the right wingtip struck the rear of the HGV trailer. The vehicle was crossing the undershoot from left to right. The pilot recalled nothing else until he became aware that the aircraft was inverted on the ground with the canopy broken (Figure 2). A roll bar behind the aircraft seats kept the cockpit off the ground protecting the occupants, and the aircraft harnesses successfully restrained both occupants in their seats. A car that had been following the HGV stopped and the occupants assisted the pilot and passenger to escape by breaking away sections of canopy perspex to clear an exit path. Ambulance personnel from the Air Ambulance base at Henstridge were quickly on scene and gave medical assistance, and they were subsequently supported by the local emergency services. There was no fire on the aircraft. Both those on board were taken to hospital by ambulance, and the pilot was released later that evening having sustained only minor injuries. The passenger remained in hospital for three days as he had sustained a broken wrist, which required surgical intervention to correct.

Figure 2
Aircraft inverted on road

Accident site

The accident happened at the unlicensed Henstridge Airfield in Somerset. The aircraft was approaching Runway 06 which is 728 m long and has a threshold displaced by 22 m. The access road leads to an industrial site on the south side of the airfield and sees a significant amount of traffic, including approximately 300 HGV movements per day. The road converges with the runway centreline from the left at an angle of approximately 20°. With the HGV converging from the left at a shallow angle and the low wing configuration of the aircraft the pilot's view of the road was significantly impeded. The accident site was approximately 70 m from the runway threshold. The access road and accident site are shown on the overhead view of the airfield at Figure 3.

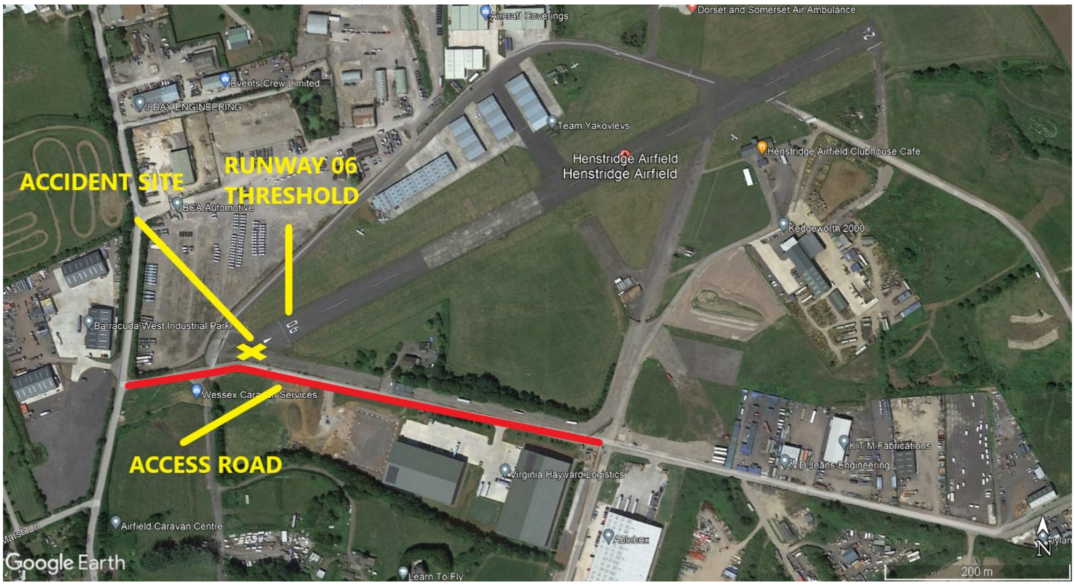

Figure 3

Henstridge Airfield and accident site

Obstruction clearance information

Obstacle clearance requirements for licensed airfields are given in CAP168[1] which states:

> *'In guidance material in ICAO[2] annex 14 Volume 1, all roads are considered to be obstacles extending to 4.8 m above the crown of the road.'*

Obstacles are not permitted to penetrate a surface defined as shown in Figure 4. The surface begins 30 m from the threshold and then has a 1 in 20 slope. The collision at Henstridge occurred approximately 70 m from the threshold therefore anything more than 2 m tall would penetrate the obstacle clearance surface. A 3° representative approach path drawn from the threshold would cross the road 3.7 m above ground.

Footnote

1 Available: https://publicapps.caa.co.uk/docs/33/CAP%20168%20Licensing%20of%20Aerodromes%20v12%20c0123%20(004).pdf [Accessed April 2023].

2 International Civil Aviation Organisation.

As Henstridge Airfield is unlicensed there is no requirement for it to comply with CAP168.

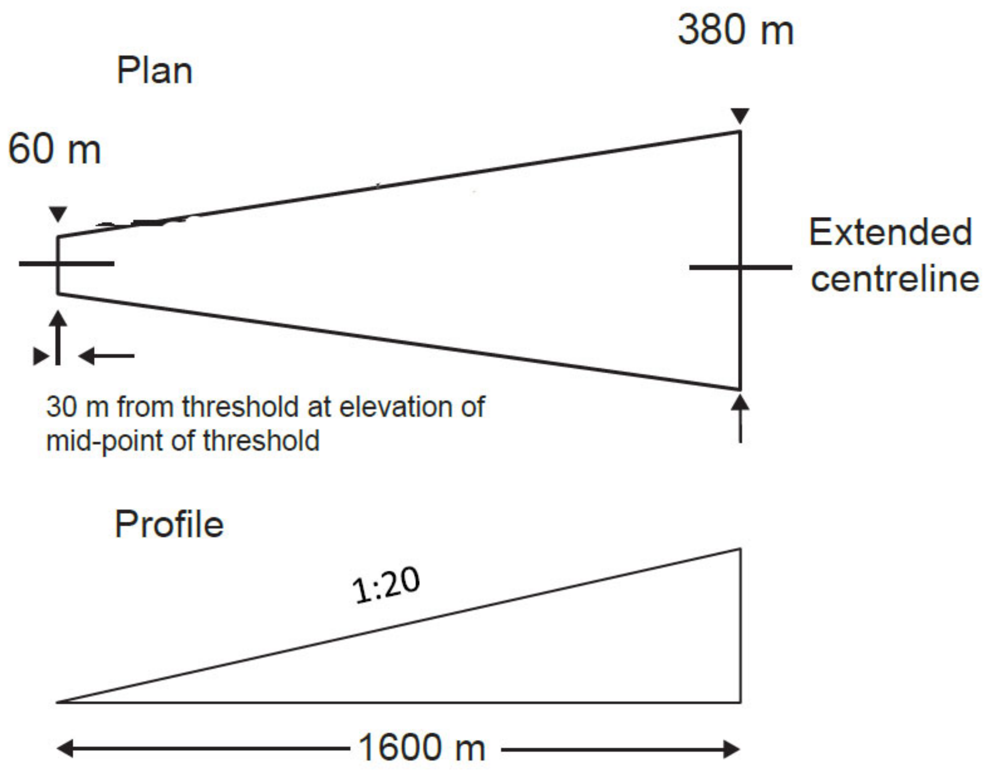

Figure 4
Approach Surface Diagram

Safety Action

The airfield operator decided to displace the threshold of Runway 06 by a further 100 m. The point at which the incident occurred would now be approximately 170 m from the threshold, the obstacle clearance surface would be 7 m above the road, and Runway 06 at Henstridge would fulfil the obstacle clearance requirements of CAP 168. A 3° path drawn from the new threshold would cross the road approximately 9 m agl.

Analysis

The pilot recalled making a normal powered approach to Runway 06 at Henstridge Airfield. The aircraft struck the top of the HGV and was therefore approximately 4 m above ground and commensurate with a 3° approach. The road converged with the runway centreline at a shallow angle and this, combined with the low wing configuration of the aircraft, meant it was unlikely the pilot would have been able to see the HGV during the approach. As the aircraft crossed the road the pilot saw the HGV very close and had no time to take avoiding action. The aircraft struck the HGV and came down inverted on the edge of the road. The roll bar in the aircraft protected the occupants as the aircraft inverted and both were able to exit the aircraft with the assistance of bystanders.

Conclusion

The aircraft struck an HGV in the latter stages of an approach to Runway 06 at Henstridge Airfield and came down inverted on a road short of the runway. Both those on board were able to escape the aircraft. The pilot sustained minor injuries and the passenger suffered a broken wrist.

The Safety Action taken by the airfield operator will make an approach to Runway 06 compliant with the obstacle clearance provisions of CAP168 even though, as an unlicensed airfield, this is not a requirement.

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only UAS investigations reviewed: April - May 2023

5 Sep 2022 **DJI Inspire 2** Orkney Islands

The landing gear shifted whilst landing and struck a rotor. The UA then fell to the ground from approximately 10 m agl.

20 Feb 2023 **MA Electric powered glider** Pulloxhill, Bedfordshire

Whilst on its second flight of the day the pilot lost control of the model glider, it entered a descending right turn and struck the roof of a unit in a nearby business park. There was minor damage to the building's roof; the model glider was destroyed.

28 Feb 2023 **DJI Mavic Enterprise Pro 2** Lewisham, South East London

Control of the UA was lost during landing following an otherwise successful flight. The UA struck a tree and was destroyed. A second UA was then flown using the same controller. Control was lost during landing but only minor damage was sustained to the UA. The operator suspected there may have been radio interference from an unknown source.

3 Mar 2023 **DJI Mavic 3** Leeds

Shortly after being launched the UA became uncontrollable. The remote pilot was unable to regain control before it struck a building and fell to the ground. The operator concluded that, contrary to standard operating procedure, the remote pilot did not check that there was a valid GPS signal and that the UA went into attitude (ATTI) mode in which it maintained a height of 12 m above the ground and was blown by the wind.

4 Apr 2023 **MA Zephyr** Near Blindley Heath, Surrey

During flight on club flying fields the signal to the model aircraft was lost and it flew out of sight.

4 Apr 2023 **MA Majestic Major** Near Maidenhead, Berkshire

The signal to the model aircraft was lost during flight and it flew out of sight.

24 Apr 2023 **DJI Mavic 3 Thermal** Peterborough, Cambridgeshire.

During takeoff, the pilot, while looking down at the controller's screen, inadvertently flew the UA into an overhead telephone cable, damaging a propeller and causing it to fall to the ground. Although an assessment for a suitable launch site was conducted, the location of the overhead cable was misjudged as the situation required the UA to be deployed quickly.

Record-only UAS investigations reviewed: April - May 2023 cont

12 May 2023 **MA Max-Thrust Riot V2** Lee-on-the-Solent, Hampshire

Control of the model aircraft was lost while approaching to landing in a gusty crosswind. The model collided with a residential property, destroying the aircraft and causing minor damage to the property. The pilot attributed the accident to the increasingly gusty wind and his limited flying experience.

13 May 2023 **MA Soar 40 Sports Low Wing** Birmingham

Two model aircraft collided during flight. The collision disconnected the battery of one which then suffered damage to the tail surfaces when it landed. The other landed without damage.

15 May 2023 **Evolve Dynamics Sky Mantis** Newcastle

The UA was approximately 20 minutes into a flight when the remote pilot noticed that one rotor was slowing down. The UA then fell onto a roof of a building and was substantially damaged.

15 May 2023 **MFE Believer** MoD Aberporth, Wales

Following a practice touch-and-go, the remote pilot turned to follow the UA but he was dazzled by the low sun. He lost visual contact with the UA, which then suffered substantial damage when it struck a metal tower in the corner of the field.

18 May 2023 **MA Limbo Dancer** Pontefract, West Yorkshire

The model aircraft would not respond to controls and flew out of sight towards scrubland.

19 May 2023 **DJI M300 RTK** Byfleet, Surrey

On descending, the UA began to spiral and the pilot was unable to regain control. It fell onto, and damaged, a stationary emergency services vehicle. Nine minutes before the loss of control the UA battery was observed to be around 60% fully charged.

20 May 2023 **DJI Avata** Keighley, West Yorkshire

The UA was flown from an indoor location to outside in order to land it. However, control was lost and the UA flew into the ground.

Record-only UAS investigations reviewed: April - May 2023 cont

23 May 2023	**MA Hobbyzone Carbon Cub S2**	Edinburgh
	During flight the model aircraft was disturbed by a wind gust and flew over trees in a built up area. The pilot was not able to recover the aircraft.	

Miscellaneous

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

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

BULLETIN CORRECTION

Aircraft Type and Registration:	1) Boeing 777-300(ER), HL-7782 2) Boeing 757-256, TF-FIK
Date & Time (UTC):	28 September 2022 at 1850 hrs
Location:	London Heathrow Airport
Information Source:	Aircraft Accident Report Forms submitted by both commanders and further enquiries by the AAIB

AAIB Bulletin No 6/2023, pages 113-124 refer:

Prior to publication two amendments were made to the report.

> On page 115 under the section 'Heathrow ground handling', the second sentence of the second paragraph 'It would only expect to provide a marshaller in the event of a failure of the guidance system.' was changed to:
>
> > 'It would only expect to provide a marshaller in the event of a failure of the guidance system as specified in the UK AIP entry for Heathrow.'
>
> On page 124 the final sentence of the conclusion 'This is a common problem at Heathrow.' was changed to:
>
> > 'Lack of stand guidance is a common occurrence at Heathrow that all parties should continue to work together to address.'

The online version of the report was corrected before the report was published on 8 June 2023.

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

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

Published July 2015.

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

Published August 2015.

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

Published November 2018.

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

Published March 2020.

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

Published May 2021.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

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

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