AAIB
Air Accidents Investigation Branch

AAIB Bulletin 7/2022

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AAIB Special Bulletins and Interim Reports

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

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AAIB
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AAIB Bulletin S1/2022 *SPECIAL*

ACCIDENT

Aircraft Type and Registration:	Piper PA-28R-200-2, G-EGVA	
No & Type of Engines:	1 Lycoming IO-360-C1C piston engine	
Year of Manufacture:	1976 (Serial no: 28R-7635229)	
Date & Time (UTC):	2 April 2022 at 0920 hrs	
Location:	Approximately 20 nm west of Le Touquet	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (missing)	Passengers - 1 (missing)
Nature of Damage:	Aircraft missing	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	69 years	
Commander's Flying Experience:	200 hours (of which 4.7 were on type) Last 90 days - 1.3 hours Last 28 days - 0.7 hours	
Information Source:	AAIB Field Investigation	

Synopsis

G-EGVA was one of seven aircraft taking part in a club ‘fly-out’ from Wellesbourne Mountford Aerodrome to Le Touquet in France. A line of highly convective cloud was forecast on the intended route in the English Channel. As they approached the middle of the Channel, one of the pilots of G-EGVA, which was operating under VFR, reported to London Information that they were in cloud. Neither of the pilots onboard was qualified to fly in cloud. Shortly after this transmission the aircraft disappeared from radar. An extensive search of the area was coordinated by the UK and French Aeronautical Rescue Coordination Centres but neither the aircraft nor its occupants were found.

The available evidence, at the time of issue of this report, suggests that control of the aircraft was lost when it entered cloud. This Special Bulletin is published to remind pilots of the danger of entering cloud when not qualified to fly in IMC, and highlights the guidance available in the CAA Skyway Code and Safety Sense leaflets.

History of the flight

On Saturday 2 April the two pilots[1] of G-EGVA were taking part in a flying club 'fly-out' from Wellesbourne airfield in Warwickshire to Le Touquet in France. Six other aircraft took part in the fly-out. One of the aircraft flew IFR[2]. The six other aircraft, including G-EGVA, planned to fly VFR each flying a similar route from Wellesbourne towards Newbury and Goodwood then east towards Le Touquet. One of the pilots of G-EGVA had filed a flight plan using a flight planning and navigation app. The route, shown in Figure 1, was planned at 5,000 ft and the flight plan gave an estimated flight time of 1 hour 38 minutes.

Whilst the fly-out was arranged by the flying club there was no coordination or joint pre-flight planning. Each of the pilots reported that they had completed their own planning and made their own assessment of the weather conditions. The six VFR aircraft took off from Wellesbourne between 0750 hrs and 0830 hrs and proceeded separately. G-EGVA was the second of the VFR aircraft to takeoff at approximately 0754 hrs but, being a faster aircraft, overtook the first aircraft near Basingstoke.

At 0759 hrs G-EGVA contacted London Information and requested that their flight plan be activated[3]. At 0816 hrs they transferred to Farnborough Radar before returning to London Information at 0839 hrs. When they returned to London Information, they reported they were at 5,000 ft and 1 nm west of Littlehampton.

At 0846 hrs a video was posted online by the right seat pilot of G-EGVA. Extracts from the video are shown in Figure 2. The video showed the aircraft in flight passing abeam Shoreham with the flight appearing to proceed normally. The aircraft's altimeter showed 5,000 ft, the heading was approximately 090° and the airspeed indicator showed approximately 115 kt. The autopilot did not appear to be engaged and the engine and fuel indications, which were visible, appeared normal. Cumulus cloud could be seen in the distance ahead of the aircraft. Both occupants were wearing lifejackets with their shoulder harnesses worn under their lifejackets.

Footnote

[1] Although G-EGVA was a single pilot aircraft, both occupants were qualified pilots and may both have been involved in the management and decision making during the flight. Witnesses and video evidence suggest the left seat pilot was flying the aircraft during the accident flight but it is possible that the right seat pilot also undertook some tasks.

[2] The aircraft flying IFR, G-BJNZ, was involved in a separate accident on the same day and is the subject of a separate AAIB investigation.

[3] The flight departed before Wellesbourne AFIS was open so they activated their flight plan once airborne.

Figure 1

Filed flight plan route via waypoints 'NUBRI', 'HAZEL', 'GWC' and 'ALESO'

Figure 2

Extract from the video posted at 0846 hrs showing the instrument panel and the cloud ahead of G-EGVA

The next radio exchange with G-EGVA occurred when London Information contacted them to confirm their position as the FISO[1] estimated they would be approaching the boundary with French airspace and intended to transfer them to Lille Radar. The radio exchange is shown in Table 1.

Time	Station	Message
0915:51	London Information	"G-EGVA WHAT IS YOUR POSITION AND ALTITUDE"
0916:08	London Information	"G-EGVA LONDON INFORMATION"
0916:10	G-EGVA	"G-VA WE'RE CURRENTLY IN CLOUD".

Table 1

Last radio exchange between London Information and G-EGVA

London Information tried to contact the aircraft several times and asked other aircraft to try to relay a message without success. At 0920 hrs the London Information FISO informed Distress and Diversion (D&D) that they had lost contact with G-EGVA. The FISO also contacted Le Touquet and Lille Information to determine if they had contact with G-EGVA; they both confirmed they had no contact with the aircraft. D&D replayed the radar recording, in which G-EGVA was last visible on radar at 0916:31 hrs at a position 20 nm west of Le Touquet, descending rapidly. Lille Information also replayed their radar, which gave similar indications.

The UK and French Aeronautical Rescue Coordination Centres were informed, and a search was launched involving both French and UK vessels and aircraft. The search continued until the following evening but initially, nothing was found of the aircraft or its occupants. Subsequently, some items were found washed up on the French Coast.

Reports from other aircraft

The pilots and passengers of the other aircraft participating in the fly-out were interviewed after the accident. All the pilots reported encountering a line of cumulus cloud in the middle of the Channel. Four of the five other aircraft flying a VFR route had been able to descend and find a gap to fly around the cloud. Figures 3 and 4 were taken at 0918 hrs and 0924 hrs by one of the other aircraft and show the cloud conditions. Waterspouts can be seen descending from the base of the cloud in Figure 3. Having flown past this weather, the four aircraft continued normally to Le Touquet, returning to Wellesbourne later the same day.

Those onboard the last aircraft in the group initially tried to descend and fly around the weather, but decided they could not find a safe route and elected to divert to Shoreham airport.

The pilot of the aircraft which flew under IFR to Le Touquet reported that he estimated the cloud tops to be at least 8,000 ft when he flew past the line of cumulus cloud at approximate 0825 hrs.

Footnote

[1] FISO - Flight Information Service Officer

Figure 3

Photograph taken at 0918 hrs showing the cloud mid Channel (waterspout circled in red)

Figure 4

Photograph taken at 0924 hrs showing cloud to the surface

Found items

In the days after the accident several items were found on the French coastline which had come from the aircraft. On 5 April 2022 a bag belonging to the left seat pilot was found at Plage d'Equihen, containing his flying licence, logbook and other flight documents. On 7 April 2022 a kneeboard belonging to the right seat pilot was found at Plage de Wimereux and on 8 April 2022 a seat from G-EGVA was found on Plage de Sante-Cecile. Figure 5 shows the approximate location of each item found and the final known position of G-EGVA.

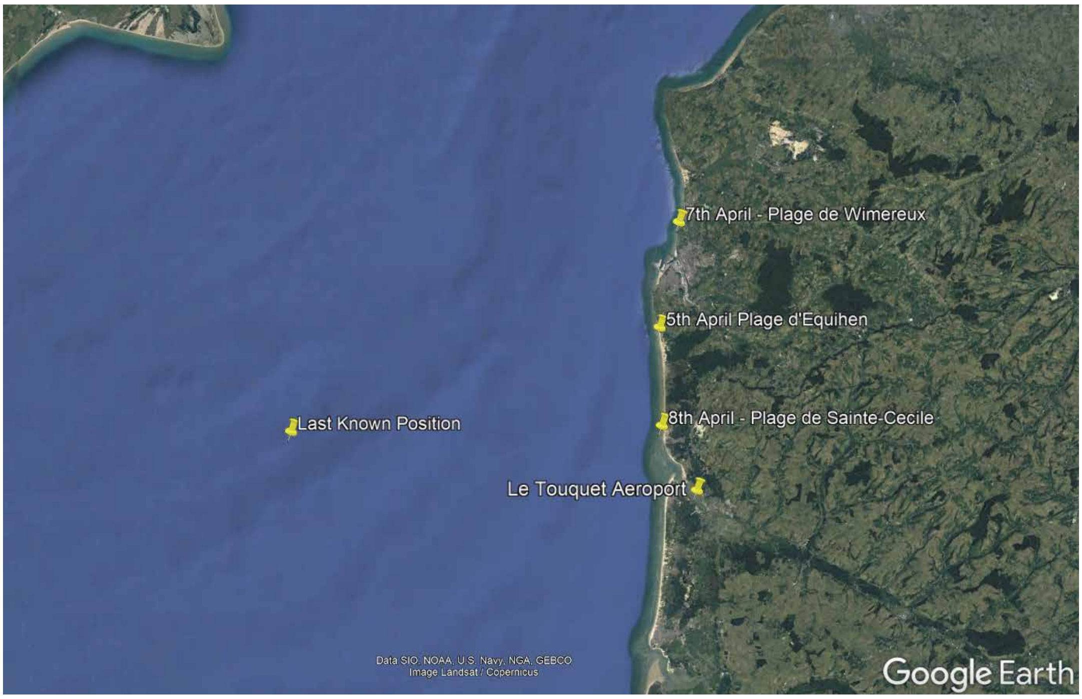


Figure 5

Location of items found on the French coastline

Radar data

Secondary surveillance radar data for G-EGVA and the nearest two aircraft of the 'fly-out' is shown in Figures 6 and 7. Figure 6 shows part of the ground track of these aircraft to the point when radar contact was lost with G-EGVA at 0916:31 hrs. Figure 7 shows the reported altitudes for these aircraft, corrected for the QNH of 1022 hPA. Indicated on both these figures is the point at which G-EGVA descended from its cruise altitude of about 5,000 ft amsl, and on Figure 7 the corresponding time when the two following aircraft were abeam this point.

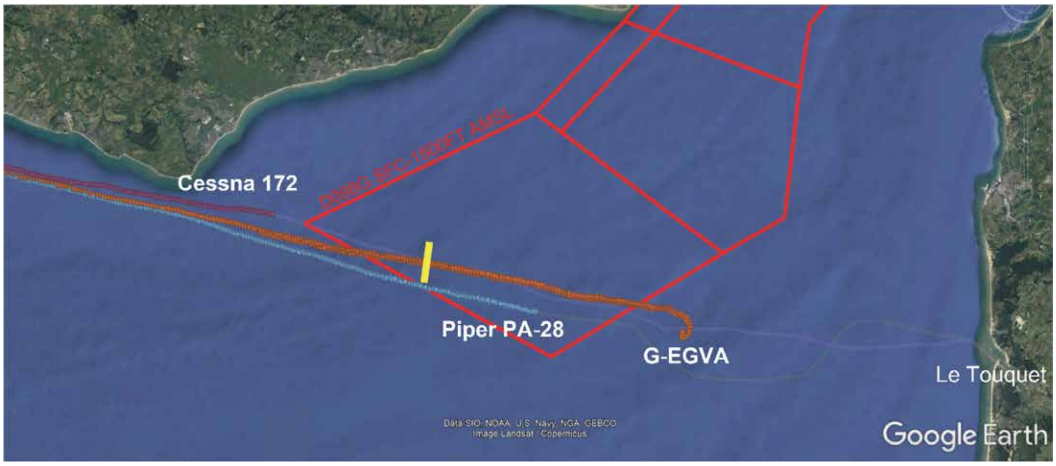


Figure 6

Radar track of G-EGVA up to the last know position at 0916 hrs with the location of two of the following aircraft shown. The yellow line on the G-EGVA's track is the point at which G-EGVA descended from its cruise altitude

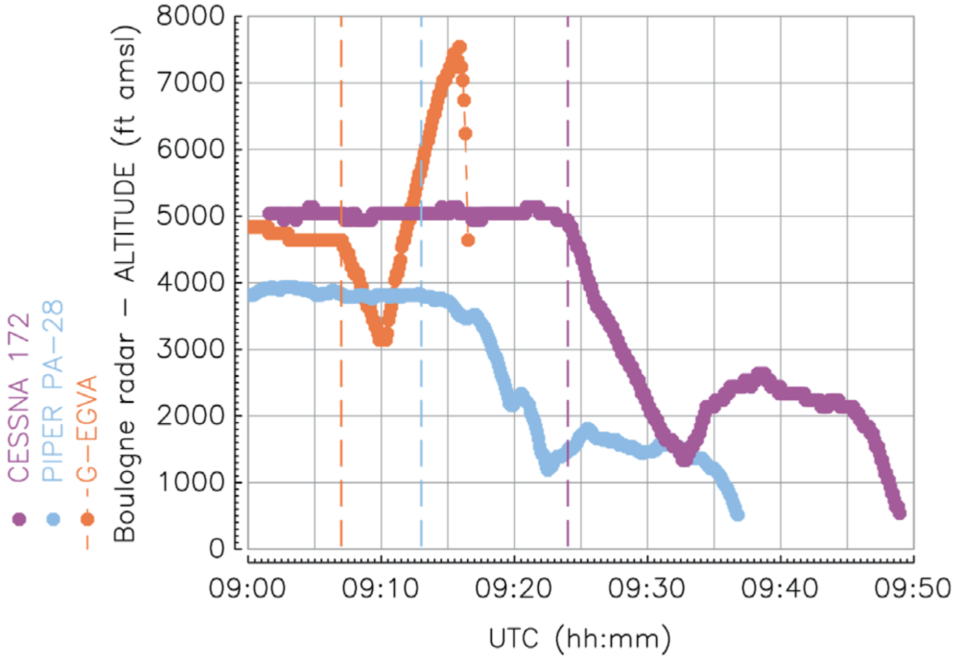


Figure 7

Altitude trace of G-EGVA and the following aircraft from 0900 hrs. The dashed line for G-EGVA shows when it descended from its cruise altitude – the corresponding dashed lines for the other aircraft show when they were abeam this point

Figure 8 is a plot of the altitude and radar-derived data for G-EGVA starting just before the descent from the cruise altitude. The plot shows that the aircraft descended to about 3,000 ft at approximately 500 fpm, where it remained for 30 seconds before climbing to over 7,000 ft at about 1,000 fpm, while maintaining an easterly track. Over the next 50 seconds the aircraft climbed 400 ft, descended 200 ft, and then climbed 300 ft, and at the same time turned right, left, and right again through a total of 50°. The aircraft then continued to turn to the right in a descent. Radar contact was lost 40 seconds later as the aircraft descended through 4,600 ft with a calculated descent rate of just under 10,000 fpm. The last recorded position was 50°34’23.49” N 001°04’11.23” E at 0916:31 hrs.

Figure 8 also shows when the last radio transmissions between London Information and G-EGVA were made. G-EGVA was descending through 7,000 ft at about 3,000 fpm and accelerating during its final transmission.

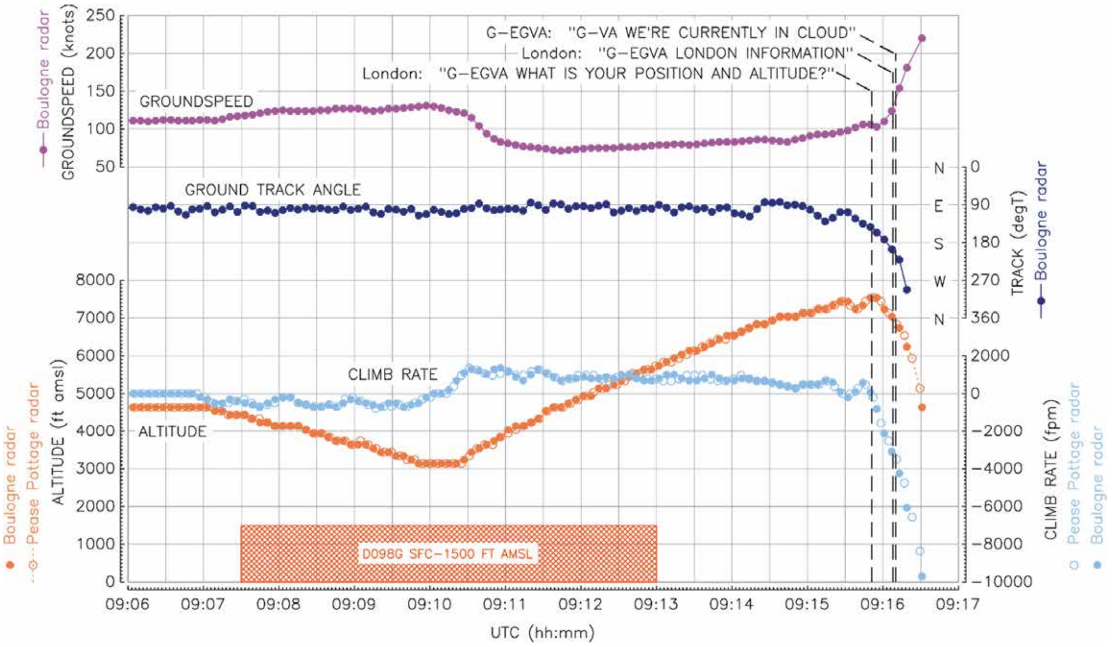


Figure 8

Altitude and radar-derived data for G-EGVA

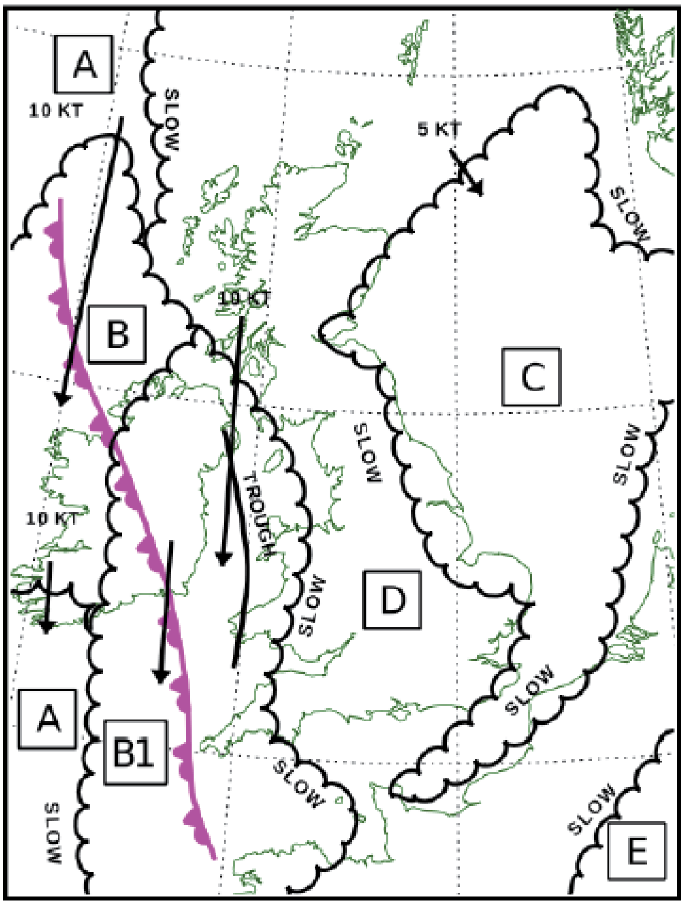
Airspace

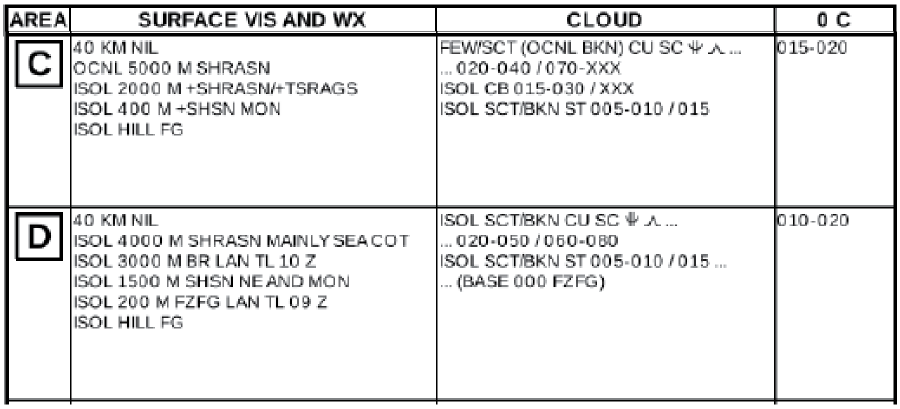
On the 2 April 2022 a Danger Area was active in the English Channel within which flight below 1,500 ft amsl was prohibited. The Danger Area is shown in Figures 6, 8 and 12. In the same area Class A controlled airspace exists above FL75. Therefore, as G-EGVA crossed the Channel, the aircraft was limited to flight between 1,500 ft amsl and FL75.

Forecast weather

On the 2 April 2022 a generally slack pressure pattern existed across the UK in association with high pressure. A convergence line lay from the Dover Strait to Le Mans, France.

An extract from the Met Office UK low-level forecast chart (F215) issued on the morning of the 2 April 2022 is shown in Figure 9. The forecast was valid between 0200 hrs and 1100 hrs. Initially the flight would have been in Area D. The conditions were forecast to be generally 40 km visibility with scattered or broken (SCT/BKN) cloud with a base between 2,000 and 5,000 ft amsl. However, there would be isolated (ISOL) patches of mist (BR) reducing visibility to 3,000 m at times, with a further risk of visibilities reducing to 200 m in freezing fog (FZFG) until 1000 hrs. Associated with this there would be scattered or broken (SCT/BKN) cloud with a base between 500 and 1000 ft, lowering to the surface at times in fog.





AREA	SURFACE VIS AND WX	CLOUD	0 C
C	40 KM NIL OCNL 5000 M SHRASN ISOL 2000 M +SHRASN/+TSRAGS ISOL 400 M +SHSN MON ISOL HILL FG	FEW/SCT (OCNL BKN) CU SC Ψ ⋏ ... ... 020-040 / 070-XXX ISOL CB 015-030 / XXX ISOL SCT/BKN ST 005-010 / 015	015-020
D	40 KM NIL ISOL 4000 M SHRASN MAINLY SEA COT ISOL 3000 M BR LAN TL 10 Z ISOL 1500 M SHSN NE AND MON ISOL 200 M FZFG LAN TL 09 Z ISOL HILL FG	ISOL SCT/BKN CU SC Ψ ⋏ ... ... 020-050 / 060-080 ISOL SCT/BKN ST 005-010 / 015 ... ... (BASE 000 FZFG)	010-020

Figure 9

Extracts from the Met Office F215 valid 2 April 2022 between 0200 – 1100 hrs

On reaching the South Coast and the English Channel, the flight moved into Area C. Again, general conditions were expected to be 40 km visibility, with few or scattered, occasionally broken (FEW/SCT (OCNL BKN)) cloud with a base between 2,000 ft and

4,000 ft. Due to the convergence line occasional (OCNL) showers of rain and snow (SHRASN) were forecast to reduce visibility to 5,000 m in places. This would reduce further in isolated (ISOL) heavy rain and snow showers or thunderstorms with small hail or snow pellets (+SHRASN/+TSRAGS) and be associated with severe icing and turbulence. The heavier showers were expected to be generated by cumulonimbus (CB) cloud with a base between 1,500 ft and 3,000 ft.

The 0°C isotherm was forecast to be between 1,000 ft and 2,000 ft.

Actual weather

Satellite images taken at half hour intervals between 0800 hrs and 0930 hrs on 2 April 2022 are shown in Figure 10. The images show small amounts of cloud across mainland southern England, with clearer skies across the south-east. A band of cloud lay through the Dover Strait into northern France at 0800 hrs, moving slightly westwards through this time period. The white colour of the cloud in the imagery indicates higher cloud tops which, along with the shape of the cloud structure, suggests showery activity.

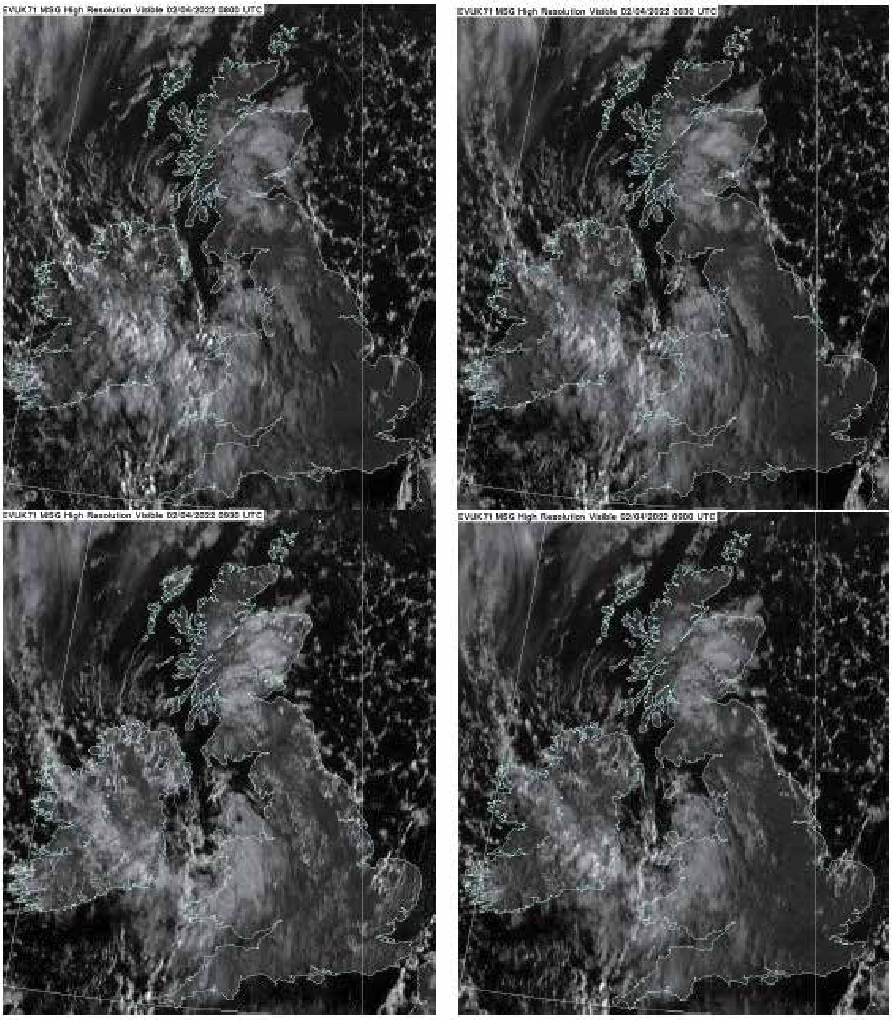


Figure 10

Satellite Imagery between 0800 hrs and 0930 hrs on 2 April 2022

Figure 11 shows four radar images between 0800 hrs and 0930 hrs on 2 April 2022. These show dry conditions across central and southern England. A band of showers is shown lying through the Dover Strait, which ties in with the cloud structure observed in satellite imagery. The colouring of the radar returns suggests some heavy precipitation to the west of Le Touquet around 0900 hrs.

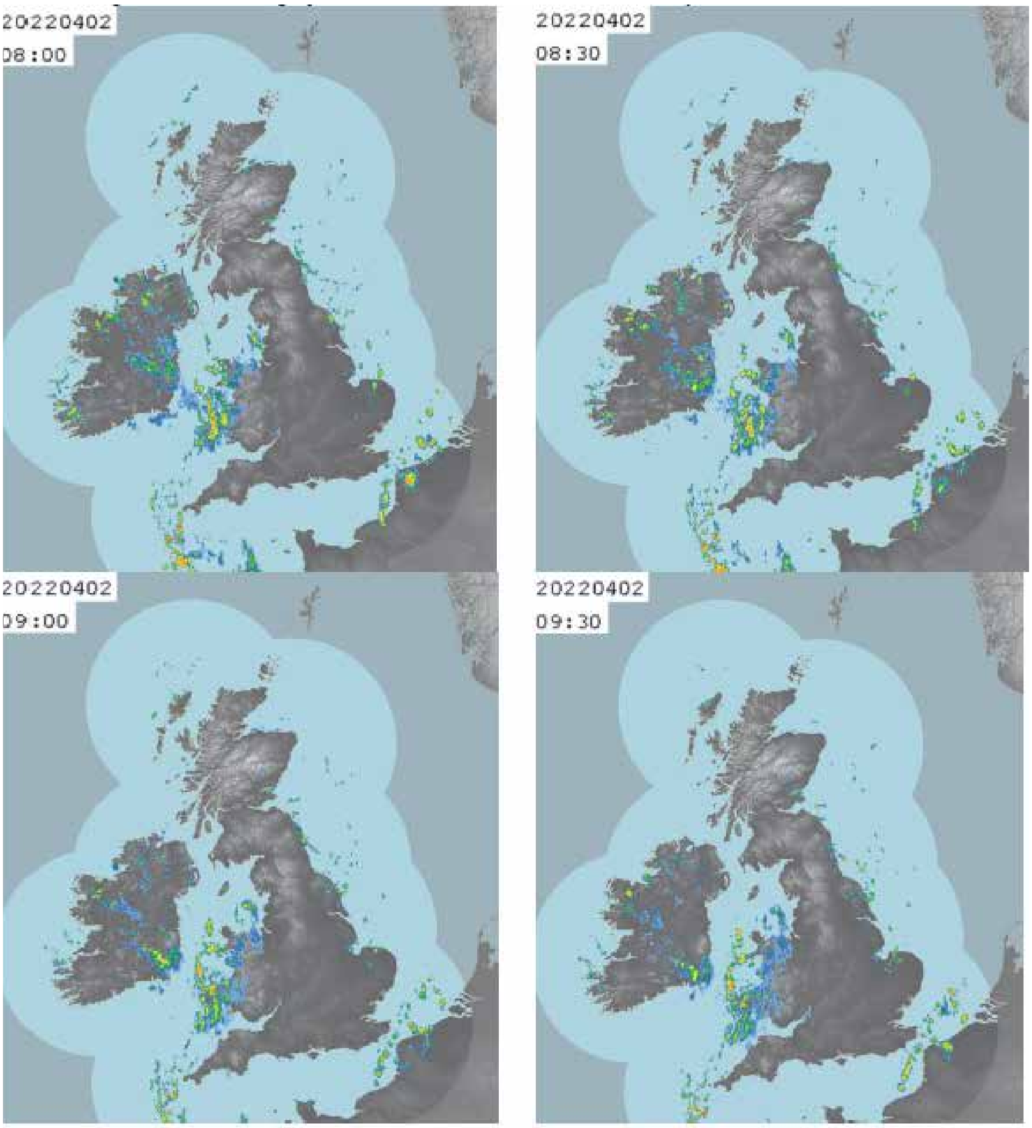


Figure 11

Radar imagery between 0800 hrs and 0930 hrs on 2 April 2022

Figure 12 shows the radar track of G-EGVA and the two following aircraft overlaid on the 0900 hrs weather radar image.

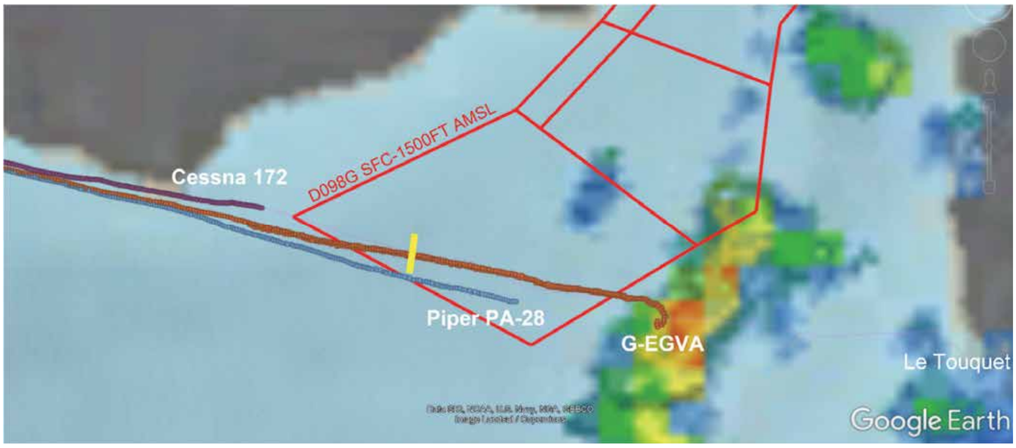


Figure 12

Aircraft tracks at 0916 hrs overlaid on the 0900 hrs weather radar image
(the Danger Area described in the NOTAM is shown in red outline)

Pilot information

Both pilots held a Private Pilot's Licence with a valid Single Engine Piston rating and had completed the complex aircraft training required to fly G-EGVA. They had both learnt to fly at the flying club in 2010 and since qualifying had flown together often. The two pilots had taken part in club 'fly-outs' together before, including to Le Touquet, when typically, one of them would fly the outbound leg and the other would fly the return.

Neither pilot held an instrument rating or IMC qualification. The right seat pilot held a night rating.

The left seat pilot's logbook showed a total of 200.4 flying hours. He had flown two previous flights in 2022; one on 23 March (0.7 hours) which was in G-EGVA and included three takeoffs and landings, and one on 11 February (0.6 hours) in a Cessna 152. He had flown 4 flights in 2021, totalling 3.6 hours, including a recency flight with an instructor. He held a valid Class 2 medical.

The flying club's records indicated the right seat pilot had 167.2 flying hours. He had also flown two previous flights in 2022, totalling 1.4 hours, both flights were in a Cessna 152. He had flown a total of 14.1 hours in 2021. He held a valid Class 2 medical.

The families of both the pilots reported that they were fit and well prior to the flight and were well rested.

Passengers who had flown with the pilots on a previous trip to Le Touquet reported that they had briefly entered cloud during that flight, but on that occasion the aircraft had continued without incident.

Aircraft information

The PA-28R-200-2 Cherokee Arrow II is a four-seat, single-engine aircraft of metallic construction with retractable landing gear. G-EGVA was equipped with a Lycoming IO-360-C1C four cylinder, horizontally opposed, fuel-injected engine.

G-EVGA's Airworthiness Review Certificate was valid until 21 March 2023. The most recent maintenance was an annual inspection carried out between 14 February 2022 and 23 March 2022. Since then, it had flown 6 hours over 10 flights. Prior to the accident flight the aircraft had accumulated 2,886 flying hours. There were no open or deferred defects recorded in the aircraft's technical log.

The aircraft was fitted with an active carbon monoxide detector. Maintenance records indicate that during the recent annual inspection the function and condition of the detector and its batteries were checked, and the aircraft was inspected for evidence of carbon monoxide contamination; none was noted.

G-EGVA's seat covers and cushions had been replaced during previous maintenance in October 2021. The front seats were equipped with a three-point harness comprising a lap strap and a diagonal shoulder harness.

Fuel

Airfield and flying club records suggest that G-EGVA had approximately 38 USG of fuel onboard when it took off from Wellesbourne. The aircraft normally used approximately 11 USG per hour so it would have contained approximately 23 USG when the accident occurred.

Aircraft seat examination

The seat recovered from the French coast (Figure 13) was examined at the AAIB. No part number or serial numbers were evident on the seat, but the style and branding of the seat covers matched those of the new leather seat covers that had recently been fitted to G-EGVA. It was identified as being one of the rear seats.

The seat cover exhibited minor scuffing and several small tears but was otherwise in good condition. The lower seat frame was severely distorted, and the forward left mounting point had separated from the frame.

Figure 13

Seat recovered from G-EGVA

Initial findings

On the day of the accident an area of convective cloud was forecast in the English Channel which crossed the route planned by G-EGVA. The forecast suggested that isolated heavy rain and snow showers or thunderstorms were to be expected with a cloud base between 1,500 ft and 3,000 ft and associated with severe icing and turbulence.

Met Office weather radar data from the time of the accident confirmed heavy precipitation in the Channel suggesting a highly active convective area. Photographs taken by other aircraft in the area at the time showed waterspouts descending from the cloud and cloud down to the surface, again confirming a highly active convective area.

The video posted on social media by the right seat pilot of G-EGVA showed the aircraft at 5,000 ft with cumulus cloud visible ahead. Radar recordings show that after this time the aircraft descended to approximately 3,000 ft then climbed to above 7,000 ft whilst continuing on a constant heading towards the cloud. It is not possible to know the pilots' intentions but these changes in altitude might have been an attempt to avoid cloud. Once reaching 7,000 ft they were unable to climb any higher due to the controlled airspace above.

Shortly after reaching 7,000 ft the radio transmission from the aircraft confirmed the aircraft had entered cloud. Neither occupant was qualified to fly in cloud. It is not known if they entered cloud inadvertently. The video recording from G-EGVA and the photographs from the other aircraft show the cloud was clearly defined and visible when several miles away. So, there should have been sufficient time to turn around if they were unable to route around the cloud. It is possible that the occupants' previous experience of flying through cloud without incident encouraged them to try to fly through it on this occasion.

It is not known exactly when the aircraft entered cloud. However, in the couple of minutes before the aircraft was lost from radar, the aircraft started to vary its heading and altitude before descending in a steepening right turn. The forecast severe turbulence and icing in cloud may have contributed to the departure from controlled flight. When the last radio transmission was made, the aircraft was descending through 7,000 ft at approximately 3,000 fpm. At the last radar point the aircraft was passing 4,600 ft and descending at just under 10,000 fpm.

Initial assessment indicated that the damage sustained by the seat recovered from G-EGVA and its liberation from the aircraft were consistent with the airframe having been subject to considerable forces and substantial disruption.

Safety message

The evidence available to date indicates that control of the aircraft was lost when it entered a highly active cumulus cloud, which had been forecast. Neither occupant was qualified to fly in IMC. It is likely the aircraft was substantially damaged on impact with the sea.

Planning

It is very dangerous to enter cloud when not suitably qualified or when not in current practice in instrument flying. The AAIB has investigated numerous accidents when control of an aircraft was lost after intentionally or inadvertently entering cloud in these circumstances[1]. The CAA's Safety Sense leaflet – *'Pilots - it's your decision!'*[2] contains advice on weather decision making. The document contains the following comment about loss of control in IMC:

> *'More than three quarters of the pilots killed when they lost control in IMC were flying in instrument conditions without an instrument qualification. Disorientation can affect anyone, particularly those who have not been adequately trained to fly on instruments and kept in practice. It is important to be able to see and recognise cloud ahead early enough to avoid it safely. Even an IMC rating does not impart sufficient skill for prolonged, intentional flight in instrument conditions. Unless you are in regular instrument flying practice it should only be regarded as a minimum skill to 'get out of trouble' if an unintentional excursion into IMC occurs.'*

Footnote

[1] Recent AAIB reports include G-CCPV, G-BHFI, G-OPEN and G-WAVS.

[2] Available at https://publicapps.caa.co.uk/docs/33/20130121SSL23.pdf [accessed 6 May 2022]

The CAA '*Skyway Code*' (CAP1535[1]) contains further guidance on pre-flight weather decision making, including the following guidance for avoiding loss of control caused by inadvertently flying into cloud:

> *'When there is either frontal convective or foggy weather around, it can be hard to predict exactly what conditions at a certain point will be. Study the weather carefully and consider options in different scenarios should the weather be worse than anticipated – calculate altitudes that if forced below by weather, you will turn back or divert.*
>
> *Do not succumb to the belief that the 'weather is never as bad as forecast' – while that is sometimes the case, it is very often the exception that breaks the rule and causes the accident.*
>
> *Decision making is generally easier on the ground away from the additional pressure of flying the aircraft – it is tempting to get airborne to 'have a look', but this could suck you into commencing a flight when it is not safe to do so.*
>
> *If faced with a decision to be made in the air, do so within the parameters you set for yourself at the start of the flight – it is no good calculating a safety altitude if once in flight you think 'oh I'm sure descending a few hundred feet further will be OK'.'*

Survivability

The radar evidence suggests the aircraft struck the water with a high rate of descent and the damage to the seat which was found suggests the aircraft was subjected to considerable forces and substantial disruption. It is therefore unlikely that the occupants had any opportunity to escape from the aircraft.

The video posted on social media showed that both occupants were wearing lifejackets. It appears to show that both occupants were wearing their shoulder harnesses under their lifejackets. This suggests that they secured their seatbelts before donning their lifejackets. When donning a lifejacket after securing a seatbelt there is a risk of becoming entangled in the belt when trying to rapidly exit the aircraft. The CAA Safety Sense Leaflet – '*Ditching*'[2] contains guidance on the use of lifejackets.

Further work

The investigation continues to examine operational, technical, and human factors which might have contributed to this accident.

Based on the other sources of available evidence regarding the accident flight, the AAIB does not currently intend to conduct an underwater search for, or recover, the aircraft

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Footnote

[1] Available at http://www.caa.co.uk [accessed 6 May 2022]

[2] Available at https://publicapps.caa.co.uk/docs/33/20130121SSL21.pdf [accessed 6 May 2022]

wreckage. Should any additional items of wreckage become available during the course of the investigation, they will be examined by the AAIB.

A final report will be issued in due course.

Published: 13 May 2022.

AAIB Field Investigation Reports

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

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

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

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A319-131, G-DBCF	
No & Type of Engines:	2 International Aero Engine V2522-A5 turbofan engines	
Year of Manufacture:	2005 (Serial no: 2466)	
Date & Time (UTC):	6 August 2021 at 0935 hrs	
Location:	During climb from Edinburgh Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 5	Passengers - 101
Injuries:	Crew - None	Passengers - None
Nature of Damage:	No damage	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	55 years	
Commander's Flying Experience:	16,651 hours (of which 4,476 were on type) Last 90 days - 43 hours Last 28 days - 26 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a flight from Edinburgh Airport to London Heathrow the autopilot and autothrust disconnected. After several minutes the flight crew were able to re-engage them but they disconnected again during the approach. The aircraft landed safely.

The autopilot and autothrust disconnects were caused by severe drift of the aircraft's Inertial Reference System due to vertical shock loads transferred into the system during the takeoff roll. The source of the shock loading was an uneven repair patch on the runway. The nose landing gear shock absorber was found to be over extended, leading to transfer of vertical shock forces into the airframe.

The aircraft manufacturer had investigated previous similar events and published guidance to maintenance organisations but had not published information to flight crew.

History of the flight

The aircraft was scheduled to operate from Edinburgh Airport to London Heathrow Airport. The aircraft departed Edinburgh at 0907 hrs and took off from Runway 06 at 0918 hrs with the commander as pilot flying. The commander described the takeoff as "normal except for a loud bang created by passing over, what felt like, a centreline light on the takeoff roll". During the initial climb, passing approximately 1,500 ft, the co-pilot saw a GPS PRIMARY

LOST message on his MCDU[1], but the message disappeared before the crew could take any action.

The rest of the climb was normal until the aircraft reached FL340 when the co-pilot saw a CHECK IRS 3/FM POSITION message on his MCDU. Shortly after this the autopilot and autothrust disconnected and the flight directors were no longer displayed. The Electronic Centralized Aircraft Monitoring (ECAM) showed AUTO FLT AP OFF, AUTO FLT A THR OFF and ENG THRUST LOCK messages, the Flight Mode Annunciator was blank and the status showed CAT 3 DUAL INOP.

The commander manually levelled the aircraft at FL350. The crew were concerned they could no longer comply with RVSM[2] requirements as the autopilot had failed, so the co-pilot made a PAN call to ATC. There were no other ECAM messages, warning lights or other indications on the flight deck to explain what had happened. The co-pilot confirmed that none of the flight deck circuit breakers had tripped. Initial attempts to restore the autopilot and autothrust were unsuccessful but, after approximately 5 minutes of manual flight, they were able to re-engage them.

The crew conducted a diagnosis, review, and decision-making process to decide how to proceed. As they attempted to diagnose the problem, they noticed that the Inertial Reference System (IRS) positions shown on the MCDU position monitor page were abnormal. At one point the positions were showing as IRS 1 NAV '- -', IRS 2 NAV '31.0', IRS 3 NAV '31.0',[3] but they were all changing over time with all three showing either '- -', greater than 30, or something sensible at different times. Normally, the difference between the three IRS readings would be less than 1 nm. Due to the uncertainty over their position the crew asked ATC for radar vectors but decided they could safely continue to Heathrow. They considered realigning the IRS in flight but, as there were no ECAM messages directing them to do this, they decided not to[4]. They also considered that the aircraft was currently in a safe state and thought that attempting a realign could make the situation worse.

The aircraft continued to Heathrow. The crew briefed for the approach and discussed the expected indications at each stage so they would detect any further instrumentation failures. They requested an extended final approach to make it easier to monitor the aircraft. The approach proceeded normally with the autopilot engaged until approximately 4,000 ft when the aircraft was on an intercept heading for the Runway 27R localiser. At this point the autopilot and autothrust disconnected again and flight directors were no longer displayed. The crew discontinued the approach and re-briefed for a manually flown raw data approach. The subsequent manually flown approach was uneventful and the aircraft landed normally with no further abnormal indications.

Footnote

[1] MCDU (Multipurpose Control and Display Unit) is the keyboard and screen used by the flight crew to interact with the flight management computer.

[2] RVSM (Reduced Vertical Separation Minima) allows aircraft to operate with reduced vertical separation. Among other requirements, the rules require a functional autopilot capable of holding altitude.

[3] The numbers show the difference between each IRS position and the flight management systems calculated position (in nautical miles).

[4] The aircraft manufacturer commented that "IRS alignments are not allowed while the aircraft is in flight. In case of realignment of more than one IR the A/P and A/THR will be lost and a reversion of the F/CTL law to alternate or direct will occur. In the aircraft operational documentation (FCOM/FCTM/QRH), there is no procedure that requests the flight crew to re-align, in flight, the IRS in NAV mode."

Recorded information

The operator provided flight data from the Quick Access Recorder (QAR) for the incident. However, the CVR was overwritten as the aircraft remained in service for five days before the AAIB was notified of the event.

The QAR data confirmed that, as the aircraft accelerated through 120 kt on the takeoff roll and without any significant flying control inputs, the weight-on-wheels signal for the nose landing gear (NLG) changed state three times within two seconds, indicative of having encountered irregularities in the runway's surface.

A post-flight report showed that, after encountering the runway surface irregularities, the IRS positions began to drift resulting in the autoflight system rejecting the input from one of the ADIRUs[5] at 0928 hrs, as the aircraft climbed through FL265. This, and another minor degradation caused by the increasing drift that affected the aircraft's braking system, were not annunciated to the crew. However, at 0932 hrs, as the aircraft neared the top of climb, the autoflight system rejected all three IRS positions causing the autopilot and autothrust to disconnect. The recorded data also confirmed that, although the IRS positions were affected, the ADIRUs continued to provide valid attitude and air data parameters.

The manufacturer's analysis of the data showed that at 0936 hrs, and again at 0941 hrs, a NAV FM/GPS POS DISAGREE ECAM message was displayed for approximately 7 seconds. This indicated a disagreement in position information between the Flight Management and Guidance Computer (FMGC) position and GPS position but the data then showed an improvement in the FMGC positions. Position information from each ADIRU then remained consistent until 1006 hrs when it once again deteriorated. At 1015 hrs, as the aircraft was on approach to Heathrow descending through 5,100 ft amsl, the autoflight system rejected data from more than one ADIRU, which resulted in the disconnection of the autopilot and autothrust.

Previous history

The operator had experienced five previous similar incidents on their Airbus A320 fleet (G-EUPY 6 August 2020, G-EUPN 1 July 2020, G-EUUV 4 October 2019, G-EUXD 11 August 2018 and G-EUUH 1 September 2017). The manufacturer reported that another operator, operating elsewhere, had also reported several similar incidents. The manufacturer's investigation showed that all these incidents occurred on aircraft fitted with Northrop Grumman Corporation (NGC) ADIRUs standard-0316/318. NGC ADIRUs have not been fitted to new aircraft since 2015, and there were 1,459 aircraft in service fitted with these units (approximately 14% of the A320 fleet).

To investigate the issues the manufacturer installed accelerometers on the NLG and the ADIRU mounting rack on several aircraft to measure the vertical forces through the NLG during taxi, takeoff, and landing. The ADIRU rejections and drift were found to be induced by abnormal levels of vibration or shock loads transmitted through the NLG to the ADIRU during the takeoff roll and rotation. The manufacturer concluded that the IRS drifts were

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Footnote

[5] ADIRU - Air Data and Inertial Reference Unit – the system is described in detail later in this report

likely to have been caused by a combination of specific inputs: vertical loads from the runway surface to the NLG, incorrect servicing of the NLG shock absorber and the ADIRUs, suffering vertical shocks when operating outside their qualification envelope.

In April 2020 the manufacturer issued a Technical Follow Up (TFU) notice titled *'In-flight severe IR drift with ADIRU NGC PN 465020-030x-0316/318 inducing possible loss of AP/FD and ATHR'* to inform operators' maintenance teams of the potential for severe drift issues and the procedure for investigating occurrences.

Aircraft examination

After landing, a maintenance team met the aircraft and conducted an inspection and service of the NLG in accordance with Troubleshooting Manual (TSM) 32-20-00-810-802 - *'Vibrations felt on the NLG during Takeoff and Lift-off Phases'* as recommended in the TFU. The team focussed on the TSM subtasks related to the NLG shock absorber which was found to be overextended by 0.6 inches.

Air data and inertial reference system (ADIRS)

System operation

The ADIRS provides anemometric, barometric, temperature and inertial parameters to the flight deck instruments and other systems. The ADIRS includes three identical ADIRUs each of which combines an Air Data Reference (ADR) and an IRS into a single unit. Although combined within a single unit, both the ADR and IRS can operate independently in case of failure of the other. The ADR uses the pitot-static, angle of attack and temperature sensors to provide parameters such as barometric altitude, Mach number, airspeed, outside air temperature, angle of attack and overspeed warning data to the aircraft systems. The Inertial Reference (IR) consists of gyroscopes and accelerometers which provide acceleration information along three axis, longitudinal, lateral, and vertical. During flight, acceleration data along each axis is resolved to provide navigation information such as aircraft track, acceleration, flight path vector, ground speed and aircraft position. The IR gyroscopes provide angular rates, heading and aircraft attitude data. The three ADIRUs fitted to G-DBCF each supplied data for the FMGC and the Flight Augmentation Computer (FAC), (Figure 1).

Once the ADIRU data is processed by the FMGC, the calculated parameters are used by the Flight Management (FM) and Flight Guidance (FG) systems. The FM system provides navigation and management of navigation radios, management of flight planning, prediction and optimisation of performance and display management. The FG system provides autopilot, flight director and autothrust commands.

Information processed by the FAC controls the rudder, rudder trim and yaw damper inputs. The FAC also computes flight envelope data and speed functions.

The processed outputs of each ADIRU are supplied to the commander, co-pilot and back-up cockpit displays.

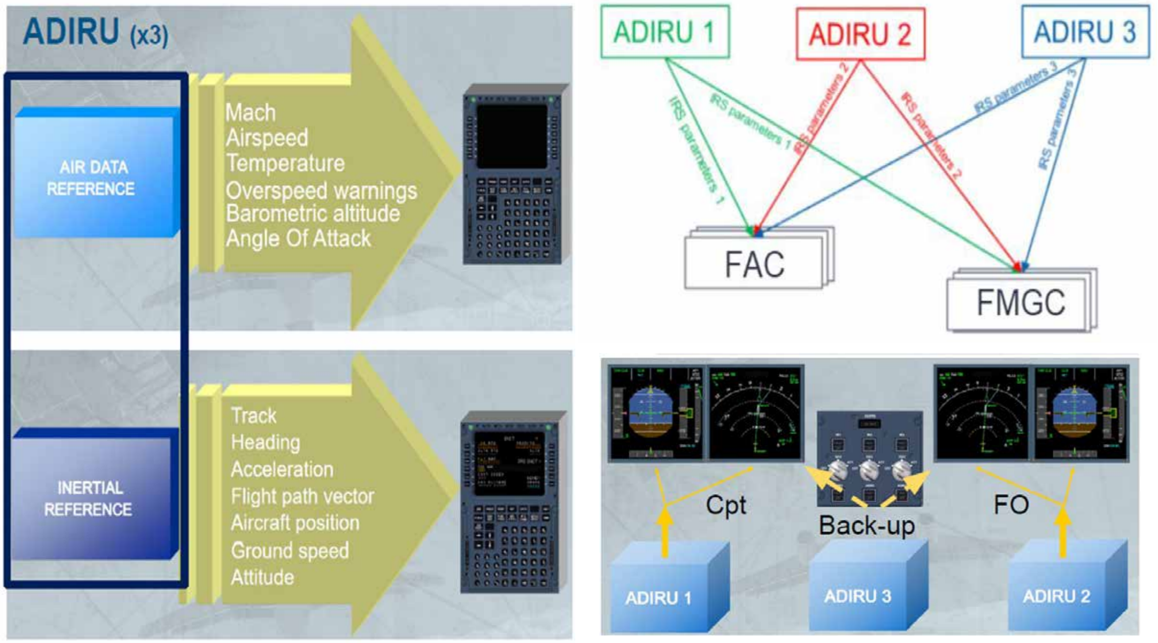


Figure 1

ADIRU data outputs, and FMGC and FAC connectivity

IRS faults

The accuracy of the output parameters of the three IRs are compared and monitored by the FMGC and FAC to detect errors. Should a parameter from one IR exceed a given error threshold, it is rejected. Table 1 shows the result of IR rejections by the FMGC and FAC, the subsequent error messages displayed and, if more than one IR rejected, the systems which are lost[6].

FMGC (FG)
The consequences of IR rejection by FMGC are the following:

- Only 2 IRs valid ➜ CAT 3 DUAL INOP
- Less than 2 IRs valid ➜ AP, FD, ATHR losses

FAC:
The consequences of IR rejection by FAC are the following:

- Only 2 IRs valid ➜ CAT 3 DUAL INOP
- Only one IR valid ➜ If IR opp valid: Loss of AP, FD, A/THR, RTL, SPD LIM, YD
  ➜ If IR 3 valid: AP loss only
- If 3 IRs are rejected ➜ Loss of AFS, RTL, SPD LIM, YD and Normal Law

Table 1

Consequences of IR rejection by FMGC and FAC

Footnote

[6] AP (Autopilot), FD (Flight Director), A/THR or ATHR (Autothrust), SPD LIM (Speed Limiter), YD (Yaw Damper), RTL (Rudder Travel Limiter), AFS (Automatic Flight System).

Severe IR drift

When an IR is affected by severe drift, the IR is rejected by the AFS and an alert message is triggered. The level of positional drift experienced can be observed on the MCDU and gives the pilot an indication of which IRs are drifting and how far. During these fault conditions, aircraft position, ground speed (GS) and drift angle (DA), can go out of tolerance causing a NAV IR 1(2)(3) FAULT to be generated, usually during final approach and landing. If the DA exceeds 90°, the IR will be classified as failed and an ECAM warning of NAV IRS 1(2)(3) FAULT generated. During flight, the aircraft's navigated position is compared with its GPS position and will generate GPS PRIMARY LOST and NAV FM/GPS POS DISAGREE messages under severe drift conditions. When GS from the IRs exceeds threshold values, the aircraft's automatic braking system also reverts to manual braking.

ADIRU installation and transmitted shock loads

The aircraft's three ADIRUs were fitted to an avionics rack located immediately aft and above the NLG bay (Figure 2). There was no anti-vibration mounting for the rack or the ADIRUs, so any vertical shock transmitted through the NLG would be transferred to the airframe and avionics rack.

As the NLG incorporates a shock absorber, when operating within its normal operating limits of travel a significant proportion of the vertical forces experienced by the NLG when traversing along runways, landing and taking-off are absorbed and dissipated. Only a fraction of this force is transferred to the airframe. When the NLG shock absorber is over or under extended, less energy can be dissipated and the proportion of forces transferred to the airframe is increased.

During takeoff from Edinburgh, the aircraft experienced a sharp vertical jolt and the NLG weight-on-wheels proximity sensors toggled on and off as the wheels crossed an uneven patch of the runway surface.

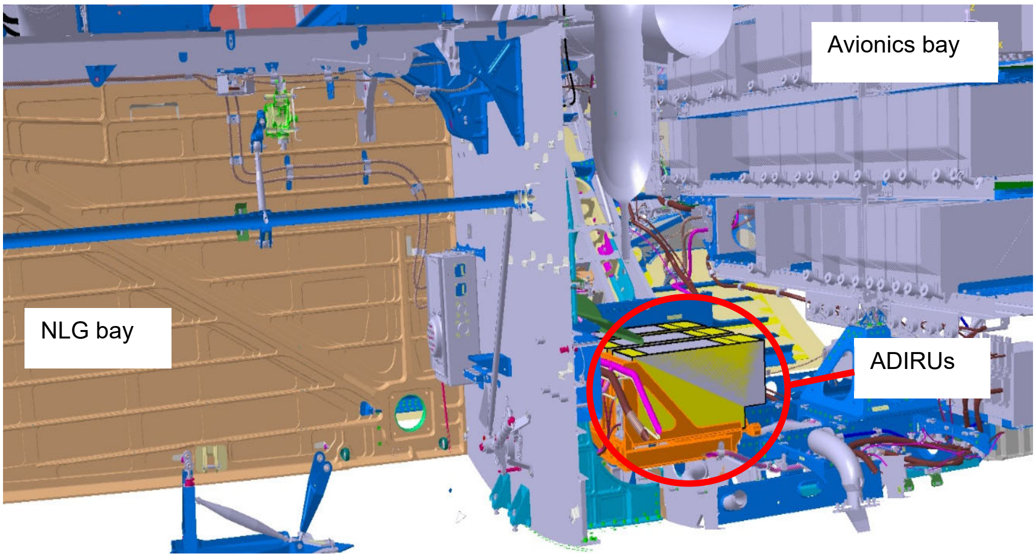


Figure 2

ADIRUs location

ADIRU environmental qualification

During aircraft development, the ADIRU was qualified in accordance with the environmental qualification requirements detailed in the Radio Technical Commission for Aeronautics (RTCA) DO-160C. This contains 23 environmental test procedures including Section 7 – *'Operational shocks and crash safety'*[7] which states:

> *'The operational shock test verifies that the equipment will continue to function within performance standards after exposure to shocks experienced during normal aircraft operations.*
>
> *These shocks may occur during taxiing, landing or when the aircraft encounters sudden gusts in-flight. This test applies to all equipment installed on fixed-wing aircraft and helicopters. Two operational shock test curves are provided: A standard 11 ms pulse and a low frequency 20 ms pulse. The 20 ms pulse may not be adequate to test against the effect of longer duration shocks on equipment that have its lowest resonance frequency (as per section 8 – 'Vibration') below 100 Hz. For such equipment, a pulse of 100 ms duration should be considered.'*

Section 7 was further divided into categories (Cat) A to D. Cat A contains tests for standard operational shocks (using shock test curves) and Cat B adds crash safety[8] to Cat A. Cat C tests for resistance to low frequency shocks and Cat D added crash safety to Cat C. Shock testing is performed by strapping a piece of equipment to a shock table and measuring shock pulses using an accelerometer.

The aircraft manufacturer stated that it was exploring how to enhance ADIRU qualification procedures to be more robust to abnormal conditions such as those encountered by G-DBCF.

NLG shock absorber

Design of the NLG shock absorber

The NLG shock absorber is an oleo-pneumatic telescopic strut arrangement with no separator piston, (Figure 3), that uses a chamber filled with compressed nitrogen gas to act as a spring to absorb the shock of aircraft landing gear vertical forces.

It also has a second chamber filled with hydraulic oil that provides damping to reduce the harmonic effect of the spring. The combination of the nitrogen spring and oil damper provides efficient shock absorption and is a common feature in large aircraft landing gears.

Footnote

[7] https://do160.org/operational-shocks-and-crash-safety/ [accessed 28 January 2022].

[8] Crash safety describes tests to determine that equipment does not detach from its mountings or pose a hazard to occupants, fuel systems or emergency evacuation equipment during an emergency landing.

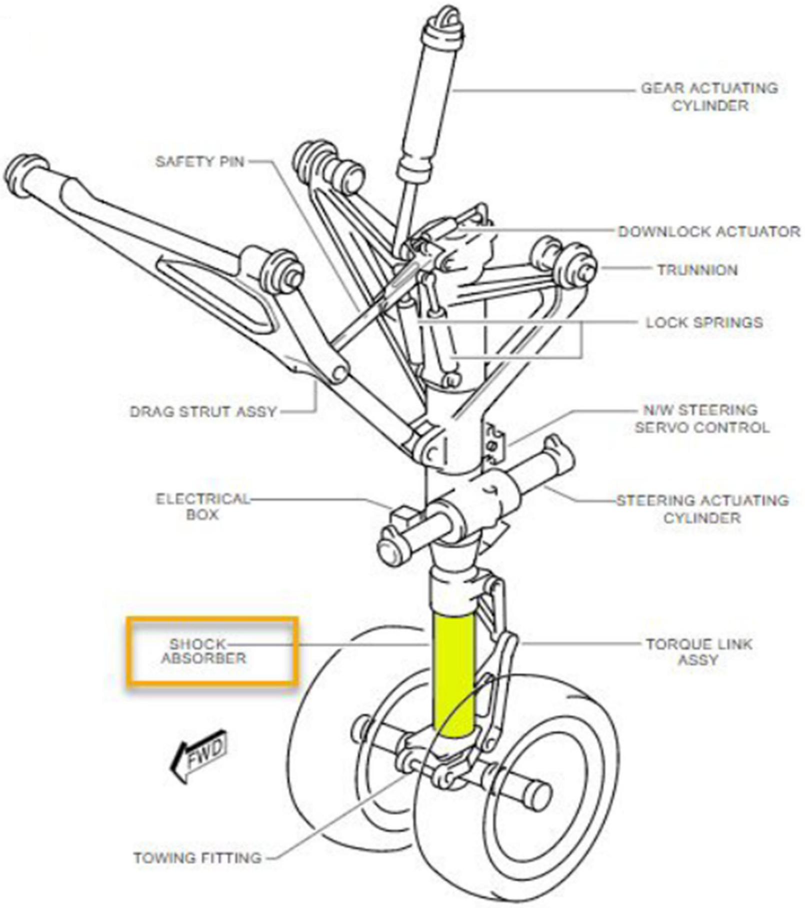


Figure 3

NLG diagram showing shock absorber cylinder

Shock absorption efficiency relies upon the balance of oil and nitrogen to ensure the shock absorber deflects within a specific range to maintain absorption efficiency. If the balance of either substance is incorrect, the shock absorber will not be able to absorb and dissipate vertical forces effectively. The result is an increase in vertical shock loads transferred to the airframe.

Servicing the NLG shock absorber

Several instances of incorrect NLG servicing had previously been reported to the manufacturer by more than one operator, indicating a potentially problematic maintenance procedure. Consequently, in 2010, the aircraft manufacturer revised the servicing task in the Aircraft Maintenance Manual and introduced a modified maintenance check of the NLG shock absorber every 24 months or 5,000 flight cycles. Should an abnormal NLG vibration event occur, a maintenance check of the assembly and possible servicing would be required. It stated that a dedicated automatic Liquid and Nitrogen Charge Equipment (LANCE) is being developed to avoid the need to jack-up the aircraft and to reduce the potential for incorrect servicing of the landing gear.

The aircraft manufacturer stated that, in the case of one of the operators who reported severe IR drift issues, the introduction of the improved servicing task and revised maintenance check of the NLG shock absorber had been effective in preventing the IR drift associated with the NGC ADIRU Standard-0316/318.

Airfield information

This incident and several previous events occurred after takeoff from Edinburgh Airport. The investigation therefore considered if there was anything unusual about the runway at Edinburgh which may have triggered these events. The operator identified the region of the runway where the abnormal vertical acceleration occurred and provided this to the airport authority. Following a detailed inspection of the runway in this area, a slightly uneven patch repair was found which was thought to be the cause. When the repair was driven over at speed, it caused a distinct jolt. The airport authority replaced the repair patch during scheduled runway maintenance in early 2022.

Information available to flight crew

At the time this incident occurred no specific information was published for flight crew describing the previous events or how to manage this type of event. Depending how the IR drift develops, some ECAM messages can be generated and the associated checklist can give the flight crew helpful instruction. However, on many occasions no ECAM messages are generated (other than those associated with the autopilot and autothrust disconnect).

During this event the data suggests that a NAV FM/GPS POS DISAGREE ECAM message was generated but was only displayed for a few seconds. The message is accompanied by an aural alert (single chime) and a Master caution light, but the message does not latch and when the conditions of FM/GPS position disagreement are no longer reached, the ECAM message will be removed. The flight crew did not report seeing it, so it is likely their attention was not drawn to the ECAM during the few seconds the message was displayed.

The aircraft manufacturer commented that, as demonstrated by this crew, IR drifts can be successful managed by the process it termed ‘fly, navigate, communicate’, and that no specific additional actions are required. The manufacturer considered publishing information to all flight crews about IR drift events, but was concerned that flight crews might then associate any GPS PRIMARY LOST message or AP and A/THR loss with a drift of the IRS. It therefore concluded that such communication would be detrimental.

Following this incident, the operator published an article in its company safety magazine describing this and a previous similar incident.

Analysis

The aircraft suffered multiple severe IR drift events in flight which caused the autopilot and autothrust to disconnect. The events were successfully managed by the flight crew and the aircraft continued to its planned destination.

The incident was caused by a chain of events, each of which was necessary to cause the eventual outcome:

1. A slight irregularity in the runway surface induced sudden vertical shock loads into the NLG.
2. An over extended NLG shock absorber reduced its absorption effectiveness, creating an increase in the vertical forces transferred to the airframe and avionics rack housing the ADIRUs.
3. The NGC ADIRUs fitted to this aircraft (fitted to approximately 14% of the fleet) were sensitive to vertical acceleration forces outside their environmental qualification envelope which induced severe drift.

Runway surface

Following these events, the airport authority found a slightly uneven runway surface patch repair which they believe may have caused the problem. It has now replaced the repair patch.

Nose landing gear leg servicing

Information provided by one of the operators indicated that the improved servicing task and revised maintenance check introduced by the manufacturer was effective in preventing their IR drift issues. However, further occurrences with other operators indicates that the issue has not been completely resolved. The development of a dedicated LANCE to improve the servicing of the NLG shock absorber is intended to reduce potential errors during maintenance activity.

NGC ADIRU

All three of the ADIRUs were tested after the event and no faults were found. During the occurrences, the air data information remained accurate throughout the flight, ruling out ADR faults. The pilots reported that aircraft attitude displays also remained accurate indicating that the IRS gyroscopes were functioning correctly. The severe positional drift experienced was probably caused by IRS accelerometer anomalies from abnormal vertical shock loads transferred to the airframe and avionics rack.

Whilst the NGC ADIRUs performed within their qualification envelope, the shock loads encountered during operation occurred outside their Cat B qualification standard. The aircraft manufacturer commented that in hindsight, the inclusion of Cat C environmental qualification criteria during aircraft design may have avoided these severe position drift issues.

Information to flight crew

When this event occurred, no specific information was available to flight crews describing the possibility of multiple IR drifts, the possible indications or how to manage the situation. The aircraft manufacturer decided that publishing such information would be detrimental.

Conclusion

The aircraft experienced severe navigation position drift in flight. The drift was caused by abnormal vertical shock loads being transferred through the overextended NLG shock absorber to the ADIRU. The abnormal shock loads were initiated by an uneven patch repair on the runway. The NGC ADIRU is particularly sensitive to sudden vertical shock loading outside its environmental qualification envelope.

Published: 16 June 2022.

Accident

Aircraft Type and Registration:	Boeing 737-4Q8, G-JMCY	
No & Type of Engines:	2 CFM56-3C1 turbofan engines	
Year of Manufacture:	1994 (Serial no: 25114)	
Date & Time (UTC):	19 January 2021 at 0237 hrs	
Location:	Exeter Airport, Devon	
Type of Flight:	Commercial Air Transport	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damaged beyond economical repair	
Commander's Licence:	Air Transport Pilot's Licence	
Commander's Age:	56 years	
Commander's Flying Experience:	15,218 hours (of which 9,000 were on type) Last 90 days - 25 hours Last 28 days - 14 hours	
Information Source:	Field Investigation	

Synopsis

During an ILS approach at Exeter Airport, the aircraft became unstable after the point where the crew had declared it stable and continued with the approach. During the final 500 ft the rate of descent exceeded the required 500 ft stable approach maximum on four occasions. All bar the first of these excursions were accompanied by GPWS "SINK RATE" alert. The subsequent hard landing resulted in extensive damage to the aircraft. There were no injuries.

The operator has taken safety action to reinforce its operating procedures with regards to the criteria for a stable approach.

History of the flight

Background information

The crew were scheduled to operate two cargo flights from Exeter Airport (EXT), Devon, to East Midlands Airport (EMA), Leicestershire, and return. The co-pilot was the PF for both sectors, and it was night.

The sector from EXT to EMA was uneventful with the crew electing to landed with FLAP 40[1].

Footnote

[1] FLAP 40 is the recommended landing configuration for performance limiting runways and in poor weather.

Accident flight

The subsequent takeoff and climb from EMA to EXT proceeded without event.

During the cruise the crew independently calculated the landing performance, using the aircraft manufacturer's software, on their portable electronic devices. Runway 26 was forecast to be wet, so they planned to use FLAP 40 for the landing on Runway 26, with AUTOBRAKE 3[2]. With both pilots being familiar with EXT the PF conducted a short brief of the pertinent points for the approach. However, while they did mention that the ILS had a 3.5° glideslope (GS), they did not mention that the stabilised approach criteria differed from that on a 3° GS[3]. From the ATIS they noted that the weather seemed to be better than forecast and the surface wind was from 230° at 11 kt.

The ATC provided the flight crew with radar vectors from ATC to the ILS on Runway 26 at EXT, Figure 2. The landing gear was lowered and FLAP 25 selected before the aircraft intercepted the GS. FLAP 40 (the landing flap) was selected on the GS just below 2,000 ft amsl. With a calculated V_{REF} of 134 kt and a surface wind of 10 kt the PF planned to fly the approach with a V_{APP} of 140 kt. At about 10 nm finals, upon looking at the flight management computer, the PM noticed there was a 30 kt headwind, so a V_{APP} of 144 kt was selected on the Mode Control Panel (MCP). The crew became visual with the runway at about 1,000 ft aal. The PF then disconnected the Auto Pilot and Auto Throttle; the Flight Directors remained on. As the wind was now starting to decrease, the V_{APP} was then reduced from 142 to 140 kt at about 600 ft aal.

As the wind reduced, towards the 10 kt surface wind, the PF made small adjustments to the power to maintain the IAS at or close to V_{APP}. At 500 ft radio altimeter (RA) the approach was declared stable by the crew, as per their standard operating procedures. At this point the aircraft had a pitch attitude of 2.5° nose down, the IAS was 143 kt, the rate of descent (ROD) was about 860 ft/min, the engines were operating at about 68% N_1 and the aircraft was 0.4 dots above the GS. However, the ROD was increasing and soon thereafter was in excess of 1,150 ft/min. This was reduced to about 300 ft/min but soon increased again.

At 320 ft RA, the aircraft went below the GS for about 8 seconds and, with a ROD of 1,700 ft/min, a "SINK RATE" GPWS alert was enunciated. The PF acknowledged this and corrected the flightpath to bring the aircraft back to the GS before stabilizing slightly above the GS; the PM called this deviation too. As the PF was correcting back to the GS the PM did not feel there was a need to take control. During this period the maximum recorded deviation was ¾ of a dot below the GS.

At about 150 ft RA, with a ROD of 1,300 ft/min, there was a further "SINK RATE" GPWS alert, to which the PM said, "WATCH THAT SINK RATE", followed by another "SINK RATE" alert, which the PF responded by saying "AND BACK..."

Footnote

[2] The manufacturer's Flight Crew Training Manual states that Autobrake 3 '*Should be used for wet or slippery runways or when landing rollout distance is limited.*'

[3] See '*Operator's operations manual*' for more detail.

The commander recalled that as the aircraft crossed the threshold, at about 100 ft, the PF retarded the throttles, pitched the aircraft nose down, from about 5° nose up to 4° nose down, and then applied some power in the last few feet. During these final moments before the landing, there was another "SINK RATE" alert. The result was a hard landing. A "PULL UP" warning was also triggered by the GPWS, but it was not audible on the CVR.

The last surface wind transmitted by ATC, just before the landing, was from 230° at 10 kt.

During the rollout the commander took control, selected the thrust reversers and slowed down to taxi speed. After the aircraft had vacated the runway at Taxiway Bravo it became apparent the aircraft was listing to the left. During the After Landing checks the co-pilot tried to select FLAPS UP, but they would not move. There was then a HYDRAULIC LP caution. As there was still brake accumulator pressure the crew were content to taxi the aircraft slowly the short distance onto Stand 10 (Figure 1). Once on stand the listing became more obvious. It was then that the crew realised there was something "seriously wrong" with the aircraft.

After they had shut the aircraft down, the flight crew requested that the wheels were chocked, and the aircraft be connected to ground power before going outside to inspect the aircraft. Once outside a hydraulic leak was found and the airport RFFS, who were present to unload the aircraft, were informed.

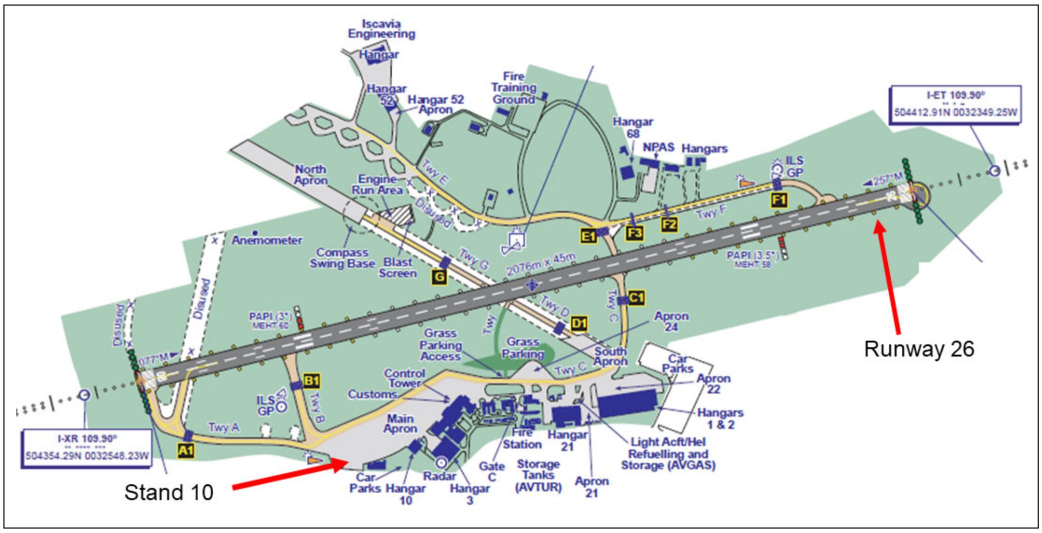


Figure 1

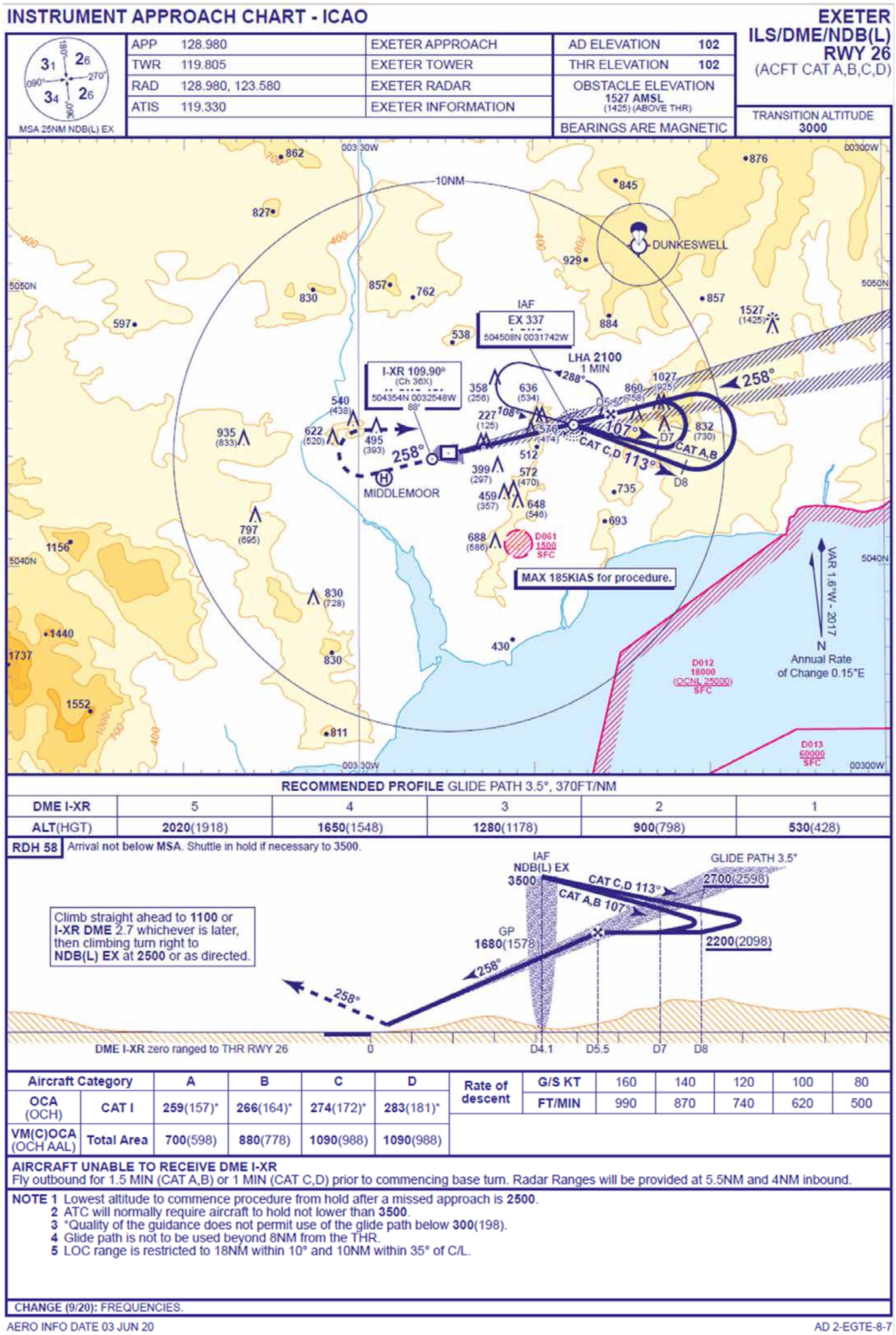
Exeter Airport from UK Aeronautical Information Publication

Airport information

Exeter Airport has one runway orientated 08/26. Runway 26 has a landing distance available of 2,036 m, PAPIs[4] set to 3.5° and an ILS with a 3.5° GS. The approach chart, from the Aeronautical Information Publication, for the ILS/DME to Runway 26 is at Figure 2.

Footnote

[4] PAPIs are a visual aid that provides guidance information to help a pilot acquire and maintain the correct approach (in the vertical plane) to an airport.



INSTRUMENT APPROACH CHART - ICAO

EXETER
ILS/DME/NDB(L)
RWY 26
(ACFT CAT A,B,C,D)

APP	128.980	EXETER APPROACH
TWR	119.805	EXETER TOWER
RAD	128.980, 123.580	EXETER RADAR
ATIS	119.330	EXETER INFORMATION

AD ELEVATION	**102**
THR ELEVATION	**102**
OBSTACLE ELEVATION **1527 AMSL** (1425) (ABOVE THR)	
BEARINGS ARE MAGNETIC	

TRANSITION ALTITUDE
3000

RECOMMENDED PROFILE GLIDE PATH 3.5°, 370FT/NM

DME I-XR	5	4	3	2	1
ALT(HGT)	**2020**(1918)	**1650**(1548)	**1280**(1178)	**900**(798)	**530**(428)

RDH 58 Arrival not below **MSA**. Shuttle in hold if necessary to 3500.

Climb straight ahead to **1100** or **I-XR DME** 2.7 whichever is later, then climbing turn right to **NDB(L) EX** at **2500** or as directed.

Aircraft Category		A	B	C	D
OCA (OCH)	CAT I	**259**(157)*	**266**(164)*	**274**(172)*	**283**(181)*
VM(C)OCA (OCH AAL)	Total Area	**700**(598)	**880**(778)	**1090**(988)	**1090**(988)

Rate of descent	G/S KT	160	140	120	100	80
	FT/MIN	990	870	740	620	500

AIRCRAFT UNABLE TO RECEIVE DME I-XR
Fly outbound for 1.5 MIN (CAT A,B) or 1 MIN (CAT C,D) prior to commencing base turn. Radar Ranges will be provided at 5.5NM and 4NM inbound.

NOTE 1 Lowest altitude to commence procedure from hold after a missed approach is **2500**.
2 ATC will normally require aircraft to hold not lower than **3500**.
3 *Quality of the guidance does not permit use of the glide path below **300**(198).
4 Glide path is not to be used beyond 8NM from the THR.
5 LOC range is restricted to 18NM within 10° and 10NM within 35° of C/L.

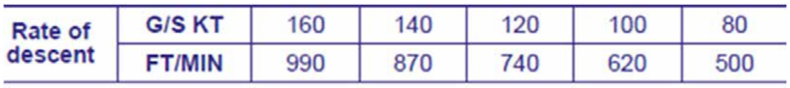
CHANGE (9/20): FREQUENCIES.

AERO INFO DATE 03 JUN 20 AD 2-EGTE-8-7

Figure 2

Approach Chart for ILS/DME to Runway 26 at Exeter Airport

The ILS chart stated that for a ground speed of 140 kt the ROD would be about 870 ft/min and 740 ft/min for 120 kt while maintaining the GS (Figure 3). By interpolation this gives a ROD of about 805 ft/min at a ground speed of 130 kt, ie close to that during the final stages of the approach.



Rate of descent	G/S KT	160	140	120	100	80
	FT/MIN	990	870	740	620	500

Figure 3

ROD from ILS/DME to Runway 26

After the accident the airport operator checked the runway lights, ILS, DME, PAPI's and pressure sensors and all were confirmed serviceable.

Crew's comments

Commander's comments

The commander stated that if the thrust is reduced to IDLE quickly, with FLAP 40, the "aircraft stops flying" due to the large amount of drag from the flaps. While the possibility of conducting a GA just before the landing was always in his mind, it was not considered as the aircraft "stopped flying" and "dropped" onto the runway so quicky he felt it was too late for him to call go-around or take control. He added that in hindsight one should have been initiated at that point, but the aircraft would have more than likely touched down during the manoeuvre.

Co-pilot's comments

The co-pilot commented that she did not know what caused the hard landing but did not believe there was a technical issue. She had no issues with operating into Exeter in the past and operating into Exeter was not a rarity. She added that she did not consider a 3.5° GS to present any additional difficulty and was comfortable and familiar with the airport.

Crews' experience

Commander's experience

The commander had a total of 15,218 flying hours, of which 9,000 were on the Boeing 737 (B737). He had been with the operator since 2014.

During his OPC on 8 January 2021 he was assessed as *Surpasses Company Standard* in six of the pilot competencies, *Expected Company Standard* in two and *Baseline Minimum Standard* in *Applied Knowledge*, where the training captain commented that "Few gaps observed and debriefed."

Co-pilot's experience

The co-pilot had a total of 19,350 flying hours, of which 5,637 were on the B737. She had been with the operator since 2015.

Prior to this accident the co-pilot had previously landed at Exeter on Runway 26, in a B737-400 on 24, 26 and 28 November 2020. These were also night sectors. During the approaches there was a 20-25 kt tailwind, at height, that reduced to about a 2 kt tailwind over the threshold.

The commander for these sectors stated all the approaches and landings were all flown well bar the last one on 28 November 2020. On the last approach, at about 200 ft aal, while manually flying, there was a "SINK RATE" GPWS alert. The co-pilot quickly adjusted the flight path and the approach remained stable. However, the aircraft drifted up into three whites on the PAPIs, due to an increase in thrust, which was corrected. The aircraft landed "a bit deep" but inside the touchdown zone. The co-pilot attributed the event to the tailwind. However, the commander at the time believed she made a momentary forward input on the control column, and, as the vertical speed indicator was fed by the aircraft's inertial reference system[5], this shortlived increase in the ROD triggered the GPWS alert.

During her previous licence proficiency check on 15 July 2020, during a single engine approach, if was noted that the aircraft produced a "SINK RATE" alert on short finals. There were also some deviations on the GA that was subsequently flown. The training captain recorded this element as passed at second attempt and assessed her *Flight Path Management* as *Baseline Minimum Standard*.

Since this accident, the operator recognised that there was no robust mechanism to monitor trends in pilots' performance across recurrent checks, therefore persistent/repetitive under performance in technical skill areas were not always identified. The operator has since introduced a number of new procedures to rectify this.

Fatigue

Given this accident happened at about 0230 hrs, the crew's sleep history was assessed to see if tiredness and/or fatigue could have been a contributory factor. It was found not to be a factor.

Aircraft information

Weight and balance

The aircraft's weight and balance were within limits. It departed with 8,400 kg of fuel. The trip fuel was expected to be about 1,800 kg.

The aircraft landed with 6,600 kg of fuel, giving it a landing weight of approximately 52,900 kg. Its planned minimum diversion fuel was 3,118 kg. The nominated diversion was EMA.

The operator commented that a B737 would use about 1,000 kg of fuel during a GA and another approach.

Footnote

[5] The inertial reference system provides inertial navigation data to aircraft systems. It uses a ring laser gyro instead of the conventional rate gyro to sense angular rate about the roll, pitch and yaw axes.

Aircraft attitude on approach

The aircraft manufacturer stated that the approximate pitch attitude at 52,900 kg, FLAPS 40 with V_{REF}+5 kt, on a 3.5° glideslope was about 1° nose up.

Meteorological information

The METAR issued at 0220 hrs stated that the surface wind was from 230° at 10 kt, visibility of 9 km, light rain, SCATTERED clouds at 1,200 ft aal, BROKEN clouds at 4,000 ft aal, temperature 12°C dew point 10°C, QNH 1009 hPa.

Operations Manual

The operator's Operations Manual (OM) Part B stated:

> *'2.1.14 Stabilised Approach*
>
> *It should be clearly understood that an unstable approach is more likely to result in a hazardous landing with the resultant high risk of an accident. The majority of unstable approaches result from a lack of appreciation of the aircraft energy level at an early part of the approach and the resultant failure to slow the aircraft in a controlled manner.*
>
> *…*
>
> *The criteria for a stabilised approach are:*
>
> *a) Aircraft in landing configuration (Note 1);*
>
> *b) Final approach speed [V_{APP}] +10/-5 kt;*
>
> *c) Rate of descent less than 1,000 ft per minute (Note 2) [1,150 ft/min for a 3.5° glideslope];*
>
> *d) ILS: Aircraft within +/- 1 dot of glideslope/LOC [localiser];*
>
> *…*
>
> *g) Normal approach thrust set.*
>
> *…*
>
> *Note 2: Rate of descent limit may be increased by 150 fpm per 0.5 degree that the published approach path exceeds 3 degrees.*
>
> *All approaches must be stable:*
>
> *a) in IMC by 1,000ft above TDZE [touchdown zone elevation];*
>
> *b) in VMC by 500ft above TDZE (Note 1)...*
>
> *Note 1: All approaches in VMC should be stable by 1,000ft above TDZE*
>
> *…*

If the Commander is in any doubt as to whether a stabilised approach can be achieved, he should review the need for a go-around at an early stage. If a stabilised approach cannot be achieved, he must ensure that a go-around is carried out.

If the parameters of a stabilised approach are not achieved at 500 feet a go around must be initiated.'

2.1.17.5 Deviations

PM should use the following calls to alert the PF at any time there is a deviation from the intended condition.

An uncorrected significant trend towards a deviation should trigger a call in a timely manner to help avoid a significant exceedance.

…If the PM notices that the PF is already correcting, a call might not be necessary.

Should there be no correction from a deviation call, the PM must call again adding appropriate describing words, such as "SPEED TOO LOW"…

Phase of Flight	***Deviation***	***PM Call***
…	…	…
Final Approach	*>1000 fpm ROD unless a greater ROD has been briefed*	*"SINK RATE"*

2.2.14 Landing Procedure - ILS

…

2.2.14.1 Allocation of Duties and Standard Calls

This table assumes a CAT I ILS approach, …

Event	***PF***	***PM***
…	…	…
500ft RA[6]	*If stable:* *"CHECK"* *If unstable:* *"GO-AROUND, FLAP 15"*	*If unstable:* *"UNSTABLE, GO AROUND"*

…

Footnote

[6] An amendment to OMB after the accident added a note to this section that states: '*For approach stability requirements, see OMB 2.1.14. Note specifically that approach stability requirements are with respect to TDZE, not Radio Altimeter height.'*

> *Note 3: Wind corrected final approach speed [V_{APP}] is calculated by adding half of the reported steady headwind component plus the full gust increment to the reference speed. The minimum final approach speed setting is VREF +5kts…*
>
> *...All further callouts by the PM may be omitted, except for the relevant callout at 500 ft RA and any deviations.'*

There was no stated requirement in the OM for both pilots to monitor that the stable approach criteria were maintained below 500 ft, with the aim of delivering the aircraft to the point in space above the runway from which a flare manoeuvre will result in touchdown at the right speed and attitude, and within the touchdown zone. This is something other operators are known to have in their OM, with a requirement to conduct a GA if the stable approach criteria are not maintained to the landing.

B737 Flight Crew Training Manual

The manufacturer's *Flight Crew Training Manual* (FCTM) also stated the same criteria for an approach to be stable as those in the OM. However, it has the following additional statement:

> **'*Stabilized Approach Recommendations***
>
> …
>
> *These conditions should be maintained throughout the rest of the approach for it to be considered a stabilized approach. If the above criteria cannot be established and maintained until approaching the flare, initiate a go-around.'*

It also has the following guidance:

> ***'Rejected Landing***
>
> *A rejected landing maneuver is trained and evaluated by some operators and regulatory agencies. Although the FCOM/QRH does not contain a procedure or maneuver titled Rejected Landing, the requirements of this maneuver can be accomplished by doing the Go-Around Procedure if it is initiated before touchdown. Refer to Chapter 5, Go-Around after Touchdown, for more information on this subject.*
>
> ***Go-Around after Touchdown***
>
> *If a go-around is initiated before touchdown and touchdown occurs, continue with normal go-around procedures…*
>
> *If a go-around is initiated after touchdown but before thrust reverser selection, continue with normal go-around procedures…*

> ***Flap Setting for Landing***
>
> *For normal landings, use flaps 15, 30, or flaps 40…When performance criteria are met, use flaps 40 to minimize landing speed, and landing distance.'*

B737 Quick Reference Handbook

The B737 Quick Reference Handbook states in MAN1.4:

> ***'Ground Proximity Warning System (GPWS) Response***
>
> ***GPWS Caution***
>
> *Do the following man[o]euver for any of these aural alerts:*
>
> - *SINK RATE*
>
> …
>
> | ***Pilot Flying*** | ***Pilot Monitoring*** |
> |---|---|
> | *Correct the flight path, airplane configuration, or airspeed.* | |
>
> …'

Operator's comments

The operator stated that during their pilots' recurrent training, prior to this event, they had conducted rejected landings/GA from different altitudes and configurations, but not from a touchdown; this practise will continue.

While OMB did not have specific guidance as to what to do in the event of an approach becoming unstable, on an ILS, below 500 ft aal, they believed that the expectation was that if an approach went unstable after 500 ft, it would lead to a GA being initiated. However, the operator believed there could be a perception amongst some of its pilots that the stable criteria applied to a single point in space rather than for the remainder of an approach.

After this accident the operator noted that there was no robust mechanism for tracking an individual pilot's performance during a recurrent check and no formal process in which to manage underperformance or individual trends identified over a series of checks or poor operational performance. They have subsequently introduced a number of procedures to rectify this. They also included stabilised approach criteria as a feature in their pilots' ground based recurrent training.

Recorded information

Recordings were recovered from the onboard FDR, CVR, Quick Access Recorder (QAR) and the Terrain Awareness and Warning System (TAWS) computer.

External sources of data included CCTV, wind data from airfield sensors, radar and ATC recordings, runway lighting data and QAR data from previous flights. These did not highlight any anomalies over and above those identified in the aircraft recordings.

The FDR recorded over 108 hours of flight data. No issues were identified with the aircraft systems prior to touchdown. While the FD was known to be on, its computed pitch and bank angles were not recorded on the FDR.

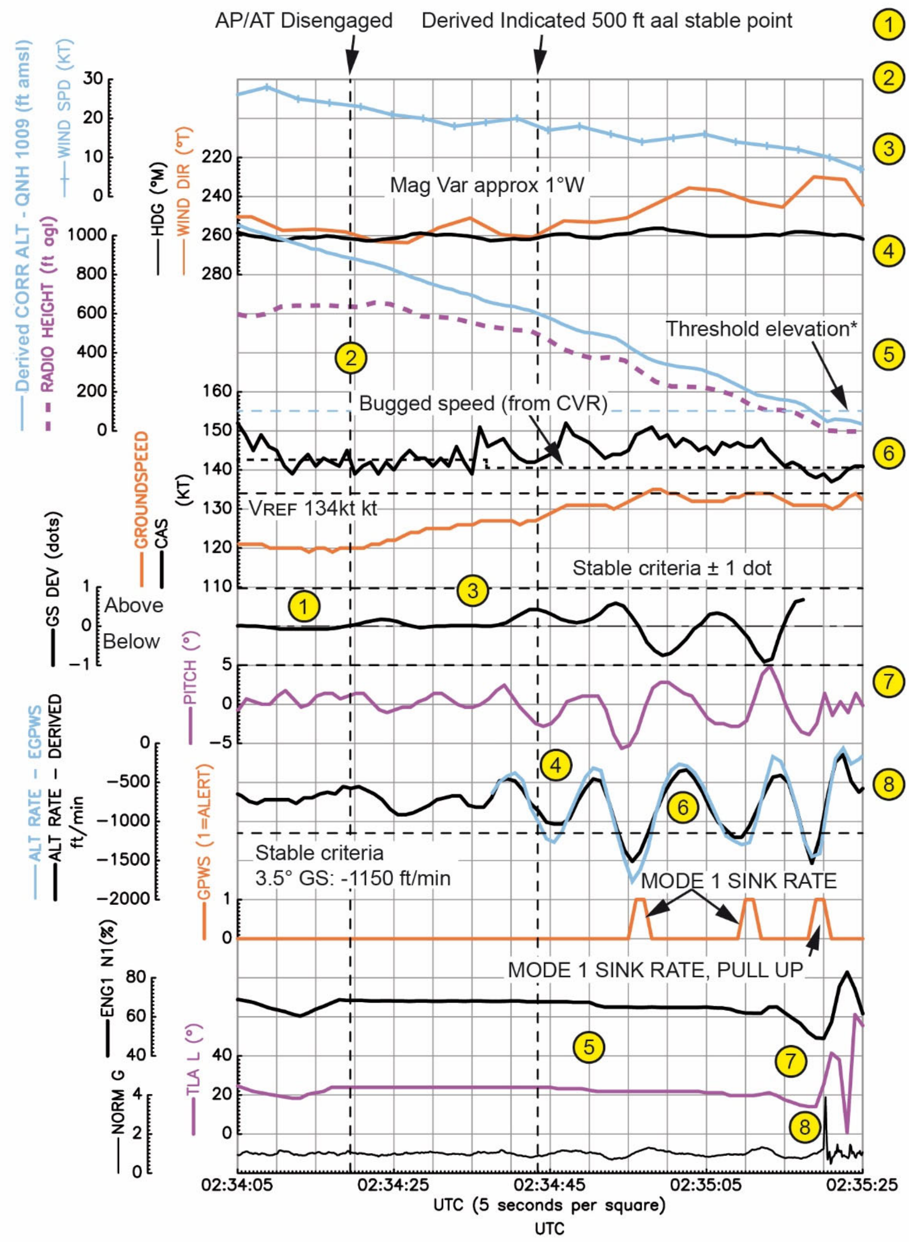
The QAR and TAWS recordings corroborated the FDR recordings. The TAWS recordings provided additional parameters not recorded by the FDR, including altitude rate. The TAWS did not record continuously, but gathered data associated with alerts that had been triggered. In this case TAWS recordings were triggered by three GPWS Mode 1 events. Mode 1 alerts are generated when the descent rate is too high for the given radio height. The alerts were recorded between data samples, at radio heights of approximately 280 ft, 150 ft and below 20 ft. Each trigger was associated with “SINK RATE, SINK RATE” cautions. The last of these also triggered a GPWS Mode 1 alert just prior to touch down. The associated “PULL UP” aural was not evident on the CVR; by the time the preceding “SINK RATE” aural had been issued, the aircraft had touched down.

Figure 4 shows the pertinent parameters associated with the approach and landing.

The recorded wind data and aircraft manufacturer calculated values based on recorded aircraft motion, indicate decreasing overall wind speeds during the descent, slowly backing to about 10 kt, 30° to the left of heading on touchdown. Wind fluctuations were also decreasing during the descent.

The data indicates that the aircraft did not stall. The maximum vertical acceleration recorded by the FDR on touchdown was 3.8g, at this point there was 3° of left roll. However, FDR sample rates and sensor locations are not ideally placed to determine peak forces on touch down. Altitude rate parameters are smoothed and so lag the aircraft dynamic behaviour. The descent rate values were decreasing on touchdown, but more detailed aircraft modelling was required to better understand the descent rate at touchdown. The airframe manufacturer assessment of the data indicates a calculated descent rate of approximately 24 ft/second. This is consistent with the trends of the combined recordings of the left and right radio heights.

After landing, the aircraft maintained a left roll attitude taxiing to the stand, varying between 1.5° and 4.5°. The right trailing edge flap angle had reduced from 40° to 37° on landing, but later in the landing roll this returned to 40°, matching the recorded left flap angle again. The master caution was triggered as the groundspeed reduced through approximately 20 kt. The FDR recorded low pressure states for the hydraulic A and B systems associated with engine 1 and 2 respectively and hydraulic B electrical systems during the taxi to stand.



① On glideslope

② AP/AT disconnected at approx 800ft aal.

③ On glideslope with increasing CAS. Pitch started to oscillate.

④ Above glideslope, then >1150 ft/min descent rate.

⑤ Small thrust reduction, increased pitch oscillations.

⑥ Increased altitude rate oscillations. Mode 1 Sink Rate alerts with associated descent rates greater than 1150 ft/min stability criteria. Head wind reducing.

⑦ Throttle reduction aligned to pitching downward.

⑧ Max recorded normal acceleration was 3.8g.

NOTE:
* Derived corrected altitude uses a QNH of 1009 hPa as declared by the crew on the CVR. At the time of landing a QNH of 1010 hPa more accurately corrects the altitude for ft amsl.

** Derived altitude rate may not reflect the same smoothing as the cockpit indication

Figure 4

Pertinent parameters from the FDR and TAWS recordings

Airfield wind data

Wind data recovered from the airfield showed instantaneous airfield readings of 12 kt from 230° on touchdown. This was steady for at least the previous two recorded readings, 10 seconds apart, at the airfield sensor location. Gusts of about 5 kt were recorded in the minutes leading up to the landing.

Aircraft information

G-JMCY was manufactured in 1994. It was modified for cargo operations in 2015, which involved the incorporation of several changes under a Supplementary Type Certificate (STC). At the time of this accident, there were no significant deferred defects recorded in the technical log, and the aircraft had accrued almost 38,000 landings and 65,500 flying hours.

Aircraft examination and description of the damage

Runway

The runway was undamaged, and the touchdown point could not be established because there were no obvious marks caused by the heavy landing. Aircraft debris on the runway consisted of small pieces of composite material, broken fasteners, and a louvre from the right air conditioning pack exhaust. There was visible evidence of fluid contamination on the runway, which was most pronounced where the aircraft had turned off when taxiing to the parking area. The fluid was not analysed but was probably hydraulic oil.

Aircraft

The fuselage skin aft of the wings was cracked and buckled, and the rear fuselage was distorted downward, Figure 5. The crown skin was creased and rippled along most of the fuselage.

Figure 5

Photograph looking aft showing distortion of the rear fuselage and rippling in the skin

Residual hydraulic oil was dripping from several areas but there were no indications of a fuel leak. Both main landing gear shock absorbers were found to be bottomed, and the left main landing gear beam was distorted upwards such that the aircraft was approximately 2° left-wing low (Figure 6).

Figure 6

G-JMCY - left-wing low due to the main landing gear beam damage

There was no obvious tyre damage and the main landing gear drag strut bolts were intact. The engine cowlings were undamaged, so it was apparent that the engines had not touched the runway during the landing. The flap drive mechanism was damaged, and the left-wing inboard driveshaft was bent; the left inboard gearbox casing and its mountings were broken (Figure 7).

Analysis

Conduct of the approach

Both pilots had previously operated into EXT and had no concerns about the ILS approach to Runway 26, despite it having a slightly steeper approach angle. The co-pilot had also conducted a FLAPS 40 landing at EMA, without event, on the previous sector.

During the cruise the crew calculated the landing performance and briefed for the approach. While they noted that there was a 3.5° GS they did not brief that they could increase the SINK RATE deviation call, for the ROD, from 1,000 ft/min to 1,150 ft/min.

The initial part of the ILS approach was flown appropriately, with the aircraft configured for the landing early and crew becoming visual with the runway at about 1,000 ft aal.

Figure 7

View looking inboard under the left-wing. Broken flap gearbox is highlighted

The criteria specified in the operator's OM for an ILS approach to be stable were that the IAS should have been no more than 10 kt above V_{APP} and no slower than 5 kt below, a ROD of less than 1,150 ft/min (on a 3.5° glideslope) and within one dot of the GS and localiser. At 500 ft RA the aircraft was configured for landing, the IAS was V_{APP} +3 kt (143 kt), the ROD was about 860 ft/min and the aircraft was slightly above the GS. In terms of the criteria for a stabilised approach, the aircraft was stable at this point albeit close to the limit of the ROD. However, the ROD was increasing and soon after exceeded the stable approach maximum ROD of 1,150 ft/min. This was reduced to about 300 ft/min but soon increased again. At 320 ft RA the ROD had reached 1,700 ft/min, which was the greatest observed on the approach. While it was reduced again shortly thereafter, the ROD exceeded 1,150 ft/min on two more occasions prior to the landing and the recorded data indicated that 1,700 ft/min was nearly reached again at about 25 ft RA. These variations in the ROD had a corresponding effect on the aircraft's position relative to the GS but while it came close to being one dot below the GS, at about 150 ft RA, it did not exceed it.

During these exceedances of the ROD the PM did not call "SINK RATE" as required by Section 2.1.17.5 of the OM. He did however, say "WATCH THAT SINK RATE", at about 150 ft RA, after the second alert, when the ROD was 1,300 ft/min. The lack of a GA command may have given the PF the impression that the PM was content for the approach to be continued, despite three GPWS "SINK RATE" alerts being generated during the final 30 seconds of the approach. Additionally, while it may not have been explicit in the operator's OM, that a GA should be executed if an approach does not remain stable, the FCTM stated '*If the above criteria* [stable approach criteria] *cannot be established and maintained until approaching the flare, initiate a goaround.*'

While the possibility of conducting a GA just before the landing was always in the commander's mind, it was not considered by him as the aircraft "stopped flying" so quicky he felt it was too late to initiate one. He added that, in hindsight, a GA should have been initiated at that point, even though the aircraft would have more than likely touched down during the manoeuvre. While the aircraft may well have touched down during a late GA, this was a manoeuvre that was described in the FCTM and had been trained for during the pilots' recurrent training.

The commander stated that the aircraft "stopped flying" just before it landed. This was probably a result of the reduction in thrust at about 100 ft RA. There was then an increase in thrust at about 30 ft RA. This was likely to have been an attempt to arrest the ROD of about 1,000 ft/min, just prior to the landing. Had the PF been more positive with her understanding of the situation and elected to GA, even if it was in the final few feet, the extent of the damage may have been reduced. If she felt she had become overwhelmed by the way the approach was progressing she could have handed control to the commander. He too could have taken control, as he recognised he probably should have, albeit in hindsight. The crew may also have been overloaded at the time to think a late GA was a realistic option.

The manufacturer's approximate pitch attitude to maintain the GS was 1° nose up. During the final 500 ft the aircraft's pitch attitude varied between 5° nose up and 6° nose down. While it is not unusual for changes to be made to the aircraft's attitude to remain on a GS, such significant variations suggest there was either an element of over controlling or too great an adjustment to correct a deviation. This probably led to the divergences below the GS and excessive ROD leading to the GPWS alerts and subsequent hard landing. While the FD was on, its computed pitch and bank angles were not recorded on the FDR, but it should have provided appropriate guidance to the crew to allow a stable approach to be maintained.

The commander also stated that he felt it was too late for him to take control or call "go around" from about 100 ft RA. While the co-pilot was making adjustments to the aircraft's path, throughout the approach as the wind reduced, SINK RATE alerts at 320 ft RA and 260 ft RA should have alerted them that the approach was not stable and a GA would have been an appropriate thing to do, despite there not being positive guidance in the OM as what to do after the aircraft has passed the stable gate at 500 ft.

The commander had confidence in the co-pilot's ability and had flown with her on many occasions, it is possible this may have led to him to feel that the co-pilot was able to handle the situation and so did not call a GA or take control.

The operator commented that a B737 would use about 1,000 kg of fuel to fly a GA and another ILS approach. With 6,600 kg of fuel on board at the time of the accident, and 3,118 kg required to go back to EMA, there was enough fuel to fly a further three approaches before a decision to divert to EMA was needed to be taken. There was thus no fuel/time pressure to land off the first approach.

Operations Manual

The operator's OM did not specifically state that an approach must remain stable from 500 ft RA (for a VMC approach) to touchdown, even though the FCTM did. Since the accident, the operator has amended the OM to clearly state that an approach '*requires an immediate go-around'* if it becomes unstable after the stable point.

At the time of the accident OM Part B referenced the stable point in 2.1.14, '*Stabilised Approach'*, with regards to the TDZE. However, in Section 2.2.14.1, '*Allocation of duties and standard calls'* it was refenced to 500 ft RA. Since the accident a note has been added to 2.2.14.1 to highlight that '*approach stability requirements are with respect to TDZE, not Radio Altimeter height.'*

Any change in IAS will need an adjustment to the aircraft's pitch attitude to maintain the GS, which will also result in change to the aircraft's ROD as shown in Figure 3. The manufacturer's predicted aircraft attitude for a 3.5° GS was about 1° nose up. Given the wind was decreasing down the GS, the aircraft would not have maintained this attitude all the way to the flare, due to the changing conditions.

Pilot's assessment

During one of the co-pilot's previous licence proficiency checks it was noted that, during a single engine approach, the aircraft produced a "SINK RATE" alert on short finals. The training captain recorded this element as passed at second attempt and assessed her Flight Path Management as Baseline Minimum Standard. Since this event the operator recognised that there was no robust mechanism for tracking an individual pilot's performance during a recurrent check and introduced a number of procedures to rectify this. While these new procedures may not have prevented the accident happening it should enable the operator to screen all of those pilots whose performance may be worthy of monitoring.

Manufacturer's assessment of the airframe damage

As part of the original crashworthiness evaluation of the Boeing 737-400 passenger aircraft, the manufacturer considered a gear-down landing at high sink rate. They concluded that the wing box would remain intact after landing at the maximum permitted weight of 121,000 lb and a sink rate of 18 ft/second.

The manufacturer reviewed the recorded data for G-JMCY and assessed that the landing occurred with mass of approximately 116,700 lb and a sink rate of 24 ft/second. The wing box remained intact, preventing fuel leakage.

If the main landing gear shock absorbers bottom during a landing, the main landing gear beams act as a structural fuse for vertical loading. Correspondingly, the drag strut bolts act as a fuse for drag loading. The left main landing gear beam on G-JMCY was visibly distorted in an upward direction, but it remained intact, as did the drag strut bolts. The manufacturer assessed that this indicated that the landing did not reach the vertical or drag load limits.

Safety margins are lower in the aft fuselage skin, thereby accounting for the damage in this area. Overall, the manufacturer concluded that the damage sustained by G-JMCY was consistent with a hard landing.

Conclusion

The aircraft suffered a hard landing as a result of the approach being continued after it became unstable after the aircraft had passed the point where the crew had declared the approach stable and continued. Despite high rates of descent being observed beyond the stable point, together with associated alerts the crew elected to continue to land. Had the approach been discontinued and a GA flown, even at a low height, while the aircraft may have touched down the damage sustained may have been lessened.

While the OM did not specifically state that an approach was to remain stable beyond the gate on the approach, the FCTM was specific that, if it did not remain stable, a GA should be initiated.

The commander may have given the co-pilot the benefit of doubt and believed she had the ability to correct an approach that became unstable in the final few hundred feet of the approach. However, had there been any doubt, a GA should be executed.

Safety actions

Since the accident the following safety actions have been taken:

> The operator has instructed their crews that, until further notice, only the commander is to conduct the landing at Exeter Airport.
>
> The operator has added a note to Section *2.1.14 Stabilised Approach* of OM B stating, '*An approach that becomes unstabilised below this point* [1,000 ft above TDZE in IMC or 500 ft above TDZE in VMC] *requires an immediate go-around.'*
>
> The operator recognised that there were no robust mechanisms to monitor trends in pilots' performance across recurrent checks. The operator has since introduced a number of new procedures to rectify this.

Published: 19 May 2022.

ACCIDENT

Aircraft Type and Registration:	Hawker Sea Fury T Mk 20, G-RNHF	
No & Type of Engines:	1 Bristol Centaurus XVIII piston engine	
Year of Manufacture:	1949 (Serial no: ES3615)	
Date & Time (UTC):	28 April 2021 at 1315 hrs	
Location:	Approximately 0.5 nm from Runway 04, RNAS Yeovilton, Somerset	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1	Passengers - 1 (Minor)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	60 years	
Commander's Flying Experience:	11,550 hours (of which 36 were on type) Last 90 days - 146 hours Last 28 days - 55 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was being positioned for a landing on Runway 04 at RNAS Yeovilton following a low engine oil pressure indication. As the aircraft began the base turn, the engine seized suddenly and the pilot was unable to feather the propeller. Due to the extremely high rate of descent required to maintain speed it was not possible to reach the runway. The aircraft struck the ground approximately 0.5 nm from the runway threshold. The aircraft was destroyed but both occupants were able to extract themselves from the cockpit.

The engine's rear crankpin bearing had overheated, leading to extensive damage within the rear crankcase and causing the engine to seize. Due to the severe damage to the engine, the cause of the rear crankpin bearing becoming overheated was not established.

History of the flight

G-RNHF was prepared for a training flight for the front seat pilot with a pilot not rated on the Sea Fury in the rear seat for familiarisation. After completing a comprehensive brief for the sortie and reviewing the technical documents for the aircraft, the crew proceeded out to G-RNHF.

After strapping in, the pilot completed the pre-start process and the engine was started using external electrical power. The pilot reported that the engine started well and ran smoothly. The oil pressure initially indicated 110 psi with the oil cold, which the pilot considered to be normal whilst the engine warmed up. The passenger noted that his oil temperature gauge was indicating that the oil was very cold. The pilot noted that his was indicating normally, and the two occupants agreed that the rear gauge was inoperative. The Sea Fury does not have a parking brake system so relies on the pilot using the foot brakes to hold the aircraft in position. As a result of this, it is preferential to complete the engine run up checks on the ramp with the wheel chocks in place. The use of chocks and the pilot pressing on the foot brakes ensures that the aircraft is secure with the much higher power setting required for the checks.

The pilot spread the wings and completed other checks of the aircraft systems before running the engine up to 2,000 rpm. He then checked the magnetos and noted that the rpm drop seemed excessive on one. He noticed that the rpm had crept back so was lower than the 2,000 he had initially set. Having tightened the throttle friction, he again set 2,000 rpm and checked the magnetos. This time the rpm drops were within limits. The pilot noted that the oil pressure was steady at 100 psi at 2,000 rpm.

The pilot then reduced power for the slow running rpm check but was reminded by the back seat occupant who was following the checklist that he had omitted to check the supercharger gear change over which should be conducted at 2,000 rpm. The pilot re-selected 2,000 rpm and the supercharger check was carried out and found to be normal.

At 1300 hrs the pilot began taxiing G-RNHF to Runway 04 at RNAS Yeovilton. After completing the pre-takeoff checks and a final briefing, the aircraft approached the final holding position. At this point with the rpm around 600, the pilot noticed that the oil pressure was about 60 psi which was outside the normal operating limits. He confirmed with the passenger that the rear gauge was reading the same. He increased power to 1,200 rpm and the oil pressure immediately recovered. The pilot noted that repeating the engine run at 2,000 rpm for the supercharger check had probably left the oil at a higher temperature than normal and that was the cause of the momentary low oil pressure. The engine was running smoothly and there were no other signs of anything abnormal.

The aircraft took off at 1309 hrs and turned to the northwest during the departure. Seeing some weather on their track the pilot turned the aircraft to the east towards clearer skies. As the aircraft was heading out to the area of operation, the pilot noted that the oil pressure was low. He immediately informed ATC, making a PAN PAN call and turned back towards the airfield. The engine continued to run, but the pilot described it is as rather “lumpy and unsteady”. He attempted to position G-RNHF for a landing on Runway 04 but having lowered the gear and flap to increase the rate of descent, the engine failed completely, generating several “violent thumps” through the airframe before it seized, leaving the propeller stationary. The pilot was unable to feather the propeller, and the increase in drag meant that it was not possible to make the airfield. The pilot made a MAYDAY call to ATC. The aircraft struck the ground around 0.6 nm from the threshold of Runway 04. The aircraft broke into several sections but both occupants were able to extract themselves from the cockpit without assistance.

Recorded information

The aircraft did not carry any devices that recorded data for the accident flight. The approximate flightpath taken by the aircraft, based on position information broadcast from it, is shown in Figure 1.

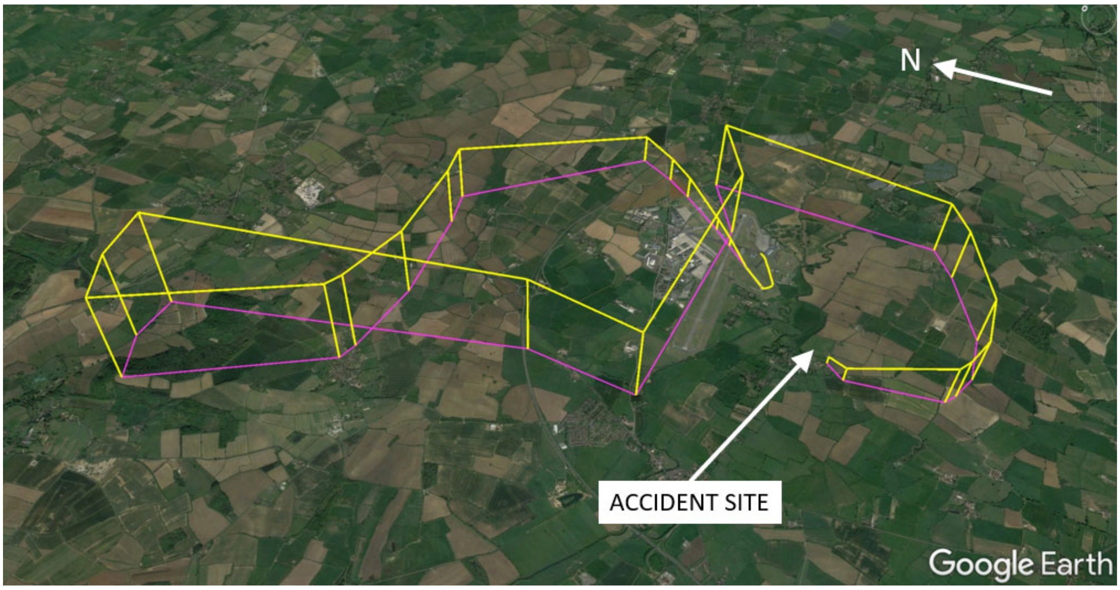


Figure 1

Accident flightpath (Image Landsat/Copernicus © 2022 Google)

The flight time between the start of the takeoff roll and the last recorded position was 5 minutes 30 seconds. It is estimated that the rate of descent, during the glide once the engine had seized, was between 7,000 and 10,000 fpm.

Accident site

The aircraft initially struck a telegraph pole, having cleared the roof of a nearby house by approximately 6 m, before it then struck the ground in a level attitude in an area of paddocks. Ground marks showed that the right main landing gear and tailwheel were extended when the aircraft touched down, however the right mainwheel then separated from the leg, which folded rearwards underneath the wing. The left main landing gear was found retracted in the wing. The aircraft slid across the surface of the paddock before striking a hedge which covered a shallow earth berm, causing the wing and engine to separate from the fuselage (Figure 2). The length of the wreckage trail from the first ground scar to the engine, which had travelled beyond the fuselage, was 95 m.

The fuselage came to rest inverted, supported by the fin and the right tailplane. It was covered in a light sheen of engine oil, which was described as normal for the type by a maintenance engineer familiar with the aircraft. No fire had occurred. The propeller was in fine pitch and all five blades were folded rearwards due to ground contact.

Figure 2

Accident site (courtesy of Defence Accident Investigation Branch)

Aircraft information

The Sea Fury T Mk 20 is two-seat, two-cockpit conversion trainer for the single-seat Sea Fury, incorporating dual controls. It is a cantilever, low wing monoplane with folding wings and retractable main undercarriage. A Bristol Centaurus XVIII radial air-cooled engine drives a five-bladed Rotol variable pitch propeller. The aircraft type entered service with the Royal Navy in 1947. Production ceased in 1955. The type had largely been retired from the Royal Navy by the late 1950s. Several Sea Furies (both single and two seat) remain airworthy around the world.

The Sea Fury T Mk 20 is a large aircraft with a maximum weight of 14,200 lb (6,441 kg), a length of 34 ft 7 in (10.5 m) and a wingspan of 38 ft 4.5 in (11.7 m). The weight of the aircraft is roughly equivalent to two Spitfires. G-RNHF was approved for passenger carrying under the CAA Safety Standards Acknowledgement and Consent regulations[1].

Centaurus XVIII engine

The Centaurus XVIII engine has 18 cylinders arranged into two radial rows of nine cylinders (Figure 3). Each cylinder has a swept volume of 2.98 litres, giving a total displacement of 53.6 litres. The engine is rated at 2,500 hp at 2,700 rpm and 9.5 psi boost pressure. The cylinders are numbered clockwise when viewed from the front, starting from the uppermost, with the front bank having even numbers and the rear bank odd numbers.

The flow of induction air-fuel mixture and exhaust gases into and from each cylinder is controlled by a sliding steel sleeve between the cylinder and piston. Each sleeve is driven by a crank, connected to gear train driven from the crankshaft, with one set of sleeve-drive gears for the forward row of sleeves and a second set of gears at the rear of the crankcase to drive the rear row of sleeves. The sleeves move in an elliptical motion and holes cut into the sleeve permit the passage of inlet and exhaust gases.

Footnote

[1] CAP 1395 Safety Standards Acknowledgement and Consent (SSAC), Edition 3, January 2021.

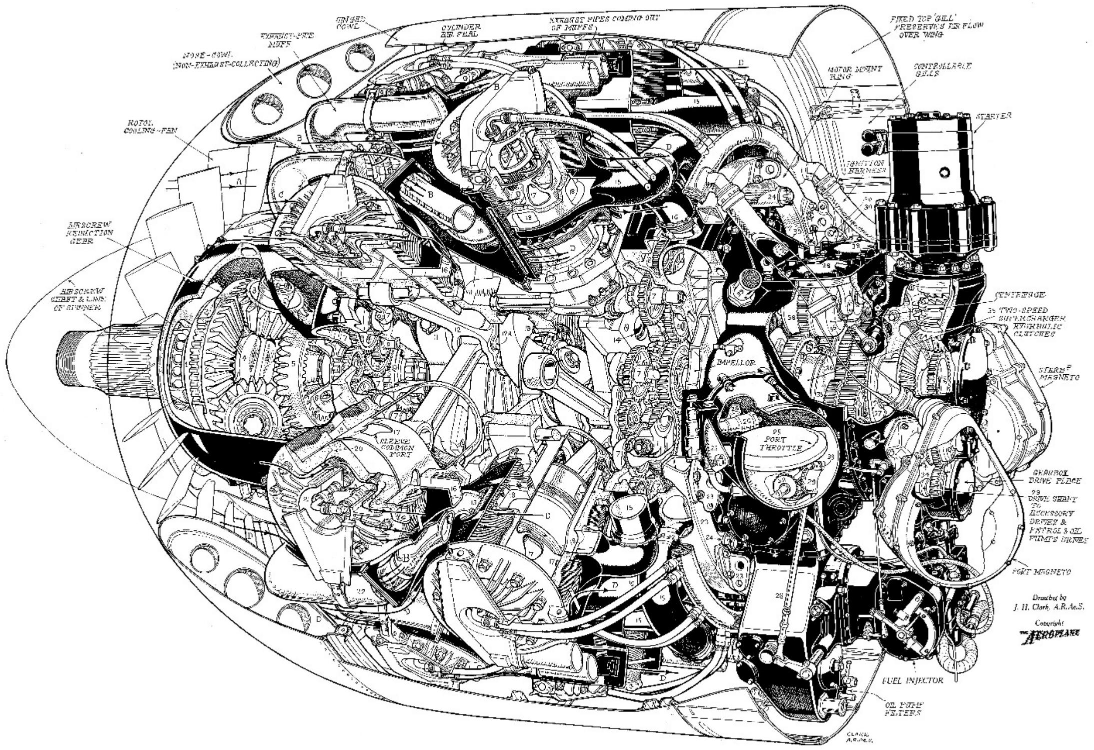


Figure 3

Bristol Centaurus engine (courtesy of Aeroplane/Key Publishing)

The crankcase is comprised of three separate aluminium alloy forgings, with circular lightening holes in the crankcase webs allowing oil to pass between the front and rear rows. The front cover, attached to the forward crankcase, encloses the front row sleeve-drive gear and supports the cover for the reduction bevel gear set that drives the propeller. A two-speed supercharger is attached to the rear of the crankcase, and a rear cover is mounted to the rear of the supercharger casing. The rear cover carries drives for two magnetos, the starter, accessory gearbox and Hobson injection carburettor.

The crankshaft is an assembly of three major components held together by four maneton[2] bolts, two each at the front and rear crankpins[3] (Figure 4). The crankpin bearings are steel sleeves coated with a tin-based soft white metal[4] bearing layer 0.015” thick. Oil is supplied to the crankpin bearings through drillings in the hollow crankshaft, and is distributed around the bearing surface through V-shaped grooves. Oil pressure is retained in the crankpin bearing by a silver-plated fixed oil retainer (Figure 5) on one side of the master rod and a floating oil retainer on the other, which also distributes oil to the articulated rod wrist pins.

Footnote

[2] A maneton bolt is a fastener used to clamp the counterweight onto the crankshaft, through controlled tightening to a defined bolt stretch.

[3] A crankpin is the part of the crankshaft to which the connecting rods are attached. In a radial engine, the master rod big end transfers all the loads from each cylinder to the crankpin.

[4] The bearing alloy was Bristol specification B.A.C.E. 25, known commercially as Hoyt No.11 Z.3, composed approximately by weight of 86% tin, 6.0-7.5% antimony, 2.5-3.5% copper, 2.25-3.25% silver and less than 0.6% nickel.

The crankpin bearing sleeves are shrunk onto the crankpin journals to provide an interference fit, to prevent the sleeve from rotating on the journal, thereby maintaining alignment between the oil supply holes in the crankshaft and the oil entry holes in the bearing sleeve. Four dogs[5] at one end of each sleeve engage with the fixed oil retainer to further restrain the sleeve from rotating on the journal.

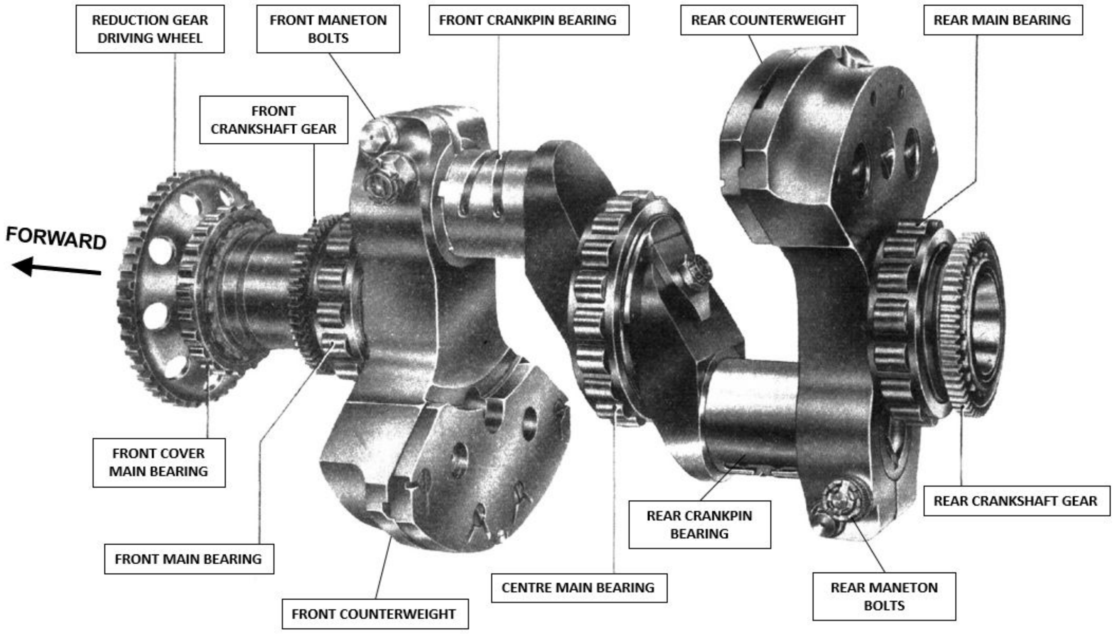


Figure 4

Crankshaft assembly

Each row of nine cylinders is connected to the crankshaft by a high-tensile steel master connecting rod, to which eight articulated connecting rods are connected via wrist pins arranged around the master rod big end. The master rod big end bore is hardened and ground to the required size at manufacture, and rides on the crankpin bearing. The crankpin bearings are reliant on the presence of a lubricating oil-film to prevent excessive bearing wear and overheating.

Footnote

[5] In engineering usage the term ‘dog’ refers to a lug or other feature that prevents movement through physical engagement.

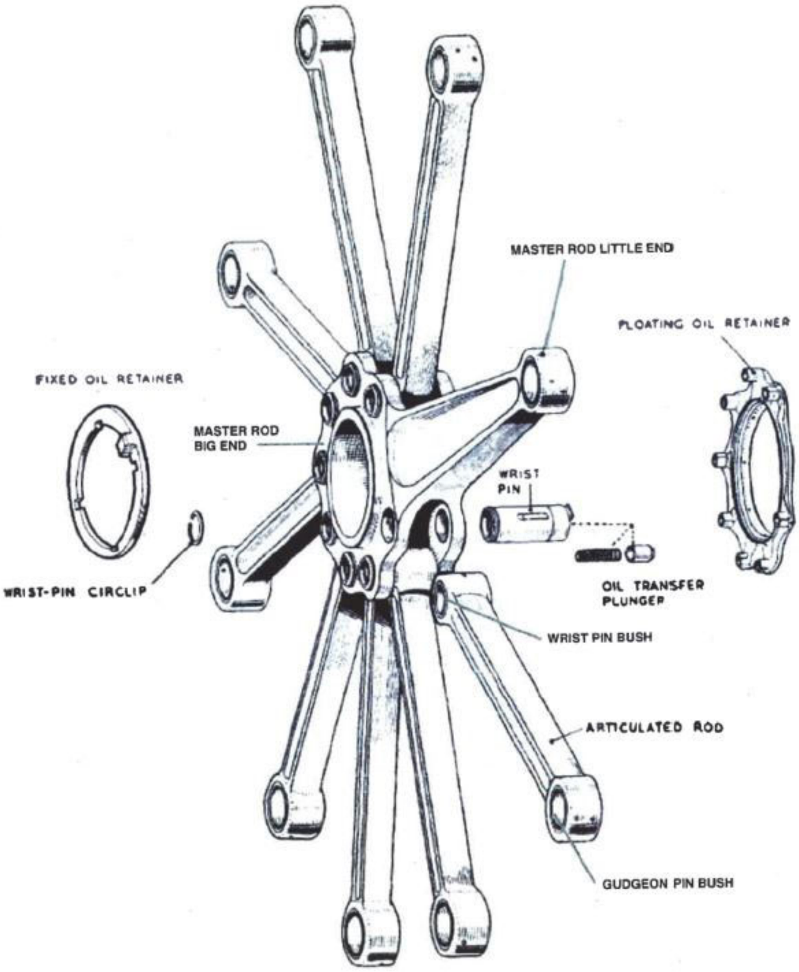


Figure 5

Master rod and articulated rod assembly

Oil grade

The *General and Technical Information publication for the Centaurus Mk 18 Aero Engine*[6], in its *Leading Particulars* section, states that the oil grade to be used in the engine is a 100-weight[7] mineral oil to Joint Service Designation (JSD) OM 270. This is a straight mineral oil with no additives. During the majority of the Sea Fury's military service life however, AeroShell Oil 100U was used, which is a dispersant[8] oil with metallic additives specifically formulated for Bristol sleeve valves engines. In 1965 the Ministry of Defence (MOD) conducted a trial of OMD 370, a 120-weight dispersant oil with non-metallic additives in Centaurus engines, however increased rates of piston ring failures, piston ring gumming and head ring failures occurred which led to the trial being halted.

Footnote

[6] AP 102B-7501-1A, January 2006 (superseding AP 4146B Vol.1).
[7] The weight of an oil is a measure of its viscosity; the higher the value, the thicker the oil is.
[8] A dispersant additive assists in keeping combustion products suspended in the oil.

Stocks of 100U oil continued to be made available to the operator through the 1980s and 1990s until supplies were exhausted in approximately 2003. Following correspondence between the MOD and a lubricant specialist, a recommendation to use AeroShell Oil W100 was made. W100 is a 100-weight dispersant oil with non-metallic additives, widely used in poppet-valve piston engines. Correspondence between the MOD and the engine manufacturer in 2015 re-confirmed the recommendation to use W100 in Centaurus engines and stated that “it is essential to keep the oil system as clean as possible”.

Following the installation of G-RNHF’s overhauled engine, approximately six hours of engine ground-running was carried out using straight 100-weight mineral oil, before the oil was drained and replaced with AeroShell Oil W100.

Oil system

The engine is of the dry-sump type with an external oil tank mounted to the firewall and an oil cooler mounted in the left wing leading edge. The capacity of the oil system is 14 imperial gallons (112 pints) and typical engine oil consumption varies between 12 and 20 pints per hour, depending on the power setting.

Oil is gravity-fed from the tank, through a wire-mesh strainer to the engine-driven oil pump located at the base of the engine sump. The oil pump incorporates both a pressure pump and scavenge pump, which protrudes into the sump and is immersed in scavenge oil. Oil is drawn into the scavenge pump through a wire-mesh strainer. Additional scavenge return pumps, driven by the sleeve valve drive gear, are located at the front and rear row crankcases to return scavenge oil to the sump. Each scavenge return pump has a perforated inlet screen.

Oil pressure is measured at the outlet of the pressure pump and is displayed on gauges in both cockpits which also display the oil temperature and fuel pressure (Figure 6).

Figure 6

Combined oil temperature, oil pressure and fuel pressure gauge in the front cockpit

A pressure relief valve within the oil pump is set to limit the outlet pressure to 100 psi. A separate high initial oil pressure (HIOP) valve in the oil pump limits excessive oil pressure during cold starts by bleeding excessively-pressurised oil to the inlet side of the scavenge pump. High pressure oil from the pump is fed into the rear of the hollow crankshaft to lubricate the crankpin bearings, crankshaft main bearings and oil jets that splash-lubricate the bottom of the pistons and sleeves. An additional feed from the oil pump supplies two oil centrifuges which remove sludge and aeration from the oil that is fed to two clutch units used to drive a two-speed supercharger. High pressure oil is also supplied to the propeller constant-speed unit through a separate wire-mesh oil strainer. A pressure-reducing valve is used to reduce high pressure oil from the pump to 30 psi to lubricate the sleeve-drive gears and accessory gearbox.

Oil scavenged from the sump is returned to the oil tank via an anti-surge valve that returns oil directly to the tank during cold starting, when the oil is cold and viscous. Once the oil temperature has risen the anti-surge valve closes, forcing oil to flow to a thermostatic valve. When the oil temperature is below 50°C, the thermostatic valve causes the oil to bypass the oil cooler allowing the oil temperature to reach its minimum working temperature as soon as possible after the engine is started. As the oil temperature rises, the thermostatic valve progressively opens allowing more oil to flow through the cooler until the oil temperature rises to 90°C, when the valve is fully opened and all oil is passed to the cooler.

Engine history

The engine fitted to G-RNHF was an overhauled unit built around a core[9] purchased in the USA and a set of cylinders, sleeves, pistons and gudgeon pins sourced from a supplier in Australia. The previous running hours of these components was not established due to a lack of service records. Other components required for the engine were either sourced commercially or issued from the operator’s parts store. A survey of the engine’s modification state was performed by the maintenance organisation which concluded that the engine conformed to a 1952 build standard, with the caveat that other modifications of a later date may have been embodied but could not be proven due to a lack of technical information or part number marking.

The aircraft’s maintenance organisation performed an overhaul of the engine based on the requirements contained in the Bristol Centaurus XVIII Overhaul Manual. The overhaul included disassembly of the engine into its constituent parts, stripping of protective finishes and geometric and NDT inspections of critical components as required by the overhaul manual. The engine was first run after overhaul in August 2017, fitted to G-RNHF which itself had undergone repairs following an accident in 2014[10]. The engine had accumulated 69.8 flying hours when the accident occurred. Apart from a minor oil leak from a magneto drive oil seal, there were no other engine-related deferred defects recorded.

Footnote

[9] The core engine consisted of the crankcase and crankshaft assembly, propeller reduction gearbox, sleeve-drive gears, supercharger and rear cover casings.

[10] AAIB Accident Report EW/G2014/07/32, published in the July 2015 AAIB Bulletin with an Addendum EW/C2014/07/02 published in the September 2017 AAIB Bulletin.

The Centaurus engine is not supported by the manufacturer under its Historic Engine Policy, and the maintenance facility and operator had to rely on copies of relevant technical publications they held on file. Original drawings and specifications for engine components were generally not available to them apart from a drawing of the crankshaft oil gland seal, which was issued to the maintenance facility by the manufacturer to allow a new seal to be produced, as no stocks were available.

Maintenance programme and engine lifing policy

The life between overhauls for Centaurus XVIII engines when in service use with the Royal Navy was set at 500 flying hours[11]. The maintenance organisation and operator noted that this figure was "difficult to achieve" based on their previous experience and they set the initial service life at 150 hours, with the intention of extending this figure based on satisfactory performance of the engine. They also agreed to perform an internal inspection of the engine at 50 hour intervals, with access inside the crankcase provided by removing one front and one rear cylinder at each inspection. The contents of the oil strainers and centrifuges were to be cleaned and examined at 25 hour intervals, and oil samples for a SOAP[12] programme were to be taken at 10 hour intervals.

The aircraft's maintenance programme required annual Primary inspections, Minor inspections every two years and Major inspections every six years. Routine maintenance was also specified at 25-hour intervals. A review of the maintenance records showed that the required maintenance had been carried out in accordance with the maintenance programme.

The aircraft entered an extended period of storage between November 2019 and April 2021 for which the engine was inhibited by coating the internal components with a 3:1 mix of engine oil and corrosion inhibitor[13]. Desiccant plugs were also fitted in place of the spark plugs. The engine was de-inhibited in February 2021 and run, following the required pre-oiling[14] process.

A Primary inspection was completed on 12 April 2021 and following the replacement of spark plugs to cure engine rough running, the aircraft flew from the maintenance facility to Yeovilton on 23 April 2021. The accident occurred on the next flight on 28 April 2021. As the period during which the aircraft's engine had not run was less than seven days, no pre-oiling process was carried out. The operator carried out a before-flight check on the morning of the accident flight, during which 1.5 gallons of oil was added to the oil tank, bringing the engine oil system level to 13 gallons.

Footnote

[11] The AAIB understands that application of certain modifications and Bristol Technical Leaflets extended the service life of Centaurus XVIII engines beyond 500 flying hours, but has not been able to confirm this.

[12] Spectrometric Oil Analysis Programme (SOAP) is a method used to monitor the health of aircraft engines and gearboxes by periodic laboratory analysis of oil samples. The laboratory tests reveal the composition and level of metallic particles suspended in the oil sample.

[13] AeroShell Fluid 2XN.

[14] The pre-oiling process ensures that the engine is sufficiently lubricated following inhibiting or when the engine has not been run for periods greater than seven days. It involves removing the spark plugs and pumping two gallons of heated oil through the engine oil system at a pressure of 60 psi, before rotating the propeller by hand through 12 complete revolutions. Following this a further gallon of heated oil is pumped through the engine oil system. The oil pipe between the tank and the engine is also purged of air in this procedure.

Meteorology

The weather forecast for RNAS Yeovilton was for a north-easterly wind, good visibility with broken cloud at 2,000 ft aal. Reports from the airfield at 1250 hrs indicated the wind was 040/17, visibility in excess of 10 km and cloud broken at 2,000 ft aal. There was little change between the 1250 hrs observation and the next at 1350 hrs.

Airfield information

RNAS Yeovilton is operated by the Royal Navy. It has a 2,292 m runway running 080-260° and a shorter 1,464 m runway 040-220° as well as a 600 m grass strip for light aircraft to the north of the main runway.

Personnel

The pilot of the aircraft has extensive 'warbird' experience including on the Sea Fury. Although this was only his second flight on the aircraft in the previous few years due to the aircraft storage and overhaul, he had flown a number of other similar types recently to prepare himself.

The passenger, although not rated on the Sea Fury, also has extensive experience on similar aircraft types. He was flying in the Sea Fury to familiarise himself with the aircraft and was able to offer some assistance to the pilot during the flight.

Survivability

Both the pilot and passenger were wearing full military style flying kit and helmets. Despite the extensive disruption to the aircraft during the accident, neither pilot suffered serious injuries. The cockpit area proved to be strong, maintaining its shape although it came to rest almost completely inverted. None of the harness straps failed and the helmets protected the occupants' heads during the accident sequence as well as during their escape from the aircraft. The pilot was able to leave the cockpit through the smashed front canopy and the rear canopy had slid back during the accident sequence allowing the passenger to vacate the rear cockpit. There was no post-accident fire.

Examination of the pilot's helmet after the accident showed that it had suffered a significant blow at some point during the accident sequence. Although the pilot suffered a small fracture to the skull, the helmet had protected him from a much more serious head injury.

Aircraft operation

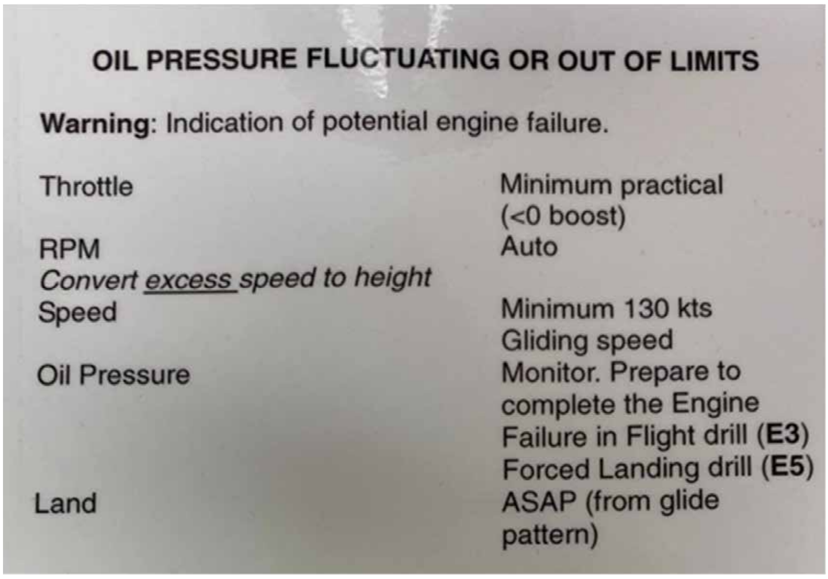
Pilot notes, maintenance manuals, engine manuals and checklists were based on the original naval military documents. The operators of G-RNHF had an extensive manual suite for the servicing and maintenance of the aircraft.

Emergency checklists

The operator of G-RNHF had developed a set of Flight Reference Cards (FRCs) which contained the normal checklist, as well as actions to be taken in the event of an emergency.

These emergency checklists included 'Oil Pressure Fluctuating or out of limits', 'Engine Failure in Flight' and a 'Forced Landing Drill'.

The operators FRCs checklist for oil pressure fluctuating or out of limit is:



OIL PRESSURE FLUCTUATING OR OUT OF LIMITS

Warning: Indication of potential engine failure.

Throttle	Minimum practical (<0 boost)
RPM	Auto
Convert excess speed to height	
Speed	Minimum 130 kts Gliding speed
Oil Pressure	Monitor. Prepare to complete the Engine Failure in Flight drill (**E3**) Forced Landing drill (**E5**)
Land	ASAP (from glide pattern)

Figure 7

FRCs Actions for Oil Pressure

The FRCs required the aircraft to be landed as soon as possible from a glide approach.

In this accident, on noticing the oil pressure issues, the pilot immediately initiated a return to Yeovilton. He did not consider that there were any mechanical signs of a failure and opted to leave the throttle where it was already located, minimising the change. Given his limited flying on the type, he decided to return to Runway 04 although this was a longer routing. Landing on Runway 08, whilst a shorter track distance, would have meant a reasonable crosswind which the pilot considered to be of a greater risk than the extra time to reach the into wind runway.

As the pilot flew the aircraft around the base turn for landing, he closed the throttle as he considered that he was too high and it was very shortly after this that the engine failed. He was unable to feather the propeller and a very high rate of descent was required to maintain the aircraft speed. Although the FRCs contained a forced landing drill, there was only around 10 seconds between the engine failing and the aircraft striking the ground. The pilot did not have the time to consider or complete the drill. This meant that both canopies were locked closed, rather than jettisoned or locked open as required by the forced landing checklist.

Whilst the FRCs required a glide approach to be flown, the seizure of the engine and propeller with no ability to feather would have rendered any glide approach path inadequate for the rate of descent that was required to maintain a suitable speed.

Engine examination

The propeller and engine cowlings were removed along with three cylinders from the rear row which revealed that the master rod and crankpin bearing had broken up, leaving the rear crankpin journal exposed (Figure 8). The remains of fractured articulated rods and pistons were visible in the bottom of the rear crankcase.

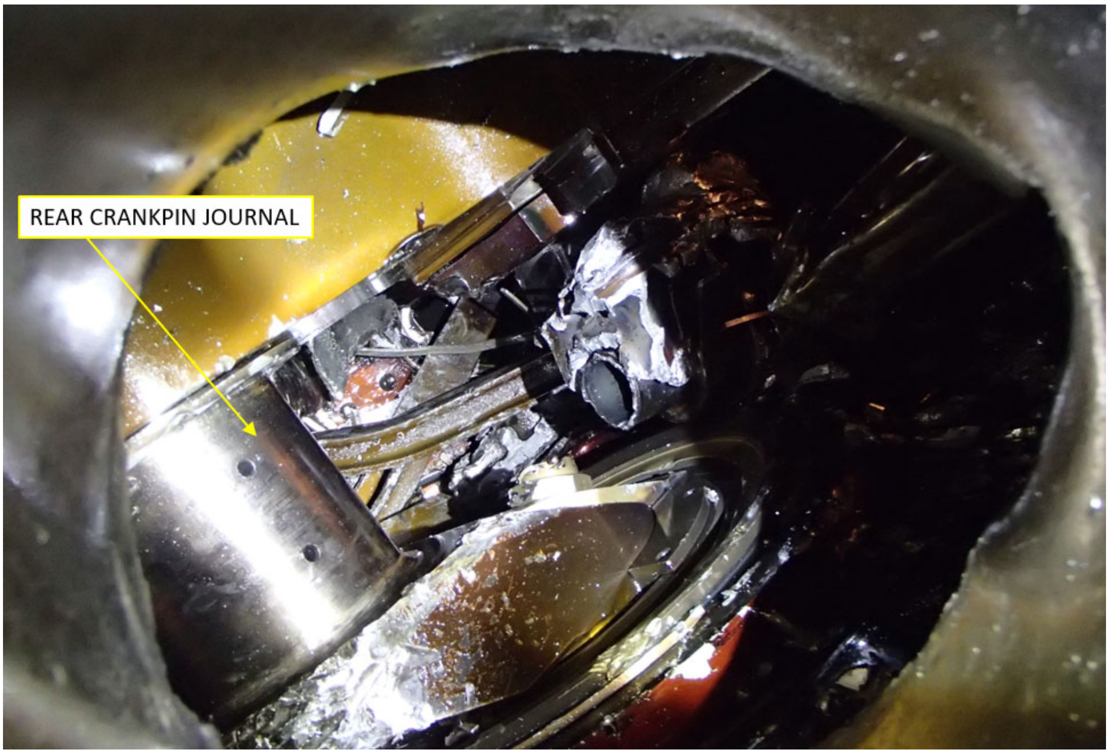


Figure 8

View inside the rear crankcase, looking down the No 17 cylinder

The engine was disassembled which showed that the front row components were largely intact, with only minor impact damage evident from debris liberated by the rear row that had entered the front row through the crankcase lightening holes. The rear master rod and articulated rods were fractured in multiple locations (Figure 9).

The fractured sections of the master rod big end showed evidence of overheating and a large number of cracks were present on the face of the master rod big end bore (Figure 10). The front master rod bore exhibited similar cracking. Examination of the cracks in the rear master rod bore showed that they were intergranular, following grain boundaries, and were coated with tin. Metallurgical assessment of the cracks noted that they were likely caused by liquid metal embrittlement (LME) of the master rod steel material with molten tin from the crankpin sleeve bearing. Three conditions are required for rapid crack propagation in steel due to LME with tin; the steel must be in a state of tension, with the steel surface free of oxidation and the liquid tin must intimately wet the steel surface. All three conditions were present in the master rod big end bores during the engine failure.

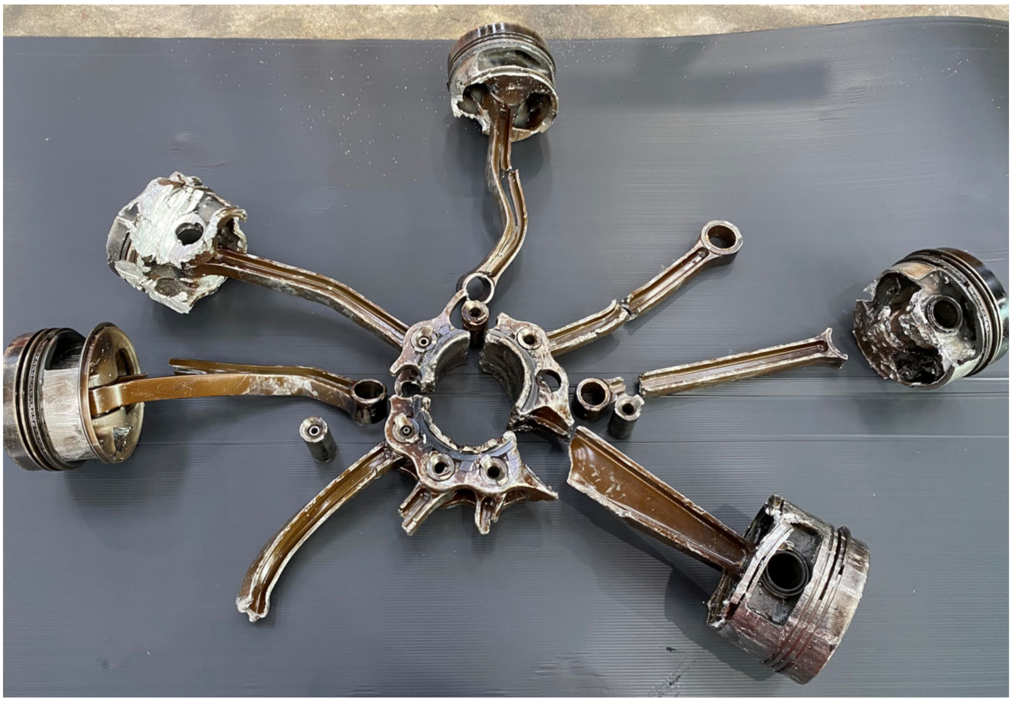


Figure 9

Front view of reassembled components of the rear row master and articulated rod assembly

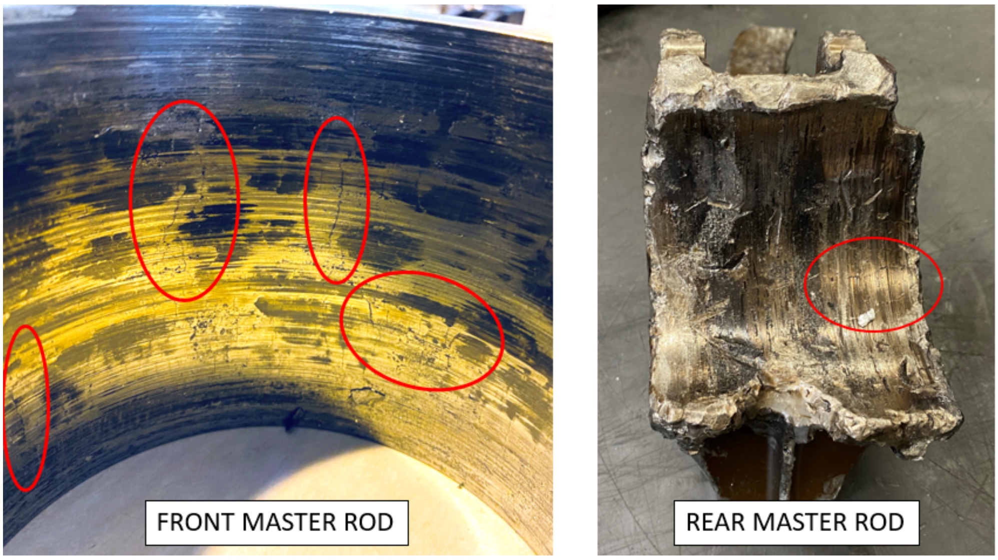


Figure 10

Cracks (circled) in the front and rear master rod big end bores

The fractures to the rear articulated rods were inspected and determined to be consistent with mechanical overload. There was no visible evidence of any progressive crack propagation, although smearing of some of the fracture surfaces during the engine failure prevented a complete examination.

The rear half of the crankshaft was bent and the rear maneton joint had slipped, opposite to the direction of crankshaft rotation, due to contact between the rear counterweight and debris within the rear crankcase liberated during the engine failure. Fretting marks were present on the mating surfaces of the rear maneton joint (Figure 11). The crankshaft rear main roller bearing had failed in overload.

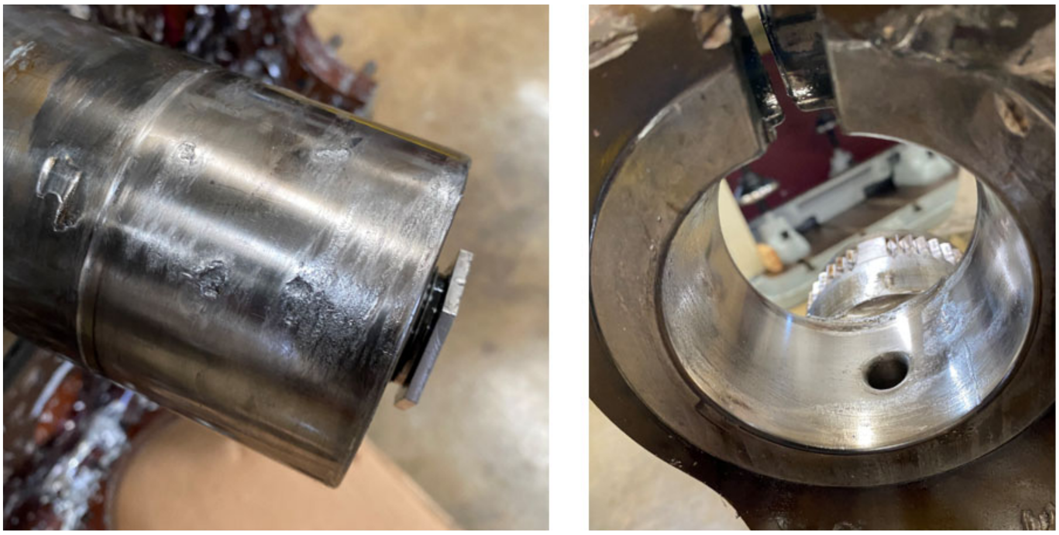


Figure 11

Fretting damage to the rear maneton joint

Both rear maneton bolts were mechanically damaged due to impacts. The degree of stretch present in the rear maneton bolts was measured during disassembly and found to be 0.009” for the rearmost bolt and 0.004” for the adjacent bolt. This was lower than the specified range of 0.013” - 0.015”, which was recorded as being applied to both rear maneton bolts in the engine overhaul records. The elemental composition and hardness of the maneton bolts were analysed, which showed that they were manufactured from BS S97 steel rather than BS S65 steel as specified on the bolt’s part drawing. BS S97 has similar mechanical properties to BS S65. The bolts were found to geometrically conform to drawing requirements.

The rear crankpin sleeve bearing was broken into three pieces (Figure 12). The sleeve’s locating dogs were sheared off and it had spun on the crankpin. The sleeve had overheated, causing the white metal bearing layer to melt and little bearing material was left on the sleeve.

Metallurgical analysis of the rear crankpin bearing confirmed the elemental composition of the white metal bearing material, along with lead bromide deposits, which are formed during the combustion of avgas fuel containing tetraethyl lead. The examination also revealed a small deposit of cadmium that had melted and resolidified on the bearing’s surface, indicating that the bearing temperature exceeded 321°C during the engine failure. The source of the cadmium was considered to be a fragment of cadmium plating from elsewhere within the engine, liberated during the failure sequence.

Figure 12

Front and rear crankpin sleeve bearings

The front crankpin bearing had missing regions of white metal bearing material adjacent to the oil entry holes (Figure 13). Examination of the missing bearing material under a scanning electron microscope showed that an antimony-tin phase of the white metal had melted due to contact with oil in excess of 232°C, leaving behind a copper-tin phase of the material which remained due to it having a higher melting point of 344°C. Some of the bearing material had been smeared, due to contact with the master rod bore once the lubricating oil-film was lost. The sleeve's locating dogs were intact and it had not rotated on the front crankpin.

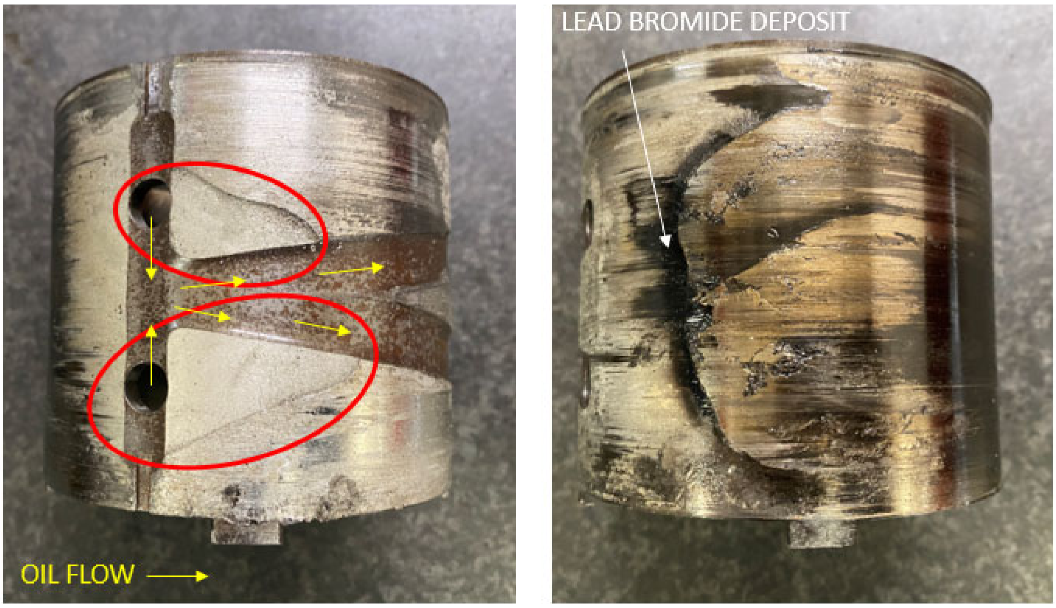


Figure 13

Front crankpin sleeve bearing, with missing bearing material circled

The rear row sleeves were all damaged at their bottom ends due to impacts received during the engine failure (Figure 14). The sleeve drives for cylinders 3, 5 and 9 had failed in shear overload and 11 had failed in bending due to an impact. The front row sleeves were largely undamaged apart from cylinders 6, 12 and 14 which had received light impact damage at their bases. The sleeve drives for cylinders 10 and 14 had failed in shear overload. All of the sleeves in both rows of cylinders exhibited elliptical scoring marks on their outer surfaces, indicating that they were all being driven normally whilst metallic debris was circulating in the engine oil system. No significant corrosion was observed on any of the engine components.

Figure 14

Typical impact damage to bottom end of a rear row sleeve (No 7 shown)

The magnetos were removed and run on a test rig. Whilst the left magneto operated normally, the right magneto sparked erratically. This magneto was disassembled, revealing that impact distortion to the casing had caused the points gap to close up, causing the erratic sparking. The ignition cable harnesses did not have any evidence of pre-accident defects, and all 36 spark plugs were in good condition with no damage observed to their electrode tips or ceramic insulation.

The pre-impact positions of the engine controls in the front and rear cockpits could not be established due to disturbance of the control rods and cables when the engine separated from the fuselage in the accident. The supercharger control valve was examined, however it was not possible to establish the supercharger gear selection at impact as the spool within the control valve is moved to the low gear position, under spring loading, once oil pressure is lost.

Oil system examination

Oil samples recovered from the oil tank, sump and crankcase all contained fine metallic debris and larger debris was trapped in the sump strainer and scavenge pump screens. A greater amount of debris was present in the forward crankcase scavenge pump screen than the rear. This could be attributed to drive to the rear scavenge pump having been lost during the engine failure sequence due to an impact of its sleeve-drive driving gear, whilst the front scavenge pump continued to be driven until the engine eventually seized.

The oil supply and return pipes between the engine and oil tank had parted in overload when the engine broke away from the fuselage. All engine oil pipes and hoses were examined and no blockages or other pre-existing deterioration was observed. The oil cooler was flushed and pressure-tested, and apart from the presence of metallic debris generated by the engine failure, no abnormalities were noted. The anti-surge, thermostatic and pressure control valves were disassembled and no defects were evident.

Mechanical drive between the crankshaft and oil pump was confirmed. The oil pump was disassembled revealing that its internal components were in good condition, including the HIOP and pressure relief valves. The crankshaft oil gland seal was installed in the correct orientation and was slightly stiff, but otherwise in good condition. The oil centrifuges were opened and a small amount of oil sludge was present. The oilways within the engine, including the crankshaft oil passages were clear of blockages and the required sealing between casings was present. The oil jets on the front crankshaft counterweight and centre bearing retaining bolt were free of obstructions, however the rear counterweight oil jet was too damaged to determine its condition prior to the engine failure.

Oil analysis results

The aircraft operator and maintenance organisation each sent engine oil samples to different laboratories for analysis (Figure 15). Oil samples were taken either from the oil sump drain point or the oil tank, and occasionally from both points. The operator's laboratory reported the results without reference to limiting values, whereas the maintenance organisation's laboratory provided warnings when the levels of certain elements exceeded thresholds set by that laboratory.

The oil analysis results were monitored by the maintenance organisation and did not give cause for any unscheduled maintenance or other investigation. Levels of tin above the warning level were ascribed to 'bedding in' of the sleeve-drive gears, which had been tin-plated during the engine overhaul. Relatively high levels of lead in the oil, thought to originate from tetraethyl lead in the avgas fuel, were seen to reduce to normal levels following an engine oil change. No warning level had been set for lead concentration level.

The maintenance organisation sent an oil sample from an oil centrifuge for analysis in July 2019, for comparison against oil drained from elsewhere within the engine oil system. This sample contained levels of metallic elements that were significantly higher than for previous oil samples. This result was interpreted by the maintenance organisation as confirmation that the centrifuges were successfully removing debris from the oil system, as was intended by their design.

Following the accident a sample of engine oil was analysed which showed that, aside from metallic particles present in the oil due to the engine failure, the oil conformed to a reference sample of unused AeroShell Oil W100 apart from the Total Acid Number (TAN). The sample TAN was 0.140 mgKOH/g, which was higher than the reference sample value of 0.016 mgKOH/g. The laboratory noted that TAN rises in engine oil during normal engine running, and that a value 1.0 mgKOH/g is regarded as an acceptable upper limit for W100 oil.

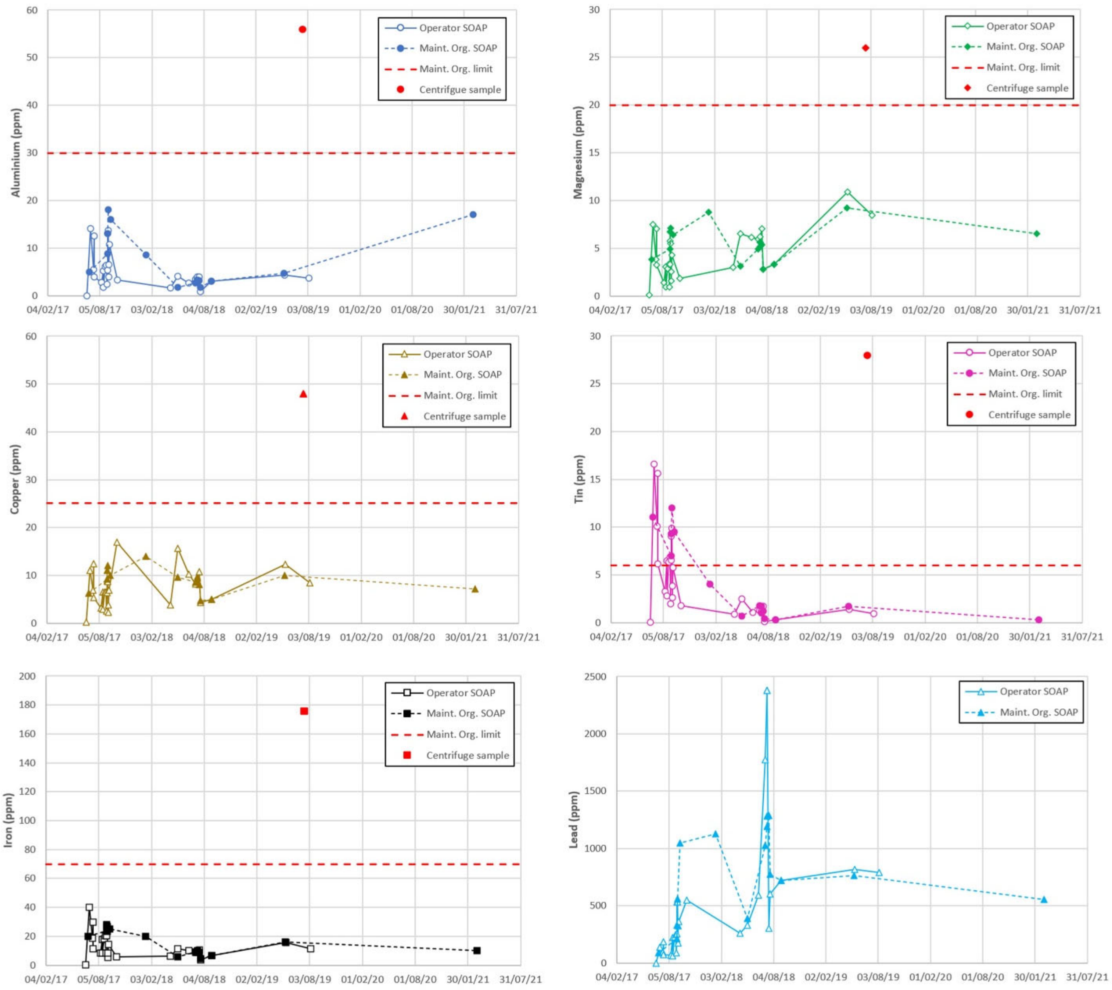


Figure 15

Summary of SOAP programme data

Other information

Sources of airworthiness information

The design standard and sources of information relating to the continued airworthiness of an aircraft operating on a National Permit to Fly (NPF) are defined in its Airworthiness Approval Note (AAN). The AAN for G-RNHF[15] was issued by the CAA in September 2010, following a review of the aircraft, its documentation and a design report submitted by the applicant. G-RNHF's NPF was issued by the CAA in 2011 and required an annual airworthiness review to remain valid, through a process resulting in the issue of a Certificate of Validity (CofV).

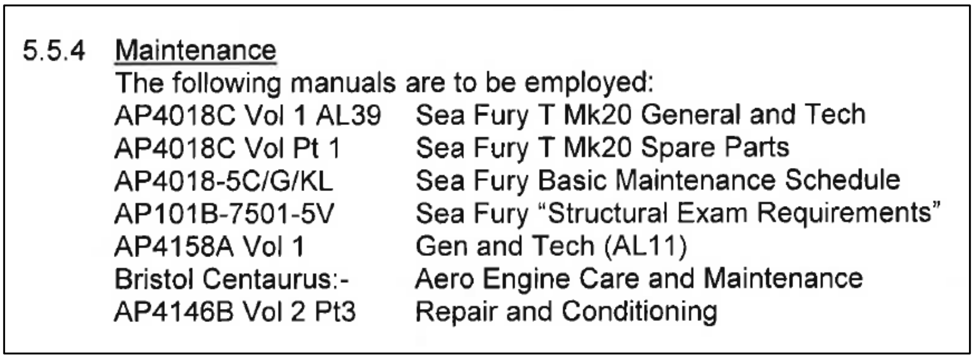
Footnote

[15] CAA Airworthiness Approval Note No. 29215, 15 September 2010.

The aircraft's maintenance organisation holds CAA approval under CAP 553 BCAR A8-25, permitting the organisation to conduct the airworthiness review and issue CofVs. G-RNHF's last CofV was issued on 9 April 2021 and was therefore valid when the accident occurred.

G-RNHF's AAN stated that the basis of approval for the aircraft included service experience with the type on the basis of precedence, along with an assessment of modifications as listed in AP4018C Volume 2, Part 1, which listed manufacturer's modifications applicable to the Sea Fury. The AAN further stated that this modification list had been assessed by the applicant and those considered relevant to the airworthiness, classified B/2 or above, had been applied. AP4018C relates to airframe modifications and does not contain modification data relevant to the engine.

Section 5.5 of the AAN provided a list of required manuals for the maintenance of the aircraft and its engine (Figure 16). The AAN stated a required amendment status for two of the manuals, but not for the others.



5.5.4 Maintenance

The following manuals are to be employed:

AP4018C Vol 1 AL39	Sea Fury T Mk20 General and Tech
AP4018C Vol Pt 1	Sea Fury T Mk20 Spare Parts
AP4018-5C/G/KL	Sea Fury Basic Maintenance Schedule
AP101B-7501-5V	Sea Fury "Structural Exam Requirements"
AP4158A Vol 1	Gen and Tech (AL11)
Bristol Centaurus:-	Aero Engine Care and Maintenance
AP4146B Vol 2 Pt3	Repair and Conditioning

Figure 16

List of required manuals from G-RNHF's AAN

In addition to the required manuals, the maintenance organisation had a copy of *Centaurus Aero-Engines Modification Lists*[16], which contains a tabulated list of Centaurus engine modifications. The title of each modification is listed, along with its Class and Repair Modification Category, but no additional description or embodiment instructions for the modifications are provided. The maintenance organisation also had a 1958 copy of the Centaurus XVIII *Illustrated Parts Catalogue*[17], which contains amendments to part numbers affected by issued modifications at that date.

Centaurus engine modifications are generally classified by a Ministry of Supply scheme of a combination of a letter and a number. The letter denotes the Repair Modification Category and the number denotes the Class of the modification. Repair Modification Categories vary between A and D (Table 1) and Class categories vary between 1 and 4 (Table 2).

Footnote

[16] AP2039, Amendment List 8, January 1963.
[17] Bristol Centaurus 18 and 57 Engines, Illustrated Parts Catalogue, Amendment List 12, January 1958.

Repair Modification Category	Meaning
A	Essential. Engines not to be dispatched without.
B	Essential when material available, on complete overhaul.
B*	As B, but must also be fitted on partial overhaul.
C	As material available.
D	Only when existing parts are worn out.

Table 1

Ministry of Supply Repair Modification Categories

Modification Class	Meaning
1	Safety modifications requiring immediate and compulsory embodiment in all engines of the type and/or mark, pending which flying is suspended.
2	Modifications of an operational character or of sufficient importance from a safety point of view to justify compulsory embodiment in all engines of the type and/or mark, but flying will not be restricted in the meantime. These modifications should be embodied before the issue of engines or aeroplanes to squadrons and similar units.
3	A desirable modification, the embodiment of which is discretionary. Commands are not entitled to refuse to accept engines which may be issued to them without these modifications embodied.
4	Modifications carried out only at maker's works and at repair depots.

Table 2

Ministry of Supply Modification Classes

In addition to modifications classified as above, a significant number of the available modifications were instead classified as Salvage, relating to the re-working of obsolete parts to a later modification standard.

The engine's modification status listed by the maintenance organisation when the engine was overhauled was compared against the list of available modifications for the Centaurus XVIII. Two Category A modifications were stated as embodied, against a total of four available Category A modifications however examination of the engine by the AAIB confirmed that all four Category A modifications were present. Sixty-nine modifications classified as B/2[18] and listed as available for the engine were not stated as embodied at overhaul, although the maintenance organisation had noted that other modifications of a later date may have been embodied, but could not be proven due to a lack of technical information or part number marking.

Footnote

[18] Repair Category B modification that was Modification Class 2.

Examination of the part numbers stamped on the sleeves revealed that two of the rear row sleeves, on cylinders 5 and 7, had been subject to salvage modification E.3338. This involved reapplying nitriding to the surface of the sleeves and stamping the modified sleeves with an additional part number[19]. The modification title for E.3338 stated that such modified sleeves were not to be used for master rod cylinders (number 7 and 8 on the Centaurus XVIII).

The operator held a copy of *Historic Centaurus Mk 18 and 58 Modification Leaflets*[20] on file, which had originally been held by the MOD before being transferred to the operator by the MOD on 1 January 2021[21]. This document had not been shared with the maintenance organisation by either the MOD or the operator, and the maintenance organisation was unaware that the operator had a copy of it. The operator stated that as the aircraft had been declared airworthy by the maintenance organisation, there was no perceived need to share the document with them.

The document contained detailed information relating to 86 modifications for the Centaurus XVIII, issued between June 1946 and April 1955. The information provided in each leaflet included the reason for the introduction of a modification, lists of required parts, embodiment instructions and illustrations. The maintenance organisation noted that whilst certain parts listed in a Modification Leaflet might no longer be available, the information contained in the leaflets was very useful in determining whether a particular modification was embodied, or was relevant to the airworthiness of the engine.

Analysis

Once the pilot and passenger had strapped into G-RNHF for a staff continuation training sortie, the engine was started normally and was described as running well by the pilot. The after start and before takeoff checks were completed on the ramp with the chocks in place as was normal practise. Although the supercharger check was missed by the pilot in his normal sequence, he was prompted by the rear seat occupant to complete it before the aircraft was taxied to the runway. There were no abnormal indications during or after the engine start.

As the aircraft approached the runway, the pilot noticed that the oil pressure was indicating 60 psi which was below the minimum limitation. This reading was confirmed by the rear seat occupant, but as the pilot increased the engine rpm to 1,200 the reading immediately recovered to a normal level. The pilot considered at the time that this might have been due to the oil being hotter than normal after the checklist items were completed. It is possible that this may have been the first indication of a problem with the engine.

Having departed from RNAS Yeovilton, the pilot began to head east towards clearer weather when he noticed that the oil pressure was low. He informed the tower at Yeovilton and

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Footnote

[19] SAL FB193081 for the rear row sleeves.
[20] AP 102B-7501-2, July 2013 (superseding AP 4146B Vol.2, Part 1).
[21] This transfer of documents coincided with the transfer of a number of historic aircraft from the MOD to the operator.

turned for the airfield. He considered that although the main runway (08) was closer, the crosswind presented a greater hazard to the aircraft and crew than the longer route to position for Runway 04.

The pilot was faced with a dramatic and complete engine seizure on the base leg turn to Runway 04. The aircraft position and height at the time of the failure, combined with the very significant increase in drag with the unfeathered propeller meant that it was not possible to reach the runway and the pilot was left with no choice but to attempt a forced landing from a very high rate of descent.

It is possible that, had the pilot decided to land on Runway 08, the engine might have still been running at touchdown but it is far from certain. There is no way to predict what caused the final failure and whether the cause may have occurred sooner had the aircraft throttle position been altered earlier in manoeuvring to Runway 08. Whilst the shorter pattern might have been considered a better option given the known outcome, the pilot was concerned about the crosswind when he had so little recent experience of the aircraft. The decision to proceed to Runway 04 was a reasonable one given that although the oil pressure was low there were no other indications of engine difficulties together with the pilot's lack of recent flying on type. Although the checklist required a glide approach to be flown, clearly given the rate of descent required once the engine had seized, any such glide approach pattern would have been rendered irrelevant as the aircraft height would still have been insufficient to reach the runway.

The time between the engine failure and the aircraft striking the ground was around 10 seconds. Although there was an emergency landing checklist that required the pilot and rear seat occupant to jettison or lock open their canopies, there was no time to complete these actions. Fortunately, both the pilot and the rear seat passenger were able to extract themselves from the wreckage as the front canopy had smashed and the rear canopy had slid open in the accident. The fact that both occupants were wearing helmets almost certainly saved them from any serious head injuries despite the cockpit coming to rest almost inverted.

Engine failure

The failure of the rear master rod resulted from overheating of the rear crankpin bearing, which caused its white metal bearing layer to melt. Increased friction between the crankpin bearing and the master rod bore was sufficient to shear the bearing sleeve's dogs, allowing the sleeve to spin on the crankpin journal. The molten tin liberated from the overheated bearing caused LME of the rear master rod big end. This promoted rapid crack propagation in the big end, leading to its eventual fracture into three main sections under the high loads imposed on it whilst the engine was running.

The damage sustained by the front crankpin bearing was caused by excessively hot oil flowing to it through the rear crankshaft, which had been heated by the failed rear crankpin bearing. This shows that some oil was still circulating within the high-pressure oil system whilst the rear crankpin bearing failure was underway. The overheated oil caused the partial melting of the front crankpin bearing, leading to similar LME-cracking of the front master rod big end although these cracks did not grow to a critical length and the front master rod remained structurally intact.

The breakup of the rear row connecting rods, pistons and sleeves occurred whilst the undisturbed front row continued to produce power, resulting in the very significant disruption observed within the rear row crankcase. The engine eventually seized when the rear maneton joint slipped, due to impacts between the rear counterweight and debris within the rear crankcase. Loss of alignment of the rear maneton joint caused sufficiently large radial loads on the rear main bearing that it failed in overload.

Despite the re-nitriding of the rear row's number 7 sleeve, which was not permitted under modification E.3338, there was no evidence to suggest that this contributed to the rear crankpin bearing failure. The sleeve had not seized in the cylinder bore and the lug at the base of the sleeve remained attached to its sleeve crank drive. All sleeves within the engine exhibited similar elliptical surface scoring due to contact with metallic debris in the engine oil whilst the sleeves were moving through their normal range of movement. Therefore the initiating event in the engine failure sequence preceded any subsequent failure of the rear row sleeves.

It is uncertain whether the loss of oil pressure observed by the pilot preceded the overheating of the rear crankpin bearing, or whether it occurred as a result of the bearing failure due to another unidentified cause, which then allowed oil to leak from it resulting in a loss of oil pressure. The remains of the bearing were too badly damaged to allow a determination of the cause of the bearing failure. It is possible that mechanical failure or rapid wear of a component within the engine, unidentified by this investigation, generated debris that circulated within the engine oil system. In this scenario any debris would reach the rear crankpin bearing first, due to the direction of oil flow within the crankshaft, and could cause rapid wear of the bearing, leading to its failure.

No pre-accident defects were identified in the engine oil system or its associated components. An unusually large number of oil samples were analysed for the SOAP programme, however after an initial 'wear-in' period, the oil analysis did not show any adverse trend that would have prompted the maintenance organisation to carry out unplanned maintenance or investigative activity.

Modifications

The maintenance organisation's assessment of the modification standard of the engine was hampered by a lack of relevant information, in particular in not having access to a complete set of Modification Leaflets covering all the issued modifications for the engine. The AAN for the aircraft only contained a requirement to consider the airworthiness implications of airframe modifications classified as B/2 or above, which the maintenance organisation complied with. The list of engine modifications embodied in the overhauled engine was therefore incomplete, however this information was accepted by a CAA surveyor when an audit visit occurred prior to operation of the aircraft with the overhauled engine.

The maintenance organisation's lack of access to Centaurus XVIII Modification Leaflets could have been partially alleviated if the operator or, prior to 1 January 2021, the MOD had shared those it held on file, however this did not occur as the maintenance organisation was unaware that they were potentially available and therefore had not asked for them.

As the investigation was unable to identify the cause of the rear crankpin bearing failure, no link can be drawn between the engine failure and the engine's modification standard. However since B/2 modifications relate to the improvement of an engine's safety or reliability, it is important that maintenance organisations have access to this information when assessing if an engine has a particular modification embodied, and if not, what the impact on its airworthiness may be.

Enquiries made by the AAIB during the investigation indicate that difficulties in access to relevant information for historic piston and turbine engines, particularly in relation to identifying engine modification status and modification data, is a systemic problem.

As a result of this investigation the CAA have agreed to meet with the engine manufacturer to discuss whether Modification Leaflets for the Centaurus XVIII can be made available to maintenance organisations servicing these engines, despite the restrictions imposed by the manufacturer's Historic Engine Policy.

Conclusion

The aircraft's engine failed shortly after takeoff on the second flight following a long period of aircraft storage. Examination of the engine identified that the rear crankpin bearing had overheated, leading to fracture of the rear master rod and destruction of the rear cylinder row components. Due to the severe engine damage, the investigation was unable to identify why the rear crankpin bearing overheated.

The point at which the engine seized on the base leg for landing left the pilot with no choice but to complete a forced landing short of the runway. Despite not having time to jettison or open the canopies, both pilots were able to vacate the cockpit once the aircraft had come to rest.

The investigation identified the difficulty maintenance organisations have in accessing technical information for historic engines, in particular that relating to engine modifications. The CAA have agreed to meet with the engine manufacturer to discuss whether Modification Leaflets for the Centaurus XVIII can be made available to maintenance organisations servicing these engines.

Published: 26 May 2022.

SERIOUS INCIDENT

Aircraft Type and Registration:	MD 900, G-LNDN	
No & Type of Engines:	2 Pratt & Whitney Canada PW207E turboshaft engines	
Year of Manufacture:	2008 (Serial no: 900-00125)	
Date & Time (UTC):	25 July 2021 at 2014 hrs	
Location:	In flight between Royal London Hospital and RAF Northolt, Greater London	
Type of Flight:	Commercial Air Transport	
Persons on Board:	Crew - 2	Passengers - 2
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Water damage to Symbol Generator and right Electronic Engine Controller	
Commander's Licence:	Airline Transport Pilot's Licence (Helicopters)	
Commander's Age:	58 years	
Commander's Flying Experience:	12,360 hours (of which 2,090 were on type) Last 90 days - 35 hours Last 28 days - 10 Hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a flight from the Royal London Hospital (RLH) to RAF Northolt, G-LNDN suffered a series of seemingly unconnected electrical system faults. The first faults related to the stability augmentation system (SAS) and the commander's flight instrument displays but did not materially affect the conduct of the flight. Later, when approximately 4 nm from their destination, the pilots were alerted to electronic engine control (EEC) system fault indications for both engines. A '*critical*' fault on the right engine required the pilots to manually control its throttle but the fault on the left engine was non-critical and the engine operated as expected in the NORMAL (automatic) control mode. The pilots were able to complete an uneventful approach and landing at RAF Northolt.

The electrical failures were the result of water ingress from the right engine bay onto electronic components located in the rear fuselage area.

Background

G-LNDN was an air ambulance helicopter hangared at RAF Northolt but routinely forward deployed to the RLH during operational hours, typically from 0800 hrs (local time) until sunset. The helicopter was operated in the multi-crew commercial air transport role and, for the incident flight, the co-pilot was initially Pilot Flying (PF).

History of the flight

Having deployed on routine tasking during the morning, G-LNDN returned to the RLH helipad shortly after 1300 hrs. During the afternoon there was no further tasking for the helicopter, so it remained on the helipad until the incident flight which departed for RAF Northolt shortly after sunset. Between 1300 hrs and 1700 hrs the helipad was subject to significant heavy showers and thunderstorms and, given its forward deployed location, it was not possible to shelter the helicopter during this period (Figure 1). The helipad's automated weather station recorded peak rainfall rates of 175 mm/hr and more than 50 mm total rainfall in the period 1300-2000 hrs (Figure 2), and the wind during this time was between 4 and 10 kt.

Figure 1

G-LNDN on the helipad at RLH during heavy rainfall

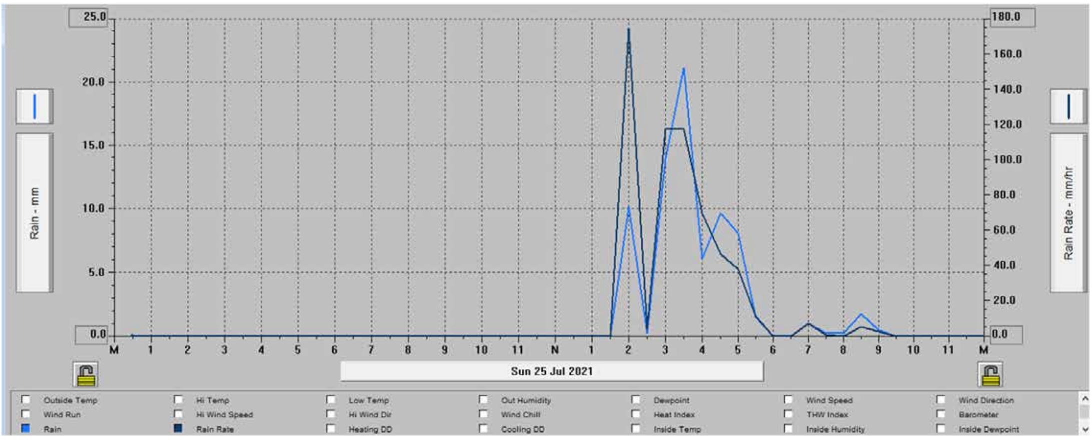

Figure 2

Rainfall chart for 25 July at RLH (times displayed are UTC+1)

At 2000 hrs the flight crew boarded the helicopter, along with two passengers, for the short flight to RAF Northolt. The start procedure was uneventful, but, having passed its built-in-test programme, the SAS would not engage prior to takeoff. Flight dispatch was conducted in accordance with the operator's minimum equipment list (MEL) which allowed day VFR flight with the SAS disengaged. The helicopter's planned flight profile would see it landing at RAF Northolt before nightfall.

After lift-off at 2014 hrs, the helicopter flew south to intercept the H4 London helicopter route above the River Thames, westwards towards Battersea. From Battersea the flight followed the H10 helicopter route to RAF Northolt (Figure 3).

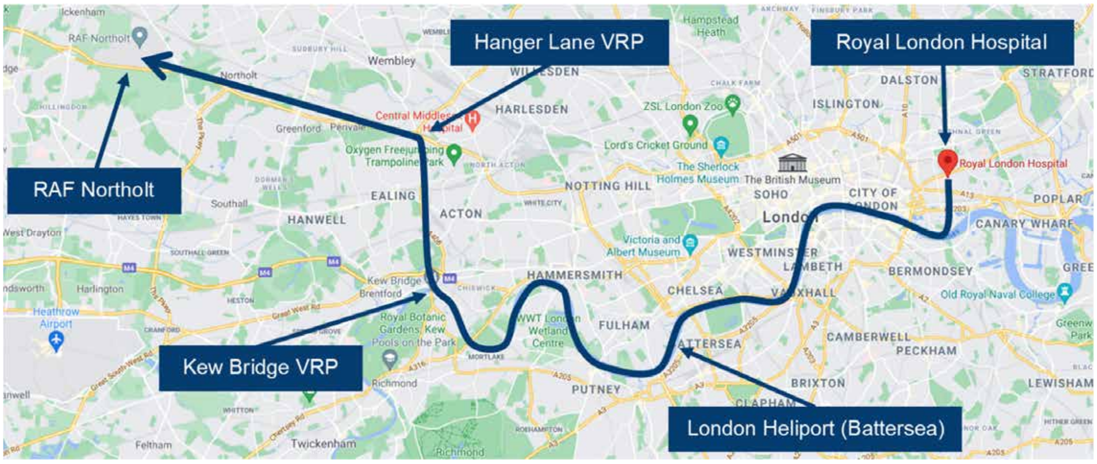

Figure 3

Overview of G-LNDN's planned route from RLH to RAF Northolt
(Map data ©2021 Google)

Shortly after passing the London Heliport at Battersea the commander's electronic horizontal situation indicator (EHSI) display (Figure 4) blanked. Then, as the helicopter approached the northerly turn at Kew Bridge Visual Reporting Point (VRP), the commander's electronic attitude display indicator (EADI) also began to fail, intermittently blanking and showing spurious caution messages. The co-pilot's electro-mechanical flight instruments were unaffected, and the flight continued northbound from Kew. Shortly after they turned westbound at the Hanger Lane VRP, the pilots were alerted to EEC system fault indications for both engines. Accompanied by an audio tone, a red FAIL warning indication on the helicopter's Integrated Instrument Display System (IIDS) (Figures 4 and 10) was displayed for the right engine's EEC (right EEC) and a yellow, non-critical failure, caution illuminated for the left engine's EEC (left EEC).

With just over three miles to go to RAF Northolt, the flight crew elected to continue to their destination as planned but the commander took control and the co-pilot assumed the role of Pilot Monitoring (PM). As part of their fault diagnosis the pilots noted that there was a torque (TQ) split between the two engines; the left engine was indicating approximately 47% TQ and the right engine was showing between 83 and 87% TQ. This was an abnormal indication because, with both throttles in the NORMAL detent, as they were, engine TQ's would normally be kept matched automatically by the EECs[1]. The pilots found that with its

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Footnote

[1] See Aircraft information.

throttle in the NORMAL detent the right engine's TQ was fixed, but it could be successfully controlled with the right engine throttle rotated into the MANUAL range[2].

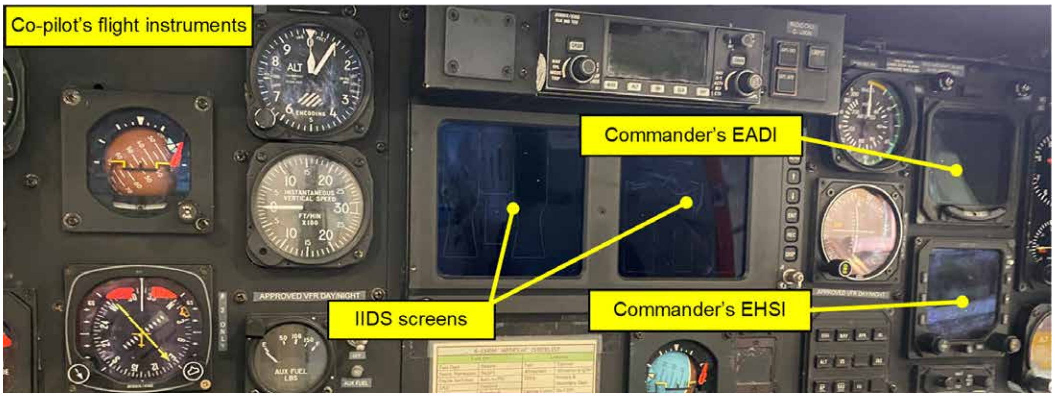


Figure 4

G-LNDN's cockpit instrument displays

The commander continued into the overhead of RAF Northolt to conduct fault diagnosis and to establish what level of automated engine control was available to him. After completing the two permitted reset attempts on each EEC, the faults remained. While it had a non-critical fault indication, the left EEC appeared to be controlling the left engine normally, so its throttle was left in NORMAL (automatic control mode) for landing. The commander then flew a slow, shallow approach to Runway 07, exercising manual control of the right engine's throttle. After a successful approach to a low hover at the runway midpoint, the commander was able to hover-taxi the helicopter to the apron where it touched down at 2046 hrs. The left engine was shut down using its rotary selector on the engine control panel (Figure 5), but, with its failed EEC, a manual shutdown procedure was required for the right engine.

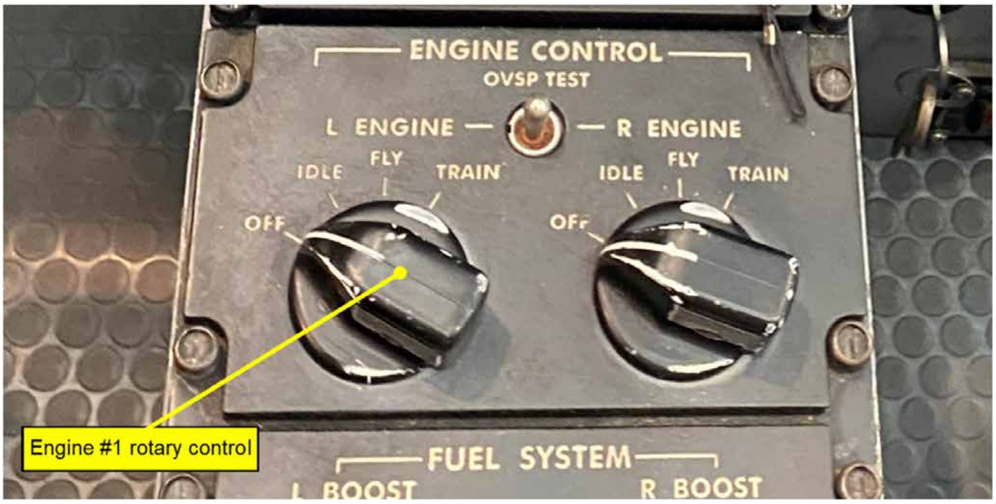


Figure 5

Engine control panel

Footnote

[2] Although the associated MAN caution was not illuminated.

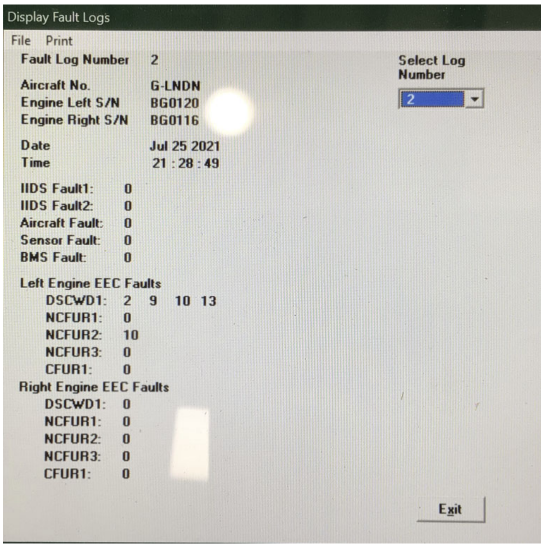
EEC malfunction procedure

Worldwide there are no simulators for the MD 900, therefore all practical emergency training is carried out on the helicopter. Training for EEC malfunctions was carried out on a regular basis and the crew felt adequately prepared for the emergency that faced them on the incident flight. Notwithstanding their preparedness for this event, the flight crew were confounded by the fault indications presented to them. From their interpretation of the Rotorcraft Flight Manual (RFM), it was not readily apparent that the non-critical fault presented for the left EEC was related to the critical fault of the right EEC. The pilots reported being further confounded in their fault diagnosis by the lack of a MAN indication on the IIDS when the right twist grip was rotated out of NORMAL.

Recorded information

The aircraft's flightpath from RLH to RAF Northolt was recorded by ground-based radar and a GPS-navigation software application[3] installed on a portable tablet computer used by the pilots. Ground-based recordings of radio communications between the pilots and ATC was also available for the flight. The helipad at RLH was monitored by CCTV, with recorded footage available for the period that the helicopter was on the helipad. The helicopter was not, and was not required to be, fitted with an accident-protected flight data recorder, image recorder or cockpit voice recorder.

The helicopter's IIDS was interrogated on the aircraft and subsequently downloaded. A fault message (Figure 6) relating to a loss of digital communications between the left and right EECs was recorded at 2028:49 hrs UTC (2128:49 hrs local time is displayed on the IIDS), which correlated with the pilots' account of when they had been alerted to the EEC system faults. Further information on this fault is included in the aircraft information section.



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Fault Log Number    2                           Select Log
                                                Number
Aircraft No.        G-LNDN                      2
Engine Left S/N     BG0120
Engine Right S/N    BG0116

Date                Jul 25 2021
Time                 21 : 28 : 49

IIDS Fault1:      0
IIDS Fault2:      0
Aircraft Fault:   0
Sensor Fault:     0
BMS Fault:        0

Left Engine EEC Faults
    DSCWD1:   2   9   10  13
    NCFUR1:   0
    NCFUR2:   10
    NCFUR3:   0
    CFUR1:    0
Right Engine EEC Faults
    DSCWD1:   0
    NCFUR1:   0
    NCFUR2:   0
    NCFUR3:   0
    CFUR1:    0
```

Figure 6

IIDS recorded fault message

Footnote

[3] ACANS manufactured by Airbox systems.

Aircraft information

The MD900 is a light utility helicopter powered by two Pratt and Whitney turboshaft engines. The helicopter has a five-bladed main rotor and utilises a 'NOTAR' system which provides anti torque stability and directional yaw control without the use of a tail rotor.

G-LNDN is an MD 902 Explorer variant equipped with two PW207E engines. The engines are mounted behind the main gearbox on the 'upper deck' which forms the cabin roof (Figure 7), with the EECs and igniter boxes for each engine mounted in avionics racking within the rear baggage compartment. This racking is below the left and right engine compartments.

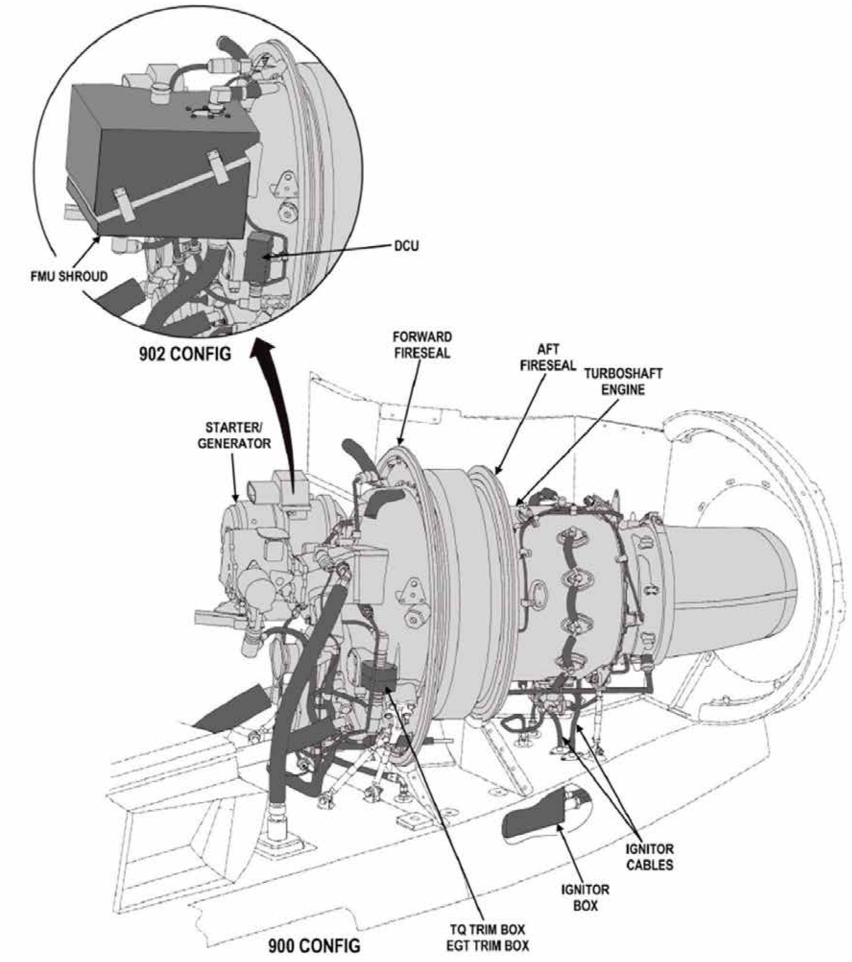


Figure 7

MD 900 left engine installation (reproduced with permission)

Each engine bay is partitioned by two firewalls. The engine's accessory gearbox and accessories, including the Fuel Metering Unit (FMU) and Data Collection Unit (DCU) are forward of the front firewall, and the engine turbomachinery to the rear of the aft firewall. The engine inlet plenum is located between the firewalls. The forward engine bay is accessed by lifting the forward access door, secured by quick access latches and can be opened without tooling. The inlet plenum cover houses the engine intake filter. The rear engine compartment is accessed by removing the rear engine cowling. The inlet plenum panel and the engine cowl are secured by screw fastenings and are only accessed during maintenance. The engine cowling has two mesh covered cut-outs, which allow airflow around the engine compartment (Figure 8). The floor of each compartment and the intake plenum has a series of drain holes to allow fluid that may enter the bay to flow out of it. The compartment to the rear of the aft fire wall is serviced by two drain holes. This compartment also has a series of thermal blankets covering the floor to protect the deck from overheating (Figure 9). These are secured in place using hook and loop fastenings. The thermal blankets lie over the drain holes, but do not obstruct them.

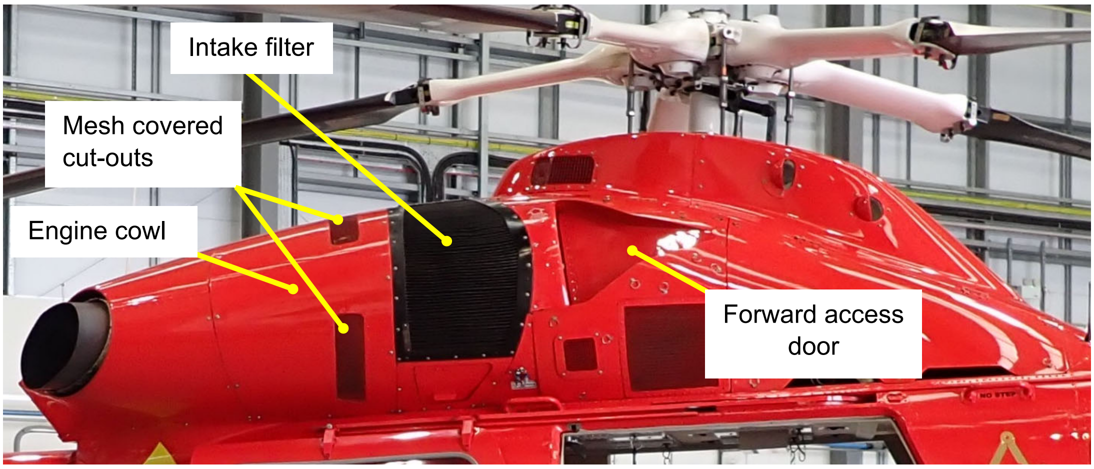


Figure 8
Right engine access doors and cowling

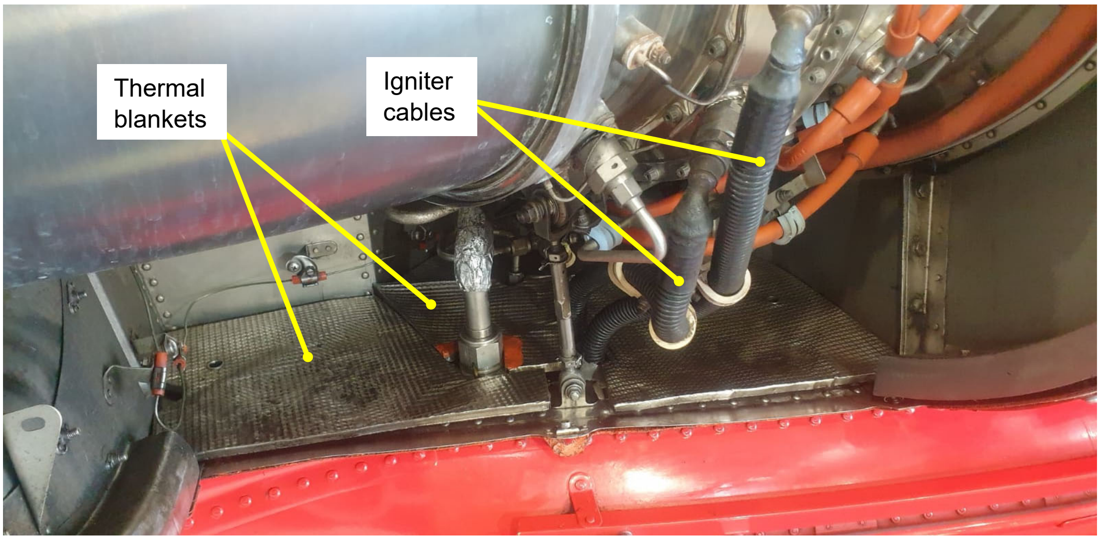


Figure 9
Rear engine compartment (right engine)

The igniter cables that connect the igniter box output to the engine igniters pass through the deck floor. The cables are encased within metal braided hoses which, in turn, are routed through a flexible sheath between the deck and the engine. The Rotorcraft Maintenance Manual (RMM) instructs the following when installing them:

> *‘(7). Connect ignitor cables.*
>
> *(a). Route ignitor cables (11) though top of deck ….*
>
> *(f). Apply sealing compound (C215) to ignitor cable flanges and screws using fillet surface sealing and mechanical fastener sealing methods …*
>
> *(g). Apply sealing compound (C215) to ignitor sheath at top and bottom’*

Control of the engines is accomplished by a Full Authority Digital Electronic Control (FADEC) system. Each engine is controlled by a single channel EEC which uses incoming signals from engine and airframe transducers and converts them into a demand signal which is sent to the FMU to regulate the fuel flow to the engine. Each EEC communicates with the opposite engine’s EEC through an ARINC[4] databus to torque match the engines. Each EEC is connected to a DCU which, in addition to storing engine performance settings, logs engine usage, status changes, events and faults.

The IIDS uses two liquid crystal colour display panels to provide engine and helicopter system information to the pilots, and they are mounted in the centre of the instrument panel (Figure 10). In addition to engine speeds, exhaust gas temperature and engine torques, the system displays cautions and warnings. It has a memory unit which stores fault information that can be downloaded to an external computer. Generated alphanumeric fault codes can also be displayed on the right display panel.

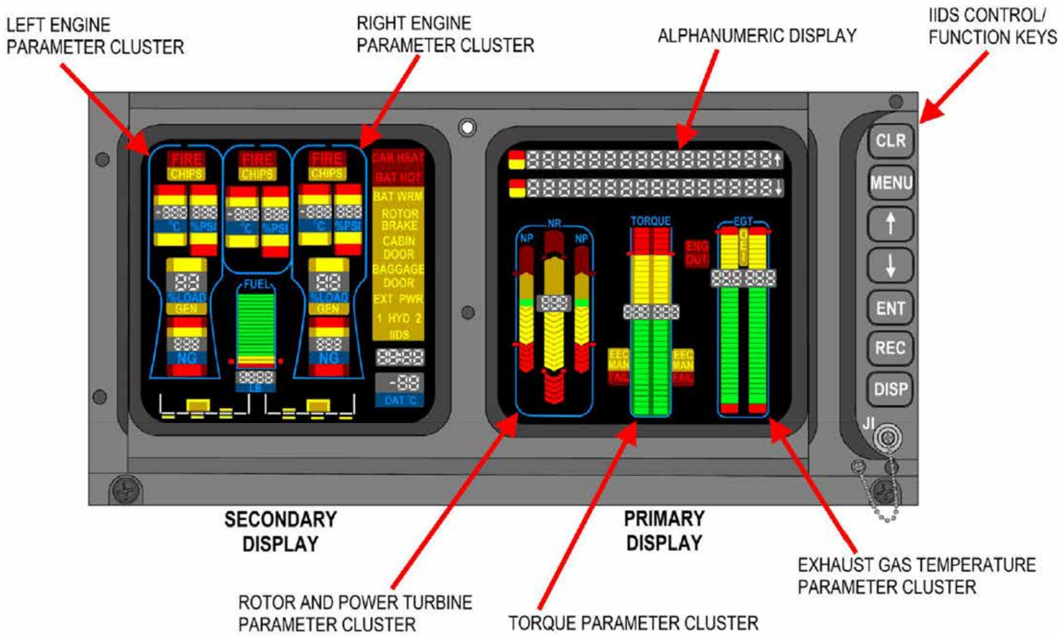


Figure 10

MD 902 [Integrated Instrument Display System] IIDS

Footnote

[4] Aeronautical Radio Inc (ARINC) is an organisation responsible for aeronautical radio and communication standards.

If an EEC becomes inoperative the stepper motor in the affected engine's FMU is fixed at its last controlled setting. The engine can then be controlled using a manual back up system where a throttle twist grip on the collective can be manipulated to modulate the engine power. In this case the red EEC FAIL caption for the relevant engine will illuminate on the primary display. If an engine twist grip is taken out of NORMAL, the yellow MAN caption should illuminate; however, it may not if the EEC is unable to transmit digital data to the IIDS. If a non-critical EEC fault occurs the yellow EEC caption will be illuminated.

The helicopter was fitted with an Electronic Flight Instrument System (EFIS) comprising an EHSI and an EADI, both mounted in the commander's side of the instrument panel. A Symbol Generator, mounted in the rear baggage compartment, interfaces with the helicopter's navigation sensors to compute and send the information that is displayed on the instruments, it also outputs data required by other systems onboard the helicopter.

MD900 aircraft operated under Instrument Flight Rules are equipped with an Automatic Flight Control System (AFCS), which incorporates a SAS.

G-LNDN had been operated as an air ambulance since August 2015, and prior to this it had been operating in the Middle East. Since operating in the UK, the left engine had been removed once, but the right engine had not been removed. The certificate of airworthiness and airworthiness review certificate for the helicopter were in date and valid.

Aircraft examination

The helicopter was moved into a hangar after the incident and the AAIB assessed it the following day.

There was no external damage to the helicopter. Internally, the fuselage lining around the rear baggage compartment was damp and water was observed dripping from its seams. Once the lining had been removed areas of the inner surface of the fuselage were damp. Water could also be seen pooling in a floor recess which secured a crew seat stay.

The Symbol Generator was found to have streaking along its outer casing and a bead of water was noticed on its locking mechanism. When it was removed the underside of the unit was wet (Figure 11). The Symbol Generator was returned to its manufacturer for assessment.

The right EEC, which is positioned inboard of the Symbol Generator, showed evidence of having been in contact with water. The unit is mounted horizontally in the helicopter and accessed by removing the rear mounts and then lowering it, hinging around the forward mounts. As the unit was lowered, water was seen dripping from the ambient pressure tapping on the rear of the unit (Figure 12). Water was also found accumulated within the JI connector when it was disconnected.

Figure 11

Underside of Symbol Generator when removed from G-LNDN

Figure 12

Right engine EEC showing water dripping from ambient pressure tapping

An attempt was made to download the event logs stored on both EECs' DCUs whilst they were installed in the aircraft. The left engine's fault codes identified an '*ARINC communication fault'* which indicates a loss of communication with the opposite EEC. Following the fault, the event codes stored indicated that the crew made transitions from NORMAL into

MANUAL and back to NORMAL during the remainder of the flight. The first transition was approximately 30 seconds after the initial fault; left engine control then remained in NORMAL until approximately seven minutes after the fault, when it was cycled to MANUAL and back to NORMAL twice in 12 seconds. Throughout this time the ARINC fault remained.

The right EEC would not power up and therefore the DCU could not be interrogated to download any event logs. The right EEC and the DCU were removed from the aircraft and returned to the engine manufacturer for investigation.

The right engine cowling was removed allowing access to the engine bay. With the thermal blankets removed it was possible to see that the rear bay drain hole was partially blocked with debris; the forward drain was clear (Figure 13). Both drains were functionally tested and showed that they could both pass fluid to the overboard drain outlets.

Figure 13

Rear and forward drain holes in right rear engine bay

The amount of sealant around the right engine igniter cables as they passed through the deck was minimal. The outer sheaths between the deck and the engine could be moved away from the deck with little force (Figure 14). A liquid solvent degreaser was sprayed on the area where the igniter cable passed through the deck. A stream of solvent was immediately observed flowing into the rear baggage compartment from around the igniter cables. This fluid flowed directly onto the right EEC. A similar assessment of the left engine igniter cables was carried out. This found that the sealant was well applied around the igniter leads and no leaks were observed when solvent was sprayed at the interface. As the right engine had not been removed whilst it had been in operation in the UK, the sealant around the igniter leads is likely to have been applied when it was being operated by its previous operator.

Interrogation of the AFCS found that the cause of the SAS fault was an ‘analogue to digital bit stuck’, that could not be attributed to a particular issue. When powered up after the incident, the SAS functioned normally.

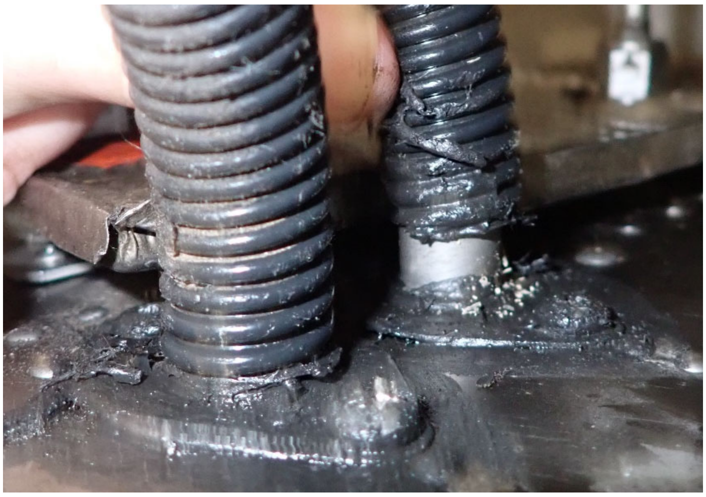


Figure 14

Right engine igniter cable sheath easily moved away from deck

Assessment of removed units at their respective manufacturers

Assessment of the Symbol Generator by its manufacturer found that although the unit turned on, there was electrical ‘noise’ on the display output. Detailed assessment of the power supply and circuit boards identified some corrosion on the Display Processor-HSI board which was likely to have been caused by exposure to water.

Assessment of the right EEC and its DCU found that, even after drying, the EEC would not power up. The DCU download did not show any information about the EEC failure but did record engine control being moved into manual. There were no further events logged on the DCU. It was considered most likely that exposure to water caused a short circuit on the power board causing the EEC to fail permanently.

Personnel

The commander had been flying MD 900 series helicopters for more than 15 years. The co-pilot had flown more than 14,200 hours on fixed-wing aircraft and helicopters and was in his second summer season as a contract pilot for the operator. He had previously been a helicopter pilot with the National Police Air Service but had not flown the MD 902 type before starting with G-LNDN’s operator.

Weighing his greater experience on type, the commander elected to take over as PF shortly after the EEC malfunctions manifested themselves. He later reflected that, in doing so he increased his own workload unnecessarily, especially given the limited flight instrumentation available on his side of the cockpit and the co-pilot’s experience level. While it did not detract from a successful outcome, he thought that, if faced with a similar situation in the future he would still take control for landing but would consider remaining as PM until fault diagnosis and approach preparation had been completed.

Other information

The operator's operating procedures define the provisions for mooring the helicopter during high winds and storm conditions. They stipulate:

> *'0.1.8 Rotor Tie-Downs and Helicopter Mooring*
>
> *During periods when very high winds are forecast, extra care must be taken. It may be necessary to anchor (picket) the aircraft itself to the ground. The aircraft rotor must be tied down in winds in excess of 35 knots to prevent possible damage to the rotor flexbeams.*
>
> *In winds greater than 40 knots or in severe storm conditions, the helicopter shall be secured in a suitable hangar. If a hangar is not available and the only option available is to leave the helicopter in the open, the helicopter shall be moored in accordance with the procedures described in the RFM Section 8 Page 8-9.'*

The RFM section 8-3 (pages 4 to 9) provides guidance for parking and storing a helicopter. The section describes the tiedowns and covers available to the operator to protect the helicopter '*from inclement weather conditions and other outside environmental factors that could cause FOD damage while the helicopter is parked, moored, or while in storage.*' and highlights in a note that *'The decision to use protective covers and tiedowns is determined by the prevailing weather conditions, length of storage/parking, and location.'* This section includes a description of covers for the engine area and upper deck (Figure 15). There was no guidance within either the operator's operations procedures or the RFM to protect the aircraft during heavy rain specifically.

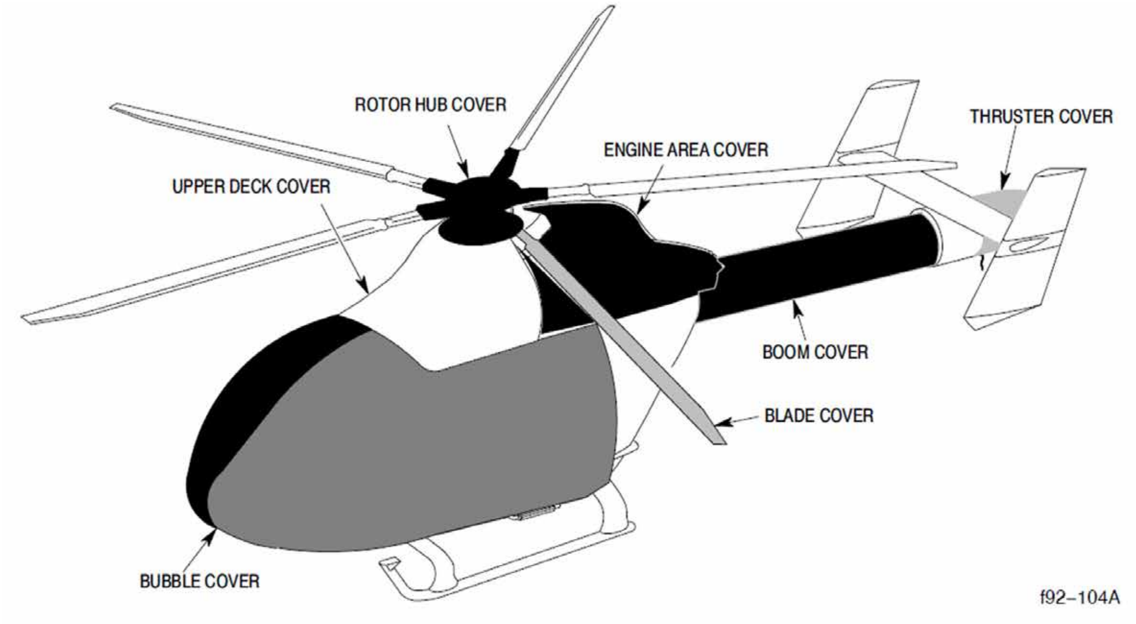


Figure 15

Covers available for the MD 900 series of helicopters

Analysis

The EHSI and EADI both failed during the flight because of a Symbol Generator malfunction. The right EEC FAIL warning indication on the IIDS was a result of the failure of the right EEC. This resulted in the MAN caption not illuminating when the pilot moved the right engine throttle out of NORMAL, because the IIDS only displays the EEC MAN indication when the EEC is transmitting digital data. The left EEC non-critical caution was due to an ARINC communication fault as the left EEC was unable to communicate with the right EEC for torque matching purposes. The left engine's EEC otherwise functioned correctly. Both the right EEC and Symbol Generator were mounted in the aft baggage compartment directly beneath the right engine and showed evidence of having been exposed to water.

G-LNDN had been parked on the helipad at the RLH at the time of heavy rainfall. During this time rainwater entered the right engine bay through the mesh covered cut outs in the engine cowling. The rainwater had then flushed debris in the engine bay toward the rear drain hole, which then partially blocked. Either because of the partial blockage of the drain hole, or through sheer volume of water overwhelming the drains in the engine bay, it started to fill. As the water level reached the igniter lead through-holes, water was able to pass into the rear baggage compartment because inadequate sealing round the igniter leads, which had been applied whilst it was operated by its previous owner, did not prevent water ingress.

The right engine had not been removed from the helicopter since it had been acquired from its previous operator. Without the intervention of an engine removal there would have been no need to remove the igniter leads and re-apply the sealing compound around the base of the igniter lead sheaths. As the engine bay cowling is only removed during maintenance inspection, pilots cannot assess the condition of the components in the engine bay during pre-flight checks. This therefore relied on maintenance inspections to assess the condition and cleanliness of this area. The positioning of the thermal blankets on the floor of the engine bay would have prevented the amount of sealant and the quality of its application from being easily assessed. It is also unlikely that the thermal blankets would have been removed during routine maintenance to expose this location. After the incident, the operator inspected the sealant around the igniters on the other MD 902 they operated and found it to be in good condition. The operator also instructed regular cleaning of the engine bays to remove debris and inspect the drain holes for contamination. It is good practice to maintain inspection and husbandry standards with all aircraft.

Had engine area or upper deck covers been used to protect the engine bays during the heavy rainfall, the pathway for the rainwater to enter the engine bay would have been blocked. The operator explored the feasibility of using engine cowl covers in addition to the tie downs and engine blanks already required, but this was considered detrimental to the operation of the helicopter when considering its three-minute launch target in its role as an air ambulance. The operator also identified risks of causing damage to the aircraft's antenna and creating possible foreign object debris (FOD) whilst removing the covers that protect the upper surfaces of the fuselage.

The commander reported that the failure of the SAS to engage after start was a rare occurrence on the MD 902 but the operator's MEL did permit day VFR flight with the SAS disengaged. The investigation found that the SAS fault was unrelated to the water ingress issue, and there were no other indications before liftoff to alert the pilots to the electrical failures that would later manifest themselves in flight.

While a distraction, the crew did not consider the commander's instrument display failures to be a significant problem because they were in day VFR flight conditions and the co-pilot's instruments were all indicating as normal. The subsequent EEC faults were less benign but did not pose an immediate risk to the helicopter. With both engines still developing sufficient power, the pilots were able to proceed to the RAF Northolt overhead where they could then fault diagnose and prepare for landing.

Had it been clearer to the pilots that the caution for the left EEC was due to its inability to communicate with the right EEC, the commander would not have taken the left engine out of the NORMAL setting to attempt an unecessary EEC reset. The lack of explicit explanation in the RFM of the potential for two separate EEC alerts relating to a single failure meant that a serviceable engine was temporarily put into manual throttle control mode when not required. While the pilots were able to diagnose that the left EEC was working satisfactorily, had that not been the case then a much more challenging double manual throttle approach would have been required. The manufacturer recognised that RFM guidance on EEC malfunctions could be more comprehensive and undertook to include additional information for pilots on EEC failure modes. The helicopter manufacturer proposed to re-write the *'EEC malfunctions'* section of the RFM to include the following text as a note:

> *'If a critical fault occurs on one EEC, a noncritical fault may occur on the other EEC. In this case, always address the critical fault first. If time permits, and it is safe to do so, the pilot may address the noncritical fault.'*

The commander considered that, with the additional knowledge and understanding of the faults that he obtained subsequent to the flight, he could have reduced his personal workload by staying as PM for longer.

Conclusion

During a period of heavy rain, water entered the right engine bay where it began to pool, possibly because of a partially blocked drain and possibly because of the sheer volume of water. Inadequate sealing of ignitor lead holes allowed water to enter the rear baggage compartment where the right EEC was located, causing it to fail. A resulting electronic communications failure with the left engine EEC caused a noncritical fault in that EEC.

The resulting events were handled effectively by the pilots, but a more comprehensive explanation of EEC system faults and reversionary modes in the RFM might have avoided any risk associated with unnecessary reset attempts on the left EEC.

Safety action

The following safety actions were taken.

> The operator inspected its other aircraft to ensure that the sealant around the igniter leads was applied correctly.
>
> The operator introduced additional maintenance procedures to ensure the engine bays remained clear of debris and the drains remained serviceable.

Published: 23 June 2022.

ACCIDENT

Aircraft Type and Registration:	Grumman AA-5, G-BBSA	
No & Type of Engines:	1 Lycoming O-320-E2G piston engine	
Year of Manufacture:	1974 (Serial no: AA5-0472)	
Date & Time (UTC):	25 September 2021 at 0837 hrs	
Location:	Teesside International Airport	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - 1 (Serious)	Passengers - 2 (Serious)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Light Aircraft Pilot's Licence (A)	
Commander's Age:	63 years	
Commander's Flying Experience:	1,614 hours (of which 830 were on type)) Last 90 days - 79 hours Last 28 days - 29 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft suffered a partial loss of engine power very shortly after takeoff from Runway 23 at Teesside International Airport. The pilot, believing the aircraft was outside the airport boundary, attempted a turnback to the airport to land. The aircraft stalled during the turn and struck the ground west of the runway near the Runway 05 threshold. The three occupants all sustained serious injuries.

Three Safety Recommendations are made with respect to pilot training for partial engine power[1] loss events.

History of the flight

The aircraft was operated by a private syndicate of owners. It had returned to Teesside Airport on 21 September 2021 after undergoing an annual maintenance inspection at Sturgate Airfield, Lincolnshire. The flight from Sturgate to Teesside took approximately 45 minutes and was conducted by one of the syndicate members. After landing at Teesside, two other members of the syndicate took the aircraft on a local flight, again lasting approximately 45 minutes. None of these pilots reported any issues with the aircraft and described it as operating "as smoothly as it ever had."

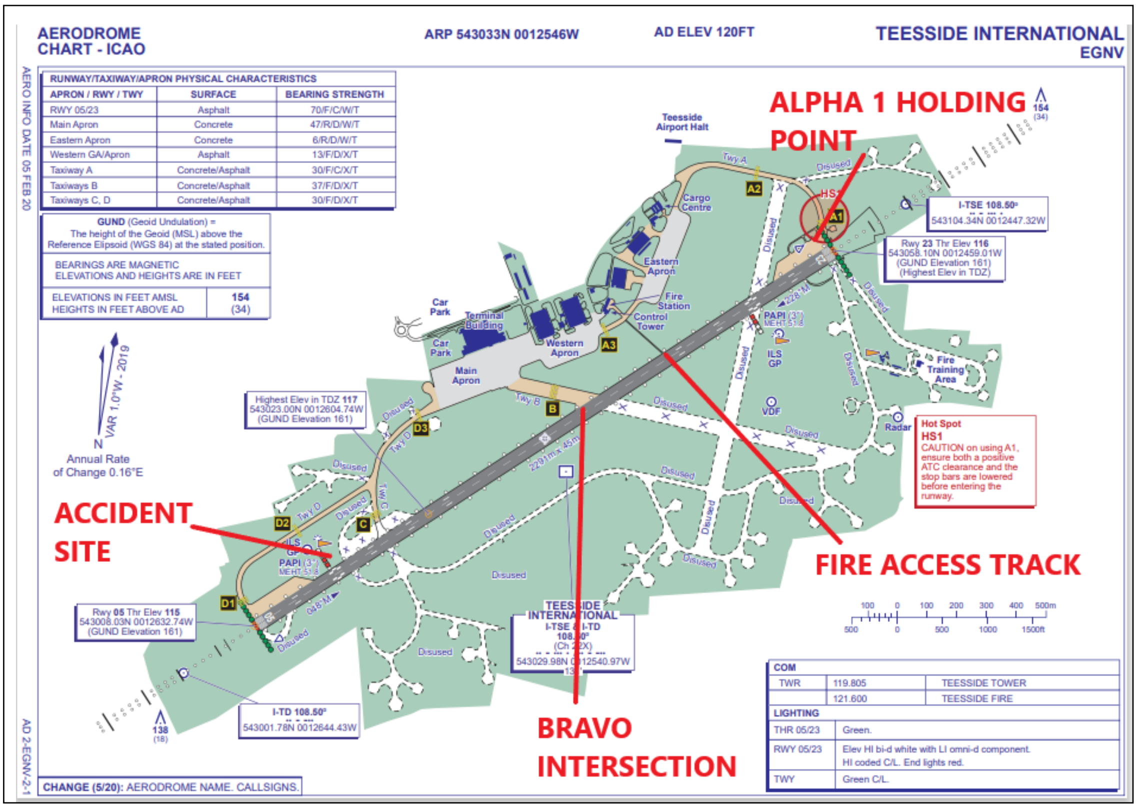
Footnote

[1] A situation where an engine provides less power than commanded by the pilot, but more power than idle thrust.

Usually, the aircraft was kept in a hangar at Teesside but, due to work being carried out there, it was parked outside after the flights on 21 September. On 24 September, the aircraft's fuel tanks were filled in preparation for flying that day. However, due to high winds that flying was cancelled.

On 25 September, the pilot had planned a local flight with two passengers. The pilot phoned Teesside ATC to book out for the flight and informed them that there would be three persons on board, gave a fuel endurance of five hours (reflecting the full fuel tanks), and a planned flight time of one hour. He also told ATC that the planned route was from Teesside to Middlesbrough and then route north to the River Tyne before returning to Teesside.

One passenger was seated in the front right seat and the second sat behind the pilot. The rear seat passenger recorded a video of the takeoff and short flight on a mobile phone. This recording was subsequently analysed, along with other sources, to assist in confirming the sequence of events. The aircraft started up normally and the pilot then called ATC for taxi clearance. He was cleared to taxi to the Alpha 1 Holding Point for Runway 23 (Figure 1). ATC saw the aircraft stop at Alpha 1 to conduct engine run up checks.



RUNWAY/TAXIWAY/APRON PHYSICAL CHARACTERISTICS		
APRON / RWY / TWY	SURFACE	BEARING STRENGTH
RWY 05/23	Asphalt	70/F/C/W/T
Main Apron	Concrete	47/R/D/W/T
Eastern Apron	Concrete	6/R/D/W/T
Western GA/Apron	Asphalt	13/F/D/X/T
Taxiway A	Concrete/Asphalt	30/F/C/X/T
Taxiways B	Concrete/Asphalt	37/F/D/X/T
Taxiways C, D	Concrete/Asphalt	30/F/D/X/T

GUND (Geoid Undulation) = The height of the Geoid (MSL) above the Reference Elipsoid (WGS 84) at the stated position.

BEARINGS ARE MAGNETIC
ELEVATIONS AND HEIGHTS ARE IN FEET

ELEVATIONS IN FEET AMSL	154
HEIGHTS IN FEET ABOVE AD	(34)

COM		
TWR	119.805	TEESSIDE TOWER
	121.600	TEESSIDE FIRE

LIGHTING	
THR 05/23	Green.
RWY 05/23	Elev HI bi-d white with LI omni-d component. HI coded C/L. End lights red.
TWY	Green C/L.

Figure 1

Teesside Airport chart

ATC cleared the aircraft for takeoff at 0834 hrs and saw the departure. The takeoff roll appeared normal and the aircraft was airborne abeam the Fire Access Track.

Approximately 14 seconds after becoming airborne, there was a significant change in the engine note. At this point the aircraft was passing intersection Bravo at a height of approximately 120 ft agl. ATC noticed its track was drifting to the right of the centreline of Runway 23 but otherwise considered that the departure looked normal.

As the aircraft reached approximately 170 ft agl, the pilot radioed ATC to report that he had suffered a loss of engine power and requested to land on Runway 05. There was another aircraft at two miles on final approach to Runway 23 and ATC directed this aircraft to go around before clearing G-BBSA to land on any runway. G-BBSA turned left towards Runway 05 and began to descend. During the turn, 57 seconds after becoming airborne, the aircraft audio stall warning began to sound. At approximately 60 ft agl, the left bank angle suddenly increased, and the aircraft descended rapidly, striking the ground 67 seconds after becoming airborne. The aircraft was extensively damaged.

On seeing the aircraft accident, ATC declared a Full Emergency and deployed the airport RFFS. One of the RFFS personnel had just completed a bird scaring run in a vehicle and was parked close to where the aircraft struck the ground. Observing the accident, he immediately moved to the aircraft where he entered the cockpit, switched off the fuel and battery master switch, and gave assistance to the occupants until the Emergency Services arrived.

ATC tried to contact the local authority Emergency Services by telephone but had some difficulties in making contact, stating "it took a long while to speak to someone," in order to request that the fire service attend the scene. The local authority Fire Service were informed at 0851 hrs.

ATC at Teesside have direct contact with the North-East Air Ambulance and asked them to attend. The Air Ambulance was airborne at 0845 hrs and landed on scene at 0847 hrs. All those on board sustained serious injuries and were evacuated to hospital.

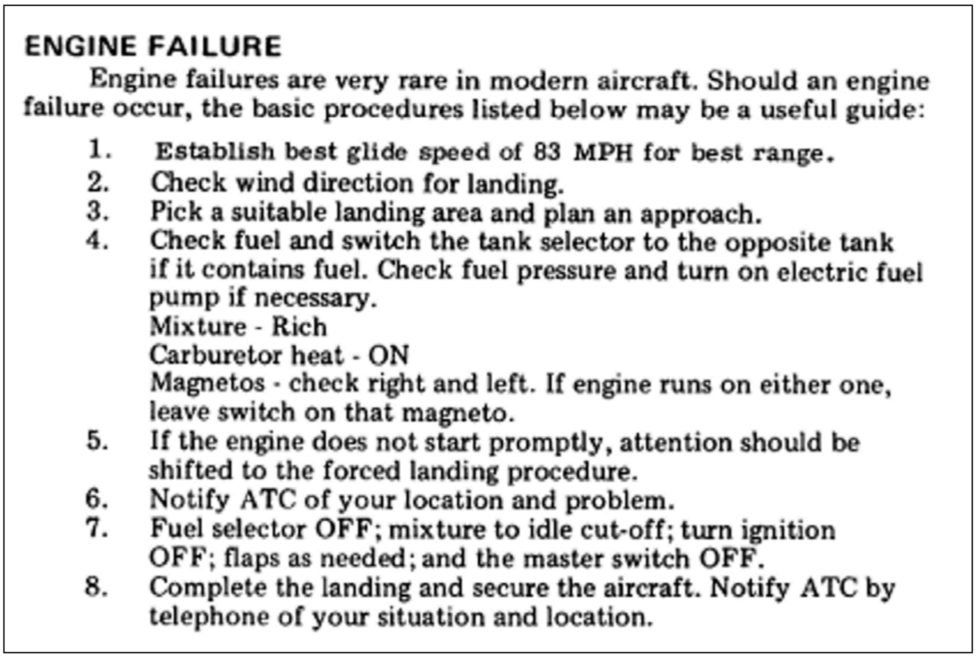
Several witnesses saw the aircraft as it became airborne and all described the aircraft engine as sounding unusual shortly after takeoff.

Pilot recollections

As a result of his serious injuries, the pilot was in hospital for several months and could not be interviewed for a significant time after the accident. His recollections were that, before the accident flight, he conducted the external and internal checks as specified by the Pilot's Operating Handbook (POH), including a check of the fuel for water contamination. All checks were normal. When his passengers arrived at the airport, he collected them from the security checkpoint and took them to the aircraft where he then briefed them on entry/exit procedures and the use of the aircraft seat harnesses. He discussed the route for the flight with them and then passed that information to ATC by phone.

The pilot and passengers then boarded the aircraft. The pilot recalls that the engine start, taxi and engine run up checks were all normal. Once cleared to do so by ATC the pilot lined the aircraft up on the runway and accelerated the engine to 2,500 rpm. He stated that he raised the nose at 76 mph and that the initial stages of the climb were normal. At what the pilot recalled was around 400 ft agl he described the engine as losing all power and recalled lowering the pitch attitude to maintain speed. There was a field ahead which, on previous flights, he had considered in the event of a forced landing. However, it contained animals, farm vehicles and people, so he considered it unsuitable. The other terrain ahead was the River Tees and so, in the pilot's opinion, a landing ahead was not viable.

In response to the loss of power the pilot said that he carried out the POH ENGINE FAILURE checklist (Figure 2). These actions were outside of the field of view of the video recording made by the passenger in the rear seat.



ENGINE FAILURE

Engine failures are very rare in modern aircraft. Should an engine failure occur, the basic procedures listed below may be a useful guide:

1. Establish best glide speed of 83 MPH for best range.
2. Check wind direction for landing.
3. Pick a suitable landing area and plan an approach.
4. Check fuel and switch the tank selector to the opposite tank if it contains fuel. Check fuel pressure and turn on electric fuel pump if necessary.
   Mixture - Rich
   Carburetor heat - ON
   Magnetos - check right and left. If engine runs on either one, leave switch on that magneto.
5. If the engine does not start promptly, attention should be shifted to the forced landing procedure.
6. Notify ATC of your location and problem.
7. Fuel selector OFF; mixture to idle cut-off; turn ignition OFF; flaps as needed; and the master switch OFF.
8. Complete the landing and secure the aircraft. Notify ATC by telephone of your situation and location.

Figure 2

Engine Failure checklist

The checklist has several items, and it would have presented a significant workload. Believing he was outside the airfield boundary the pilot commenced a turn to return to the airport. As it came into view, he realised he had insufficient height to reach the runway and chose a green area in which to land stating "It looked good enough to land. Good area. I put it down there." His recollection was of flaring the aircraft to control the touchdown and that the stall warner sounded just before touchdown.

The pilot stated that he would not normally consider a turnback as an option but that he practised turnback manoeuvres three times in the year preceding the accident and that these were conducted with a 15° to 20° Angle of Bank (AOB). When asked about the option of landing ahead on the remaining runway, the pilot said that with the aircraft close to maximum takeoff weight, he felt he would have used a considerable length of runway to get airborne and climb to the height he recalled reaching. He therefore considered that landing ahead on the runway remaining was not an option.

Accident site

The aircraft came to rest on the grass to the west of the runway, close to the Runway 05 threshold (Figure 3).

Figure 3

Accident site, looking south with the Runway 05 threshold behind

The aircraft had struck the ground with its left wingtip and, following a significant nose impact, had then rotated approximately 180°, coming to rest 11 m beyond the main impact ground scar. There was a strong smell of fuel at the accident site, but the RFFS had sprayed the aircraft with foam shortly after their arrival and no fire had occurred. The flaps were up.

Airfield information

Teesside International Airport is a commercial airport located between Darlington and Stockton-on-Tees. It is about ten miles (16 km) south-west of Middlesbrough. The airport has one runway 05/23 which is 2,291 m long. Beyond the threshold there is 184 m of asphalt surface, which is not declared as part of the runway length and then a further 210 m of grass surface before the airport boundary fence.

Meteorology

The weather report for Teesside at 0820 hrs gave a wind of 180° at 3 kt, visibility greater than 10 km, a temperature of 16°C and a dewpoint of 14°C.

Weight and balance

With the full load of fuel and three passengers, the takeoff weight of the aircraft was 2,075 lbs. The MTOW for a Grumman AA-5 is 2,200 lbs. The calculated whole moment for the aircraft's load distribution was 182,490 lb-in. When plotted on the POH chart (Figure 4), the result shows that the aircraft was within its mass and C of G envelope.

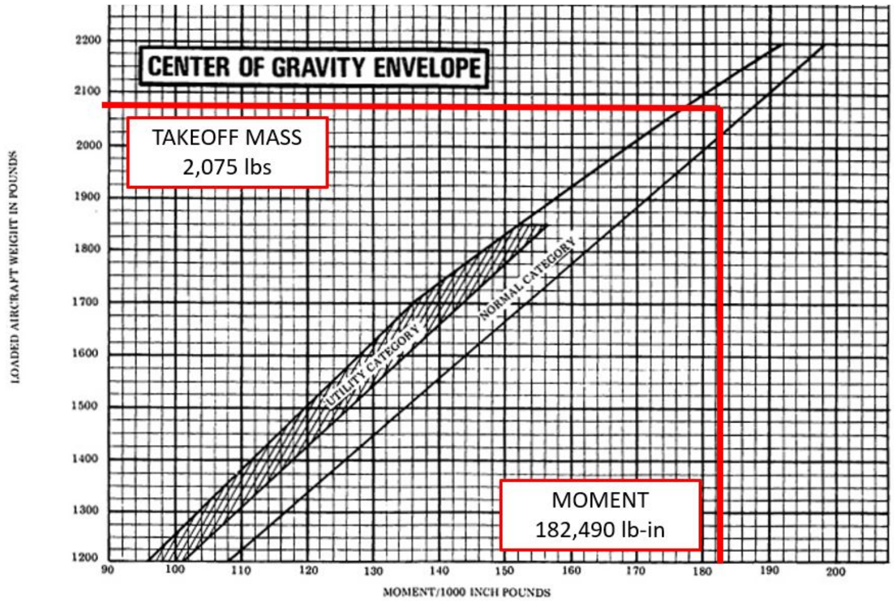


Figure 4

Centre of gravity envelope chart

Recorded information

Recorded information for the accident flight was available from the following sources:

- a tablet computer fitted in the cockpit of the aircraft, which had recorded the aircraft's Global Navigation Satellite System (GNSS) derived position and altitude,
- a video/audio recording made by the passenger seated in the rear of the aircraft using a mobile phone,
- closed-circuit television (CCTV) footage of the aircraft during the later stages of the flight, and
- RTF communications between the pilot and controller.

Summary of recorded data

Analysis of the audio from the mobile phone recording, in conjunction with the GNSS data, showed that, during the takeoff roll and initial climb, the aircraft's engine was operating at about 2,500 rpm, with the aircraft climbing at 500 fpm with an airspeed of 80 mph (70 kt)[2]. However, shortly after getting airborne, and at a height of 120 ft agl (Figure 5), the engine speed suddenly reduced to about 2,100 rpm. The aircraft continued to climb to 170 ft agl, by which time its airspeed had reduced to 70 mph (61 kt) and the aircraft started to level off. This coincided with the pilot advising ATC of the problem and asking to land on Runway 05, and with the aircraft starting to turn right onto a heading of about 245°.

Footnote

[2] Derived from the recorded groundspeed and a reported wind from 180° at 3 kt.

The aircraft's engine continued to operate at about 2,100 rpm for the next 10 seconds, with the airspeed and height stabilised at about 70 mph (61 kt) and 200 ft agl respectively. However, when the aircraft was almost overhead the intersection of taxiways C and D, the engine speed further reduced to about 1,500 rpm and, whilst maintaining altitude, airspeed quickly reduced to about 64 mph (56 kt). This coincided with a brief activation of the stall warner in the cockpit. The aircraft then started to turn left towards the runway whilst descending. The aircraft's bank angle continued to increase, and its descent rate reached about 1,000 fpm. As the aircraft reached a height of about 100 ft agl, the stall warner activated again, and continued to sound, until the aircraft struck the ground five seconds later. It was estimated that the aircraft's bank angle had reached about 40° during the final descent.

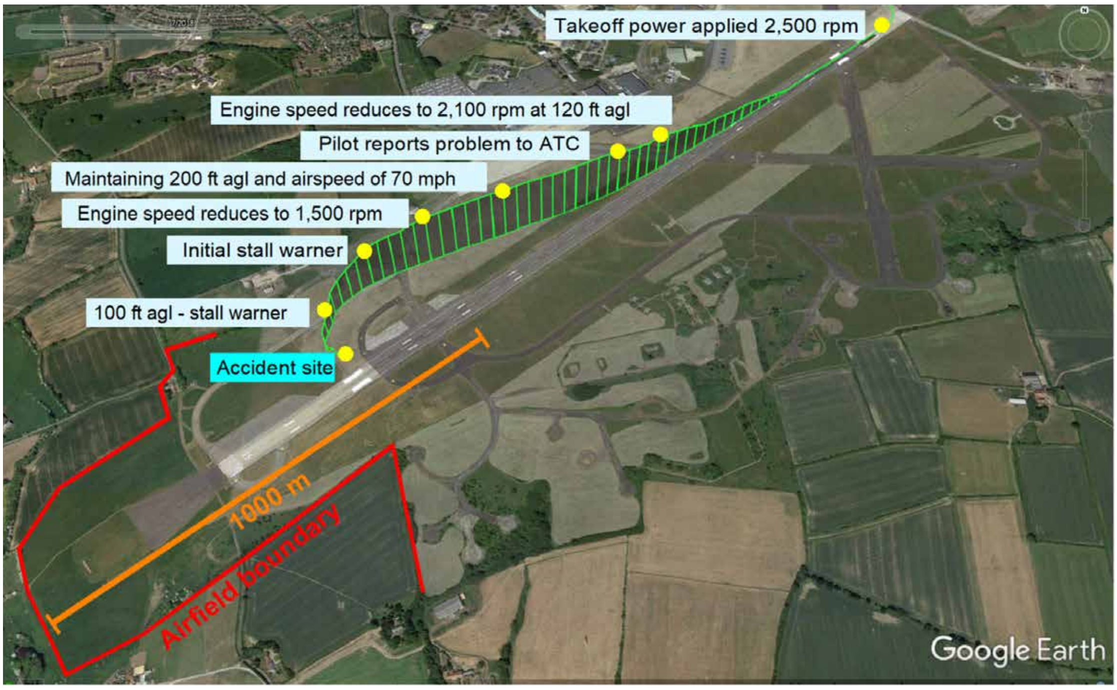


Figure 5

Aircraft flight path during the accident flight
© 2021 Google, Image © Maxar Technologies

Table 1 provides the runway length remaining to the end of Runway 23, and distance to the airport boundary, which is beyond the end of the runway, for key points during the takeoff.

Cockpit view during the accident flight

Analysis of the aircraft's flight path using a flight simulation, indicated:

- When the engine rpm initially reduced to about 2,100 rpm and given the aircraft's position and attitude at that time, the pilot would not have been able to see the runway ahead of him.
- As the aircraft climbed to a height of about 180 ft agl, given the aircraft's position and attitude at that time, the simulation indicated that the runway would have been visible with about 1,000 m of the runway remaining.

Engine speed / RTF communication	Aircraft position	Runway 23 length remaining
Engine speed reduced to 2,100 rpm.	120 ft agl overhead the right edge of the runway.	1,300 m of runway remaining (1,700 m to the airport boundary).
Pilot reports engine problem to ATC and starts to turn onto a heading of 245°.	170 ft agl and 25 m laterally from the right edge of Runway 23.	1,100 m of runway remaining (1,490 m to the airport boundary).
Engine speed reduced to 1,500 rpm.	200 ft agl and 140 m laterally from the right edge of Runway 23.	600 m to the airport boundary if its heading of 245° was maintained (1,000 m to the airport boundary for a heading of 225°).

Table 1

Aircraft position relative to end of Runway 23 and airport boundary

Aircraft information

The Grumman AA-5 is an all-metal low-wing four seat light aircraft fitted with a 150 HP Lycoming O-320-E2G piston engine. The aircraft had undergone a recent annual maintenance inspection that was completed on 21 September 2021, during which a new propeller and replacement nose landing gear torque tube were fitted, and the engine rocker covers and gaskets were replaced. The maintenance engineer who carried out the annual inspection stated that the carburettor and airbox were visually inspected, but not removed or disturbed, during this maintenance activity.

Carburettor

The aircraft's engine was fitted with a Precision Airmotive Corporation MA-4SPA carburettor. The aircraft's maintenance programme, approved by the aircraft's owners, stated a maximum time between overhaul of the carburettor of 2,000 flying hours or 12 years, whichever occurs first. The carburettor manufacturer stated, in Service Bulletin MSA-3[3], a maximum time between overhaul of the carburettor of 2,000 flying hours or 10 years, whichever occurred first.

At the time of the accident, the carburettor had accumulated 601 flying hours and six years in service.

Fuel is supplied to the carburettor from the engine-driven fuel pump and enters the induction airflow via the main jet, where it is mixed with the induction air. When the throttle is advanced, an accelerator pump within the carburettor supplies additional fuel to the induction air through an accelerator pump discharge tube (Figure 6).

Footnote

[3] Precision Airmotive Corporation Service Bulletin MSA-3 Revision 1, Overhaul Periods for Float Carburetors, 18 November 1991.

The accelerator pump discharge tube, which is made from brass, is a close fit to its mating bore in the carburettor body. It is secured to the carburettor body with adhesive4 when the carburettor is manufactured or overhauled.

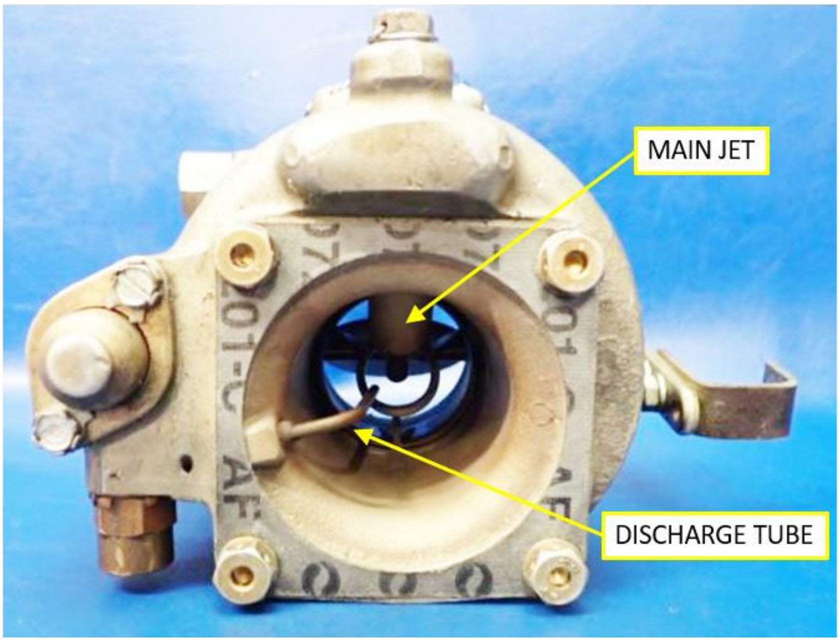


Figure 6

Reference image of an MA4-SPA carburettor (not G-BBSA carburettor)

Aircraft examination

The damage to the aircraft was consistent with a significant impact in a nose-down, left wing low attitude. The flaps were in the full UP position. The fuel selector valve was set to draw fuel from the left wing tank. The fuel feed pipe between the left wing and the fuselage had fractured and no fuel remained in the left wing tank. 32 litres of Avgas 100LL was recovered from the right wing tank.

The engine's crankshaft was free to rotate, and the crankcase was intact with all four cylinders securely attached. Both magnetos were securely fixed to the rear of the accessory case and the ignition harness was in good condition, with all ignition leads attached to their respective spark plugs. No engine oil leaks were evident, and the oil was of normal appearance. There was no deformation of any of inlet or exhaust valve pushrod tubes.

The fuel lines between the firewall and the engine were in good condition and all fuel fittings were tightly secured. The electric fuel boost pump was disassembled, and fuel was present in the pump and the fuel strainer mesh was clear of foreign objects. The engine-driven mechanical fuel pump was disassembled, and fuel was observed inside the pump. The pump's rubber diaphragm was in good condition.

Footnote

[4] Loctite Retaining Compound RC-680.

The induction airbox was removed from the engine to provide access to the carburettor. The carburettor was securely screwed to the engine sump and the required gasket between the carburettor and sump was present. Fuel was present in the carburettor float bowl, with no evidence of contamination by water or debris. The carburettor throttle and mixture control linkages were securely attached to the cockpit control cables.

As the engine's crankshaft was free to rotate, the engine was removed from the aircraft and supported on a sling to allow a basic compression test to be performed. This involved disconnection of the ignition harness from the spark plugs and removal of the upper spark plug from each cylinder. Rotation of the crankshaft, whilst a thumb covered the upper spark plug hole, revealed a normal degree of compression on cylinder Nos 1, 2 and 3, but no compression on cylinder No 4[5]. The aircraft wreckage was then secured for transport to the AAIB's facility at Farnborough for detailed examination.

Engine examination

The engine basic compression test was repeated once the aircraft wreckage was recovered to the AAIB, but this time a normal degree of compression was noted on all four cylinders. Borescope inspection of cylinder No 4 revealed that a C-shaped foreign object was present in the cylinder (Figure 7). Witness marks were present on the exhaust valve seat faces caused by contact of a hard foreign object, which would have prevented the exhaust valve from closing correctly. It was considered likely that the C-shaped foreign object had been trapped beneath the exhaust valve when the engine was examined at the accident site, but that it had come loose during transportation to the AAIB.

Figure 7

Borescope images inside cylinder No 4

The No 4 cylinder was removed from the engine and the piston crown, inlet and exhaust valve surfaces were examined. Numerous hard-body impact marks were present on the piston crown, and the faces of the inlet and exhaust valves also showed impact marks where combustion residues had been removed from the valve faces (Figure 8). No such impact marks or foreign objects were observed in Nos 1, 2 or 3 cylinders.

Footnote

[5] Cylinder 4 is the rear left cylinder, when viewing the engine from above.

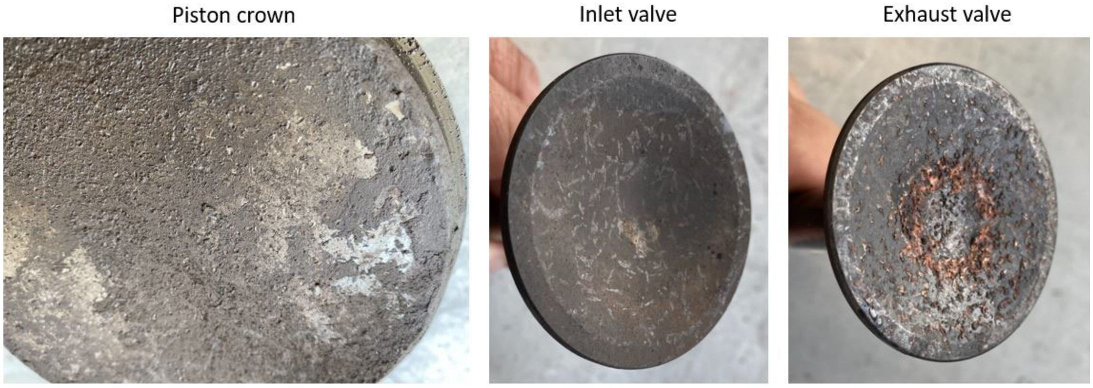


Figure 8

Impact marks on cylinder No 4 piston crown, inlet and exhaust valves

The aircraft's exhaust muffler was cut open, but no additional foreign objects were identified within. The C-shaped foreign object was of tubular cross section which had been flattened due to impacts on the tube's outer diameter (Figure 9).

Figure 9

Foreign object recovered from No 4 cylinder

The foreign object was examined by a metallurgist who confirmed that it was a section of brass tube, composed of 'cartridge brass[6]', which the carburettor manufacturer confirmed was the same material specified for the accelerator pump discharge tube[7]. A section of the foreign object was subjected to a micro-hardness test, which showed an average hardness value of 95 HV[8]. The carburettor manufacturer stated that the hardness condition specified for the discharge tube material was ½ hard[9], which equates to approximately 126 HV. The metallurgist considered that the lower measured value of 95 HV is consistent with the foreign object being stress-relieved in the elevated temperatures of the engine's No 4 cylinder.

Footnote

[6] Cartridge brass is an alloy of copper (70% by weight) and zinc (30% by weight).
[7] SAE-CA260 or UNS C26000 seamless brass tube, ½ hard condition.
[8] Hardness as measured by the Vickers Pyramid Hardness testing method.
[9] ½ hard is a measure of material hardness, based on temper.

The ends of the foreign object were examined under a scanning electron microscope which showed fractures at either end of the tube fragment. One end of the object also showed evidence of partial shearing of the tube cross section.

The cross-sectional area of the foreign object's tube section was measured and found to match to the discharge tube section geometry specified by the carburettor manufacturer.

When G-BBSA's carburettor was examined, it was noted that the accelerator pump discharge tube was missing (Figure 10).

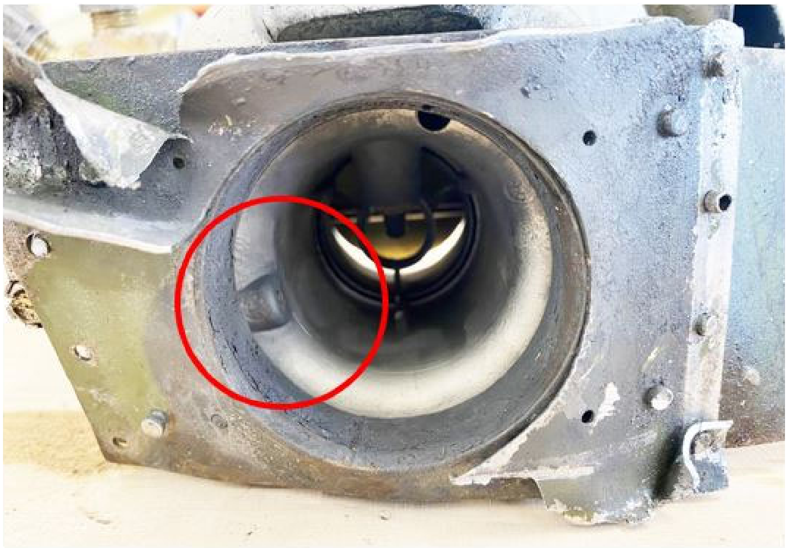


Figure 10

Missing accelerator pump discharge tube from G-BBSA carburettor

A search of the ECCAIRS[10] database did not return any records of carburettor accelerator pump discharge tube release events. An additional search of the FAA Service Difficulty Reporting System database returned three records, covering a total of five separate events of discharge tube release. These events all occurred to Lycoming O-320 powered aircraft, over the period between 2002 and 2014.

Although the issue of the release of the discharge tube does not appear to be a widespread problem, the CAA have agreed to discuss the airworthiness concerns relating to such events with the FAA, at their next joint Continued Operational Safety Working Group meeting. This will ensure that the FAA is aware of the findings of this investigation in their role as the regulator of the engine's Type Certificate holder.

Footnote

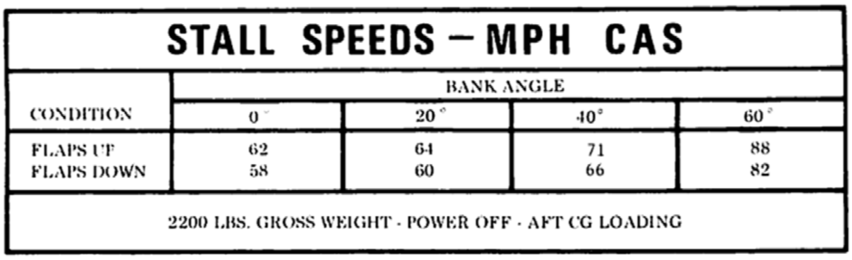
[10] European Co-ordination Centre for Accident and Incident Reporting Systems.

Aircraft performance

The POH gives the following information about stalling:

> *'The AA-5's stalling characteristics are conventional in all configurations. Elevator buffeting occurs approximately 3 mph above the stall and becomes more pronounced as the stall occurs. An audible warning horn begins to blow steadily 5 to 10 mph above the actual stall speed.'*

The stalling speed of the aircraft increases with increasing AOB. The POH contains the table (Figure 11) to indicate the relationship between AOB and stalling speed. Flaps are not used for takeoff.



STALL SPEEDS – MPH CAS

CONDITION	BANK ANGLE			
	0°	20°	40°	60°
FLAPS UP	62	64	71	88
FLAPS DOWN	58	60	66	82

2200 LBS. GROSS WEIGHT - POWER OFF - AFT CG LOADING

Figure 11

POH stall speeds

Australian Transport Safety Bureau Report

The Australian Transport Safety Bureau (ATSB) have published a booklet[11], '*Avoidable Accidents No. 3 - Managing partial power loss after takeoff in single-engine aircraft'* to raise awareness of issues relating to partial power loss.

In the research period, from 2000 to 2010, there were nine fatal accidents resulting from response to a partial power loss compared to no fatal accidents where the engine failed completely. The research data also indicated that a partial power loss was up to three times more likely to occur than a total loss.

A total loss of power is something for which pilots are regularly trained and for which there exists a simple set of checks and procedures. The training emphasises the limited time available and endeavours to make the pilot's response second nature. Following a total power loss, a forced landing is inevitable, whereas in the partial power case pilots are faced with a more complex decision of whether to continue the flight or to make an immediate forced landing. Training for partial loss of power is seldom conducted and not a requirement of the UK licencing syllabus.

Footnote

[11] https://www.atsb.gov.au/media/4115270/ar-2010-055_no3.pdf [accessed 13 May 2022].

In examining the response of pilots to partial power loss the booklet states:

> *'The course of action chosen following such a partial power loss after takeoff can be strongly influenced by the fact that the engine is still providing some power, but this power may be unreliable. As the pilot, you may also have a strong desire to return the aircraft to the runway to avoid aircraft damage associated with a forced landing on an unprepared surface. The complexity of decision making in such circumstances is further compounded by the general lack of discussion and training on this issue. In dealing with this, you will need to rely on your knowledge and experience.'*

In order to prepare for events such as partial power loss the booklet emphasises the importance of pre-flight planning and pilot self-briefing. It also states that the following factors should be considered before every flight:

'» *the runway direction and the best direction of any turn*

» *the local wind strength and direction on a particular day*

» *terrain and obstacles*

» *decision points (taking into account aircraft height and performance) where different landing options will be taken, such as:*

  – *landing on the remaining runway or aerodrome*

  – *landing outside the aerodrome*

  – *conducting a turn back towards the aerodrome.'*

The booklet also suggests a list of initial actions in response to a partial loss of power:

'» *Lower the nose to maintain the glide speed of the aircraft.*

» *Conduct the basic initial engine trouble checks as per an engine failure in accordance with manufacturer's advice. However, this should be done only if there is sufficient time.*

» *Maintain glide speed and assess whether the aircraft is maintaining, gaining or losing height to gauge current aircraft performance. This will help to inform the options available for landing.*

» *Fly the aircraft to make a landing, given the aircraft's height and performance, and the pre-planned routes for the scenario. If turning is conducted, keep in mind an increased bank angle will increase the stall speed of the aircraft. Keeping the aircraft in balance will minimise rate of descent in any turn.*

» *Re-assess landing options throughout any manoeuvres. Be decisive but be prepared to modify the plan if required.*

» *Land the aircraft. Have a minimum height planned to roll wings level. It is suggested in Civil Aviation Safety Authority (CASA) documentation*

> *that turns should not be attempted below 200 feet. However, this will depend on the aircraft's roll rate, the present airspeed and personal experience. Maintain glide speed up to the point of flare; this will ensure that when flaring there is enough energy to arrest the vertical descent rate.'*

Below the minimum turning height of 200 ft, the report suggests that a straight climb or a descent to land are the only options. ATSB occurrence statistics indicate that many partial power losses could have been prevented by thorough pre-flight engine checks. Some conditions reported as causing partial power loss after takeoff are fuel starvation, spark plug fouling, carburettor icing and pre-ignition conditions. In many cases, these conditions may have been identified throughout the pre-takeoff and on-takeoff check phases of the flight sequence.

The ATSB booklet also emphasises the importance of maintaining glide speed till the point of flare, stating:

> *'ATSB occurrence reports show that the initial actions taken by the pilot do not necessarily affect the final outcome — what is more important is that the primary focus be on maintaining airspeed to prevent stalling and also allow energy for flare, rather than diagnosing problems. Thought should be firmly on where the aircraft is going, maintaining control and situational awareness, and dealing with the situation at hand.'*

CAA publication CAP 1535 - The Skyway Code, refers to the ATSB booklet in its section dealing with engine failure but otherwise contains relatively little information on the techniques required to manage partial power loss situations.

Other information

Although, before a flight, a pilot in command is required to give a briefing to any passengers on emergency equipment and procedures, there is no requirement to brief how engine malfunctions will be addressed.

An operator with a large fleet of light aircraft was consulted about the handling of engine failures or partial power loss after takeoff. In their opinion, a turnback from low height should only be attempted when no safe landing area is available within gliding range ahead. The objective of a turnback is to allow the aircraft to reach a safe landing area, not necessarily a reciprocal runway. Their procedures state that a turnback should only be considered above 500 ft agl and that the manoeuvre should be carried out using 45º AOB (to achieve a quicker rate of turn and thus minimise the height loss) and a gliding speed increased by 5 kt to reduce the chance of an accelerated stall[12] in the turn. For training, the turnback is only carried out from 700 ft agl and under the supervision of an instructor.

Footnote

[12] An accelerated stall is a stall that occurs at an airspeed higher than normal due to a higher load factor (g loading). When an aircraft is in a bank or when applying positive g, the wing has to create additional lift to support the aircraft since the load factor has increased.

The flying school at Teesside do not teach or conduct turnbacks, nor do they teach a pre-departure emergencies briefing. Such exercises are not required in the UK PPL syllabus. Other members of the syndicate that owned the aircraft were asked about turnbacks and stated that they had not considered them.

The Australian syllabus for PPL training[13] does include a specific exercise to address a partial power loss event, but not one that occurs immediately after takeoff. The issue is covered as part of a forced landing exercise, and contains the following elements:

> *'(i) identify partial power failure condition*
>
> *(ii) perform recall actions*
>
> *(iii) adjust flight controls to re-establish flight path that maximises performance for partial power condition and maintain a safe airspeed margin above stall speed*
>
> *(iv) establish radio communications where possible*
>
> *(v) perform partial engine failure actions*
>
> *(vi) formulate a plan to recover aeroplane to a safe landing area or aerodrome, taking into account that partial failure might lead to a full power failure at any time*
>
> *(vii) manoeuvre the aeroplane to a selected landing area or aerodrome using the remaining power to establish an optimal aircraft position for a safe landing*
>
> *(viii) advise ATS or other agencies capable of providing assistance of situation and intentions*
>
> *(ix) re-brief passengers about flight situation, brace position and harness security*
>
> *(x) maintain a contingency plan for coping with a full power failure throughout the manoeuvre*
>
> *(xi) when a safe landing position is established, shut down and secure engine and aeroplane.'*

Previous AAIB investigations

During the period 2011 - 2021 the AAIB completed 16 field investigations in which the partial loss of power was involved. Arising from those 16 accidents, there were 15 fatalities and 9 serious or life-threatening injuries. In two of these accidents there were no injuries, and both were as a result of flying the aircraft under control to a successful forced landing or ditching. There were five attempted turnbacks, all of which resulted in fatalities or injuries.

Footnote

[13] Part 61 Manual of Standards Instrument 2014 (legislation.gov.au), Volume 2, Paragraph 2.3 A6.3(b) (https://www.legislation.gov.au/Details/F2021C00449) [accessed 13 May 2022].

Analysis

Cause of the engine partial power loss

The foreign object found in the No 4 cylinder was a portion of the accelerator pump discharge tube that had released from the carburettor and been drawn into the cylinder by the induction airflow. The discharge tube had broken up due to contact with the inlet and exhaust valves, during which the ability to seal the cylinder during the engine power stroke was lost. The engine was therefore running on only three cylinders, resulting in high vibration and a considerable loss of power.

The abrupt nature of the engine power loss, following normal operation at full power during the initial stages of the takeoff, was not consistent with carburettor icing.

The reason for the release of the discharge tube was not established. Retention of the discharge tube within the carburettor relied on a bonded joint that had held for the previous six years and 601 flying hours. The discharge tube had not been disturbed during the recent annual maintenance inspection. Searches performed on the ECCAIRS and FAA Service Difficulty Reporting System databases returned relatively few records of similar previous occurrences, indicating that discharge tube release is an infrequent event.

Pilot's response to the loss of engine power

The pilot was presented with a challenging situation just a few seconds after takeoff and a decision of whether to land immediately or continue the flight, with an underperforming engine. At the point of the initial engine symptoms becoming evident, the aircraft was at 120 ft agl and there was 1,300 m of runway remaining. This would have been sufficient to descend and land on the runway. However, when the engine rpm reduced, the aircraft was in a climbing attitude and so the extent of runway remaining would not have been immediately evident to the pilot. The pilot reduced the nose-up attitude to maintain airspeed but the aircraft did not pitch down below a level attitude so the view of the runway would still have been obscured. The engine was still developing sufficient power to maintain airspeed and to make a shallow climb which continued up to 180 ft agl.

Approximately six seconds after the first engine symptoms, the pilot told ATC he wished to land on Runway 05, and this was coincident with the aircraft altering heading to the right to conduct a teardrop turn to the reciprocal heading. At this point, although the pilot believed he was outside the airfield boundary, his view of the runway would have remained at least partially obscured by the nose of the aircraft. There was approximately 1,100 m of runway left ahead of the aircraft and a landing on Runway 23 would have been possible. The engine continued to run at approximately 2,100 rpm for the next 10 seconds and the aircraft's speed and height stabilised at approximately 70 mph and 200 ft agl respectively.

The engine rpm then reduced further to 1,500 rpm. The aircraft was displaced approximately 140 m the right of the runway on a heading of 245° and at 200 ft agl. The airport boundary was 600 m ahead though a shallow left turn to 225° would have given a clear area of 1,000 m ahead and allowed a landing off the runway but across grass. Beyond the airfield boundary the land slopes down to the River Tees.

As suggested by the ATSB report, giving consideration to or briefing emergencies prior to takeoff would have helped anticipate the decision-making issues. With his knowledge of the aircraft's performance and of the geography of the airport, the pilot could have, prior to the flight, determined decision outcomes for a variety of heights rather than having to do so in a high workload, abnormal situation. This pre-determination could also have taken into account the inability to see the runway remaining.

When the engine rpm reduced for a second time the pilot was turning toward the runway but intending to land on the grass. Assessment of the CCTV indicates that the pilot used a bank angle of approximately 40°. From the POH table at 40° AOB the stalling speed is increased to 71 mph. As the aircraft began the turn its speed was 64 mph so, as the AOB increased, the stalling speed rose above the actual airspeed and the aircraft stalled. The ATSB report suggests that pilots should brief a minimum height below which they will not turn and suggests 200 ft agl below which a landing ahead or climb ahead are the only choices.

A lack of practice at conducting turnback manoeuvres would have made the pilot's workload extremely high. He was using a high AOB, close to the ground at low speeds whilst under significant pressure. His workload was further increased by conducting the ENGINE FAILURE checklist. These factors would have made a successful turnback with very limited power extremely challenging. It is likely that the attention of the pilot became focussed on achieving the required turn to reach his selected landing area and that he did not adjust the airspeed to avoid the accelerated stall.

Preparation for partial power loss events

A partial power loss event, in particular immediately after takeoff, presents the pilot with challenging, unfamiliar decisions in an environment where aircraft handling is demanding and the timeframe is short. Although addressed during Australian PPL training, the issue is not covered in the UK PPL syllabus, and current CAA Safety information only addresses the issue through reference to other documents. It is therefore not straightforward for pilots to prepare themselves appropriately to deal with such malfunctions. There are opportunities, both during ab initio training and, subsequently, during revalidation flights with an instructor/examiner, to cover this issue. Therefore, to assist pilots in preparing to deal with partial power loss events in an effective manner, the following Safety Recommendations are made:

Safety Recommendation 2022-005

It is recommended that the UK Civil Aviation Authority require ab initio pilots to undergo training in the management of partial power loss situations in single-engine fixed-wing aeroplanes.

Safety Recommendation 2022-006

It is recommended that the UK Civil Aviation Authority provide detailed guidance on techniques for managing partial power loss situations and to promote their use by instructors and examiners when conducting training for a rating revalidation in single-engine fixed-wing aeroplanes.

Safety Recommendation 2022-007

It is recommended that the UK Civil Aviation Authority updates its General Aviation safety promotions to include information for pilots regarding techniques for managing partial power loss situations in single-engine fixed-wing aeroplanes.

Conclusion

The engine suffered a partial loss of power during takeoff due to a portion of the accelerator pump discharge tube having been released from the carburettor into the No 4 cylinder. Following this partial loss of power at low altitude the pilot decided to turn back to land, although post-accident analysis of the circumstances shows there was a sufficiently clear area ahead in which to effect a landing. During the turn, at a low airspeed, the aircraft stalled and struck the ground. All three occupants sustained serious injuries in the impact.

Management of a partial power loss event is not covered in the PPL syllabus and there is limited information provided for pilots conducting renewal or revalidation of licences. Three Safety Recommendations are made to address these topics.

Safety action

The CAA has agreed to discuss the airworthiness concerns relating to discharge tube release events with the FAA, who are the regulator of the engine's Type Certificate holder.

Published: 16 June 2022.

ACCIDENT

Aircraft Type and Registration:	Rogers Sky Prince, G-CJZU
No & Type of Engines:	1 Continental Motors Corp O-200-A piston engine
Year of Manufacture:	2009 (Serial no: 00118-1507)
Date & Time (UTC):	30 June 2021 at 1536 hrs
Location:	Near Goodwood Aerodrome, West Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	65 years
Commander's Flying Experience:	706 hours (of which 16 were on type) Last 90 days - 89 hours Last 28 days - 19 hours
Information Source:	AAIB Field Investigation

Synopsis

After takeoff the engine in G-CJZU suffered a partial power loss[1]. This power loss became more significant as the aircraft reached 300 ft aal. The aircraft had little natural stall warning and was not fitted with an artificial stall warning device. A safe flying speed was not maintained, and the aircraft departed from controlled flight at a height from which it was not possible to recover. The aircraft descended steeply and struck the ground nose first. The accident was not survivable.

Examination of the engine could not find any faults that could have caused or contributed to the loss of power. The aircraft had sufficient fuel for the flight. Insufficient supply of fuel to the engine from the tanks could have caused the power reduction but the damage to the aircraft meant that it was not possible to establish the condition of the fuel system or level of fuel supply. It is also possible that a fault in the ignition system could have contributed to the power reduction, but the damage from the post impact fire meant that the integrity of the electrical system could not be fully assessed. Weather conditions were also conducive to carburettor ice forming on the taxi out to the runway. It is possible that carburettor ice formation caused the engine to lose power after takeoff.

Footnote

[1] A situation where an engine provides less power than commanded by the pilot, but more power than idle thrust.

Whilst the investigation of G-CJZU was in progress, a further event involving partial power occurred in which the three occupants of the aircraft were seriously injured[2]. The aircraft suffered a partial loss of engine power shortly after takeoff and the pilot attempted a turnback to land on the reciprocal runway. The aircraft stalled during the turn and struck the ground west of the runway. Three Safety Recommendations were made in that report with respect to pilot training for partial power loss events. These Safety Recommendations, whilst not a part of this report, were formed on the basis of information from both accidents and are supported by the events described here.

History of the flight

G-CJZU had been advertised for sale and the passenger had contacted the pilot to express his interest in the aircraft. The pilot arranged for the passenger to come and see the aircraft as well as experience a flight in it. The passenger arrived at Goodwood and proceeded to spend some time with the pilot and G-CJZU.

At 1529 hrs the aircraft was seen taxiing for takeoff on Runway 32 and having completed the power checks, the aircraft began its takeoff at 1533 hrs. Having become airborne from the runway, the aircraft made a 20° right turn to avoid overflying the village of East Lavant as required by the Goodwood noise abatement procedures. The aircraft was observed by witnesses both on the airfield and around the flightpath. The witnesses described their impression that the aircraft seemed to be low and slow, and that it was struggling to climb.

CCTV showed the aircraft level or begin to descend shortly after the noise abatement turn. A decrease in pitch attitude can be seen on the CCTV lasting around seven seconds before the pitch attitude increased again. Approximately 30 seconds later, the aircraft began a gentle turn to the left but rapidly became unstable with an increasing bank angle and the nose began to drop. The aircraft was last visible dropping behind a tree line with a very nose low attitude and a high bank angle. The aircraft struck the ground at 1536 hrs having turned through almost 180° to be facing the aerodrome. Both the pilot and passenger were fatally injured.

Accident site

The aircraft wreckage was located in the corner of a field adjacent to a line of trees. The wreckage distribution was confined to a small area. The aircraft was severely damaged and had been subject to an intense post-impact fire. The ground around the wreckage was fire damaged and was wet from the application of foam by the Airfield Fire Service who attended the scene. The aircraft had struck the ground nose first and the engine was partially lodged in the layer of clay type soil; a hydraulic lift was required to extract the engine from the ground. Parts of the splintered propeller were found on the accident site. There were witness marks where the left wing had struck the ground; there were no observable witness marks from the propeller. It was not possible to determine the position of the cockpit controls prior to impact due to the impact forces and fire damage.

Footnote

[2] AAIB Report Grumman AA-5, G-BBSA AAIB Bulletin 7/2022 - https://www.gov.uk/aaib-reports/aaib-investigation-to-Grumman-AA-5-G-BBSA [Accessed June 2022].

Recorded information

Several electronic devices were recovered from the accident site; however, all were damaged in the post-impact fire and no data could be recovered from them. CCTV footage from the aerodrome captured the aircraft beginning its takeoff roll. Other footage (Figure 1) captured the aircraft airborne, starting just before the intersection of Runways 14/32 and 06/24, through to its descent to the ground. Analysis of the footage suggests that shortly after passing over the runway intersection at about 150 ft aal, the aircraft levelled off for about six seconds before climbing to about 300 ft aal over the next 26 seconds (so averaging about 350 ft/min). The aircraft is then seen to descend and roll left into a steep dive towards the ground. After disappearing from view behind a row of trees, smoke from the post-impact fire can be seen.

Witness information

There were several witnesses who saw and/or heard G-CJZU during the accident flight. All reported very similar recollections. Those who saw the aircraft commented that it seemed slow and low after takeoff and did not seem to climb away as they expected. One witness describes seeing the wings rock as it struggled away. Once the aircraft had completed the noise abatement turn, attention was drawn to the aircraft by what witnesses described as a cough from the engine, followed a few seconds later by silence. This silence was followed shortly afterwards by the aircraft seeming to bank sharply left, with the nose dropping before the witnesses lost sight of it behind a line of trees. Those who heard the aircraft striking the ground heard what they described as a “thump” before they saw an intense fire break out immediately.

Aircraft information

The Rogers Sky Prince is based on the Jodel D150 Mascaret (D150). The D150 is a two-seat low-wing tailwheel undercarriage touring aeroplane of all wood fabric-covered construction, previously factory produced as a type-certified aeroplane but now supplied in the form of a set of drawings. The standard drawings for building the D150 are of French origin but an English language version was developed in Australia. Aircraft built using these English language plans are known as the Rogers Sky Prince.

G-CJZU (Figure 2) was built in Spain and completed in 2009. In 2017 it was purchased and imported into the UK. It was sold to the present owners in 2019. The engine fitted was a Continental O-200A.

G-CJZU was significantly heavier than a standard D150, probably due to differing wood specifications within the build. This added around 20% to the empty weight of G-CJZU compared to a factory built D150. The aircraft was fitted with a fuel tank in each wing and a large main tank in the fuselage. With the heavier basic aircraft weight and two people on board, the aircraft maximum takeoff weight was liable to be exceeded if the pilot wished to use the fuselage tank as well as the wing tanks. The operator had put in place procedures to ensure the weight was calculated carefully if pilots wished to make use of the extended range with the fuselage tank in use. It was normal practice for this tank to be left empty.

Figure 1

Approximate ground track (note rising ground at the top of the chart) and composite image from CCTV showing G-CJZU flightpath (two-second spacing between aircraft)

Figure 2
Rogers Sky Prince G-CJZU (used with permission)

The aircraft had brake pedals only on the left side of the cockpit, with the fuel selector mounted on the floor between the legs of the left seat pilot. The fuel selector was reported to be difficult to reach, requiring that the pilot slip their shoulder straps off in order to reach down to move it. The fuel selector had four positions (LEFT, MAIN, RIGHT and OFF).

The aircraft engine mixture control was a pull/push lever with a red round knob fitted on the end. This mixture control was the same shape and had very similar dimensions as the engine carburettor heat control lever which was fitted next to it. The only difference between the two levers was the colour of the knob fitted to the end. The controls are shown in Figure 3.

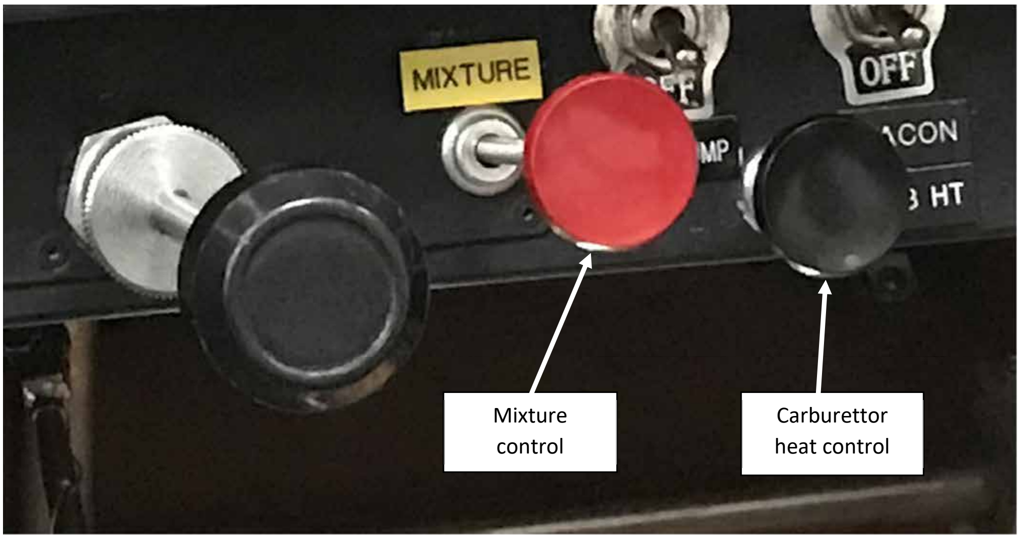


Figure 3
Cockpit controls (used with permission)

Although it was not a requirement on G-CJZU, it is good practice that such controls have different shapes and/or movement to ensure that a pilot does not inadvertently operate the wrong control.

Aircraft examination

The main aircraft structure had been severely damaged by the fire, the most significant identifiable structure were the main wing spars, but even these had been almost completely burned. Examination of the steel control lines showed no evidence of loss of integrity of the flight control system. Whilst the control surfaces which connected to the control lines had been destroyed by the fire, the steel elements of the connections were intact. Due to the angle at which the aircraft struck the ground, the cockpit was severely damaged. Electrical wiring looms had suffered extensive heat damage. The fuel system had been fragmented by the impact; the wing fuel tanks had been separated from the fuel pipes which had been distorted, bent and fractured by the impact forces. The electric fuel pump was in place, but both the inlet and outlet pipes had become separated from the pump, this was likely due to the effects of heat on the pump housing. It was not possible to obtain a fuel sample from the aircraft fuel system. The aircraft was predominantly refuelled at Goodwood, and no other aircraft reported issues with fuel supplied from the same source as G-CJZU. The main fuel selector valve was relatively undamaged (Figure 4).

Figure 4

Fuel Selector Valve

The engine, whilst having suffered some impact damage was relatively intact. The carburettor had been almost completely sheared off its attachment and the fuel inlet hose connector had been destroyed by the impact. The propeller had been fragmented on impact, but the propeller hub and part of the blade were still connected to the engine (Figure 5).

Figure 5

Engine recovered at accident site

Engine examination

The engine was stripped and inspected at an engine overhaul facility. This included the fuel pump, magnetos and spark plugs, carburettor, as well as the mechanical components. There was no evidence of any pre-existing defects that could not be explained by the ground impact or the post-impact fire.

Fuel selector valve examination

The fuel selector valve was inspected, tested and disassembled at the manufacturer's facility. The valve was found to be assembled correctly and functioning satisfactorily, and the valve position correlated with the valve switch position, which was selected to the right hand tank.

Weight and balance

It was not a requirement of the regulator nor the flying group to record the fuel remaining at the end of the flight in the aircraft log. The investigation was able to establish a day when it is likely that the wing tanks were full, and using the flight times and fuel uplift figures, it was possible to calculate that there was sufficient fuel in the aircraft for the planned flight.

Although the AAIB could not establish an exact fuel load in the aircraft at takeoff, calculations with full wing tanks and using the actual pilot weights, the aircraft was below the maximum authorised weight and within the limits for centre of gravity. Due to the closeness of the wing tanks to the datum centre of gravity in the aircraft, a decrease in fuel load would have made very little difference to the calculated flight centre of gravity.

Aircraft Maintenance

The aircraft underwent a Permit to Fly renewal on 16 September 2020 and undertook a satisfactory permit renewal flight on 18 September 2020. On 28 June 2021, following reports of a smell of fuel in the cockpit, the owner requested that a maintenance organisation conduct a visual inspection of the aircraft to determine if there were signs of a leak. The technicians conducted a visual inspection of the fuel tanks, pipes and selector and could not see any leaks. The engine cowlings were removed, and a stain observed on the engine driven pump inlet union. This union was replaced; leaks and functional checks were conducted, all of which were satisfactory. The owner subsequently flew the aircraft and could not detect any smell of fuel and did not observe any other anomaly with the fuel system or aircraft operation.

Aircraft performance and handling

Takeoff and climb

The CCTV images in which the aircraft appeared just after lift off was analysed and it showed that the aircraft had travelled approximately 480 m to get airborne. This was consistent with the performance tables from the flight manual which suggest that an aircraft at maximum takeoff weight would require 565 m to reach a height of 15 m (50 ft). The aircraft was not operating at maximum takeoff weight.

In 2021 the propeller on the aircraft was changed due to a fault with the one previously fitted. A flight test was performed to measure the aircraft performance on 1 June 2021. The results showed that the aircraft achieved an average rate of climb of 450 fpm from 1,000 ft amsl upwards for the five-minute test. No vibration was reported, and the engine limits were all observed to be normal throughout the flight range. The manufacturer of the propeller reviewed the performance figures from the flight test and considered that these figures looked within a normal range.

Other pilots who had flown G-CJZU over the previous few weeks reported that the climb rate was around 300 fpm and that the pitch attitude needed to be reasonably flat to keep the best rate of climb speed of 75 mph. CCTV of the aircraft climb out was shown to some witnesses who were familiar with the aircraft. They noted that the climb rate looked normal for the first 12 to 15 seconds of flight before it seemed that the climb stopped, and the aircraft flew level or began to descend.

Stalling

The Sky Prince is built using plans closely based on the original Jodel D150, although the individual nature of the build will give each aircraft slightly differing handling characteristics. The magazine *Air Pictorial* in 1964[3] reported the stall, both clean and with flap, in the D150 to be *'fairly sudden'* in nature with *'no perceptible aerodynamic warning'*. The article reported that there was tendency for the left wing to drop with full flap or if there was some power applied at the time of the stall. Pilots who had flown G-CJZU recently reported varying

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Footnote

[3] Paul, G.J.C. (1964) 'Air Test No. 51 Jodel D.150 Mascaret', *Air Pictorial*, July 1964.

experiences with the stall on the aircraft. Some reported no wing drop and others noted significant wing drop that occurred regardless of the configuration. The pilots agreed with the Air Pictorial assessment of the stall being sudden and there was little natural warning.

The stall speed of the G-CJZU was recorded when a flight test was conducted for the import of the aircraft into the UK from Spain. The clean stall speed was listed as 54 mph, with the stalls with flaps in both takeoff and landing configurations listed as 50 mph. The aircraft was not fitted with a stall warner, nor was there a requirement for one to be fitted.[4]

Meteorology

An aftercast was obtained from the UK Met Office. This indicated that the weather over the UK was a slack pressure pattern with a high pressure south of Iceland. The weather in the Goodwood area was benign with good visibility, light to moderate winds from the northwest and a cloud base above 2,000 ft amsl. The temperature was 18°C with the surface dewpoint of 12°C.

With the temperature and dewpoint as forecast, the carburettor icing risk was moderate at cruise power, and severe at descent power. The aircraft had taxied at Goodwood for at least four minutes in conditions where it is possible that carburettor ice could have formed. The engine type fitted to G-CJZU is known to be susceptible to forming carburettor icing during taxi if the conditions are likely to promote its formation. Taxiing on grass also increases the chance of ice forming due to the higher relative humidity close to the grass. CAA *Safety Sense Leaflet 14 - Piston Engine Icing*[5] states that:

> *'...ice may build up at the low taxiing power settings, and if not removed may cause engine failure after take-off.'*

It suggests that if ice formation is likely on taxiing, the carburettor heat should be operated for 15 seconds immediately prior to takeoff.

It is unlikely that carburettor icing would have formed with the engine at takeoff power[6]. If ice does form in the carburettor, it leaves no sign once it has melted.

Airfield information

Goodwood Aerodrome is a grass airfield located 1.5 nm north-north-east of Chichester, West Sussex. Runway 32 has a TORA of 1,127 m. There are noise abatement procedures in operation including for takeoff on Runway 32. This procedure requires the pilot to turn right by 20° as soon as possible after departure to avoid East Lavant village which is positioned

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Footnote

[4] The relatively more diverse nature of Permit to Fly aircraft (amateur-built, vintage and ex-military) means that designs qualifying for a Permit to Fly rarely meet the detail requirements in full of modern civil aircraft certification codes such as EASA Certification Specification - Very Light Aircraft (CS-VLA).

[5] CAA *Safety Sense Leaflet 14 – Piston Engine Icing* January 2012. Available at http://publicapps.caa.co.uk/docs/33/20130121SSL14.pdf [Accessed January 2022].

[6] CAA *The Skyway Code (Version 3)* March 2021. Available at https://publicapps.caa.co.uk/docs/33/CAP1535P%20Skyway%20Code%20Version%203.pdf [accessed September 2021].

around 750 m from the upwind end of the runway. This heading is to be maintained until well clear of the village and practice engine failures after takeoff are not permitted until well beyond the village.

The area beyond the end of Runway 34 is flat with a number of large fields before the village of East Lavant. Beyond the village the land begins to rise gently for about a further kilometre before the rise becomes steeper up to the top of the South Downs.

Personnel

The pilot of the aircraft was also the co-owner. He held a PPL with over 700 hours total experience, a significant proportion of which was in tail wheel light aircraft similar to G-CJZU. He was also a Class Rating Instructor which allowed him to instruct for the issue, revalidation or renewal of a class or type rating for single-pilot aeroplanes. The pilot was sitting in the left seat.

The passenger on the flight also held a valid PPL. He had around 200 hours total experience and had recently completed a tailwheel conversion. The passenger was not a member of the operating club and therefore signed a passenger form before the flight. The passenger was sitting in the right seat.

The combination of the occupants and their qualifications meant that legally either occupant could have been operating the controls, although friends and colleagues of the pilot commented that he was very thorough and would have been flying the aircraft even though he was qualified to allow the passenger to operate the controls under his supervision. Equally those who knew the passenger thought it unlikely he would have been operating the controls of an aircraft with which he was not familiar. The injuries identified in the pilot's hands and feet could indicate that he might have been in contact with the controls as the aircraft struck the ground, but it was not possible to be definitive.

Post-mortem examinations of both the pilot and passenger showed no pre-existing conditions that could have caused or contributed to the accident. It is likely that both occupants died at impact before the fire began.

Dealing with partial power loss

Partial power losses present the pilot with a challenging situation where decision making is key to the successful handling of the emergency. The training syllabus for the UK PPL does not include handling partial power as a specific item. The training concentrates on engine failure after takeoff and pilots practise responding immediately to a complete loss of power. In the case of an engine failure after takeoff, the pilot is faced with a known situation, and this requires little in the way of a complex decision-making process. The partial loss of power is more difficult as the pilot must assess the power level and therefore what options may be available. Such an event may require the pilot to make timely decisions such as to go for a forced landing which can be counterintuitive especially when an engine is still running.

The Skyway Code published by the CAA discusses the difficulties in dealing the partial power losses:

> *'Partial engine failures can confuse the decision making process. Assess whether the failure is likely to become worse – for example if rapidly losing oil pressure, the engine may not run for much longer. Take a positive decision to either put down in a field or continue to an aerodrome, depending on your judgement of the problem.*[7]'

In 2013 the Australian Transportation Safety Bureau (ATSB) published a report[8] in their '*Avoidable Accidents*' series which analysed the accident statistics for partial power losses. This report showed that in the period from 2000 to 2010 of occurrences reported to the ATSB, a partial loss of engine power on takeoff was more than three times more frequent than a total loss of power. Of the 242 partial engine failures, nine resulted in fatalities whilst there were no fatalities in the 75 total power loss events. A common factor in the fatalities was a loss of control. It is vital to remain at or above a safe minimum speed and to watch the angle of bank.

> *'The most severe outcomes have occurred when the partial loss of power resulted in the aircraft descending slightly (or being maintained at altitude with increasing angle of attack resulting in airspeed bleeding off), rather than an almost complete loss of power, where it was clear that height could not be maintained. If you feel yourself wanting to stretch the glide, tighten a turn, or maintain height, check the airspeed indicator. If the airspeed has bled off from the glide speed, lower the nose, reduce bank angle if in a turn and re-consider landing options.'*

The ATSB key messages are:

- Pre-flight checks prevent partial power loss

  ATSB occurrence statistics indicate that many partial power losses could have been prevented by thorough pre-flight checks.

- Pre-flight planning and pre-takeoff briefings

  Consider your actions in the event of a partial power loss as much as you would for a total power loss during the pre-flight planning and briefing. This gives you a much better chance of staying in control and ahead of the aircraft.

Footnote

[7] CAA *The Skyway Code* (*Version 3*) March 2021. Available at https://publicapps.caa.co.uk/docs/33/CAP1535P%20Skyway%20Code%20Version%203.pdf [accessed September 2021].

[8] ATSB *Avoidable Accidents No. 3 Managing partial power loss after takeoff in single-engine aircraft* 2013. Available at https://www.atsb.gov.au/publications/2010/avoidable-3-ar-2010-055/#:~:text=ATSB%20occurrence%20statistics%20indicate%20that%20many%20partial%20power,spark%20plug%20fouling%2C%20carburettor%20icing%20and%20pre-ignition%20conditions [accessed October 2021].

- Stay in control

  Have a minimum speed and maximum bank angle which you stick to even if it means reassessing the situation during manoeuvres.

The report concludes with:

> *'Most fatal and serious injury accidents resulting from partial power loss after takeoff are avoidable.'*

Teaching partial power loss

Pilots are taught to handle a complete power loss after takeoff but are rarely taught how to deal with a partial power loss. It is not required under the UK PPL syllabus as a specific item. There is also no requirement to check or assess pilots for the handling of partial power during recurrent checks or training. Many pilots complete their PPL with little or no exposure to the challenges of a partial power scenario. Few have discussed what actions might be needed with a more experienced pilot or instructor. Pre-flight discussions tend to focus on a total loss of engine power and the likely landing areas available.

The Civil Aviation Safety Authority of Australia (CASA) includes the teaching of partial power scenarios as part of the PPL syllabus requiring pilots to reach competency standards[9] for licensing. These standards include knowledge of dealing with partial power, as well as the effects of partial engine power on performance, flight profile, range and landing options.

Partial power has been covered during instructors' seminars and on safety seminars by organisations such as GASCo over the last few years.

Previous events

The AAIB has investigated numerous occurrences of partial power loss in single engine aircraft over the last 10 years of which at least nine others[10] have resulted in fatal injuries to occupants. Three accidents in the same period where partial power was a factor resulted in no injuries to the occupants. In all three of these the pilot ditched or completed a forced landing with the aircraft under full control[11].

The accident to G-YIII[12] has many similarities to G-CJZU. The report states:

> *'The suggested action following an engine failure on takeoff is to land within 30° left or right of the aircraft heading. This course of action is most obviously indicated when an engine failure is total, but more complex for the pilot to determine when the engine continues to run but is not developing full power.'*

Footnote

[9] Part 61 Manual of Standards Instrument 2014 (legislation.gov.au), Volume 2, Paragraph 2.3 A6.3(b) [accessed 13 May 2022].

[10] G-BUDW, PR-PTS, G-ADXT, G-NDOL, G-CDER, G-EWZZ, G-YIII, G-GBXS, G-ASXY (these can be accessed at www.aaib.gov.uk).

[11] D-EESE, G-TLET, G-ARNZ (these can be accessed at www.aaib.gov.uk).

[12] AAIB investigation to Cessna F150l, G-YIII available at https://assets.publishing.service.gov.uk/media/55252d2340f0b61392000007/Cessna_F150l_G-YIII_04-15.pdf [accessed January 2022].

Partial power loss can also involve the pilot concentrating on diagnosing the problem, sometimes at the expense of flying the aircraft. As the pilot attempts to ascertain the cause of the partial power loss it is possible that the significant positive action required to avoid the airspeed reducing may be missed or delayed. The aircraft may also be out of balance since the amount of rudder deflection applied for full power at takeoff may no longer be appropriate.

The report into the accident of G-BGBN[13] in which both occupants suffered serious injuries states:

> *'This accident reinforces the advice that following engine failure it is essential to maintain flying speed and control of the aircraft. It is the experience of the AAIB that a controlled crash landing straight ahead is preferable to stalling at low level.'*

On the 25 September 2021, a Grumman AA-5, G-BBSA suffered a partial loss of power just after takeoff. The pilot attempted a turnback to land on the reciprocal runway but at approximately 60 ft aal, the left bank angle suddenly increased, and the aircraft descended rapidly, striking the ground 67 seconds after becoming airborne. All three occupants of the aircraft suffered serious injuries. The report into the accident made the following Safety Recommendations:

Safety Recommendation 2022-005

It is recommended that the UK Civil Aviation Authority require ab initio pilots to undergo training in the management of partial power loss situations in single-engine fixed-wing aeroplanes.

Safety Recommendation 2022-006

It is recommended that the UK Civil Aviation Authority provide detailed guidance on techniques for managing partial power loss situations and to promote their use by instructors and examiners when conducting training for a rating revalidation in single-engine fixed-wing aeroplanes.

Safety Recommendation 2022-007

It is recommended that the UK Civil Aviation Authority updates its General Aviation safety promotions to include information for pilots regarding techniques for managing partial power loss situations in single-engine fixed-wing aeroplanes.

Footnote

[13] Piper PA-38-112 Tomahawk, G-BGBN, 5 June 2013 available at https://assets.publishing.service.gov.uk/media/5422f6cb40f0b613420005a7/Piper_PA-38-112_Tomahawk__G-BGBN_03-14.pdf [accessed January 2022].

The Safety Recommendations attempt to address the issue of pilot training and development from ab initio trainees, to experienced pilots both through practical training as well as through publicity and education.

Analysis

Evidence from the CCTV and witnesses indicated that G-CJZU suffered a partial loss of power on reaching 150 ft aal after takeoff. Witnesses described an aircraft struggling to climb and being slow and low. Witnesses familiar with the aircraft performance who were shown the CCTV agreed that the aircraft initially seemed to climb normally before levelling off.

Having levelled off for about six seconds, the aircraft then continued to climb. Estimates from the CCTV suggest that the aircraft reached approximately 300 ft aal. Witnesses reported that they heard the engine of the aircraft stutter or cough before the noise ceased entirely about five seconds later. It is probable that the partial power loss became more significant or complete at this point. The left wing was then seen to drop, and the aircraft began to rotate to the left, descending rapidly. It struck the ground, nose first and a fire broke out. The accident was not survivable.

The reason for the partial and then significant loss of power could not be established. There are three main reasons why a piston engine may experience partial power: a mechanical failure in the engine; failure in the ignition system; or fuel starvation.

Examination of the engine revealed no pre-existing faults or damage that could have inhibited operation of the engine. Inspection of the magnetos indicated they were likely to have been functioning, and no faults were observed with the spark plugs, but due to the fire damage, it was not possible to determine the integrity of the ignition system. The investigation was able to establish that there was sufficient fuel in the main tanks for the planned flight but was unable to establish that there was an adequate supply of fuel to the engine. Due to the extensive damage to the aircraft in the post-crash fire it was not possible to examine all of the fuel system, nor establish the position of most of the cockpit controls.

The meteorological conditions on the day of the accident were conducive to the formation of carburettor icing during taxi, especially on grass. The engine of G-CJZU was known to be susceptible to the formation of carburettor ice. Ice formed during taxiing or a delay in takeoff can cause an engine to fail if it is not cleared by selecting the carburettor heat for 15 seconds before takeoff. Any ice that had formed in the carburettor would have melted rapidly in the post impact fire and with the air temperature at 18°C. The formation of such ice leaves no detectable signs in the engine once the ice has melted.

Partial loss of power after takeoff can be a challenging emergency and one that is rarely taught or practised. The topic of partial power is not required to be covered in the UK PPL syllabus or in recurrent checks, so it was unlikely the pilot had practised it routinely. Statistics from the ATSB suggest that it is three times more common than a total power loss and much more likely to lead to fatal injuries. Unlike total power loss, where the actions to be taken are clear, partial power loss requires the pilot to assess the situation without delay and take decisive action to ascertain if the aircraft can still fly at a safe speed and height. Pilots can be distracted by trying to identify and rectify the problem rather than concentrating on flying the aircraft. Pre-flight planning and briefing, as well as having and remaining within a speed and bank angle limit, might save your life. The ATSB report and previous accidents investigated by the AAIB show that the loss of control after a partial power loss is almost inevitably going to lead to fatal or very serious injuries.

The AAIB have investigated a further 15 partial power accidents since 2010, of which nine have resulted in fatal injuries. In the report into the accident to G-BBSA, where the pilot was faced with a partial power situation just after takeoff, three Safety Recommendations were made in regard to training for pilots to deal with partial power scenarios. Those recommendations are backed up by the events in this report.

The D150 has little natural stall warning and the original factory-built model was fitted with an artificial stall warner. G-CJZU was reported to be similar to the D150 with a lack of natural stall warning and the tendency to drop the left wing in all configurations, but was not fitted with a stall warner. The pilot's attention was probably taken up with trying to solve the cause of the partial or significant power loss, and this meant that his attention may not have been on the airspeed. With little power available and no significant nose down attitude, the airspeed would have reduced rapidly, perhaps unnoticed by the pilot. As the airspeed reduced to the stall speed, the pilot would have had little warning before the aircraft stalled and the wing dropped. The aircraft was below the height at which it could be recovered.

Conclusion

After takeoff G-CJZU suffered a partial power loss which then became more significant as the aircraft climbed through 300 ft aal. The aircraft then departed from controlled flight and stuck the ground nose first. Both occupants received fatal injuries. It was not possible to determine the cause of the partial and then more significant power loss.

The ATSB published a report in 2013 detailing research into partial power loss and contains some key messages for pilots to aid them in dealing with partial power should it occur.

Safety actions/Recommendations

In the AAIB report into the accident to G-BBSA on 25 September 2021, where the pilot was faced with a partial power situation just after takeoff, three Safety Recommendations were made in regard to training for pilots to deal with partial power scenarios. The G-BBSA report can also be found in this Bulletin. Those recommendations are equally applicable to the issues raised by this report, and as a result no further Safety Recommendations are made.

Published: 16 June 2022.

AAIB Correspondence Reports

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

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

The accuracy of the information provided cannot be assured.

ACCIDENT

Aircraft Type and Registration:	Glasair II-S RG, G-IIRG	
No & Type of Engines:	1 Lycoming IO-360-B1E piston engine	
Year of Manufacture:	1994 (Serial no: PFA 149-11937)	
Date & Time (UTC):	22 February 2022 at 1710 hrs	
Location:	Near Boreham, Wiltshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Landing gear collapsed, damage to wings, lower surface of the fuselage, propeller and engine shock-loaded	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	70 years	
Commander's Flying Experience:	10,767 hours (of which 52 were on type) Last 90 days - 5 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft's engine failed in flight due to fuel starvation, resulting in a forced landing and damage to the aircraft. The cause of the fuel starvation was selection of an empty fuel tank after engine rough running had occurred whilst the main wing fuel tank was selected.

History of the flight

The pilot was returning to RNAS Yeovilton having departed from North Weald Airfield at 1627 hrs. He elected to keep the retractable landing gear selected DOWN for the flight, as he had experienced difficulty lowering the landing gear on arrival at North Weald, which had required the use of the emergency lowering procedure. The pilot stated that on departure from North Weald there were approximately 127 litres of fuel in the wing tank and that the expected fuel burn for the flight to Yeovilton was about 76 litres. He had not checked the fuel level in the aircraft's auxiliary header tank, and the fuel gauges did not display the fuel level in this tank.

The flight initially proceeded uneventfully, apart from the pilot stating that right rudder and left aileron inputs were required to keep the wings level with the landing gear down whilst cruising at the maximum gear extended speed of 140 mph. Whilst the aircraft was in the vicinity of Marlborough, at an altitude of 2,500 ft in moderate turbulence, the engine began to run roughly. Having noted that the fuel contents were sufficient in the wing tank, which was the selected tank, the pilot carried out checks on the ignition, mixture, propeller and throttle controls but the engine continued to run roughly. The pilot then changed the fuel selector valve to draw fuel from the header tank. The engine recovered and ran normally for approximately 15 seconds, before then losing all power, leaving the propeller windmilling.

The pilot stated that rather than attempting to further troubleshoot the loss of engine power, he prioritised selecting a suitable landing site and having made a MAYDAY call, carried out preparations for a forced landing. He selected a grass field that was into wind and had an upslope. The aircraft landed heavily in the field, forcing the landing gear to retract and partially push the main landing gear legs through the upper wing skins. The aircraft slid on its belly before striking a post and wire fence, which brought the aircraft to a halt (Figure 1). Neither the pilot nor his passenger were injured in the accident.

Following the accident the header tank was observed to be empty. There was no evidence of a fuel leak from the aircraft prior to the accident.

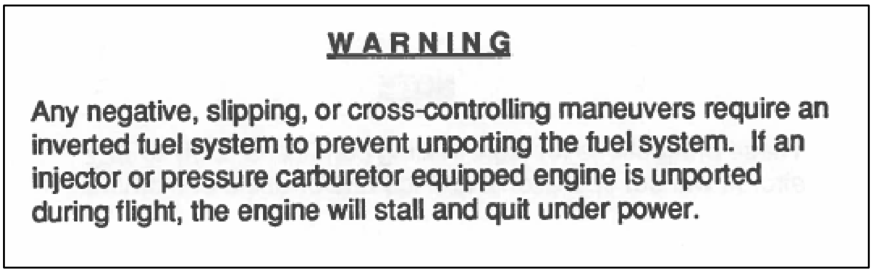
Figure 1
Accident site

Fuel system information

The standard Glasair II-S RG fuel system has a main tank in the leading edge D-section of the wing and a header tank on the aft surface of the firewall. G-IIRG was also fitted with optional wing tip tanks that gravity-fed into the main wing tank, bringing the wing tank fuel capacity up to 193 litres. The header tank has a capacity of 30 litres. When the wing fuel tank is selected, fuel is drawn from a sump fitted to the low point of the wing tank, on the aircraft centreline. The aircraft was not fitted with an inverted flight fuel system and the engine was fuel-injected.

A fuel selector valve in the cockpit enables the fuel to be drawn from either the wing or header tanks, or set to OFF. Three other members of the aircraft's ownership group stated that it was their standard practice to leave the header tank full, as a known fuel reserve in flight, and to visually inspect the header tank contents prior to flying the aircraft.

The Pilot's Operating Handbook (POH) for the aircraft contains the following warning, Figure 2:



WARNING

Any negative, slipping, or cross-controlling maneuvers require an inverted fuel system to prevent unporting the fuel system. If an injector or pressure carburetor equipped engine is unported during flight, the engine will stall and quit under power.

Figure 2

POH warning relating to fuel supply interruptions in flight

The POH also states that:

> *'Slips longer than 30 seconds in duration are prohibited while drawing fuel from the main fuel tank. If less than ten (10) [US] gallons of fuel [37.9 litres] remains in the main tank, slips are prohibited entirely when drawing fuel from the main tank'.*

Analysis

At the point in the flight when the engine began to run roughly there was sufficient fuel available in the wing tank. The most likely reason for the rough running was an interruption to the fuel supply to the engine, since the engine initially ran smoothly again once the header tank had been selected. It is probable that a prolonged sideslip, in combination with turbulence, caused the wing tank sump to be exposed to air inside the wing tank and for air to become entrained within the fuel supply to the engine. Selection of the header tank, which was mostly empty, then caused the complete loss of engine power as the residual fuel in the fuel line between the header tank and the engine was quickly consumed.

The pilot selected a suitable field to land in, however contributory factors in the resulting hard landing may have included the field upslope and difficulty in judging height when landing into a low sun angle.

Conclusion

The aircraft's engine lost power in flight due to fuel starvation following selection of a fuel tank that was empty, after engine rough running had occurred whilst the main wing fuel tank was selected. The cause of the rough running was likely to be due to air being draw into the engine's fuel supply due to fuel movement in flight within the wing tank. The aircraft's

POH contains warnings of interruption to the engine fuel supply from the wing tank due to flying in a sideslip condition.

SERIOUS INCIDENT

Aircraft Type and Registration:	Reims Cessna F172M, G-MOFO	
No & Type of Engines:	1 Lycoming O-320-E2D piston engine	
Year of Manufacture:	1974 (Serial no: 1192)	
Date & Time (UTC):	9 January 2022 at 1947 hrs	
Location:	Newcastle International Airport	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Light Aircraft Pilot's Licence	
Commander's Age:	72 years	
Commander's Flying Experience:	233 hours (of which 4 were on type) Last 90 days - 13 hours Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

During a night flight, the pilot misidentified road lights for runway lights and drifted south of the airport. While the pilot was establishing his position, the aircraft descended to approximately 300 ft agl.

History of the flight

The incident flight was the pilot's first night solo during a Night Rating course. While downwind for a right-hand circuit, the pilot lost sight of the runway, misidentified lights from the nearby A1 dual carriageway and drifted off course to the south. While attempting to reacquire the runway lights he inadvertently allowed the aircraft to descend. On realising he was lower than intended the pilot initiated a climb. Coincident with this, Newcastle ATC called for the pilot to climb when they saw the aircraft's transponder Mode C altitude reducing toward 500 ft. Ground elevation in the area of the descent was approximately 200 ft amsl. Once safely level, the pilot turned back toward the airfield. With assistance from Newcastle ATC, he regained visual contact with the runway and landed from an abbreviated left-hand circuit. Salient points from the pilot's SkyDemon track log are reproduced at Figure 1. After a "debrief and a long ground brief on Newcastle features and radio procedures," the pilot's instructor cleared the pilot to continue his night-flying training.

AAIB comment

The pilot's inadvertent descent highlights the increased risk from distraction, in this case looking for the runway lights, in situations where external visual cues are reduced.

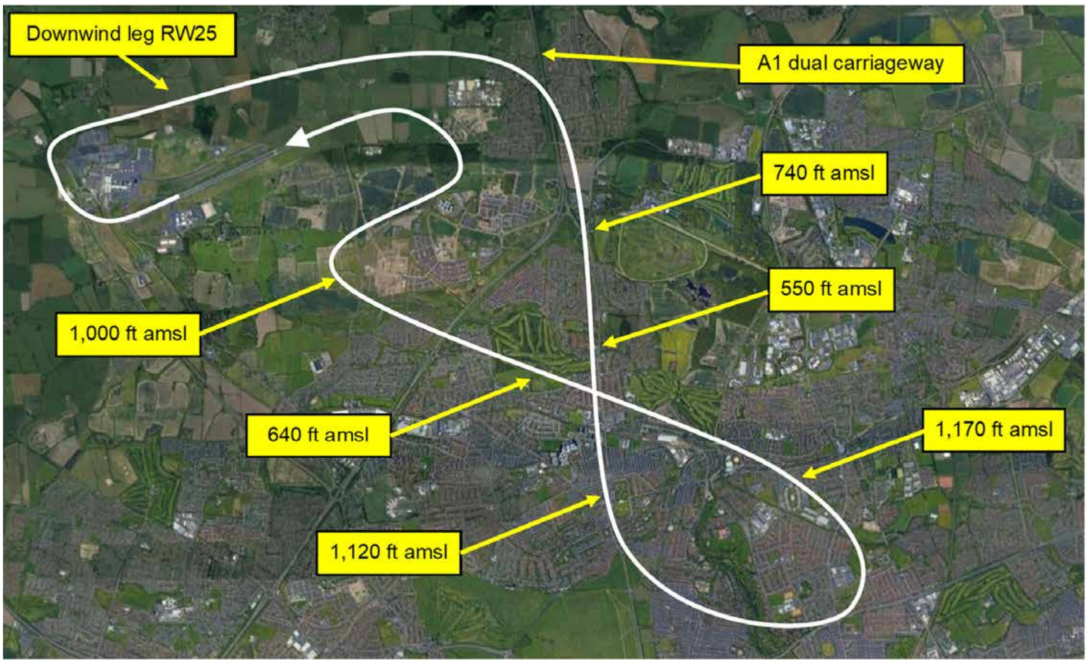


Figure 1

Approximate track and altitude of G-MOFO reproduced from SkyDemon recording
(Imagery ©2022 Bluesky.CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky.Landsat / Copernicus, Maxar Technologies, Map data 2022)

ACCIDENT

Aircraft Type and Registration:	Vickers Slingsby T65A Vega, G-EECK	
No & Type of Engines:	N/A	
Year of Manufacture:	1979 (Serial no: 1917)	
Date & Time (UTC):	13 October 2021 at 1216 hrs	
Location:	Near Portmoak Airfield, Scotlandwell, Kinross	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Serious)	Passengers - N/A
Nature of Damage:	Damaged beyond economical repair	
Commander's Licence:	Other	
Commander's Age:	70 years	
Commander's Flying Experience:	212 hours (of which 64 were on type) Last 90 days - 5 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB	

Synopsis

The pilot lost control of the glider and struck the ground after the canopy became insecure soon after takeoff.

The canopy had not been secured properly during the pre-flight preparation due to the pilot, and a person assisting him with the canopy, being distracted.

History of the flight

Background information

The canopy on the Slingsby T65A Vega has an opening hinge on the nose of the glider and opens vertically at the rear (Figure 1).

The canopy lock is located on the top of the fuselage behind the pilot's head. The pilot commented that it was not possible for him to lock the canopy, or to see the locking indicator, when seated in the glider due to his stature and his requirement to use a seat back. He would normally be assisted by his syndicate partner in lowering the canopy, engaging the lock and checking the indicator button was flush. The syndicate partner would then say, "canopy closed and locked". When the syndicate partner was not available, the pilot would ask for assistance from someone else and brief them this procedure.

Figure 1

Slingsby T65A Vega glider showing canopy open and side window

The accident flight

On the day the day of the accident, the syndicate partner was not available, so the pilot obtained assistance from a gliding club member who he briefed on the canopy locking procedure.

The pilot stated that as he was distracted talking to the club member and not fully focused on his flight, he did not complete his cockpit pre-flight checks correctly. As the club member was also distracted by the conversation with the pilot, he did not complete the canopy locking procedure. However, the pilot convinced himself that when the canopy was closed, it was also locked.

The glider subsequently took off on a winch launch from grass Runway 28. At the time the wind was from about 290° at 8 kt. Soon after takeoff, at approximately 300 ft agl, the canopy started to bounce up and down and the pilot realised it was not locked. At about 500 ft agl he released the winch cable and levelled the glider with the intention of making an abbreviated circuit, landing halfway down Runway 28.

Conscious that if the canopy detached in flight it may damage the empennage, he opened the left side panel window and pressed down on the canopy's lower rim with his right hand. His arms were thus crossed in front of him while he controlled the glider with his left hand.

During the circuit, the pilot realised he was unable to simultaneously hold down the canopy, hold the control column and select the flaps and airbrakes. Therefore, on the final approach he attempted to secure the control column between his legs while he temporarily let go of the control column to select the flaps. However, when he did so the glider started to 'porpoise', probably because the glider was not in trim. He then lost control and the glider struck the ground at an attitude of about 20° to 30° nose down, cartwheeled and came to rest inverted in a field of vegetables in the undershoot of Runway 28 (Figure 2). This left the pilot trapped upside down in the cockpit supported by his harness.

Rescuers from the airfield were quickly on scene. The pilot was removed from the glider after his seat harness and parachute straps had been cut and a famer had lifted the glider with a forklift tractor. The pilot was subsequently taken by an air ambulance to hospital. He sustained serious injuries including a broken arm.

Figure 2

G-EECK after the accident

Pilot's comments

The pilot believed that the canopy eventually detached just before the glider struck the ground.

The pilot commented that the primary cause of the accident was inadequate pre-flight checks. He added that while he was technically current, he was out of regular flying practise and so a lack of recency also contributed to the accident. Additionally, he believed he was overconfident on the day, as he was in a hurry to get airborne and was thinking of the flight ahead and not the launch.

Analysis

The glider became airborne with its canopy not closed and locked. This led him to secure it with one hand while trying to fly the glider and configure it for landing with the other. This meant he released the control column during the approach and lost control.

Despite him not being physically able to secure the canopy on the ground, he had a procedure in place to overcome this. However, despite this, he and his assistant became distracted in conversation at a critical time of the flight's preparation, the result of which was that the canopy nearly came off in flight. Had it done so, it may have damaged the glider to such an extent that control may have been lost at a greater height leading to more serious consequences.

This accident highlights how easy it can be to become distracted, and the consequences. Flight preparation is a critical phase of any flight, and it would be wise to treat this part of a flight as a time where only things related to the operation of the flight are discussed.

Conclusion

The glider's canopy was not secured during the pre-flight preparation because the pilot and his assistant became distracted. This led to the canopy becoming unsecure soon after takeoff.

While distractions are a part of life, it is good airmanship to notice when this happens and try to return to a point in a procedure before the distraction occurred so anything that was missed can hopefully be spotted and rectified.

ACCIDENT

Aircraft Type and Registration:	Zenair CH 750, G-CIJZ	
No & Type of Engines:	1 Rotax 912ULS piston engine	
Year of Manufacture:	2015 (Serial no: LAA 381-15118)	
Date & Time (UTC):	17 December 2021 at 1350 hrs	
Location:	2 miles west of Wideford Hill, Orkney	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Landing gear damaged and seized engine	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	68 years	
Commander's Flying Experience:	13,968 hours (of which 29 were on type) Last 90 days - 29 hours Last 28 days - 12 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

Approximately 15 minutes into a flight the pilot detected a hot smell and a lack of engine oil pressure. With high vibration and smoke entering the cockpit, the pilot shut down the engine. During the subsequent forced landing the aircraft landed heavily in soft ground damaging the landing gear.

Subsequent inspection of the engine found that a brass pipe connecting the oil pressure transducer to the engine had failed in fatigue causing loss of oil from the engine. At some point in the aircraft's history the oil pressure transducer had been relocated from the standard position to the engine frame which increased relative movement of the pipe in flight.

History of the flight

The pilot took off from Lamb Holm Airfield to conduct some upper air handling in the local area. About 15 minutes into the flight he detected a hot smell and on checking the engine instruments he observed that the oil pressure was reading zero. As he was over hilly terrain and with the engine still running he headed towards Kirkwall and descended, considering a precautionary landing in a field. About two minutes later there was intense vibration from the engine and he immediately shut the engine down and commenced an emergency descent from approximately 1,800 ft.

With smoke entering the cockpit he informed ATC of the problem and that he was executing an emergency landing into a field west of Wideford Hill. The pilot selected a suitable field into wind, but the bright low sun meant that he did not observe power lines crossing the threshold until 400 ft agl. Assessing that he was too close to the wires, the pilot turned through 60º to land in a closer grass field. The aircraft landed heavily in the soft ground. The pilot was unhurt, but the landing had damaged both the main and nose landing gear, and the engine had seized.

Investigation

Inspection of the engine found that a brass pipe connecting the oil pressure transducer to the engine had failed causing loss of oil from the engine. Normally the oil pressure transducer is mounted directly on to the front right hand side of the crankcase. At some point in the aircraft's history the oil pressure transducer had been relocated from the standard position to the engine frame (Figure 1).

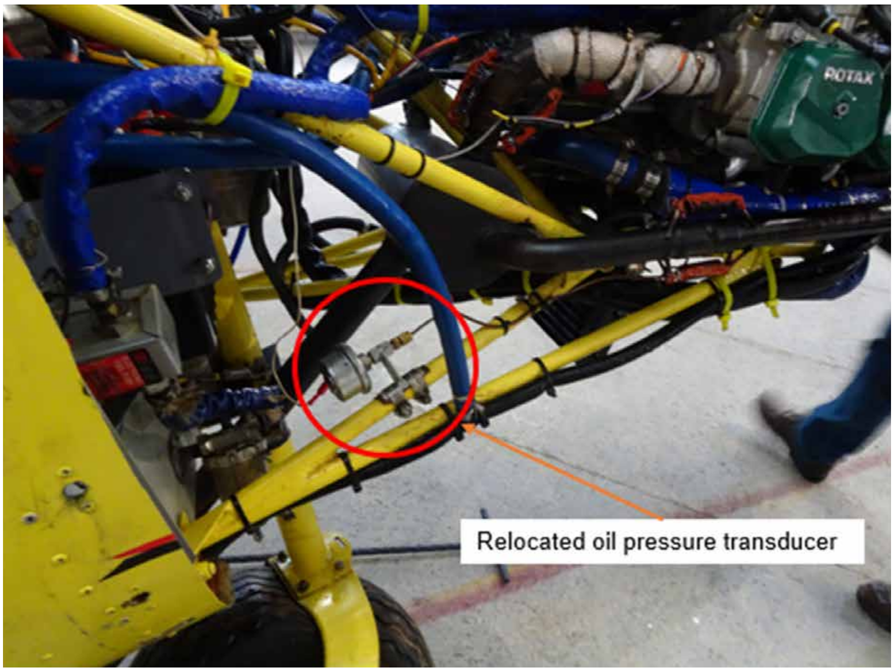


Figure 1

Image showing relocated position of the oil pressure transducer

It is not uncommon to see oil pressure transducers on Rotax 91x Series engines remotely mounted as there is a perception that it reduces fluctuating oil pressure readings. The standard Rotax installation is for the oil pressure transducer to be mounted directly on the crankcase. If relocated it is more normal to see a flexible hose between the engine oil pressure outlet fitting and the transducer. The brass pipe used to connect the transducer on G-CIJZ had failed at the engine fitting (Figure 2), most likely due to fatigue exacerbated by the relative movement between the engine and the frame the transducer had been mounted on.

Figure 2
Image showing location of pipe fracture

Oil pressure transducer considerations

When considering the remote location of the oil pressure transducer, the relative movement between the engine and transducer needs to be factored into the modification. The LAA have recently highlighted[1] this issue to owners and inspectors.

Footnote

[1] Light Aviation March 2022 - ‘*Engineering Matters*’ published by the LAA.

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 2022

5 Mar 2022 **DJI Matrice M300** Ffynongroyw, Flintshire

The UA was operating at a height of 115 m when an ESC (Electronic Speed Controller) error occurred on one of the motors. The UA fell to the ground in the back garden of a house and was extensively damaged.

24 Mar 2022 **DJI Matrice 210 RTK** Selby, North Yorkshire

Shortly after takeoff at a height of 5 m the UA suddenly flew away at high speed. Neither the speed nor the direction of the UA could be controlled. The remote pilot used attitude mode to intentionally force the UA into a grassed area to avoid collision with nearby cooling buildings.

25 Mar 2022 **DJI Matrice M300** Merthyr Tydfil, Mid Glamorgan

During a photographic flight the UA controller showed a prop motor 4 error and the UA fell to the ground, landing in a field. When recovered the arm supporting motor 4 was found to be broken and the number 4 propeller and motor would not rotate without the application of significant force.

26 Mar 2022 **DJI Mavic 2** Chilworth, Surrey

While being flown approximately 70 m from the remote pilot and in 'Sport' mode, which inhibited its onboard obstruction sensors, the UA struck the branches of a tree and fell to the ground. The pilot reflected that, with the aircraft 70 m away, depth perception was challenging and if he had enabled the collision sensors by switching to 'positional' mode and used the camera to check for potential hazards the accident might have been avoided.

2 Apr 2022 **DJI Mavic Enterprises Advanced** Coniston, Cumbria

The UA was operating in a quarry. The remote pilot lost contact with the UA and it struck the wall of the quarry before falling into a lake.

7 Apr 2022 **DJI Matrice 210** Ipswich, Suffolk

The UA became unresponsive to any of the remote pilot's commands shortly after takeoff. It drifted towards the nearby river, descended into it and became partially submerged.

10 Apr 2022 **MA Big Swift Glider** Dunsfold Aerodrome, Surrey

The model glider disappeared into cloud and went missing. It was not recovered.

Record-only UAS investigations reviewed: April - May 2022 cont

13 Apr 2022 **Delair UX11** Delair UX11

The Delair UX11 is a fixed wing UA used for mapping. During a survey flight in an unpopulated area, the remote pilot activated a land command due to high winds. Whilst returning to land the UA became unstable, probably due to the wind and associated turbulence off surrounding hills, and the right wing detached.

18 Apr 2022 **DJI Mavic Enterprise Adv** Tyburn, Birmingham

As the UA was returning to it's launch point it stopped reacting to control inputs and descended, uncontrolled, to the ground.

24 Apr 2022 **DJI Matrice M300** Manchester

The UAS was being used to inspect the inside of a vertical shaft in a railway tunnel as part of planned maintenance activity. The top of the shaft had been capped and the tunnel was not in use at the time of the inspection. As the UA entered the shaft it drifted horizontally and failed to respond to the pilot's commands. Approximately 1 m into the shaft the UA hit the shaft wall and fell onto the rail track.

29 Apr 2022 **DJI Mavic 2** Doncaster, Yorkshire

A night survey using torches detected telephone cables prior to deploying the UA. However, the UA subsequently collided with a telephone cable and fell out of control to the ground. The remote pilot considered that he may have missed the cable during the survey,as a result of the light conditions in the area of operation.

30 Apr 2022 **MA Powered Glider Alegra 2M** South Kyme, Lincolnshire

On the last flight of the day, in fading light, the remote pilot realised that the glider had moved significantly north and disappeared from view in some low-lying mist. The pilot closed off the transmitter and activated the fail safe to land the glider. The aircraft could not be found.

15 May 2022 **MA foam, electric powered** Birch Vale, Derbyshire

Despite the remote pilot's attempts to land the model, it was blown away from the pilot by the wind and was not recovered.

15 May 2022 **MA fixed wing** Inskip, Lancashire

The remote pilot lost sight of the blue model aircraft against the blue sky. The aircraft has not been recovered.

Record-only UAS investigations reviewed: April - May 2022 cont

22 May 2022	**DJI Mavic Mini**	Near Ben More, Isle of Mull

The remote pilot lost connection with the UA. It subsequently struck a bus about 600 m away; the bus suffered a cracked windscreen.

24 May 2022	**Autel Evo II Pro**	Chalfont St Peter, Buckinghamshire

Whilst ascending inside a shaft, the UA suffered a compass error and started manoeuvring in a clockwise rotation. The UA did not respond to the remote pilot's inputs and was subsequently recovered from the bottom of the shaft. The compass error was believed to have been caused by environmental interference.

27 May 2022	**Ultra-UAS**	Predannack Airfield, Cornwall

The manufacturer was testing cross wind landings. During the twenty-first landing roll out, the remote pilot and the observer noticed the nosewheel start to shimmy that developed very rapidly into an aggressive wobble that subsequently caused the nosewheel fork to detach.

Miscellaneous

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

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

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

1/2015	Airbus A319-131, G-EUOE 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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