Air Accidents Investigation Branch

AAIB Bulletin 6/2024

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

Accordingly, it is inappropriate that AAIB reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

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(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Field Investigation Reports

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

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

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

Accident

Aircraft Type and Registration:	Airbus A321-253NX, G-OATW
No & Type of Engines:	2 CFM International SA LEAP-1A33 turbofan engines
Year of Manufacture:	2020 (Serial no: 10238)
Date & Time (UTC):	4 October 2023 at 1151 hrs
Location:	London Stansted Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 11 Passengers - 9
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to several cabin windows and impact damage to the left horizontal stabiliser
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	4,905 hours (of which 2,300 were on type) Last 90 days - 128 hours Last 28 days - 27 hours
Information Source:	AAIB Field Investigation

Synopsis

A cabin window was seen to be loose shortly after takeoff and several windowpanes were missing after the aircraft landed. The windowpanes fell out because they had been damaged by infrared energy emitted by high-intensity lights during a filming event the previous day.

The investigation found four previous occurrences on other airframes, but knowledge of them was not widespread in the aviation community. The report considers the cause of the damage and how the filming was risk assessed and supervised.

In response to this accident the aircraft manufacturer intends to publish two articles to highlight the damage that can be caused by high-intensity lights. The aircraft operator highlighted the need for a suitable aviation-focused risk assessment when carrying out this type of activity with an aircraft.

History of the flight

The aircraft was scheduled to embark on a multi-sector charter away from base for several weeks. On board were three pilots, an engineer, a load master and six cabin crew. The co-pilot was the PF for the first sector, which was a positioning flight from London Stansted Airport to Orlando International Airport, Florida. Prior to the boarding of the passengers the commander completed a pre-flight inspection of the exterior of the aircraft and noted nothing untoward. At the same time, several engineers were carrying out an external inspection; the daily and ETOPS[1] inspections, prior to departure. In addition to the 11 crew, there were nine passengers on board. The passengers sat together in the middle of the aircraft just forward of the overwing exits.

The aircraft departed a few minutes ahead of schedule and took off from Runway 22. Several passengers recalled that after takeoff the aircraft cabin seemed noisier and colder than they were used to. As the aircraft climbed through FL100, and the seatbelt signs were switched off, the loadmaster, who had been seated just in front of the other passengers, walked towards the rear of the aircraft. He noticed the increased cabin noise as he approached the overwing exits and his attention was drawn to a cabin window on the left of the aircraft. He observed that the window seal was flapping in the airflow and the windowpane appeared to have slipped down[2]. He described the cabin noise as 'loud enough to damage your hearing'. Figure 1 shows the window in flight.

The loadmaster told the cabin crew and then went to the flight deck to inform the commander. At this stage, the aircraft was climbing through FL130, there were no abnormal indications on the flight deck and the aircraft pressurisation system was operating normally. The flight crew stopped the climb at FL140 and reduced airspeed whilst the engineer, and then the third pilot, went to look at the window. Having inspected the window, it was agreed the aircraft should return to Stansted. The cabin crew told the passengers to remain seated and keep their seatbelts fastened and reminded them about the use of oxygen masks if that became necessary.

The cabin was quickly secured and the flight crew initiated a descent, first to FL100 and then to FL90. They established the aircraft in a hold whilst they completed the overweight landing checklist, confirmed landing performance and briefed for the return to Stansted. The commander flew the approach and landing to Runway 22. This was uneventful; landing at 1151 hrs with a total flight time of 36 minutes. With the airport RFFS in attendance the aircraft taxied to the apron, where the passengers disembarked normally.

Having parked and shut down, the crew inspected the aircraft from the outside and saw that two cabin window assemblies were missing and a windowpane and seal were dislodged on a third window. During the flight the crew had only been aware of an issue with a single windowpane. The cabin had remained pressurised normally throughout the flight.

Footnote

1 ETOPs stands for Extended Range Twin Operations.
2 The crew were not aware if this was only the outer pane or both panes.

Figure 1

View of the left side cabin window aft of the overwing exit

Previous activity

The day before the occurrence flight the aircraft had been used for filming on the ground, during which external lights had been shone through the cabin windows to give the illusion of a sunrise. The lights were first shone on the right side of the aircraft for approximately five and a half hours, with the light focused on the cabin windows just aft of the overwing exits. The lights were then moved to the left side of the aircraft where they illuminated a similar area on the left side for approximately four hours. Photographs taken during filming showed six sets of flood lights on both sides of the aircraft. Figure 2 shows the lights positioned on the left of the aircraft.

Figure 2
Flood lighting on the left side of the aircraft

Recorded information

The aircraft was fitted with an FDR and CVR which were removed and successfully downloaded at the AAIB. The flight was captured on both recorders and the CVR confirmed reports from the flight crew interviews.

The aircraft took off from Stansted at 1115 hrs, climbing progressively to a maximum of 14,504 ft[3] at 1123 hrs (Figure 3). The cabin altitude increased during this time, reaching a recorded maximum of 1,536 ft. The aircraft then descended to FL 100 initially, followed by a further descent to FL 90 while circling to the north-west of the airport. No pressurisation warnings were recorded during the flight, which landed back at Stansted Airport at 1151 hrs.

Footnote

[3] Pressure altitude is recorded to a reference pressure of 1013 hPa.

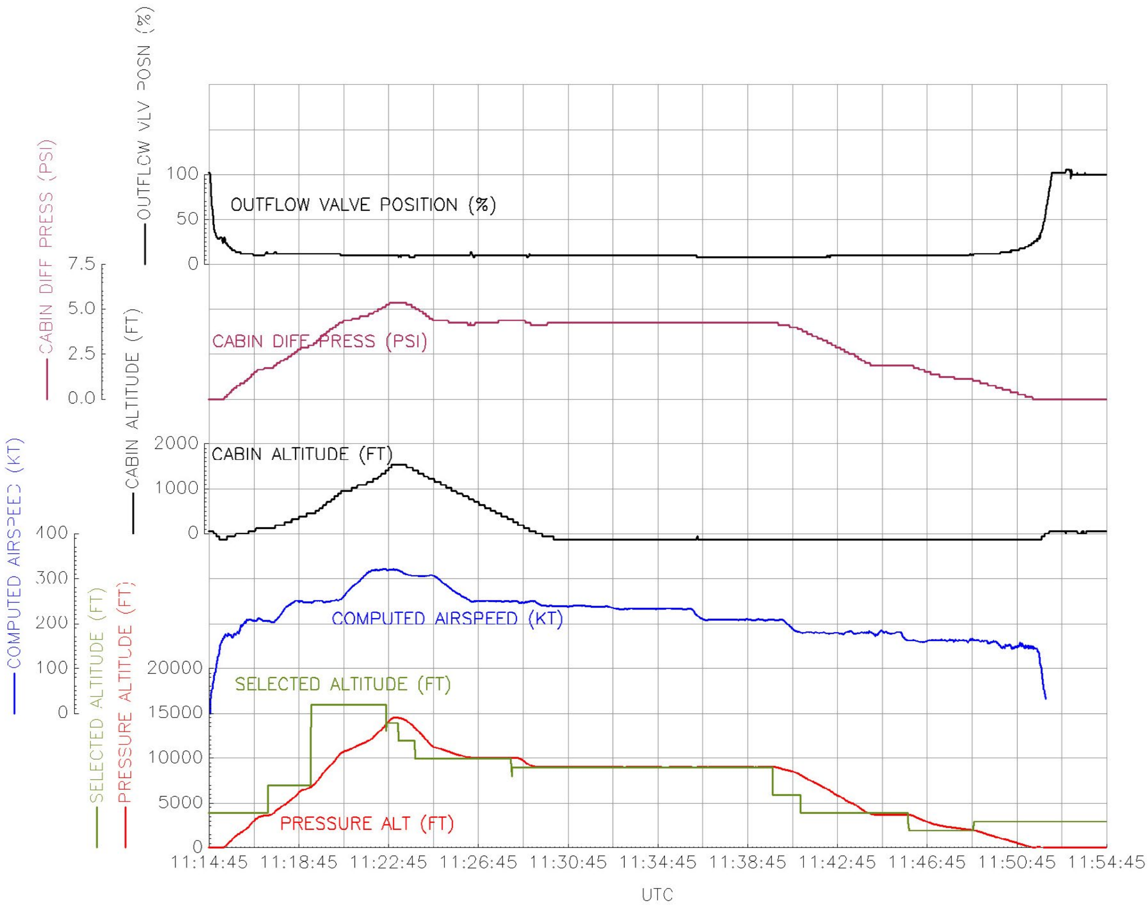


Figure 3
G-OATW FDR data

Cabin windows description

Construction

Each cabin window assembly consists of two windowpanes and a rubber seal. The windowpanes fit into two slots in the rubber seal to form a 'dry' assembly, meaning that no adhesives or sealants are used. The window assembly is held in compression against the window frame using a metal retainer, six eyebolts and six nuts (Figure 4). The outer surface of the cabin window is flush with the outer surface of the fuselage.

A vent hole through the inner pane lets cabin pressure into the space between the inner and outer panes. Both panes can both carry the full differential pressure across the fuselage, providing redundancy if either pane should fail.

A third windowpane is attached to the cabin trim. This is commonly referred to as a scratch pane, and this is the windowpane that passengers can touch. It is sacrificial and protects the inner windowpane from damage. It does not form part of the load bearing structure.

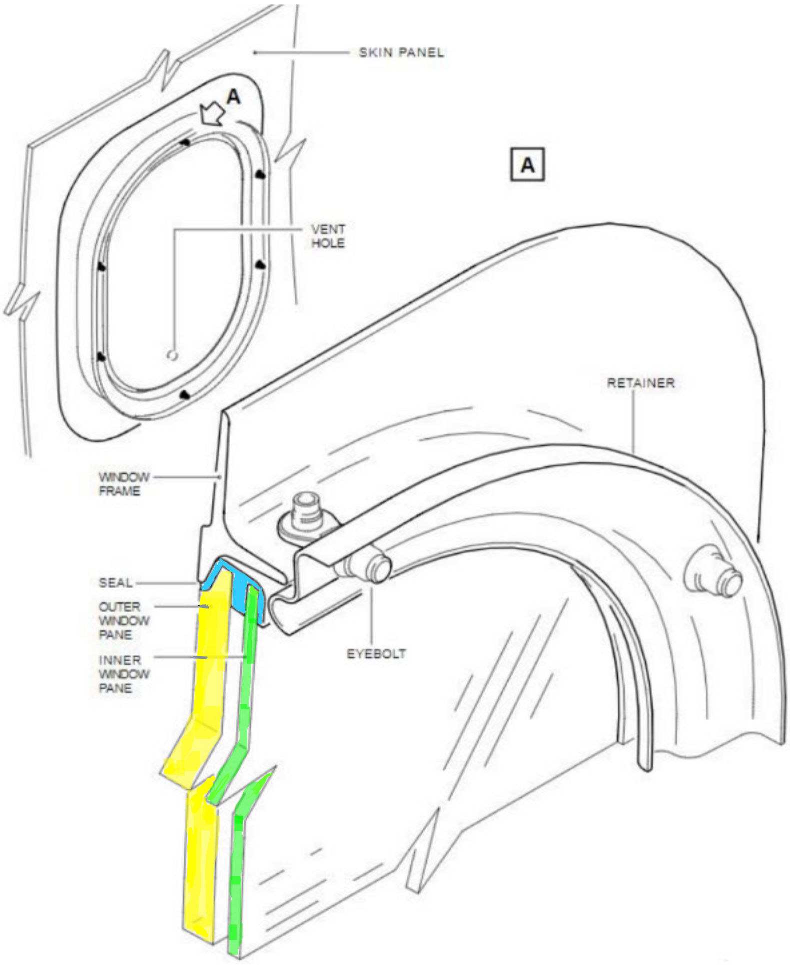


Figure 4

Schematic of the cabin window assembly – scratch panel is not shown
(outer pane, inner pane and rubber seal are highlighted)

Manufacturing process and specification requirements

The Airbus A321 is certified to operate in a maximum outside air temperature of 55°C. The specification for the cabin windows requires them to withstand a maximum temperature of 80°C, thereby providing a safety margin.

The outer and inner windowpanes are made of stretched acrylic. This requires cast acrylic to be heat soaked near its softening point whilst it is stretched into its finished shape. The performance specification[4] includes post-production dimensional stability properties and there are two requirements relating to thermal relaxation (Table 1).

Footnote

[4] Performance specification MIL-PRF-25960.

Temperature	Allowable thermal relaxation (shrinkback)
110°C	10% maximum
145°C	37.5% minimum

Table 1

Extract from performance specification MIL-PRF-25960

Aircraft examination

Cabin windows

Two cabin window assemblies were missing in their entirety, and the inner pane and seal from a third were displaced but partially retained (Figure 5). The forward edge of a fourth window protruded from the left side of the fuselage (Figure 6). The four windows were adjacent to each other, just aft of the left overwing exit. All the scratch panes remained in place, so there was no direct, unrestricted aperture into the passenger cabin.

A shattered inner windowpane was recovered from the entrance to a rapid-exit taxiway during a routine runway inspection after the aircraft landed. This windowpane would have separated during takeoff as this location was not passed by the aircraft during the landing roll. The airport operations team reported that no other parts were found during follow-on routine checks of the paved surfaces or additional checks of the grass around the rapid-exit taxiway.

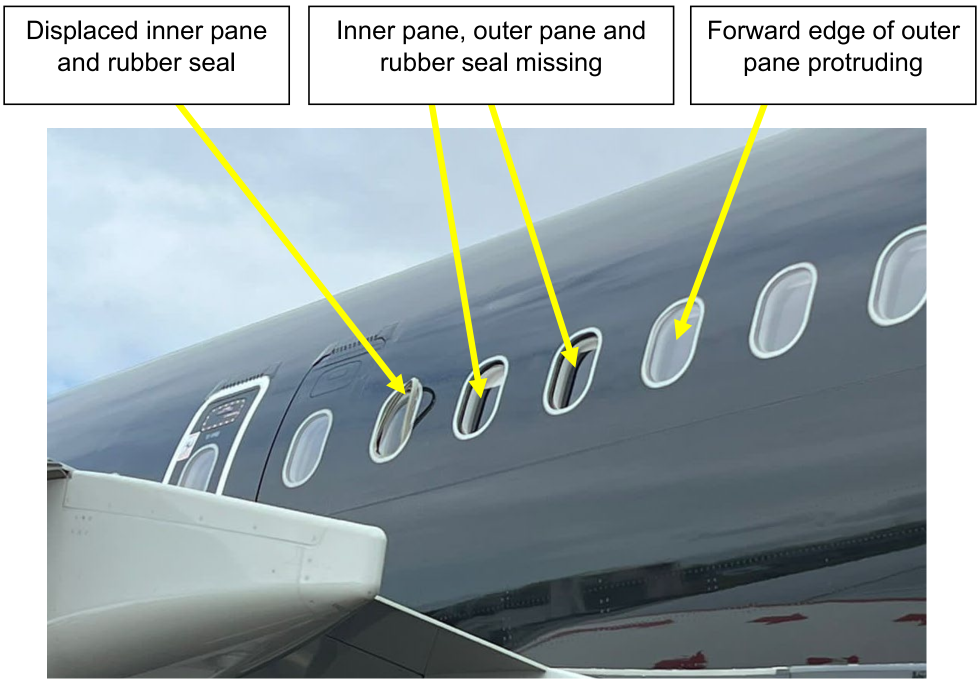


Figure 5

Displaced and missing windowpanes on the left side of the aircraft

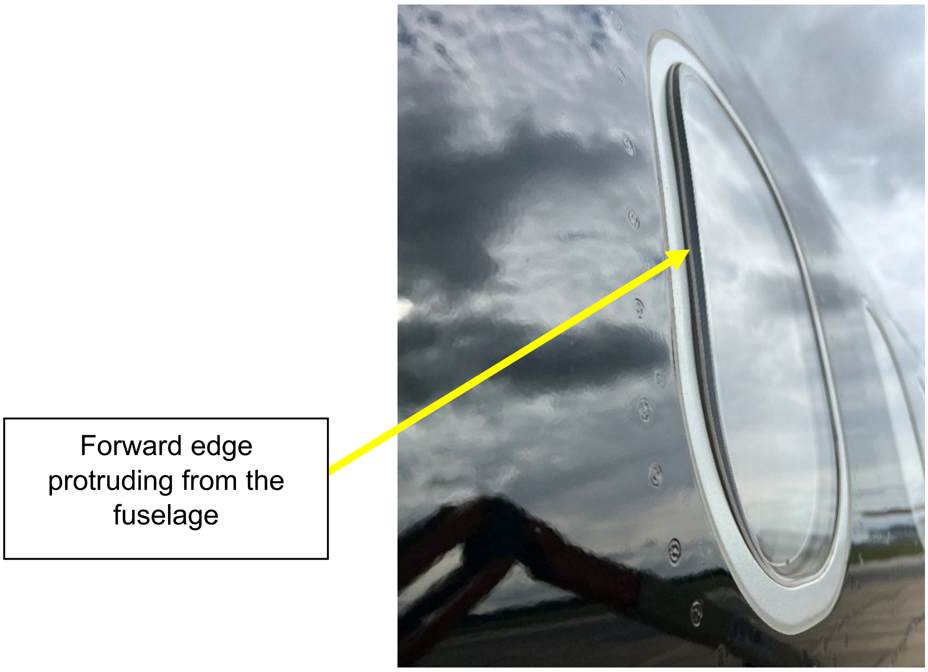


Figure 6

Forward edge of the outer pane protruding from the fuselage

Removal of the cabin lining inside the passenger cabin revealed that, despite the missing and dislodged windowpanes, the window retainers were in good condition and correctly installed (Figure 7).

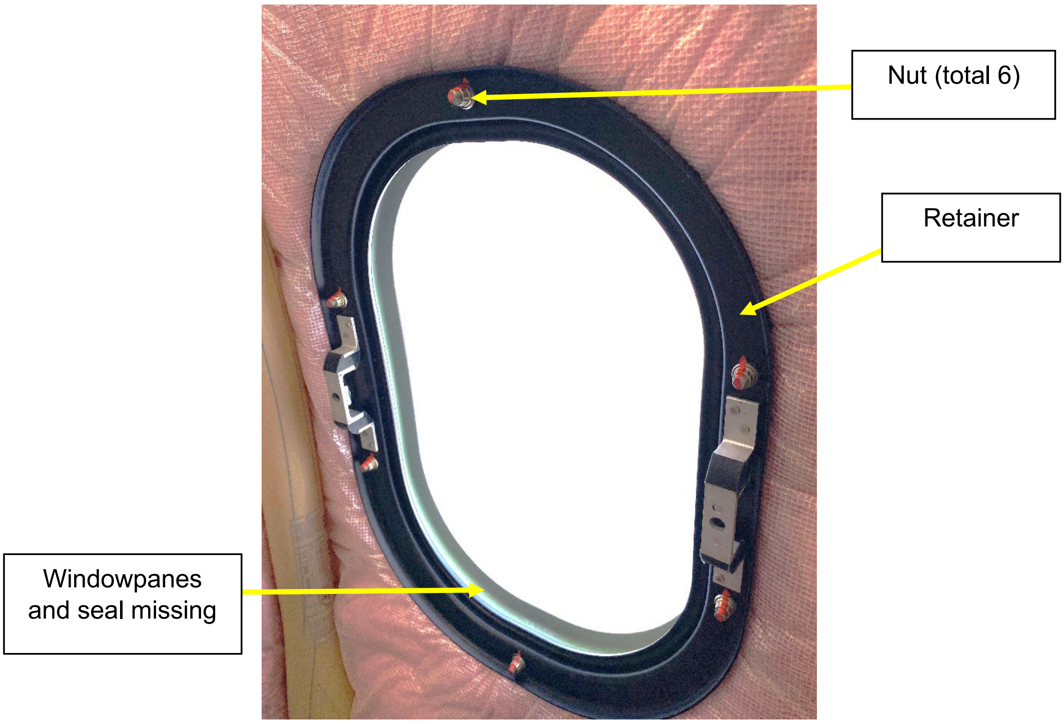


Figure 7

Correct installation of the retainer but the window assembly is missing

The foam ring material on the back of the cabin liners was found to be melted in the areas adjacent to the windows that were damaged or missing (Figure 8).

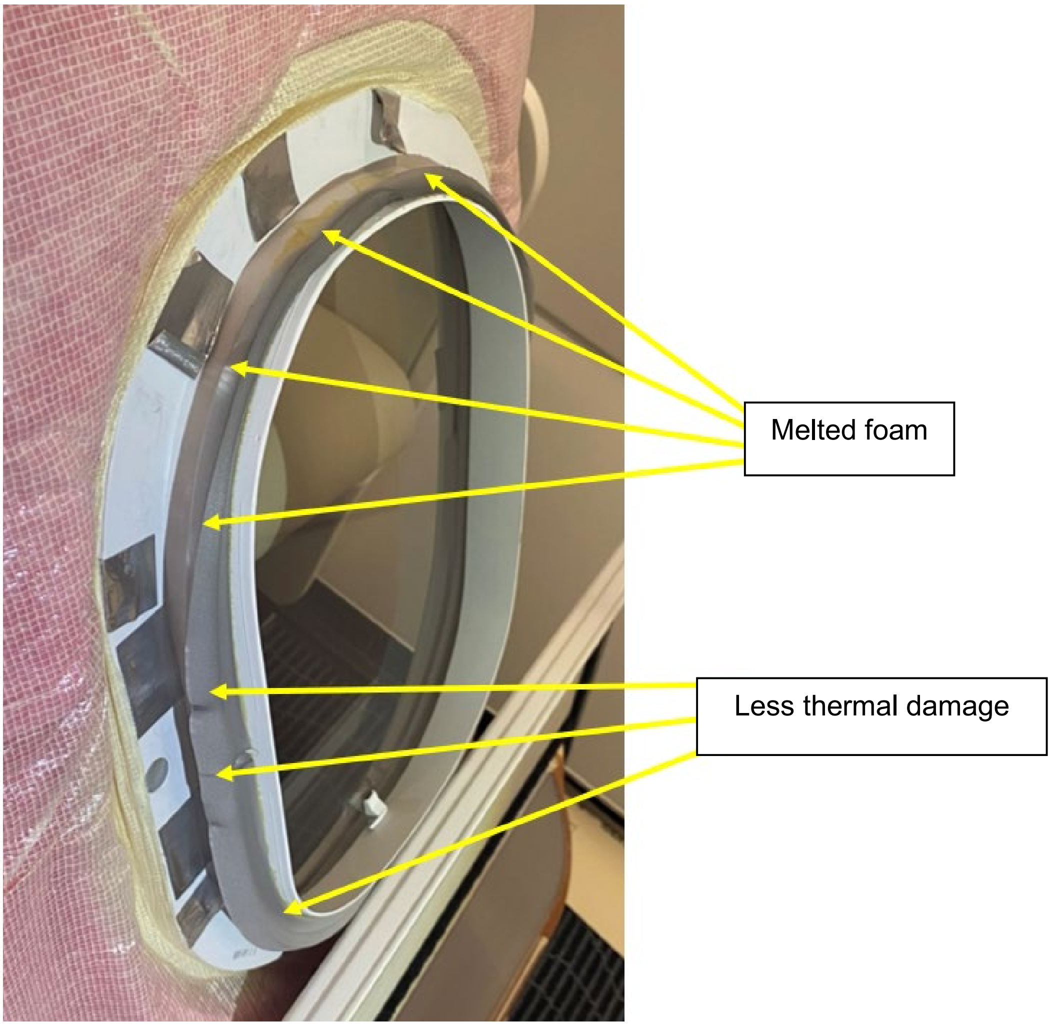


Figure 8

Foam ring material affected by elevated temperatures

With the AAIB in attendance, the operator removed several cabin liners from the right side of the passenger cabin. This revealed additional thermal damage and window deformation in the area around the overwing emergency exit, but to a lesser extent than the left side of the aircraft.

Horizontal stabiliser

The underside of the left horizontal stabiliser leading-edge panel was punctured. Small pieces of acrylic were found inside the stabiliser when the leading-edge panel was removed.

Detailed examination of the cabin windows

Displaced windowpane and seal

The inner windowpane that was loosely retained after the aircraft landed was found to be shrunk and deformed around its periphery (Figure 9). The corresponding rubber seal was undamaged, but the deformed windowpane no longer formed an effective interface with it.

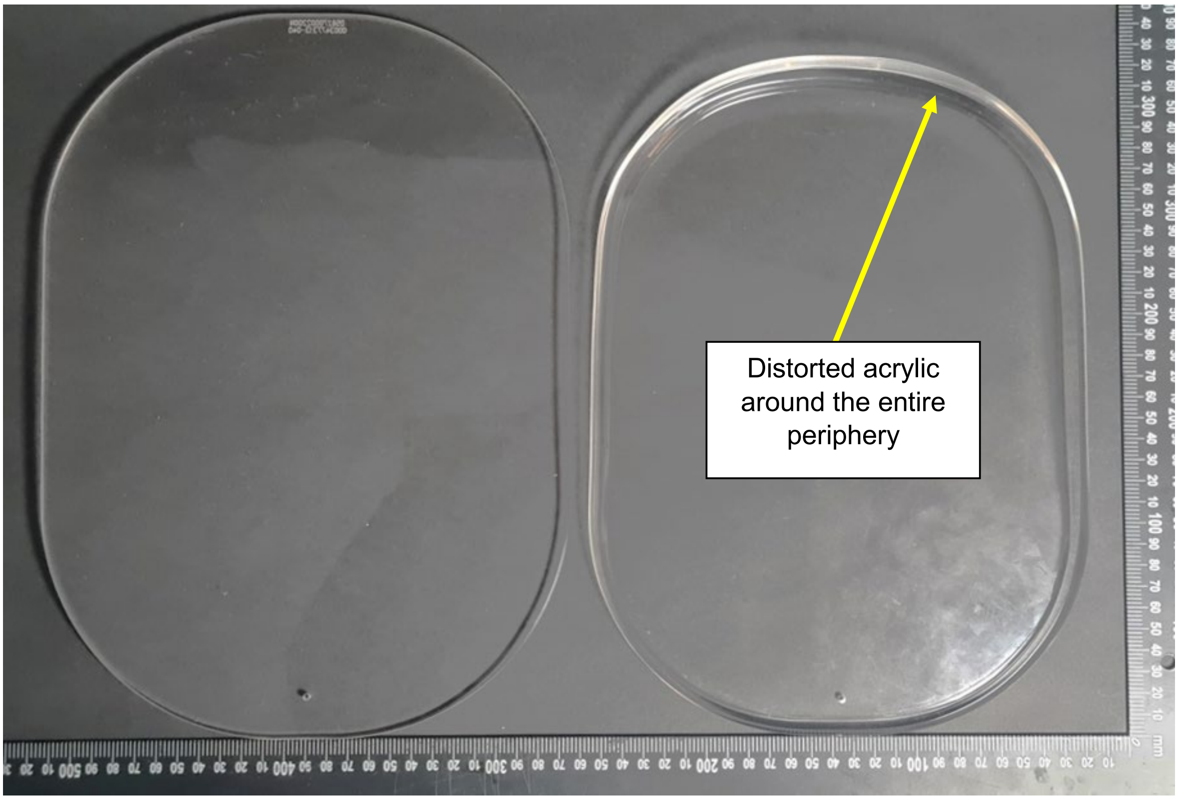


Figure 9

A serviceable inner windowpane (left) and the damaged inner windowpane (right)

Protruding window

The inner and outer windowpanes were both distorted in the area that protruded from the fuselage. The outer windowpane was more damaged than the inner, and the distortion affected the interface with the slot in the rubber seal (Figure 10). After the windowpanes were removed from the rubber seal, they could not be refitted because of the distortion. The rubber seal appeared undamaged.

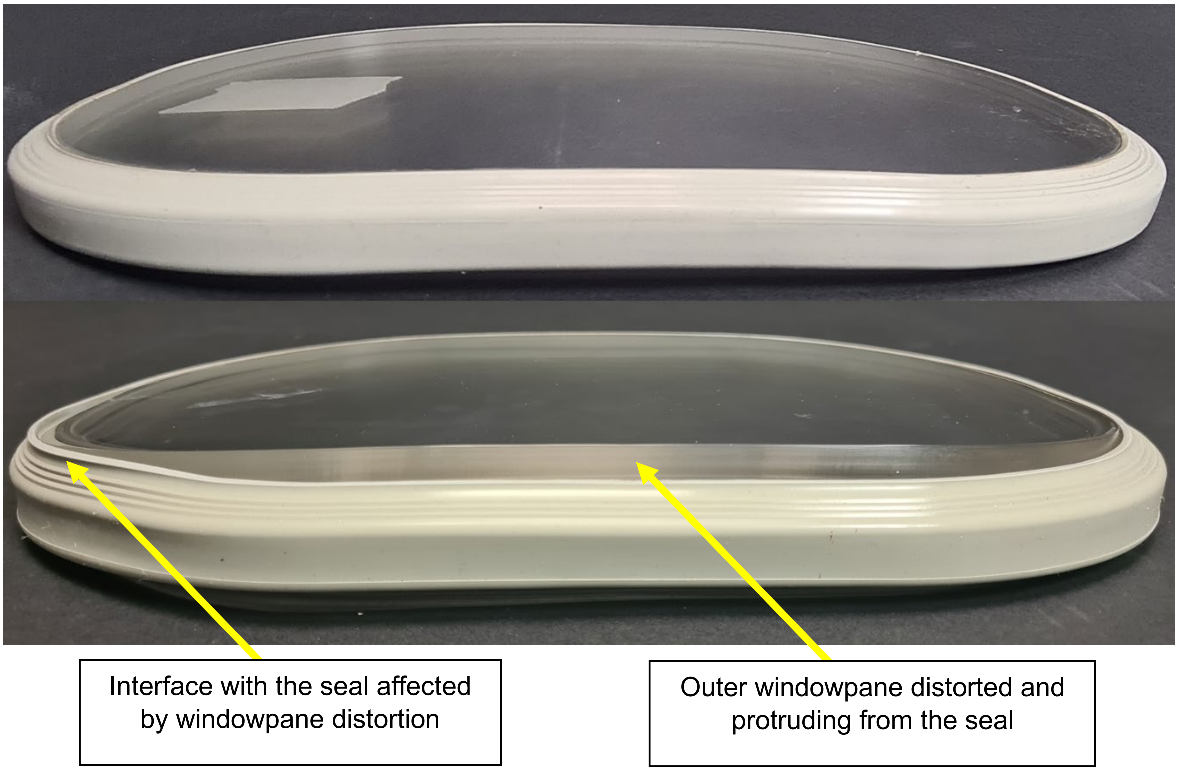


Figure 10
A serviceable window assembly (top) and the protruding assembly (bottom)

Shattered windowpane

A vent hole in one of the broken parts showed that the shattered remains were from an inner windowpane[5] (Figure 11). The window was distorted around its periphery and had shrunk.

Footnote

5 This was believed to be an outer windowpane when AAIB Special Bulletin S2/2023 was issued in November 2023.

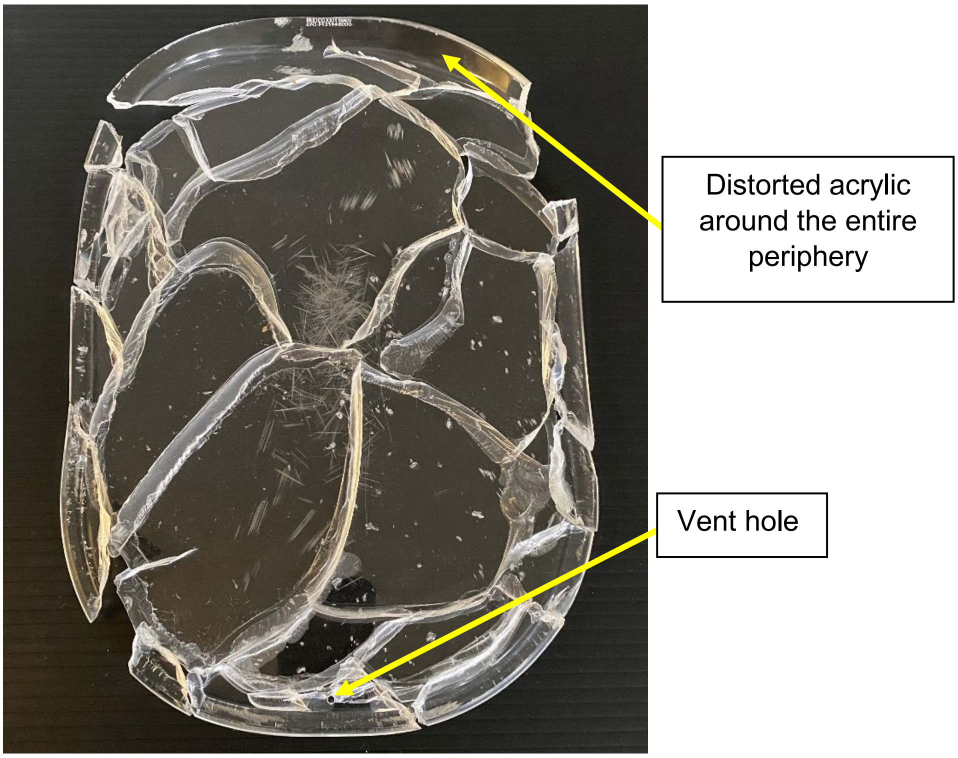


Figure 11

Reconstructed remains of the shattered windowpane

Dimensional checks

The approximate dimensions of the windowpanes were compared with serviceable items (Table 2).

Description	Inner pane		Outer pane	
	height (mm)	width (mm)	height (mm)	width (mm)
Serviceable window	346	250	346	250
Window displaced from fuselage	322 (~7% reduction)	235 (~6% reduction)	Not recovered	Not recovered
Shattered window	322 (~7% reduction)	235 (~6% reduction)	Not recovered	Not recovered
Window protruding from fuselage	344	245 (~2% reduction)	345	240 (~4% reduction)

Table 2

Comparison between window dimensions

Filming activities

Organisations involved in the filming

The aircraft was owned by the operator and operated exclusively for a tour company offering all-inclusive jet expeditions. The operator was responsible for airworthiness and maintenance. The tour company commissioned a video production company to film an advert on the aircraft. The video production company contracted various other individuals required for the filming, including the director of photography and the gaffer (see below), and hired the required equipment, including the external lighting. The filming was organised by the tour company in collaboration with the operator, video production company, airport authority, fixed base operator and the contractors. A permit from the airport authority was required to conduct the filming airside at Stansted. It took place outside the hangar of the fixed base operator who provided facilities during the filming such as catering and escort to and from the aircraft.

Key roles

A gaffer's role is to set-up electrical equipment for a film shoot to realise the look defined by the director of photography. For the filming on G-OATW, the gaffer chose the lights that would be hired and co-ordinated a team of electricians to set them up to ensure that requirements were met. He described his responsibility for safety as covering the electrical equipment and the safety of the personnel using it. He had worked with aircraft during previous filming, but he did not have an aviation background.

The producer of the film shoot is responsible for overall coordination and management during the filming. For the work on G-OATW, the producer was responsible for monitoring health and safety on location.

Lighting set-up

The gaffer said that the original plan was to film the aircraft in a hangar. Ideally, diffuser material[6] would be held in frames and mobile platforms would be used to support the lights so that the windows could be illuminated. This concept was rejected because of the risk of something falling onto the wing, so larger, directional lights were chosen. He had used similar lights previously and they could be positioned further from the aircraft whilst still providing sufficient illumination. The characteristics of the lights meant that they would be able to replicate the lighting conditions during a sunrise.

Eventually, the filming was conducted outside. The plan to use the higher power lighting remained but the free-standing frames and diffusers could not be used because of the risk of damage due to wind. They were unable to attach the diffuser material to the aircraft exterior because this could damage the paintwork, so it was attached to the scratch panes inside the aircraft.

Footnote

6 A light diffuser spreads out light to eliminate unwanted glare.

Safety management of the filming activity

The video production company produced a risk assessment for the filming on G-OATW which was reviewed by the tour company, operator, airport authority, fixed base operator and the gaffer. These parties did not produce separate risk assessments for the activity. The operator explained that there is a risk assessment process in place for any department to use for activities like this. In this case the responsible department decided it was unnecessary because filming was being conducted on the ground and was similar to activities conducted by the tour company in the past.

The video production company's risk assessment focused primarily on the health and safety of people involved in the filming work. The risk assessment included a hazard checklist. For most hazards identified from the checklist, further detail described persons at risk; control measures and level of risk with and without the controls (categorised as low, medium or high). The specific nature of the risk associated with each hazard was not explicit. Not all the identified hazards were assessed in detail. For example, '*Scenic / set materials – non-fire retardant / toxicity tested / glass / polystyrene*' was marked as a hazard on the checklist but not discussed further.

The use of electricity and lighting feeds was identified from the hazard checklist. The focus of the control measures was around procedures for dealing with faulty electrical equipment and the use of a diesel generator truck. A copy of a contractor's specific risk assessment for the temporary connection of the generator was included. The use of lights shining through the aircraft windows was mentioned in association with this hazard, but no specific risks or controls were described.

A licenced engineer employed by the operator was assigned to stay on board the aircraft during the filming. He supervised the APU, which was running to provide air conditioning, and ensured that no one entered the flight deck and interfered with any switches or controls. He sat on the flight deck for most of the time. Other representatives of the operator were present at times but did not have specific instructions to supervise the filming. A representative of the tour company was present throughout the filming.

External lighting

Six halogen Maxibrute 12 lights[7] were used for the filming, with a combined lighting capacity of 72,000 W. The filming company reported that the lights were switched on for four hours on the left side of the aircraft and five and a half hours on the right side. The lights on the left side were focused on six windows behind the overwing emergency exit. The lights on the right side were spread over a larger area.

Photographs of the filming showed that the lights were approximately 6 to 9 m from the window areas where damage occurred (Figure 12).

Footnote

[7] Maxibrute_12 (filmgear.net) [accessed 13 October 2023].

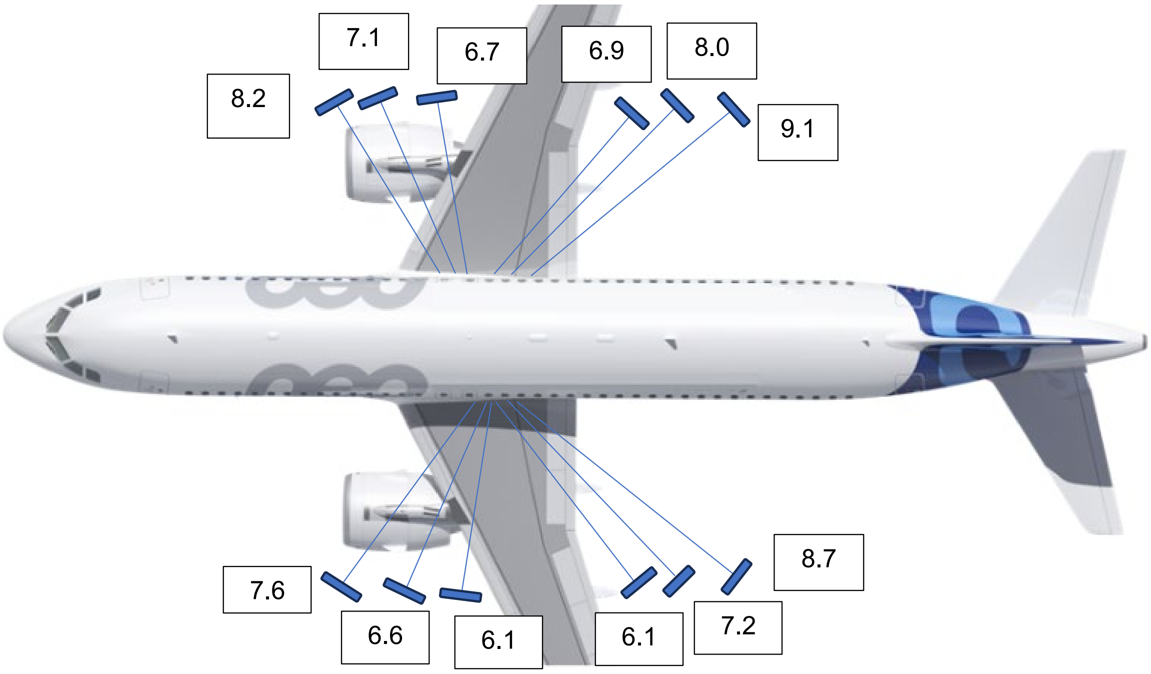


Image for illustration only – not to scale

Figure 12

Approximate distance of the flood lights from the fuselage during the filming activity

An online datasheet for the lights included the information in Table 3.

Parameter	Value
Lighting capacity	12,000 Watts
Minimum distance from object to be illuminated	10 m
Minimum distance from a flammable object	1.5 m
Maximum surface temperature	200°C

Table 3

Data extracted from the flood light datasheet

The minimum recommended distance from the object to be illuminated is based on the lighting manufacturer's test data. According to this test data, when an object is illuminated by a single Maxibrute 12 light from 10 m, the surface temperature will increase by 30°C after 30 minutes. The temperature will then remain constant. If the light is 8 m from the object, the surface temperature will increase by 45°C and, if the light is 6 m away, the temperature will increase by 64°C. The combined effect of six Maxibrute 12 lights, with some of their output overlapped, is unknown.

The gaffer was not aware of the manufacturer's datasheet or any other written guidance or limitations on how the Maxibrute 12 lights should be used. The company that rented the equipment to the filming organisation said that the lights were not accompanied by any operating limitations or datasheets. The only cautions and warnings that were displayed on the lights related to:

- Disconnecting the power before changing a bulb
- The maximum temperature of the housing
- Not mounting the fixture on a combustible object
- Not covering the vents

Personnel

The gaffer was an electrician who had worked in the filming industry for more than 30 years. There are no technical qualifications or requirements to become a gaffer, but most people progress to the role via the electrical trade.

Other information

Heating effects of solar energy and halogen lights

Spectral power distribution and absorptivity

A typical spectral power distribution for a halogen bulb[8] shows that most of the energy is in the infrared (IR) wavelengths (Figure 13). Energy from the sun is filtered by the atmosphere, dust and humidity, and mostly arrives at lower altitudes in the visible spectrum.

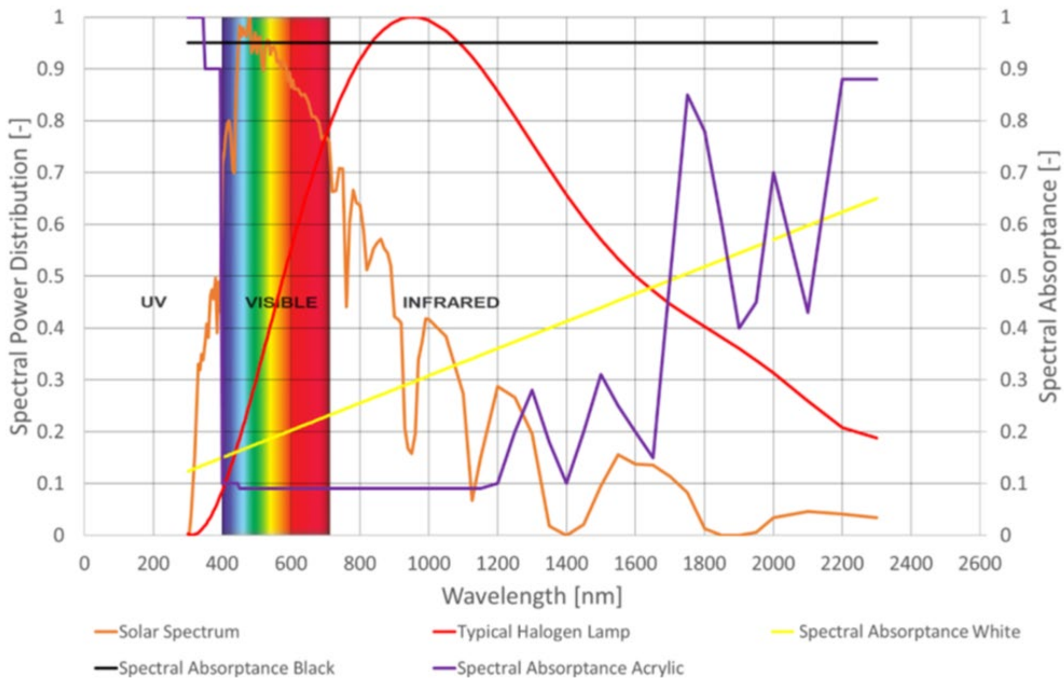


Figure 13

Spectral power distributions and material absorptivity
(used with permission)

Footnote

8 Graphical representation provided by the aircraft manufacturer. The halogen data is based on black body radiation of a tungsten filament at 3,100 K, which is similar to the properties of the bulbs that were used during the filming.

The amount of heat absorbed by a material is proportional to its absorptivity. Black paint has a high absorptance across the entire spectrum whereas the absorptance of white paint increases with increasing wavelength. Acrylic transmits most visible wavelengths but is more absorbent in the IR spectrum. These absorption properties explain why acrylic and white painted structures remain relatively cool in sunlight, but black painted structures become hotter. In the IR spectrum, all three materials absorb energy.

Thermal conductivity

The thermal conductivity of a material is a measure of how effectively it can conduct, and therefore dissipate, heat. Table 4 shows the aircraft manufacturer's data for the thermal conductivity of the aluminium alloy and acrylic.

Material	Thermal conductivity (W/m/K)
Aluminium alloy	~ 120
Acrylic	~ 0.2

Table 4

Comparison of thermal conductivity

The low thermal conductivity of acrylic means that any heat accumulated by the cabin windows is poorly transferred away by conduction. The aluminium fuselage, however, can spread the heat much more effectively. This explains why the acrylic cabin windows reach higher temperatures than the fuselage when subject to IR energy. The temperature achieved will depend on the duration of exposure, the distance, and the power of the source.

Previous occurrences

The investigation identified four previous occurrences where acrylic cabin windows were damaged by high temperatures during filming activities using high-intensity lights. In those four cases the damage was identified and repaired before the aircraft flew. It would only be reportable as an accident or serious incident if it was identified during a period of operation when there was an intent to fly.

Airbus

An Airbus A321 sustained cabin window damage during a filming event when the aircraft was outdoors. Spotlights were positioned just inboard of the engines, approximately 1.5 to 1.8 m from the cabin windows (Figure 14).

Figure 14

Lighting arrangement during a previous filming event
(image used with permission)

The AAIB does not know the specifications of the lights or how long they were turned on. The window damage was readily visible after the filming (Figure 15).

Figure 15

Thermal damage sustained by an outer windowpane on an Airbus A321
(image used with permission)

When the damage was reported to Airbus, it was not aware of any other occurrences, and considered the circumstances to be outside the anticipated operating conditions. No action was taken apart from providing technical advice to repair the aircraft.

Boeing

One operator informed the AAIB that six cabin windows were damaged on a Boeing 787 during a filming event inside a hangar. The windows were illuminated using three 2,000 W lights positioned on mobile platforms outside the aircraft. The windows suffered significant deformation and one had a hole burned through the windowpanes (Figure 16).

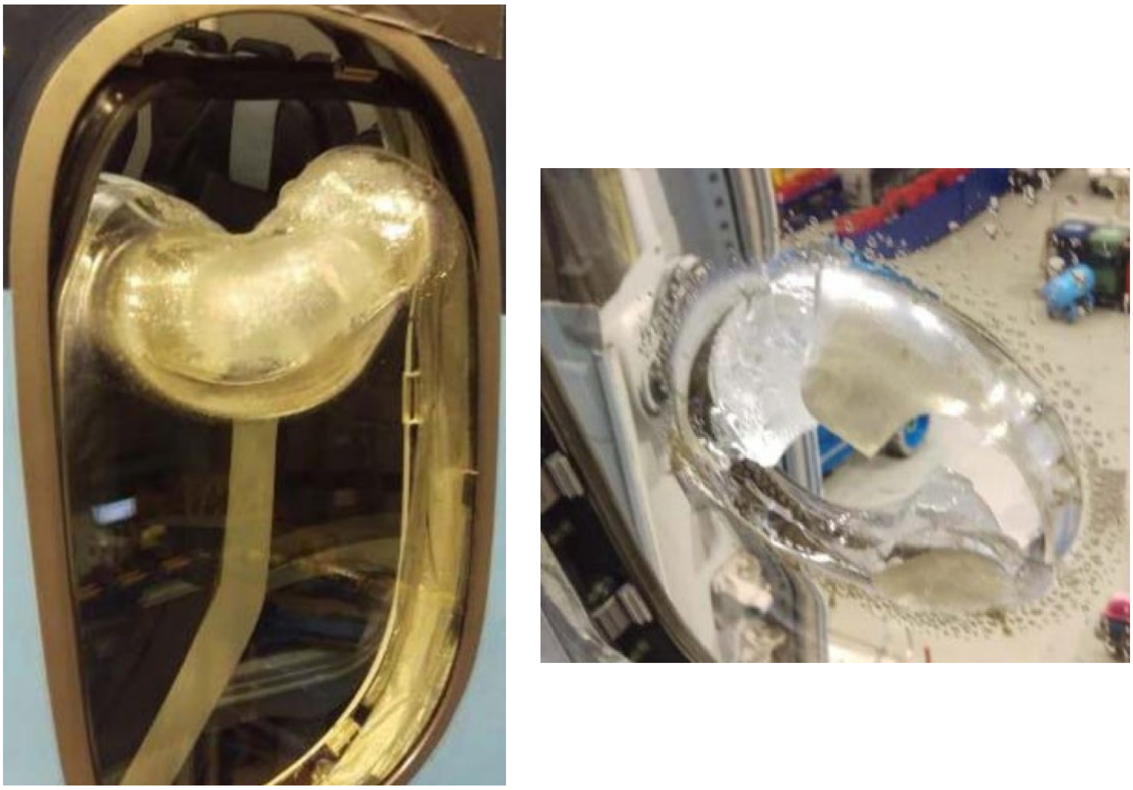


Figure 16

Deformed outer windowpane and a hole through the cabin window
(images used with permission)

The operator carried out a test using a single light and a cabin window mounted in a jig. With the window illuminated from 1 m, the temperature of the acrylic after 35 minutes was stable at 44°C. When the distance was reduced to 30 cm, visible damage occurred after 16 minutes and an acrylic temperature of 127°C. The outer windowpane was penetrated 88 minutes later at a temperature of 155°C.

In March 2020 Boeing issued a Fleet Team Digest article following three reports of acrylic cabin windows of Boeing 787 aircraft sustaining thermal damage during filming. Boeing cited elevated acrylic temperatures due to the absorption of IR energy and recommended that operators avoid using high-intensity lights during filming activities. If high-intensity lights are used, it recommended that operators:

- Keep the lights well away from the cabin windows
- Use lights that do not emit heat or lights that minimise heat generation (low IR)
- Minimise the time the lights are on
- Turn the lights off when they are not required
- Monitor the temperature of the cabin windows

Light Emitting Diode (LED) lighting

LED lights are a more efficient alternative to incandescent lights. They use less power and emit less heat. A LED version of the Maxibrute 12 light is available.

Other operators

The AAIB contacted 12 other UK Air Operator Certificate (AOC) holders to ask about their approach to the safety management of on-aircraft filming. Information was received from six operators and is summarised in Appendix A. Five of the six stated they had some experience with on-aircraft filming. Four of the six have previously produced or would expect to produce a written risk assessment for this activity. One has previously relied on a 'verbal' risk assessment for the activity. Most operators emphasised the importance of engineering supervision for the activity. One operator had identified the risk of heat from external lighting damaging a composite fuselage but none of the operators had previously identified the risk of heat damaging aircraft windows except for an operator that had previously suffered damage from this cause.

Analysis

Pre-flight inspection

The pre-flight inspection was carried out by the commander. Additionally, as the aircraft was going to be away from its base for several weeks, several engineers were also present prior to departure, completing additional checks of the aircraft. They did not identify any cabin window defects before the flight.

In-flight turn back

The aircraft returned to the departure airport because noise levels in the passenger cabin were excessive, and one cabin window was visibly loose. After the aircraft landed, seven parts were missing:

- Three outer windowpanes
- Two inner windowpanes
- Two rubber seals

All the scratch panes remained in place so there was no direct, unrestricted aperture between the passenger cabin and the outside air. There were no symptoms of any pressurisation issues, indicating that for the duration of the flight the amount of air leaking from the passenger cabin remained within the capacity of the pressurisation system.

Broken windowpane recovered from the taxiway

A shattered inner windowpane was recovered from the entrance to a rapid-exit taxiway. The broken remains showed thermal distortion around its periphery, and it was apparent that the windowpane had shrunk. The distortion and shrinkage meant that the windowpane no longer formed an effective interface with the slot in the rubber seal. This made it more likely to fall out due to vibration or the differential air pressure between the passenger cabin and the outside environment.

The aircraft did not pass the rapid-exit after landing, so the inner windowpane fell out when the aircraft took off. For this to happen, the outer windowpane must already have fallen out, but neither it nor the rubber seal were found.

Damaged horizontal stabiliser

The underside of the left horizontal stabiliser leading-edge panel was punctured, and small pieces of acrylic were found inside, indicating that it had been struck by at least one cabin windowpane. The damage had no adverse effects on the controllability of the aircraft.

Windowpane damage

The day before the occurrence flight both sides of the aircraft were illuminated by six halogen light arrays with a combined power output of approximately 72,000 W. The lights were positioned closer to the aircraft than the minimum recommended distance and the acrylic windows absorbed IR radiation, with very limited ability to dissipate this energy into the surrounding structure or air. As time progressed, the temperature of the acrylic increased to the point that the material softened and started to deform and shrink. The window retainers apply a compressive force around the periphery so, as the acrylic softened, this force may have exacerbated the distortion. The temperature that the acrylic achieved is unknown, but two of the windowpanes had reduced in size by approximately 6%. The manufacturing process specification indicates a maximum of 10% shrinkage at 110°C so it is likely that these windows achieved a temperature that was approaching this value. This is beyond the aircraft's certified operating limits.

Previous occurrences

There have been at least four previous occurrences (one Airbus A321 and three Boeing 787) where acrylic cabin windows have been damaged by high-intensity lights during filming. The damage was identified and repaired before flight, so it is likely that it was more obvious than G-OATW.

In 2020, Boeing issued a Fleet Team Digest article citing three events where damage was caused by the absorption of IR energy from high-intensity lights. The article was applicable to Boeing 787 operators, but this investigation shows that other aircraft with acrylic windows could also be similarly affected.

Safety action

In response to this accident, Airbus published an In Service Information document to highlight the risk of acrylic window damage when using high-intensity lights. The document is available to all Airbus customers. Airbus also published an article in their online Safety First magazine[9].

EASA published a Safety Information Bulletin[10] to highlight the risk of damage when using high-intensity lights close to an aircraft.

Safety management of filming

The lights were used closer to the aircraft than recommended in their datasheet. It is not known whether the lights could have been placed further away and still achieve the desired look for the filming. The gaffer was responsible for setting up the lighting but was not aware of the datasheet prior to the investigation. According to the gaffer, equipment datasheets are not routinely consulted when hiring equipment and the selection and safe use of such equipment relies on experience rather than data and standard procedures. There are no formal qualifications or training required to undertake the gaffer role and the lighting hire company did not place any restrictions or give any information on how it could be used. Overall, this indicates that an aircraft operator should not rely on a video production company and its contractors to ensure aircraft safety.

The filming on G-OATW was risk assessed by the video production company in collaboration with the other involved parties. As the process was led by the film production company, the focus was on the safety of personnel during filming. However, the potential to damage the aircraft cosmetically or for people to access the flight deck and interfere with controls was identified during the risk assessment or planning and it was managed with the use of engineering supervision during the filming. No one involved anticipated that the lights could damage the acrylic windows. Following this event, the operator reminded the department responsible for the filming of the need to use its own risk assessment process for such activities.

Other operators were consulted after the publication of the AAIB Special Bulletin about this event and provided information about their own approach. Most stated they would do their own assessment with varying degrees of formality. None of them, except for the operator who had suffered previous damage from the same cause, had previously anticipated this type of damage in their assessments. This would require specific technical knowledge of the lighting equipment and the properties of the windows. There could be benefit in using more technical evidence, such as lighting datasheets, as part of the risk assessment process when hazardous equipment is going to be used on or near an aircraft.

Footnote

[9] Safety First | Airbus Link to the Airbus Safety First website [accessed 9 January 2024].
[10] EASA SIB 2024-04 Risks from using high power lights close to aircraft structures [accessed 8 March 2024].

At least four other operators have previously encountered the same issue, but the window damage was identified and repaired before flight, so the events were not independently investigated. Boeing acted to inform other Boeing 787 operators about the events they were aware of but the learning from other events was not spread within the aviation or filming communities. A problem like this is hard to anticipate because it is caused by equipment and material properties that are not visible and information about them is not easily accessible. Openly sharing safety related learning, even if the consequences do not reach the threshold for independent investigation, increases the ability of the aviation community to manage risks.

Conclusion

Several cabin window components were lost during the flight. High-intensity lights that were used during a filming event emitted sufficient IR radiation to heat the acrylic windows to a temperature sufficient to soften them leading to distortion and shrinkage. The distorted windows fell out because of vibration or the pressure differential across them as the aircraft climbed after takeoff. The aircraft returned to the departure airport for an uneventful landing.

Safety actions

The following safety actions were taken:

1) The operator reminded the department responsible for the filming of the need to use the risk assessment process for activities like this.

2) Airbus published an In Service Information document to highlight the potential adverse effects of using high-intensity lighting near an aircraft.

3) Airbus published a Safety First article highlighting the possible adverse effects of using high-intensity lighting near an aircraft.

4) EASA published a Safety Information Bulletin highlighting the risk of damage when using high-intensity lighting near an aircraft.

Appendix A

Summary of six UK passenger operators' approaches to managing filming activities on aircraft

Operator	Summary of response
1	The approach to filming depends on the location, for example, in a terminal, simulator or engineering facility. LED lights are generally used when lighting is required. An example risk assessment was provided. In relation to the aircraft exterior, it identified this risk: '*Aircraft safety critical equipment and features on its exterior which if impacted will impact its airworthiness'.* The listed controls for this were: engineering supervision; keeping a safe distance and awareness of audiovisual equipment being used in the vicinity of the aircraft.
2	Filming is a common activity for the operator and there is a mandatory checklist in the Corporate Safety and Security Manual covering all aspects to be considered. The press office is accountable for the filming overall and engineering retains responsibility for the aircraft. All filming requires a risk assessment covering people, environment, facilities, and aircraft. A health and safety walkaround and briefing is conducted prior to filming including an aircraft engineer, the press office and the filming team. This process sets the conditions for the filming, which is continuously supervised by a licensed engineer who is a health and safety specialist. Heat from the lighting has been a concern in the past, primarily when being used in a hangar in case it triggers the fire protection system. During recent filming of an aircraft with a composite fuselage, LED lights and diffusers were used, and an engineer performed temperature checks on the fuselage side.
3	This operator previously suffered damage to the windows of a Boeing 787 from the heat of lighting used during filming (discussed above in the previous occurrences section). The event was investigated by the operator. A lack of engineering supervision was identified as one of the contributory factors in the event. Now, according to the operator's safety management manual, any change that can impact safety by introducing new hazards, risks, or impacting existing risk mitigation should trigger the management of change process. This process includes risk assessment and escalation to the appropriate level of management.
4	A production company was granted permission to conduct filming on board an aircraft on the ground and during flight. No additional lighting was used. The aircraft commander was briefed. No specific hazard identification or risk assessment process was conducted because it was normal operations that were being filmed.

Operator	Summary of response
5	Filming activity would be managed in accordance with the Safety Management Manual and the Health and Safety Manual. It would require departments to undertake risk assessment, ensure appropriate supplier selection, ensure that all relevant areas are informed, and that appropriate supervision and oversight is in place in relation to both the aircraft and people involved in any undertaking.
6	Filming activity was recently completed by a trusted supplier that has had a relationship with the operator for five years. Low heat LED lights were used internally and externally to the aircraft. A verbal risk assessment was completed prior to filming with input from Head of Marketing, Director of Engineering, Hangar Manager, Production Team and Marketing Agency. The main risk to the aircraft identified was potential collision by heavy equipment being moved around the aircraft. Filming was continuously supervised by an engineer.

Published: 18 April 2024.

Accident

Aircraft Type and Registration:	AW109SP, G-RAYN	
No & Type of Engines:	2 Pratt & Whitney Canada PW207C turboshaft engines	
Year of Manufacture:	2019 (Serial no: 22401)	
Date & Time (UTC):	1 November 2022 at 1726 hrs	
Location:	Nantclwyd Lodge, near Llanelidan, Denbighshire	
Type of Flight:	Non-commercial operation	
Persons on Board:	Crew - 1	Passengers - 5
Injuries:	Crew - None	Passengers - 1 (Serious) 4 (Minor)
Nature of Damage:	Helicopter destroyed	
Commander's Licence:	Commercial Pilot's Licence (Helicopters)	
Commander's Age:	47 years	
Commander's Flying Experience:	3,815 hours (of which 1,565 were on type) Last 90 days - 81 hours Last 28 days - 24 hours	
Information Source:	AAIB Field Investigation	

Synopsis

While climbing away from an unlit field landing site, at a height of approximately 40 ft agl, G-RAYN's main rotor blades struck trees and sustained catastrophic damage. The helicopter fell to the ground, coming to rest on its right side. The fuel tanks maintained their integrity and there was no fire. The pilot was able to shut down both engines and, with the assistance of onlookers, helped the passengers to escape from the cabin. One of the passengers was seriously injured in the accident. Of the five passengers, at least four had not fastened their seatbelts prior to departure.

No causal or contributory technical factors were identified with the helicopter during the investigation. The investigation found that the accident resulted from the unintended rearward transition of the helicopter into a stand of trees during a planned vertical departure at night from an unlit field landing site. The flight had been scheduled as a day departure but the takeoff became delayed until after nightfall.

The investigation found several operational barriers which might have prevented this accident but were either breached or not present. These included a misunderstanding of the applicable operator-level restrictions for the non-revenue flight being undertaken and opportunities missed during the planning process to anticipate and mitigate for flight delays.

Distraction and time pressure led to the pilot not completing auditable weight and balance (WB) calculations before leaving Biggin Hill, this potentially contributed to the helicopter being overweight when it took off on the accident flight. While the pilot had assessed the available lighting as sufficient for the intended takeoff profile, the visual cues available to him on the night proved inadequate for the detection of the subsequent unintentional rearward drift toward the trees behind the helicopter.

The passengers did not exert any pressure on the pilot to delay beyond the planned departure time, and the pilot did not consider that a night departure would pose an unacceptable risk.

The investigation thought it likely that, had all passengers been secured by their seat harnesses, the level of injuries sustained could have been less severe. For frequent flyer passengers, or those focused on time pressures, it might be tempting to see safety briefings and seatbelts as an unnecessary encumbrance. In helicopters with seating and cabin configurations like G-RAYN's, once pilots are in their seats, it is not possible for them to visually check the security of their passengers' seatbelts/harnesses. Nonetheless, it is important for all parties to understand that an aircraft commander is under a legal obligation to ensure passengers are appropriately briefed and have their harnesses secure for all takeoffs and landings.

While the pilot carried out a strategic pre-flight risk assessment, a more effective and targeted tactical Threat and Error Management (TEM) approach to each phase of the operation could have provided an additional safety barrier for the flights being undertaken.

Following the accident safety action has been taken by the operator to improve its night flying procedures, ground equipment and training.

History of the flight

The pilot flew G-RAYN from Biggin Hill on the morning of 1 November 2022 tasked with transporting five passengers to and from a field landing site in North Wales for a day's game shooting. The helicopter was owned by the lead passenger, but routinely maintained and operated by the third-party operating company who provided the pilot. For flights in support of the owner's requirements, G-RAYN was operated as a non-revenue flight under the regulations for '*non-commercial air operations with other-than complex motor-powered aircraft'* (NCO)[1]. It was being flown by one of the operator's '*company approved*' pilots contracted by the owner on a daily rate.

The pilot arrived at Biggin Hill at approximately 0645 hrs. His scheduled duty check-in time was 0700 hrs, 30 minutes before takeoff. While he had arrived early, much of that extra time was taken up with an unanticipated supportive conversation with a very recently bereaved colleague. The pilot self-briefed the weather, refuelled G-RAYN to approximately 600 kg of fuel and completed the prescribed pre-flight walk round check of the helicopter before taking off at 0727 hrs.

Footnote

[1] UK Regulation (EU) No 965/2012, Annex VII.

Having flown G-RAYN from Biggin Hill, the pilot landed at the helicopter owner's private landing site (Lisvane) north of Cardiff at 0830 hrs and embarked the five passengers and their luggage. The flight from Cardiff to North Wales was uneventful and the helicopter landed near Llanelidan at 0920 hrs. The field landing site was listed in the operator's company landing site directory (CLSD) with the reference code LEA2. The designated landing location was a flat area of grass adjacent to a stand of trees and a shooting lodge (Figure 1). To the northwest of the landing area the ground sloped down and away toward several isolated trees, as indicated by the chevrons in Figure 1.

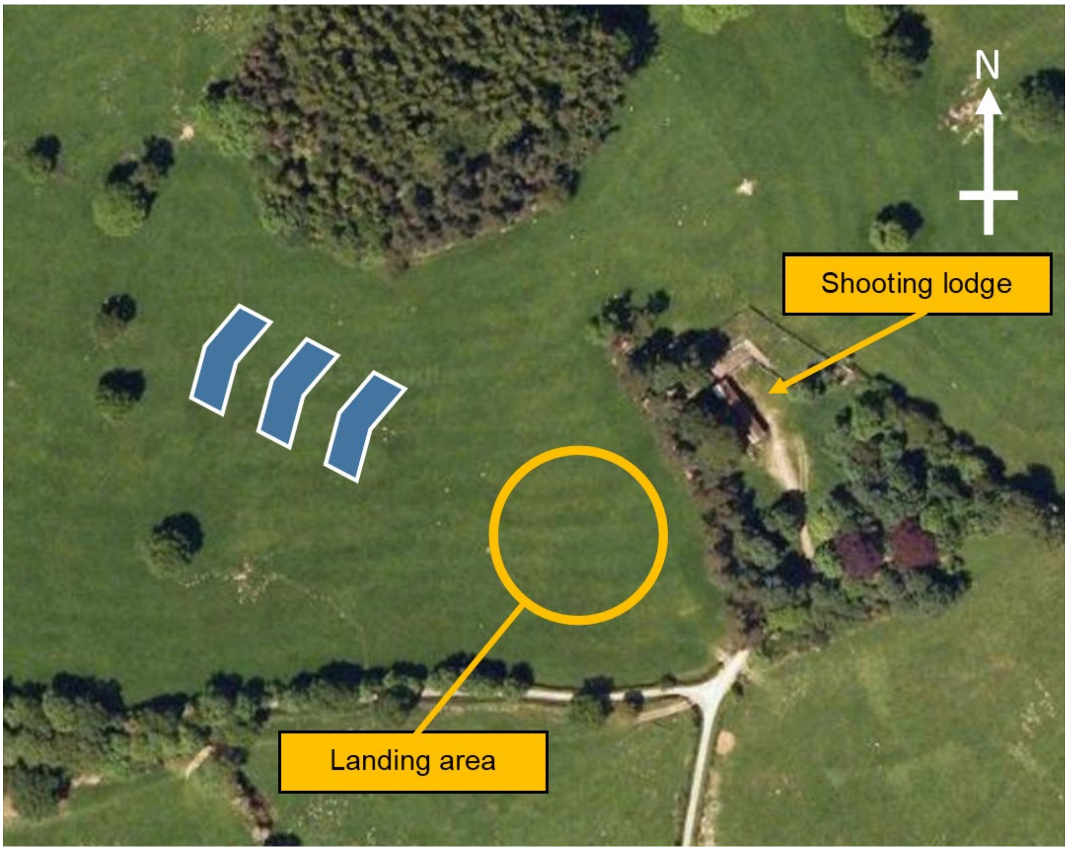


Figure 1

LEA2 field landing site near Llanelidan
(©2023 Bluesky, Infoterra Ltd & COWI A/S, CNES / Airbus, Getmapping plc, Maxar Technologies)

After disembarking his passengers, the pilot flew G-RAYN to Hawarden Airfield (Hawarden) to refuel. The pilot's firm recollection was that, after arriving at Hawarden, he refuelled the helicopter to 400 kg, calculating his required uplift of 250 kg[2] from the indicated fuel quantity he observed prior to shutdown. The total fuel quantities recorded by the helicopter's onboard systems were 206 kg on arrival at Hawarden and 456 kg when it departed for LEA2[3].

Footnote

2 Receipted uplift of 320 litres of Jet A1 fuel with an assumed specific gravity of 0.78.
3 See *Recorded data/Recorded fuel quantity* section.

The tasking for the return flight showed a scheduled departure time from LEA2 of 1630 hrs. Sunset was at 1645 hrs, with the end of official evening civil twilight, marking the transition from twilight to night, occurring at approximately 1718 hrs[4].

The passengers were not ready to depart on schedule and remained in the shooting lodge until approximately 1715 hrs before walking to the helicopter and taking their seats. The pilot remembered seeing the passengers rearranging their seatbelts after sitting down but did not visually confirm they had securely fastened them prior to the cabin door being closed.

The pilot's recollection was of having approximately 340 kg of fuel on board the helicopter before the flight and that he "took his time" after engine start to burn off additional fuel because he knew the helicopter would be close to its maximum takeoff weight (MTOW). The landing site was unlit but the pilot was satisfied there were sufficient visual references available for him to safely conduct a vertical departure. The helicopter's external lights were illuminating the area immediately around the helicopter and he could see what he described as a "vague horizon" ahead. The pilot judged that lights from the shooting lodge's windows to his right would be an adequate lateral marker for the departure climb.

The pilot reported that, after lifting into the hover, he translated G-RAYN forward and left to increase separation from the treeline and turned into wind. He used the beam from the helicopter's controllable search light to orientate himself in relation to the nearest trees. The pilot then directed the beam forward and down to illuminate the grass ahead of the helicopter before committing to the departure. The initial climb proceeded as the pilot expected but passing approximately 30-40 ft, he felt what he described as a "massive jolt" and immediately ascribed it to a significant rotor head imbalance. The helicopter began shaking violently and fell to the ground, ending up on its right side. Eyewitnesses, who were standing at the edge of the treeline behind G-RAYN and watching it take off, reported not hearing or seeing anything unusual with the helicopter prior to it striking the trees.

After the helicopter stopped moving, the pilot orientated himself in the cockpit, unstrapped and stood up to open the left cockpit door, which was by now above him. He reported hearing the engines still running and that he then turned the engine controls to OFF and closed the fuel valves. After doing this, the pilot could still hear a high-pitched whining noise which he determined was the rotor head spinning at high speed. He applied the rotor brake to try and stop it turning but this had no discernible effect.

The pilot climbed out onto the left, now top, side of the helicopter and opened the cabin door so the passengers could escape. Four of the passengers were able to vacate the helicopter with varying degrees of outside assistance but the fifth was lying unconscious at the bottom of the cabin. Through the combined effort of the pilot, the other passengers and some onlookers, the unconscious passenger was manually extracted from the helicopter. At this point he was in significant medical distress. The casualty was carried to the lodge and CPR was administered by the pilot under the guidance of the emergency services operator. After the application of CPR, the casualty regained a reportedly "more-normal" colour but did not fully regain consciousness. He sustained serious injuries in the accident and was subsequently hospitalised for several months.

Footnote

4 See *Meteorology* section.

Accident site

The helicopter came to rest at the base of a tree approximately 30 m from the shooting lodge. The main fuselage of the helicopter was intact but the tail boom had separated and been thrown forward of the point of ground impact (Figure 2).

Figure 2

Overhead view of G-RAYN accident site

There was a large amount of debris spread around the surrounding area, mainly consisting of fragments from the rotor blades and branches from the trees. A detailed GNSS plot was taken of the main components of wreckage, impact marks and debris. There was no evidence of fuel leaks and there was no post-crash fire. There were clear impact marks near the top of the trunk of the tree adjacent to the helicopter wreckage and a significant swathe of branches had been cut from the top of this tree and landed adjacent to the main fuselage (Figure 3).

Figure 3

Ground view of main accident site

Helicopter description

General

The AW 109SP is a member of the Agusta family of twin engine, light class helicopters. The SP version features three main modifications: the introduction of a new composite fuselage structure material, a four-channel digital autopilot and a new cockpit layout with four Chelton display units (EFIS) and integrated COMM/NAV management system. The SP has a fuel system designed to be crashworthy such that in the event of an accident the amount of fuel that leaks from the tanks is kept to a minimum. The helicopter is powered by two Pratt and Whitney Canada PW207C turbine engines. The AW109SP was designed to meet the certification requirement[5] of providing '*reasonable protection*' to each occupant from the dynamic loads experienced in a crash landing if they are properly using the seats, safety belts, and shoulder harnesses.

Fuel system

The fuel storage system has two main forward independent tanks, one main rear tank and two auxiliary fuel tanks. Each main forward tank supplies fuel to its associated engine, the forward tanks are gravity fed by the rear tank. The total usable fuel capacity of the main tanks is 563 litres (450 kg)[6] with the auxiliary fuel tanks providing an additional 184 kg capacity. The fuel system is installed inside the helicopter and fuel vent lines are bonded to the airframe and are fitted with flame arrestors.

Fuel indication

The fuel indicating system (Figure 4) consists of the fuel monitoring and indicating systems to provide fuel system malfunctions and system indications. The fuel indicating system gives a continuous indication of the quantity of fuel contained in the fuel tanks and the pressure in the fuel system. Five variable-capacitance fuel probes are installed inside the tanks (two probes in the left bottom tank, two in the right bottom tank, one probe in the top tank). The tanks sense the difference in the dielectric constant of fuel and air. A change in the fuel level in the tank causes a change in the probe capacitance. Two independent electrical lines supply the Fuel Control Unit (FCU) with 28 V DC electrical power. When the quantity of fuel in the tank changes, the probes send an electrical signal to the FCU, which processes it and then sends proportional output currents to the Data Acquisition Unit (DAU). The latter sends the fuel quantity signals to the No 2 Electronic Display Unit (EDU) where the fuel quantity is continuously displayed. Another function of the FCU is to continuously monitor the system for faults. The FCU has two independent channels (left and right) and faults are monitored at channel level: when the analogue output signal of either FCU channel is less than 1.93 mA, the affected fuel quantity readout displays a white box with three red dashes.

Footnote

[5] As prescribed in CS 27.562 of Certification Specifications, Acceptable Means of Compliance and Guidance Material for Small Rotorcraft CS-27, dated 14 November 2003.
[6] Based on a specific gravity of 0.8 for Jet A1 Fuel.

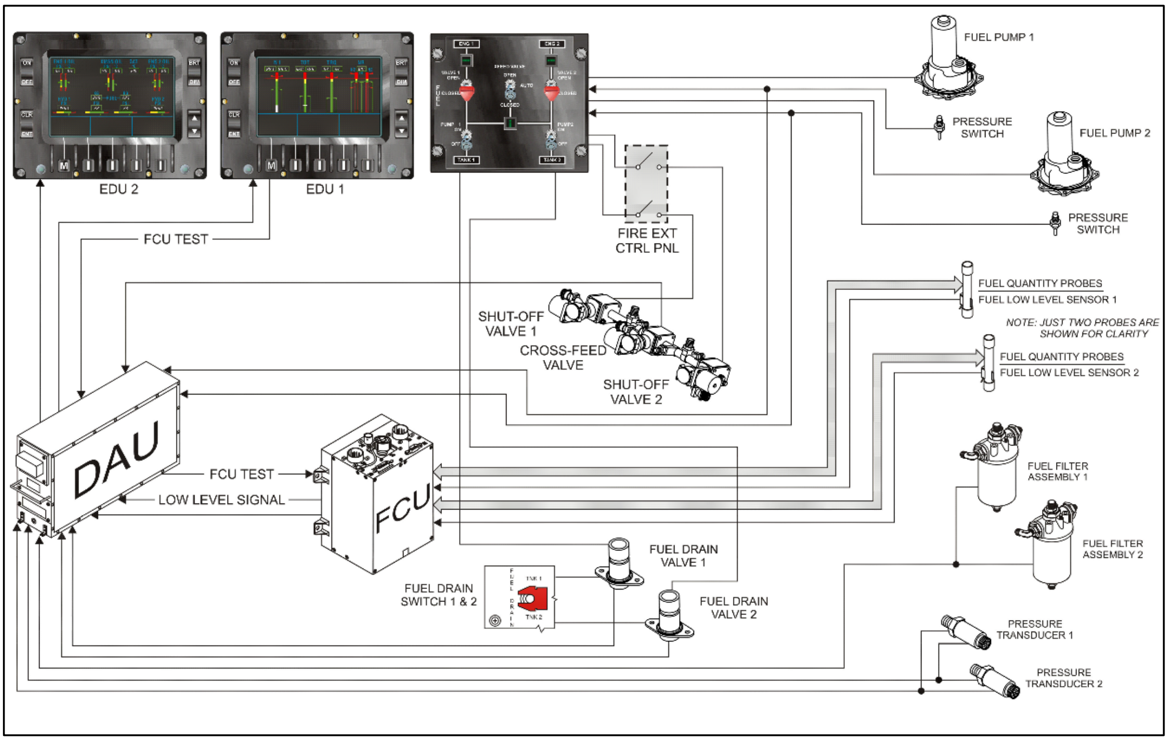


Figure 4

Fuel indication system schematic

Fuel quantity is displayed to pilots as separate totals for the left and right tanks rather than being presented as a single combined fuel total (Figure 5). Pilots are required to mentally sum the figures to calculate the total amount of fuel on board.

Figure 5

EDU fuel display

Helicopter cabin

Crashworthy seating and seatbelts are provided for the pilot and for the co-pilot. The seat structure consists of two lateral carriers milled from high tensile aluminium alloy. Between those carriers the seat bucket and the backrest are fixed. These two parts are made of an aramid and carbon fibre material. The seat is equipped with an approved four-point safety belt system: lap belts are fixed on the seat while shoulder belts are guided by an aluminium tube downward to the inertia reel fixed on the rear of the backrest. The front edge of the seat pan is hinged to the two carriers. Two links struts connect the rear edge of the seat bucket with two energy absorbers mounted in the carriers. Under severe vertical loads the seat pan rotates downward at its rear edge so that the load on the spinal column is reduced.

The passenger/cargo compartment occupies the rear portion of the cabin, access is provided by large sliding doors on each side of the helicopter. The passenger seats are provided with a fibre-reinforced structure to which the seat cushions attach by Velcro fasteners. The seats are also provided with a removable headrest. A four-point safety harness with a quick-release coupling holds the occupant to the seat. The four ends of the belts are fixed to the seat bucket. The shoulder-belt is guided over the upper edge of the seat bucket downward to the inertia reel. The inertia reel is fixed to the rear of the seat bucket and is equipped with a manual lock device for the shoulder belts. The seats are supported by two boomerang-shaped legs made of a high tensile aluminium alloy which carry the seat bucket and contain the energy absorbing device and act as rails for vertical stroking when severe vertical loads are applied to the seat assembly.

Helicopter maintenance

The Airworthiness Release Certificate was valid until June 2023. Responsibility for operation and maintenance of the helicopter had transferred to the operator in September 2022. After receipt and induction of the helicopter onto the operator's Continuous Airworthiness management system an annual maintenance was undertaken on the helicopter in October 2022. During this maintenance an issue with the fuel indication system was identified. After extensive fault diagnosis the cause was isolated to the FCU which was replaced. No further anomalies with the fuel control system were highlighted by crews in the technical logbook for the 26 sectors flown between the annual maintenance and the last recorded flight on 31 October. No technical logbook entry had been opened for the 1 November series of flights.

Recorded information

Introduction

The helicopter was not fitted with a flight data recorder or cockpit voice recorder, as neither was required by regulation. However, recorded data was available from the helicopters two Multi-Function Displays, two Primary Flight Displays, the DAU and two engine Data Collection Units (DCU). This provided time series data recorded at a rate of once per second, for the helicopter's most recent five hours of operation, which had been accrued between 30 October 2022 and 1 November 2022. Recorded parameters included the helicopter's indicated airspeed, groundspeed, altitude, normal acceleration, GNSS derived position, pitch and roll attitude, heading, total fuel quantity, rotor rpm (Nr) and engine collective position, torque, N_1 and N_2 speeds. The DAU and DCUs also provided snapshots of engine and system related faults and exceedances.

A tablet computer was fitted in the cockpit, which was operating a software navigation application[7]. This provided a recording of the helicopter's GNSS derived position, altitude, and groundspeed. The software application could also be used by the pilot to calculate the helicopter's WB.

Image footage and ambient sound of the helicopter during the accident takeoff was captured by a CCTV camera fitted to a private dwelling located 290 m south of the accident site. The helicopter's external lights were evident in the footage, which included its anti-collision lights fitted to the upper and lower fuselage, position lights fitted to the left horizontal stabiliser and end of the tail boom, and landing/taxi lights on the left sponson.

Accident flight

The recorded data showed the helicopter was parked on a heading of 315° and positioned (Figure 6) about 23 m from where it subsequently struck trees.

At 1722 hrs the No 1 engine was started, followed about 90 seconds later by the No 2 engine. The helicopter lifted into the hover (Figure 7 Point A) at 1726:06 hrs and made a left turn onto a heading of 305°; engine torque was 88% and the recorded fuel quantity was 405 kg. The helicopter's pitch attitude was about 6° nose-up and the collective was gradually raised, with engine torque increasing to 91%. This coincided with the start of the CCTV footage, which subsequently showed the helicopter moving slowly backwards towards the stand of trees. The engine torque continued to increase, and the helicopter climbed while also turning left onto a heading of 287°. The helicopter's pitch attitude had briefly reduced to about 3° nose-up during the turn, but then increased to nearly 8° nose-up (Figure 7 Point B and Figure 8). The pitch and roll attitude then stabilised at about 7° nose-up and -3° left roll, with the helicopter now having climbed to approximately 25 ft agl (Figure 7 Point C and Figure 9).

The collective was raised further, and engine torque increased through 106%. A few seconds later, at 1726:28 hrs, while travelling backwards at a groundspeed of about 7 kt and at a height of approximately 40 ft agl, the helicopter struck the stand of trees. The main rotor rpm (Nr) rapidly reduced from 100% and the helicopter pitched down to nearly 50° and rolled left to 83° as it then descended. Very shortly after, the helicopter struck the ground in a nose-down attitude before rolling onto its right side, where it came to rest. A few seconds later the No 2 engine was shut down, followed about one minute later by the No 1 engine. The main rotor head stopped rotating about 30 seconds later.

The audio from the CCTV camera contained sounds consistent with the rotation of the helicopter's Nr and tail rotor. The derived rotational speeds were consistent with the data recorded by the helicopter. There was no evidence of unusual sounds prior to the helicopter striking the trees.

Footnote

7 SkyDemon, VFR Flight Planning Software and GNSS Navigation [accessed 14 November 2023].

The WB function of the software navigation application was reviewed with the assistance of its manufacturer. This showed that for the flights flown on 1 November 2022, the pilot's weight was set at 85 kg, co-pilot, passengers and luggage were set at 0 kg and the total fuel was set to 640 kg. An additional 108 kg was also set for "floats"; although these were not fitted to G-RAYN. Based on these settings, the application would have provided a visual alert because the helicopter's WB were outside of the limitations entered into the software.

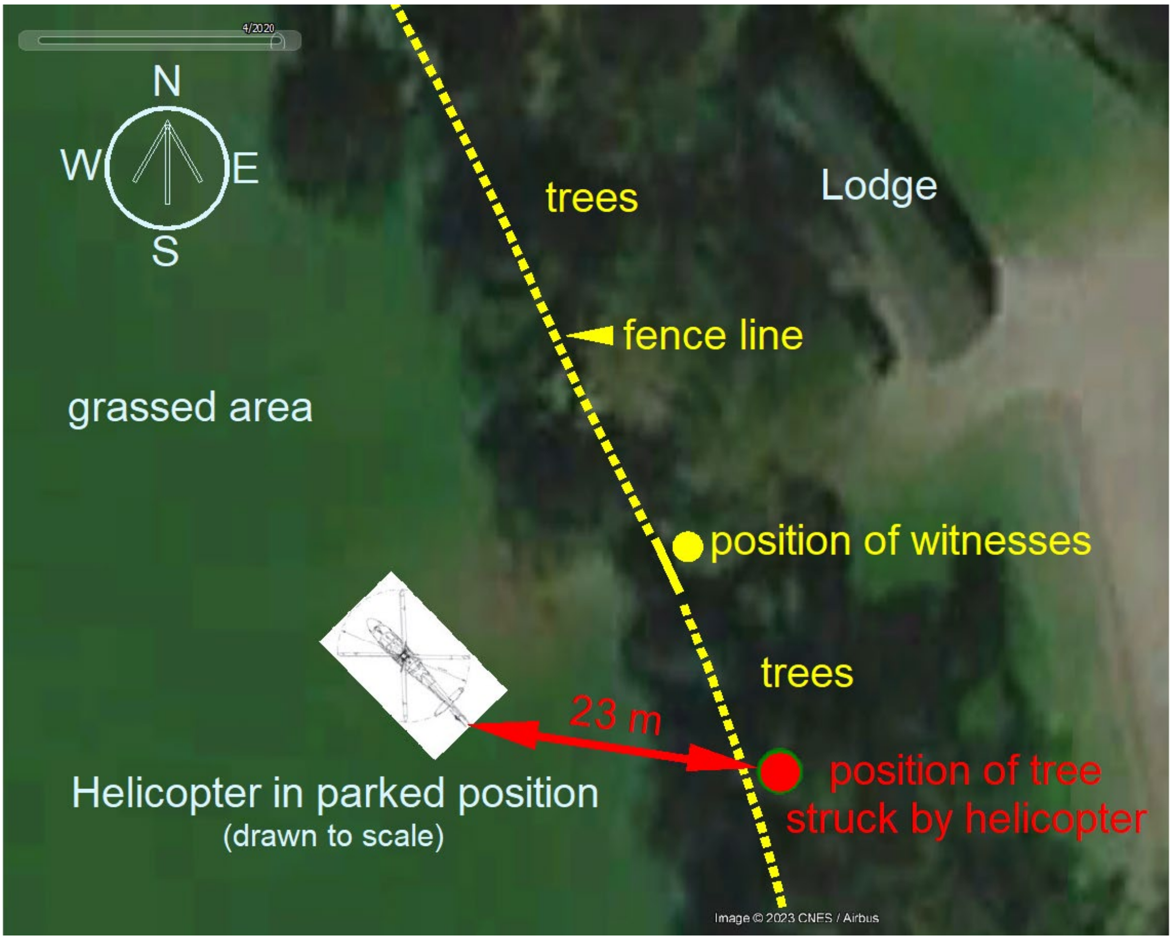


Figure 6

Position of helicopter prior to takeoff
(©2023 Bluesky, Infoterra Ltd & COWI A/S, CNES / Airbus, Getmapping plc, Maxar Technologies)

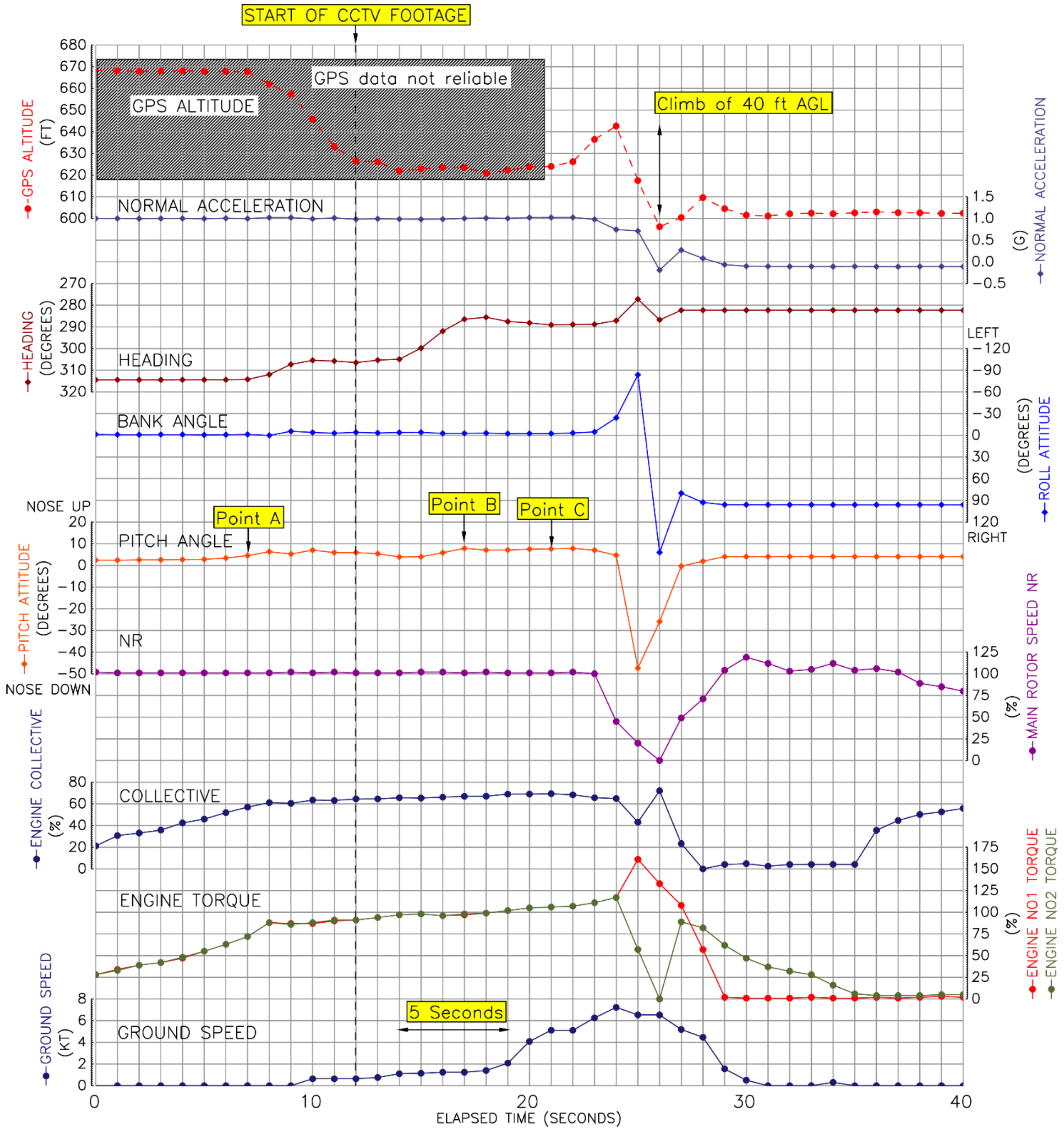


Figure 7

Flight data during the accident

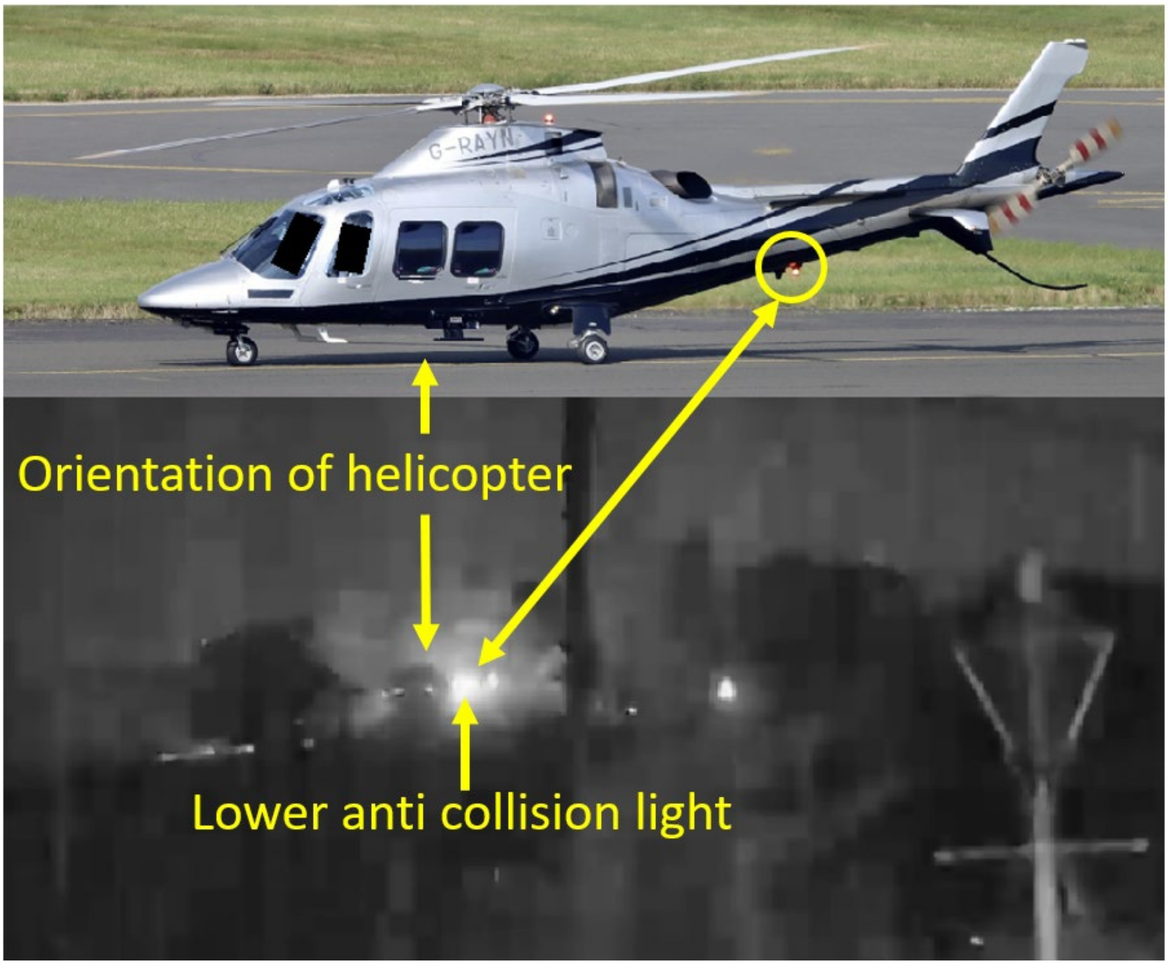


Figure 8

CCTV image as the helicopter started to climb

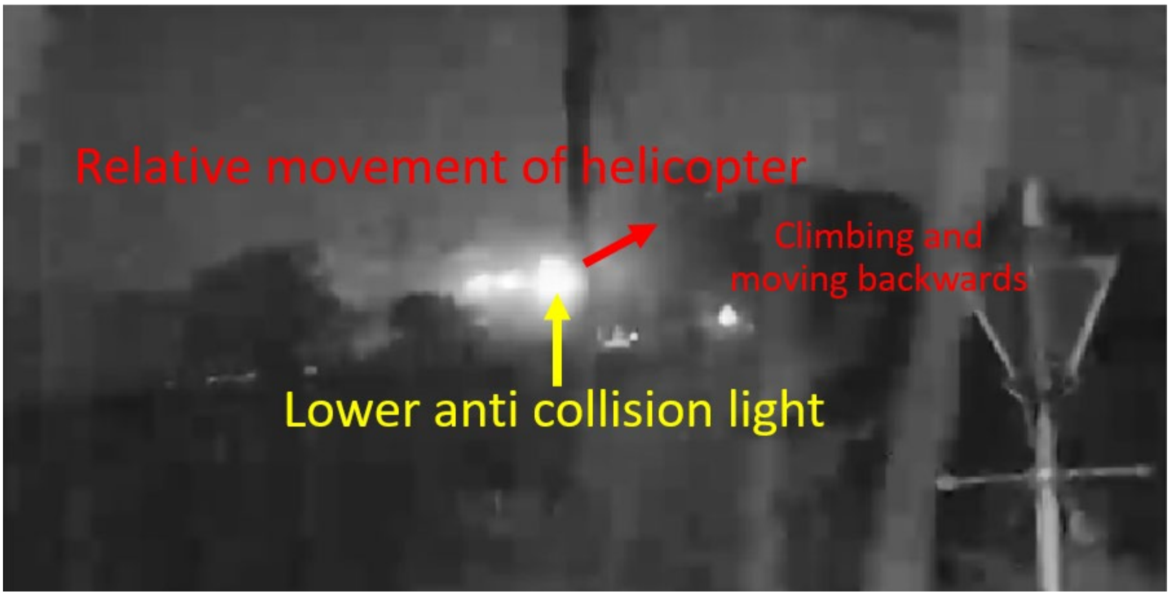


Figure 9

Image of helicopter shortly before striking trees

Recorded fuel quantity

Table 1 shows, in sequential order, the helicopter's total fuel quantity recorded at takeoff for each of the flights flown on 1 November 2022. Upon landing at Hawarden, the sensed fuel quantity was 206 kg and upon recommencement of the recording, when the helicopter was on the ground, the total fuel quantity had increased to 456 kg. This was consistent with the receipted uplift of 320 litres of Jet A1 fuel with an assumed specific gravity of 0.78 which equates to just less than 250 kg.

Takeoff location	Fuel quantity (kg)
Biggin Hill Airport	592
Lisvane	380
Lodge (LEA2)	245
Hawarden	448
Lodge (LEA2)	405

Table 1

Recorded fuel quantity during takeoffs on1 November 2022

Aircraft examination

A general visual inspection of the wreckage was conducted. While the main fuselage body was intact the nose was damaged and the tail boom had detached from the fuselage. The main rotor blades had all detached from the rotor head and were severely damaged.

A detailed inspection of the upper deck including the Main Gearbox (MGB) and Rotor Head was performed. All the main rotor pitch links and rotating scissor were severed. The fracture surfaces of these damaged components exhibited the characteristics of overload failures.

The No 1 hydraulic system filters were intact, but the No 2 system filters had both 'popped.' These filters sense a differential pressure of 70 psi between inlet and return. They are spring loaded and magnetic and can be set off by impact forces.

Several locking nuts on the bolts on the case connecting the MGB with the rotor head were found not properly in contact with the joint surface of the MGB upper case. These were all on the right side of the casing. However, it was determined that this happened during the lifting operation to recover the aircraft which caused the bolts to stretch; the vector of force during the lifting operation would have initially been at 90° to the rotor head which would have placed a bending moment on the rotor head and placed these bolts under tension.

Flying controls

The flying control system was examined. A visual check of the system did not reveal any damage to the flying control rods or linkages up to the damaged section of the rotor head.

The upper deck panels were removed and flight controls disconnected from the servo actuators to check the free movement of the mechanical link and continuity of movement.

From the co-pilot position the cyclic and collective full range of movement was achieved with the mixer unit reaching its backstops. However pedal movement was limited by nose deformation and the control run could only be checked up to the yaw actuators, due to the tail detachment at this section.

From the pilot position the cyclic and collective operation resulted in full and free range of movement of the mechanical flying controls. To fully examine the system in yaw the co-pilot controls were disconnected from the connecting bar to see if full and free range of movement could be achieved using the pilot's pedals. The range of movement on the pedals was different with greater movement on the right pedal than the left. The control mechanism would hit the forward backstops on the servo but not the rear backstop. There remained a clearance of approximately 4 mm.

Examination of the fuselage showed impact damage that corresponds with the location of the control run for yaw channel. Borescope inspections in this area revealed some impact damage and a foreign object that had likely entered the structure during ground impact. It was not possible to assess if the control rod was distorted, but examination of the routing of the control run showed it contacting some of the surrounding structure. The extreme forces needed to separate the tail rotor boom from the fuselage would have resulted in high bending moments being applied to the fuselage and yaw control run which would have distorted its alignment.

Tail boom and tail rotor

Inspection of the detached tail boom and the tail rotor showed impact marks on the left side of the tail. One of the tail rotor blades was cut at the root and the other one damaged. The tail rotor blade that detached had impact damage on its leading edge. The tail rotor drive shaft was twisted at its broken section confirming rotation at the moment of impact. The tail rotor output shaft was distorted as a result of the high bending moments applied during the impact with the trees.

Cockpit survey

The following observations were made from a survey of the cockpit:

- Fuel Control Panel: both shutoff valve switches were found in the CLOSED position, the XFEED valve switch was in the AUTO position.
- Rotor Brake lever in ON position.
- Engine Control Panel: ENG 1 knob found in IDLE, ENG 2 knob in OFF position.
- Landing lever in DOWN position.
- Overhead panel: Engine levers in flight position (the Engine Control Panel overrides this throttle position).

- NO 1 and 2 GEN BUS switches in OFF position (as expected being a magnetic retaining type).
- Two circuit breakers had tripped: WRX and Anti-collision light breakers. No other circuit breakers had tripped.

Avionic units

The Flight Control Computer and FCU were inspected and found to be physically intact. These were removed for further testing. Similarly, both engines' Digital Control Units (DCU) were inspected and removed so that data from these could be extracted.

Organisational information

Basic regulation

Regulations for air operations with aeroplanes and helicopters within the UK are detailed in UK Regulation (EU) No 965/2012[8] (965/2012). These regulations include detailed rules for operators of aircraft engaged in both commercial and non-commercial air activities. The regulations are intended to be proportionate, with the most stringent criteria being applied to commercial air transport (CAT) operations. Aircraft operators may further limit the scope of their activities by publishing more restrictive guidance for their own operations. Requirements for '*non-commercial operations of an AOC holder with aircraft listed on its AOC*' are detailed in 965/2012 at ORO.AOC.125.

Company operations manual

G-RAYN's operator published an operations manual (OM) containing instructions to be followed by its personnel. Compliance with the OM was required to ensure that all CAT flights were planned and executed in accordance with applicable policies and requirements. The OM contained a statement that it had been '*issued in accordance with the EASA Implementing Rules*' and that it complied with the acceptable means of compliance and guidance material contained within Annex III to 965/2012, '*Organisation Requirements for Air Operations*' (Part-ORO), and with the terms and conditions of the company's Air Operator's Certificate.

The OM consisted of four parts, published as separate manuals:

- **Part A (OMA) General**: non-type-related operational policies, instructions, and procedures.
- **Part B (OMB) Type-Related Helicopter Operating Matters**: type-related instructions and procedures, including differences between types, variants, and individual helicopters.

Footnote

8 Available at Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (Retained EU Legislation) (caa.co.uk) [accessed 16 January 2023].

- **Part C (OMC) Route & Aerodrome Instructions**: instructions and information needed for the area of operation.
- **Part D (OMD) Training**: training instructions for personnel.

The OMA required that '*every flight undertaken by the Company for whatever reason shall be conducted in accordance with the provisions of* [the] *Operations Manual*.' While the OMA was written primarily to support CAT operations it did allow for differences when conducting non-revenue flights. The scope of non-revenue flights listed in the OMA included '*flights for a private owner using their aircraft with company approved pilots.*' The accident occurred on a non-revenue, NCO flight, flown by one of the operator's pilots.

The OMA[9] listed specific differences from the CAT requirements for non-revenue and non-CAT flights. These included:

- fuel requirements,
- IFR destination alternate requirements,
- helicopter performance criteria,
- pilot age limitations,
- helicopter flights over water, and
- pilot licensing requirements for IFR flights.

The OMA also gave guidance regarding the degree of flexibility that could be used in the following areas for non-revenue flights:

- flight time limitations,
- long term CAA permissions and exemptions,
- carriage and use of an electronic flight bag, and
- night helicopter landing site (HLS) operations.

Specifically, the OM contained no derogation for night HLS operations, stating[10], '*all Categories of flight, (CAT/SPO/NCC/NCO) shall without exception, shall* [sic] *be flown IAW the Company Operations Manual.*'

The investigation heard that, culturally within the industry, NCO operations for helicopter owners in their own aircraft were often referred to as 'private' flights; a description used before the category NCO was adopted by regulators to encompass such activity. This legacy terminology contributed to the pilot's misunderstanding that, being a 'private' flight, he could choose to apply commander's discretion regarding all additional limitations contained within the OMA, provided he complied with the higher-level regulations of 965/2012.

Footnote

9 OMA 8.7 '*Non-revenue / Non-CAT Flights*.'
10 OMA 8.7.9 '*Night HLS*.'

Training and checking

Part-ORO specifies the requirements to be followed by an air operator conducting CAT and non-commercial operations with complex motor-powered aircraft (NCC) operations. Part-ORO subpart FC (Flight Crew) establishes requirements to be met by an operator in relation to flight crew training, experience, and qualification. ORO.FC.230 details the requirements for recurrent training and checking, including the requirement for operator proficiency checks (OPC) ORO.FC.202(b) '*Single-pilot operations under IFR or at night'* stipulates that '*the recurrent checks required by ORO.FC.230 shall be performed in the single-pilot role on the relevant type or class of aircraft in an environment representative of the operation*.' Due to the diverse range and scope of operations covered by these regulations, the UK Regulator does not explicitly specify more detailed requirements for proficiency checks, instead delegating that to individual operators. The investigation found that the UK Regulator's interpretation was that, for an operator that conducts night operations, '*an environment representative of the operation*' would include an element of night flying.

The OMD required any of the operator's pilots without a valid Instrument Rating (IR) to undergo a night proficiency check before operating VMC at night. Thereafter, each second proficiency check was to be conducted at night. This requirement did not apply to the accident pilot because he held a valid IR. In the preceding five years, none of the accident pilot's licence proficiency checks or OPCs flown on the AW109 had involved any night flying. The pilot completed his AW139 helicopter type course in early 2022, the two OPCs he had undertaken on that type were conducted in a flight simulator and did include night elements. The pilot recalled previously receiving training on night operations using a NATO-T lighting system[11] and being accompanied by a senior company pilot on "many of [his] first night flights in and out of sites." He also thought it likely that he had departed from unlit HLSs at some point in his career but could not recall specific occurrences.

In having flown three takeoffs and landings at night on the aircraft type and three instrument approaches in the previous 90 days, the pilot met the OMD criteria for night recency.

Safety management system

Through their safety management system (SMS), the operator had identified five top risks to their organisation. These included the heightened risk associated with '*off-airfield night landings*.' While potentially implicit, the SMS did not specifically extend the scope of that risk acknowledgement to off-airfield night departures.

At the operator's '*Flight Operations Safety Action Group'* meeting held in September 2022 it was reported that a new contractor for deployable lighting provision for off-airfield operations had been found but the new system would benefit from '*further integration and practise before being used operationally*.' A training event for pilots and ground crews to practise the associated procedures under controlled conditions on a '*dusk running into dark exercise*' had been booked for 25 October 2022 but was postponed due to a key participant's illness.

Footnote

[11] See *Airfield Information, HLS Lighting provision* section.

Operational oversight and commercial pressure

The OMA contains a policy statement that no commercial pressure from the company, or its employees should be placed on individual aircraft commanders to undertake a particular flight.

Given the nature of the company's business, its pilots are often conducting single-pilot operations at remote locations and needing to manage customer expectations in a dynamic and pressurised, commercially competitive environment. Expectation from clients to deliver an anticipated level of service irrespective of unforeseen complications can, on occasion, be at odds with the flight safety imperative. To limit such pressure on pilots, the OMA directs that company ground operations staff should act as the primary customer interface. This responsibility starts from when tasking is first proposed. To further separate the commander from commercial pressure, '*whenever practical*,' go/no-go decisions by pilots on live operations are communicated to customers by ground operations staff or 'a *pilot not involved in the flight.*' The OMA says that, where there is '*the likelihood of a divert or delay*,' customers should be made aware of contingency plan options in advance to help manage their expectations during a flight.

The pilot reported that delayed departures were not uncommon when undertaking corporate tasking. Pilots were often required to adopt a flexible and proactive approach to emerging problems to achieve their assigned tasking.

The shooting party had not been given a latest-possible departure time and did not exert any pressure on the pilot in relation to the day's flying schedule.

Tasking and flight planning processes

The OMA lists operational factors[12] that should be considered during the quotation process. These areas include:

- *'day/night considerations,'*
- *'the suitability of any unlicensed landing sites,' and*
- *'times of sunrise/sunset if applicable*.'

On receipt of a task enquiry, the operator's ground operations department use a commercially available software planning tool (planning tool) to validate the viability of the proposed flight schedule. The intended flight routing and timings, as well as crew, passenger, and luggage weights, are input to the planning tool for it to evaluate task feasibility. The system uses detailed weight, centre of gravity (CG) and performance data for the assigned helicopter to determine limiting conditions for the tasking on a sector-by-sector basis. For each sector, the planning tool calculates a range of acceptable fuel levels for departure that would keep the helicopter within MTOW, CG and Final Reserve fuel limits. Potential exceedances, such as CG out of limits or insufficient fuel on board to complete any proposed sector, are flagged to the planner. All such exceedances require an alteration of flight parameters in the draft

Footnote

[12] OMA 2.3.3 Operational considerations for acceptance of a task.

plan to resolve the issue before a workable flight plan can be generated. If, for example, the revenue payload meant MTOW considerations limited the maximum fuel on board at departure to less than was required to fly the proposed sector, a reduction in payload or the addition of an intermediate refuelling stop would be required to clear the warning. Similarly, sunrise and sunset times are automatically calculated for each landing and takeoff site. Greyscale shading for each sector is used to indicate to the planner if it would be day, night, or twilight at the planned arrival/departure time. This shading is not carried over into the operator's pilot tasking documents. Detailed lighting and fuel data could potentially be included on the pilot tasking paperwork but the operator's version of the planning tool was not configured to do this.

Planned for 15 minutes before sunset, the flight from LEA2 to Lisvane was shown as a day departure in the planning tool. Although both sites were listed as Estimated HLSs in the CLSD, and therefore day-only under OMA rules[13], contingency options had not been developed to mitigate the effect of potential delays precluding a daytime departure from LEA2. From the outset, the planned arrival time at Lisvane was after nightfall[14].

The operator's pilots routinely received their tasking through documentation generated by the planning tool. This typically included printed route and payload data for the assigned duty. The pilots then used third-party software on their company-issued tablet computers for detailed flight and fuel planning. Route and waypoint data could be uploaded from the planning tool directly into pilots' tablets using a weblink. The planning tool was not configured to export WB data to the third-party software applications used by the pilots. The operator's standard duty check-in time for pilots ahead of a flight was 30 minutes prior to departure and allowed time for final planning and pre-flight preparation of the aircraft. To give pilots more time for detailed planning, the ground operations staff would aim to send tasking documentation no later than the day prior, although this was not always possible for short-notice tasks.

The pilot received the flight paperwork for the 1 November task the day beforehand and uploaded the route waypoints to his tablet computer navigation application. He reported that using this application, he calculated fuel requirements for each sector on a 'fuel-to-fuel'[15] basis. The pilot also reported being aware that sunset would be approximately 15 minutes after the scheduled departure time from LEA2. At the time, it was his understanding that the OMA alleviations for non-revenue flights could be applied to night HLS operations, thus allowing him to depart the unlit site after dark. Accordingly, he was unconcerned about a delayed departure and did not pass a last possible day takeoff time to the passengers.

TEM

For multi-pilot operations the acceptable means of compliance (AMC) for the inclusion of TEM[16] in Crew Resource Management (CRM) training are outlined in AMC1 ORO.FC.115

Footnote

13 See *Airfield information* section.
14 Using the OMA definition of nightfall being 30 minutes after sunset.
15 Planning refuelling levels to ensure compliance with Final Reserve requirements for each sector.
16 The practice of planning and thinking ahead to predict/identify potential errors and threats and consider strategies to manage or mitigate those that do occur.

of 965/2012 (AMC1). A corresponding AMC for single-pilot operations is specified at AMC2 ORO.FC.115 and directs that training should focus on the elements specified in Table 1 of AMC1. TEM is included as a required topic in the '*General principles*' section of the referenced table. The investigation noted that TEM training is a core element of the current pilot training syllabi for LAPL onwards and widely referenced in Part FCL.

The operator established risk management and mitigation activities through its SMS and TEM was included in the operator's syllabus for initial and recurrent CRM training[17]. The operator reported that CRM, "including TEM," would be assessed during OPC and Line Check flights.

The pilot reported that he would be expected to manage and mitigate on-the-day risks using his own judgement. For the flight from LEA2 to Lisvane he assessed the most significant threats to be the weather, and any lengthy delay that might result in an extended flight duty period or an unscheduled night stop in Cardiff. He completed a written risk assessment, as detailed in the OM Part A2[18], before leaving Biggin Hill. The OM risk assessment format was derived from the European Helicopter Safety Team (EHEST) Excel Tool[19]. The EHEST tool is intended to be completed before flight and aims to help inform pilots as to whether their planned flight is '*safe enough to be undertaken*.' Not all the operator's personnel fully appreciated the principle of TEM being a complimentary and proactive, flight phase-by-flight phase, tactical strategy focused on anticipating potential immediate threats to safe operation.

Following TEM principles helps pilots focus on and mitigate conceivable human, technical, and environmental threats engendered by the actual conditions prevailing during the immediate phase of flight. Threats identified may be less generic or different to those identified during a pre-flight risk assessment.

Survivability

Crashworthiness

Despite the helicopter being subject to dynamic and complex loads during the impact sequence no fuel had leaked and there was no post-impact fire. The main fuselage retained its integrity during the accident sequence and protected the occupants from external hazards.

Regulatory requirement

NCO.OP.150 of 965/2012[20] places a requirement on the pilot in command of an aircraft to ensure that '*prior to and during taxiing, takeoff and landing…each passenger on board occupies a seat or berth and has his/her safety belt or restraint device properly secured.*'

Footnote

17 OMD 5.1: 'Flight crew CRM training: General Principles.'
18 OMA A2 2.4.19: 'Helicopter Commanders Pre-Flight Checklist and Risk Assessment.'
19 EHEST pre-departure checklist. Available at https://www.easa.europa.eu/en/downloads/23352/en [accessed 7 February 2023].
20 Available at NCO.OP.150 Carriage of passengers (caa.co.uk) [accessed 11 January 2024].

Passenger briefing

The OM[21] stipulates a requirement for passengers to be appropriately briefed before flight, including on the operation of '*normal and emergency exits*' as well as '*the use of safety belts/ harnesses.*' Because the flight was in support of the helicopter owner, who was a frequent flyer, the pilot did not consider that a refresher pre-flight safety briefing was required. He was not aware that some of the passengers had not flown in that model of helicopter before.

Use of restraint devices

As well as placing a responsibility on commanders to ensure that each passenger is briefed on seatbelt/harness operation before takeoff, the OM[22] also requires them to ensure that each passenger has their safety belt/harness properly secured before takeoff and landing.

Of the five passengers on board, four remembered not fastening their seatbelts prior to departure, it was not conclusively determined whether the fifth passenger had fastened theirs. One passenger ascribed the reason for not wearing their seatbelt to the dim lighting in the rear cabin making it difficult to locate '*the correct belts with the necessary attachments*.' Another passenger did not fasten their seatbelt because others had not been wearing theirs on the morning flight so he chose not to for the return journey.

The most seriously injured passenger had been sitting in the right rear cabin seat. The other passengers had been thrown from their seats during the accident sequence and some, if not all, had ended up on top of him. The investigation did not have supporting data to enable a determination of the dynamics of the passengers' trajectories within the cabin from the time when the helicopter struck the trees until it came to rest on the ground.

While not requested by the passengers on the accident flight, the pilot reported that, in his experience, it was not unheard of for frequent flyer corporate passengers, in the interests of expediency, to encourage flight crews to close the cabin doors and begin their pre-flight procedures as soon as the passengers were on board, rather than waiting to visually check that all seatbelts were fastened. The previous experience of one of the lead passengers was that the operator's "pilots would always carry out a safety briefing, and included in those briefings would be the importance of wearing a seatbelt."

Weight and Balance

G-RAYN had a certified MTOW of 3,175 kg. The helicopter's empty weight was recorded as 2,269 kg when it was last weighed on 8 September 2022. The operator uses a mix of standard and actual weights for passengers, baggage and crew. For the 1 November series of flights, the weights being used were as follows:

- Crew: standard weight of pilot and personal effects, 85 kg.
- Passengers: actual weights listed on tasking sheet, total 467 kg.

Footnote

[21] OMA 8.2.2.2.4 Passenger Brief and OMA 8.3.16 Passenger Briefing.
[22] OMA 8.3.11.2 Passenger Restraint Devices.

- Baggage: the weight listed on tasking sheet was 25 kg but the pilot assessed the weight of loaded luggage to be 20 kg.

Using the figures above, with crew, passengers and baggage, but minus fuel, the weight of G-RAYN would have been 2,841 kg. In that configuration, MTOW would have been reached with 334 kg of fuel on board.

The morning flight from Lisvane took off with an indicated 380 kg of fuel, giving a TOW of 3,221 kg.

At the accident site the AAIB recovered 520 litres of fuel from the helicopter's tanks, which equated to 405.6 kg using an assumed specific gravity of 0.78. Allowing for 10 kg of unusable fuel being present in its systems when the helicopter was weighed, G-RAYN's all-up weight at the time of the accident was an estimated 3,237 kg. The corresponding longitudinal CG position would have been 3,403 mm aft of datum (Figure 12).

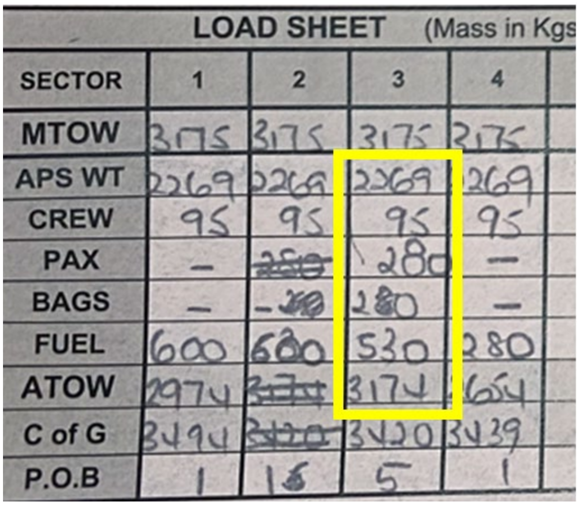
The pilot stated that 340 kg was his calculated startup fuel at LEA2 to remain within MTOW limits once the shooting party was on board. He was not able to provide the investigation with auditable WB calculations for the day's flying. He had not completed a manual loadsheet load, either standalone or as part of a technical log entry for the day's flying, and the WB function on the pilot's software navigation application had not been changed from its default parameters[23]. While 965/2012 does not require it for NCO flights, OMA directs that WB documentation for all categories of flight should be retained by the company for a minimum period of three months.

A review conducted by the operator, of actual vs assumed fuel consumption rates for the AW109SP, revealed that the assumed figure of 240 kg/hr for planning purposes was overly pessimistic and that 220 kg/hr was more representative. They considered that this pessimistic planning consumption rate would have contributed, in part, to the helicopter arriving at destinations with more fuel than anticipated.

The OMA[24] also required final WB data for all flights to be recorded on the relevant sector record page in the aircraft's technical log. A review of G-RAYN's technical log showed that this requirement was not always complied with for NCO flights. Additionally, during a review of technical log pages on board the helicopter at the time of the accident, it was noted the loadsheet data for sector three of G-RAYN's flying on 2 October 2022 was incorrect. While the actual takeoff weight (ATOW) was recorded on the sector record page as 3,174 kg, the total of the masses listed for helicopter on that sector ('*APS WT, CREW, PAX, BAGS'* and *'FUEL*') was 3,194 kg (Figure 10)[25].

Footnote

[23] See '*Recorded information'* section.
[24] OMA 8.1.8.11.1 Mass and Balance Data and Documentation/Records.
[25] 2,269 + 95 + 280 + 20 + 530 = 3,194 kg.



LOAD SHEET (Mass in Kgs				
SECTOR	1	2	3	4
MTOW	3175	3175	3175	3175
APS WT	2269	2269	2269	2269
CREW	95	95	95	95
PAX	–	~~250~~	280	–
BAGS	–	– ~~260~~	280	–
FUEL	600	600	530	280
ATOW	2974	~~3174~~	3174	2654
C of G	3494	~~3420~~	3420	3439
P.O.B	1	1 5	5	1

Figure 10

Extract from G-RAYN's technical log sector record page for 2 October 2022

Helicopter performance

Hover attitude

The helicopter manufacturer performed a simulation based on the accident takeoff weight, CG, and wind conditions, to establish the pitch and roll attitude, and engine torque necessary to have maintained a stationary hover. This showed the required pitch attitude was 4.0° nose-up and, depending upon being in or out of ground effect, the required roll attitudes and power settings were 3.3° and 3.8° left bank and 81% and 95% torque, respectively.

The manufacturer also performed simulations to establish if the helicopter could maintain a stationary hover when the pitch attitude was at 7° nose-up, as recorded during the accident takeoff. This showed that at the MTOW of 3,175 kg it was possible, but the CG would need to be set at 3,583 mm which would be outside the certified longitudinal envelope (Figure 11). With CG set at 3,430 mm, the maximum longitudinal aft position for the helicopter at MTOW, it was not possible to maintain a stationary hover with a pitch attitude of 7° nose-up.

Another simulation using the recorded pitch and roll attitude, heading and collective position was performed for the weight and CG calculated for the accident takeoff. The manufacturer concluded that, based on the accident data, the helicopter would not have maintained a steady hover position, but would have moved rearwards while also climbing.

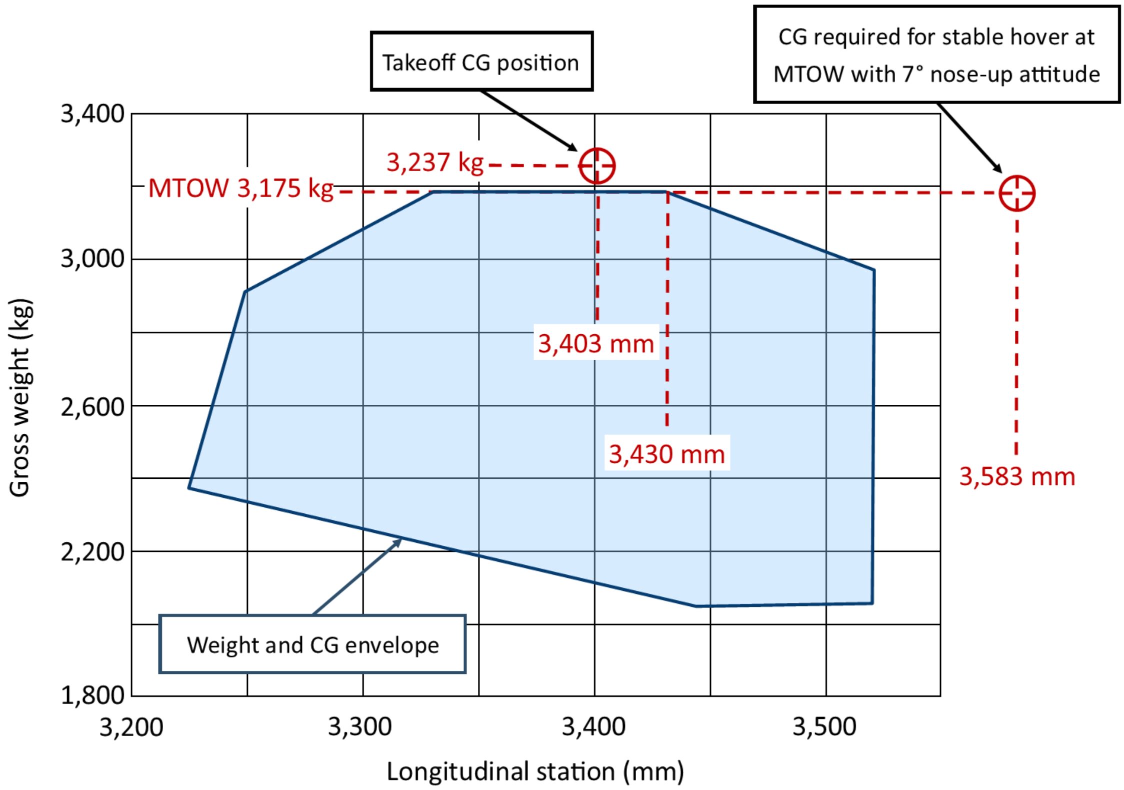


Figure 11
Weight and longitudinal CG envelope for G-RAYN

Performance Classes

Under the aviation regulatory framework, operational regulations are specified according to the single engine failure capability of a helicopter in a defined area of operations. These are designated as Performance Classes.

- In areas where Performance Class 1 (PC1) operations are planned the helicopter must be able to safely continue the flight or land within the rejected takeoff or landing area.
- Performance Class 2 (PC2) requires that the helicopter should be capable of either being safely flown away or executing a forced landing during takeoff and landing.
- Performance Class 3 operations are those where, should an engine fail, a forced landing will be required.

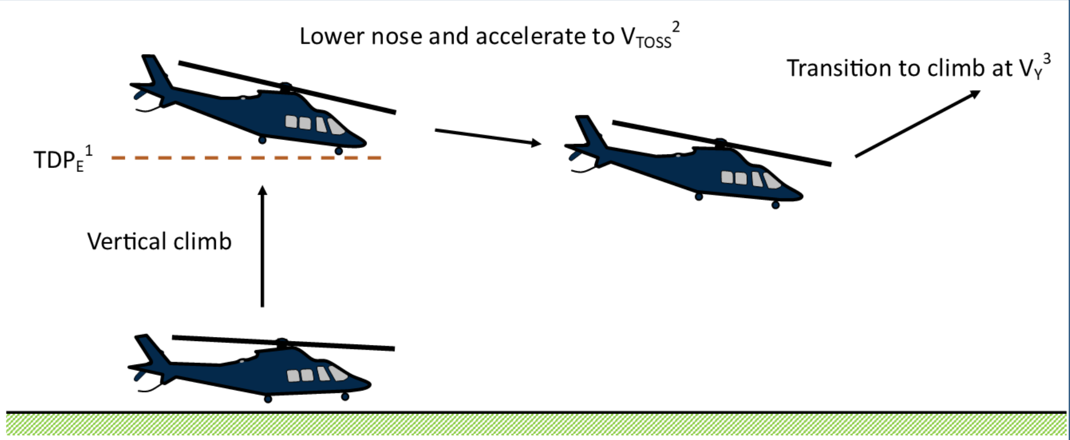
Performance class compliance for routine operations

Notwithstanding the OMA day-only restriction on LEA2, the physical characteristics of the site would, under the OMB criteria[26], have allowed the commander to depart using helicopter PC2 criteria. Nonetheless, the pilot elected to conduct a Category A vertical

Footnote

26 OMB Part B2 Section 4.2 *Performance Applicability – General Operating Restrictions*.

takeoff profile (Figure 12) which was compliant with PC1 operations and described in the RFM[27]. This was in line with the OMB direction[28] that *'the Commander shall endeavour to operate the helicopter in* [PC1] *whenever possible thereby maximising the safety margin for the passengers at all times.*' Due to the presence of trees behind the helicopter, the pilot elected to fly a vertical rather than '*back-up*' procedure which would have required an initial rearward climbing flightpath (Figure 14).



Notes:

1. TDP_E = Extended takeoff decision point height. For engine failure below TDP_E height reject the takeoff, otherwise continue. TDP_E height to be in the range 35-75 ft above the takeoff surface.
2. V_{TOSS} = Takeoff safety speed (35 kt).
3. V_Y = Best rate of climb speed (80 kt below 10,000 ft AMSL).

Figure 12

Overview of Category A ground level vertical departure profile

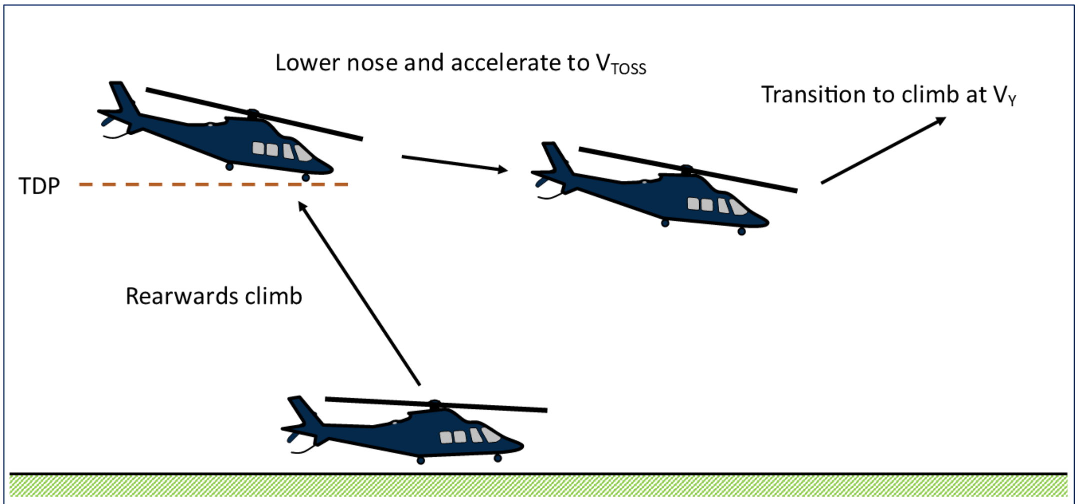


Figure 13

Overview of Category A ground level back-up takeoff procedure

Footnote

27 AW109SP RFM Supplement 4 Part E *CAT A Operations, Ground Level Heliport*.
28 OMB Part B2 paragraph 4.2.3.

The pilot's experience was that, after power was applied to commence the climb for a vertical departure, the AW109 type was very stable and would invariably climb vertically with little longitudinal drift. For Category A 'back-up' procedures, the pilot reported needing to apply a conscious and positive pitch up to initiate the necessary rearwards movement. He did not recall making a positive pitch up of that nature during the accident flight takeoff. Based on previous experience, he estimated that he would have needed to hold approximately 5° nose-up to maintain his longitudinal position in the hover.

A comparison between the recorded pitch attitudes and groundspeeds during the Category A back-up departure flown from Lisvane that morning and the attempted vertical departure on the accident flight is shown below (Figure 14). Other than the temporary reduction in pitch attitude as the pilot turned into wind at LEA2[29] the pitch attitude profiles are broadly similar. The takeoff from Lisvane was a crosswind departure, whereas the helicopter was experiencing a headwind as it climbed from LEA2, this could explain the difference in rearward ground speed acceleration rates observed beyond the 20 second point on the Figure 15 chart.

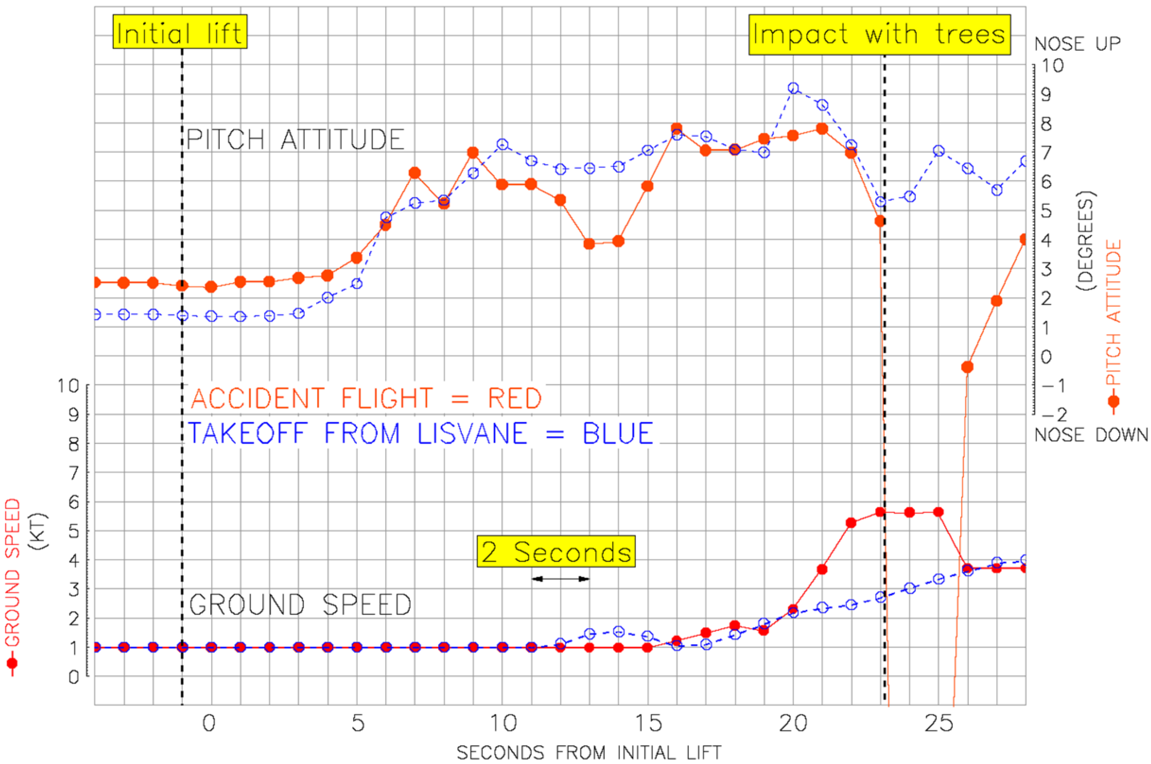


Figure 14

Comparison of Lisvane (blue) and accident flight (red) Category A departures

Footnote

[29] Between 10 and 15 seconds on the chart and described fully in the *Recorded information, Data interpretation* section.

Meteorology

The conditions in the vicinity of Llanelidan during the period of 0700-1900 UTC on the day of the accident were generally fine with good visibility, however, occasional showers throughout the period reduced reported visibility to between 8,000 and 9,000 m. Surface winds were recorded as being generally west-south-westerly at 5-11 kt. At the approximate time of the accident RAF Shawbury, 28 nm east-south-east of LEA2, was reporting 1-2 oktas of cloud at 2,200 ft with complete cloud cover at 4,000 ft. At the same time, Hawarden, 15 nm east-northeast of LEA2, was reporting light rain with 3-4 oktas of cloud at 2,400 ft and 5-7 oktas of cloud at 3,700 ft. Visibility in that light rain had reduced to 8,000 m, previously it had been reported as ≥10 km.

The reported weather was above the OMA minimum requirement for night VFR flights by pilots holding a valid IR, of 3,000 m visibility and cloudbase 1,200 ft above nearby terrain.

The pilot recalled that when he walked to the helicopter for the accident flight, "the rain had all but stopped and the wind had died off to a gentle westerly breeze."

Met Office data indicated that on 1 November 2022, local sunset at LEA2 was 1645 hrs. The end of official evening civil twilight would have been approximately 1718 hrs.

Airfield information

The operator's OMA refers to an unlicensed heliport as an HLS. HLSs could be heliports intended for regular use, with a Final Approach and Takeoff area (FATO) in place, or ad hoc ones using an area of ground that has been assessed or surveyed as suitable for the purpose. Pre-approved HLSs are listed in the CLSD. A standard CLSD entry would include site details, such as contact and navigational information, as well as mapping and imagery of the landing area. The final page of a CLSD entry is titled '*Area Survey (If Applicable)*' and includes a table on which the nature, location and height of relevant surveyed obstacles can be listed.

Depending on the degree of prior surveying that has taken place, a site is assessed as falling into in one of the operator's three HLS categories: Surveyed, Measured or Estimated. The three categories allow a degree of operational flexibility to use unlicensed and ad hoc HLSs, balancing operational imperative against the time available for pre-survey of a site. The OMA directs that, where '*time permits and an existing acceptable site survey report is not available the site should be surveyed in accordance with the procedures described at* [OMA] *paragraph 8.10.5*.' The OMA also highlights that *'the Company has a duty of care to both the crew and the passengers to pre-survey sites prior to use whenever operationally possible*.' Only once the appropriate procedure, as described at OMA 8.10.5 has been carried out, can an HLS be considered for categorisation as a Surveyed site.

The HLS categories have different operating restrictions. For example, Surveyed sites can be used at night subject to certain caveats, but Measured and Estimated HLS '*may be used by Day only.*'

The overall length (D) of the AW109SP type including the rotor is 12.96 m. The OMA requires that for day operations, the touchdown and lift off (TLOF) area of an HLS must be at least the larger of twice the helicopter length, (ie 2D) or the minimum heliport/helipad size detailed in the approved helicopter flight manual. For night operations the TLOF must be at least four times the helicopter length (ie 4D) or 110 m x 60 m, whichever is the greater. For the AW109SP, 4D is approximately 52 m so for night HLS operations the minimum acceptable TLOF area of 110 m x 60 m applies. The Limitations section of the AW109SP RFM[30] did not detail a minimum heliport/helipad size.

CLSD entries for Lisvane and LEA2

On the flight paperwork provided to the pilot, the Lisvane and LEA2 CLSD entries were both depicted as having been created on 25 March 2019. Comparing the entries for Lisvane and LEA2 revealed discrepancies in presentation and approval status (Figure 16). While Lisvane was listed as an Estimated HLS, the CLSD appeared to give approval for both day and night operations. This was in contradiction with the generic '*use by day only*' OMA restriction for other than Surveyed sites. Additionally, at 107 m x 93 m, the longest dimension quoted in the CLSD for Lisvane was below the OMA requirement of 110 m x 60 m for a night HLS. LEA2 was listed as an Estimated HLS and the '*Day/Night*' box only contained a dash symbol rather than an explicit 'day' or 'day and night' annotation. The investigation also noted the CLSD categorised sites as Estimated, Measured and Full rather than Estimated, Measured and Surveyed.

Neither CLSD entry contained detailed obstacle or obstruction data, although adjacent power lines were depicted on satellite imagery of the Lisvane site. Nonetheless, the pilot was aware of the presence of trees at the LEA2 site and was familiar with the Lisvane HLS.

Information later provided by the operator revealed that Lisvane had been surveyed for night operations on 28 January 2017. The relevant details were recorded in their legacy CLSD which was superseded in 2019 (Figure 15). The Lisvane survey details not been transposed to the new format CLSD. On the 2017 CLSD entry, the site dimensions for Lisvane were recorded as 93 m x 48 m.

Footnote

30 AW109SP RFM (Document N°109G0040A018) Section 1.

2019 CLSD entry: Lisvane

Landing Site Contact		Navigational Information	
Site Name	[redacted]	OS Grid Ref	[redacted]
Site Address	Lisvane, [redacted]	Lat / Long	[redacted]
Contact Name and Number	[redacted]	Estimated, Measured or Full	E
Email	[redacted]	Elevation	295' AMSL
Day / Night	Day + Night	GPS	[redacted]
Landing Fee	£		

Site Details					
Site Dims (M)	Lighting	Terrain	Nearest Fuel	Obstacles	Airspace/Freq
93m x 107m	None	Grass	Cardiff Heliport (EGFC)		N/A
High Resolution Photo of Landing Site					

2019 CLSD entry: LEA2

Landing Site Contact		Navigational Information	
Site Name	[redacted]	OS Grid Ref	SJ 102 507
Site Address	Llanelidan, LL15 2RD	Lat / Long	N 53 02.81 W 003 20.37
Contact Name and Number	[redacted]	Estimated, Measured or Full	E
Email		Elevation	591' AMSL
Day / Night	-	GPS	LEA2
Landing Fee	£		

Site Details					
Site Dims (M)	Lighting	Terrain	Nearest Fuel	Obstacles	Airspace/Freq
112m x 330m	None	-	Hawarden (EGNR)		N/A
High Resolution Photo of Landing Site					

2017 CLSD entry: Lisvane

Landing Site Contact		Navigational Information	
Site Name	[redacted]	OS Grid Ref	[redacted]
Site Address	[redacted]	Lat / Long	[redacted]
Contact Name and Number	[redacted]	Estimated, Measured or Surveyed	S
Email		Elevation	89m
Day/Night	Day/Night (See Night survey page 5)	GPS	

Site Details					
Site Dims (M)	Lighting	Terrain	Nearest Fuel	Obstacles	Airspace/Freq
93x48	None	Grass	Cardiff	Wires (Red)	Card 119.150

Site Description / Specific Instructions	Site Approach
Concrete Helipad. Lights have been installed but are untested (as of 20.01.17).	Best approach from the South, overshoot option to the NW to avoid wires

Figure 15

Extract from CLSD entries for Lisvane and LEA2

HLS lighting provision

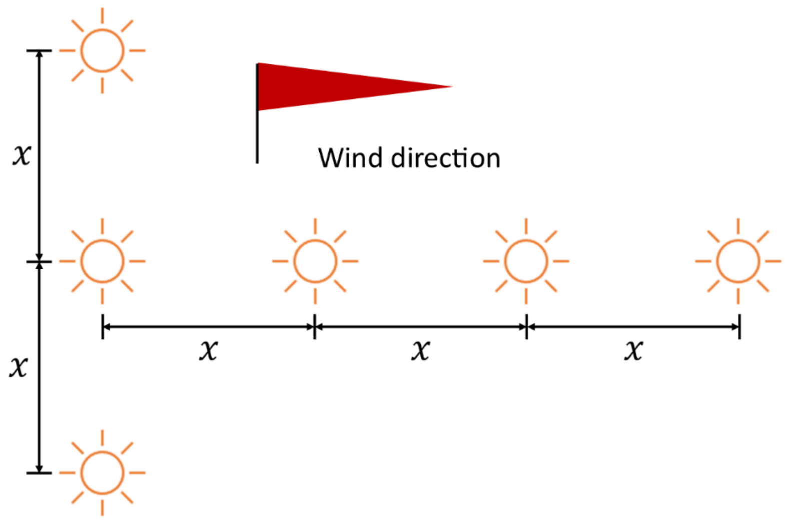
Given the restriction on use by day only, no minimum lighting standard was specified for an Estimated HLS.

The operator's minimum lighting standard[31] for night flights at Surveyed HLSs was:

> *'(i) A dedicated lighting system that clearly defines the TLOF and all obstacles in the approach/departure paths. [or]*
>
> *(ii) Secondary lighting from surrounding buildings and structures such that the TLOF/FATO is easily defined and surrounding critical obstacles in the approach/departure paths can be easily seen. [or]*
>
> *(iii) Mobile lighting or mobile floodlights.'*

The lighting at LEA2 on the evening of the accident flight did not meet the above criteria.

For pre-planned night operations at an HLS without an established lighting system, the operator had engaged a third-party contractor to deploy suitable lighting. The preferred solution was a set of portable lights laid out in the NATO-T lighting configuration as shown below in Figure 16. Deployable lighting had not been requested to support the accident flight.



Omni-directional white lights, with dimension x being approximately 10 m.

Ideally visible from 4 nm away and orientated for helicopter to approach into wind.

Figure 16

Depiction of NATO-T lighting layout

A note in the Site Description section of the Lisvane CLSD entry stated that helipad lights had been installed at the HLS but remained '*untested*.' The date of that observation was

Footnote

31 OMA 8.10.5.5.2 Lighting.

20 January 2017 (Figure 17). The arrival at Lisvane had been planned for 1715 hrs, a night arrival based on the OM definition of night starting 30 minutes after sunset. Prior to boarding the helicopter, its owner informed the pilot that he had turned the Lisvane helipad lights on using an application on his mobile phone.

Site Description / Specific Instructions / Approach Info / Pilot Comments			
Concrete Helipad. Lights have been installed but are untested (as of 20.01.17). Best approach from the South, overshoot option to the NW.			
Date Created	25/03/19	Date Amended	18/10/22
Created By:	[redacted]	Amended By:	[redacted]

Figure 17

Note referring to lighting installation at Lisvane

While on the ground at LEA2, the pilot had visually assessed the site as being suitable for the intended flight but had not completed the full site survey process as described in the OMA.

Personnel

The pilot began his flying career in 2000 and had been employed by the operating company for more than five years at the time of the accident. He had over 1,500 hours flying time on the AW109 type although only a small proportion of which were on the AW109SP variant.

The pilot's licence and medical were valid for the flight and he held a current IR. He completed his AW109 OPC the day before the accident and reported being in good health and sufficiently rested when he attended for duty on 1 November.

Tests and research

Fuel system

Due to the necessary disruption of the aircraft and fuel system during the recovery process it was not possible to perform an end-to-end test of the fuel system to prove it's serviceability. However, a key component of the system, the FCU, was removed and tested at the manufacturer's facilities in France. Testing of the FCU showed it to be serviceable and in good condition. The data from the DAU download was also examined for evidence of fuel system faults present prior to the estimated time of impact with the trees. No fault codes relating to the fuel system could be identified in the data. Examination of the aircraft logbooks revealed no indications of anomalies or faults with the fuel system reported by crews on the flights prior to the accident.

Flight Control Computer

The Flight Control Computer (FCC) was removed from the helicopter and taken to the manufacturer in France for testing. The FCC was subjected to visual inspections, automatic bench testing and supplementary manual testing. All but one test point was passed, the failed test point related to the Channel 1 Coupling light CPL indication. There was no evidence that this indication light fault was present at the time of the accident. But as the output was indication only and did not influence command of the autopilot modes this was considered to not have been relevant to the accident sequence.

Engine DCUs

Data was successfully extracted from the engine DCUs. From this information it was established that both the engines were serviceable and performing normally prior to the accident. Fault codes were seen on the system but these were attributable to the high resistance forces exerted on the rotor drive system during the impact with the trees.

Other information

Hover references

Helicopter pilots use visual references, referred to as 'markers,' to maintain a stable position over the ground. By picking suitably visible objects when the helicopter is established in the desired location, pilots can detect, and correct, any drift away from the target position by reference to the alignment of their markers with other objects or the cockpit structure. Normally, a distant forward marker would be used to assess heading and lateral drift, while a distant lateral marker is used to detect longitudinal drift (Figure 18). Pilots would also generally choose a close-in lateral marker for height assessment and fine position keeping.

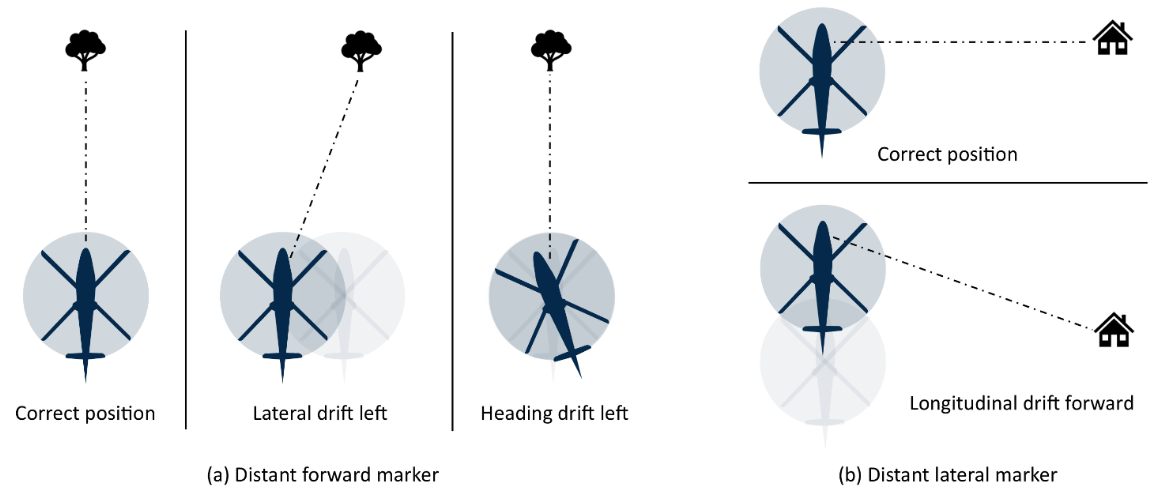


Figure 18
Distant forward and lateral markers

Heading changes affect the angular orientation of markers relative to the helicopter's longitudinal and lateral axes (Figure 19). In a degraded visual environment without two usable distant markers, it is more challenging to correctly determine if the change in marker orientation results from positional rather than heading drift.

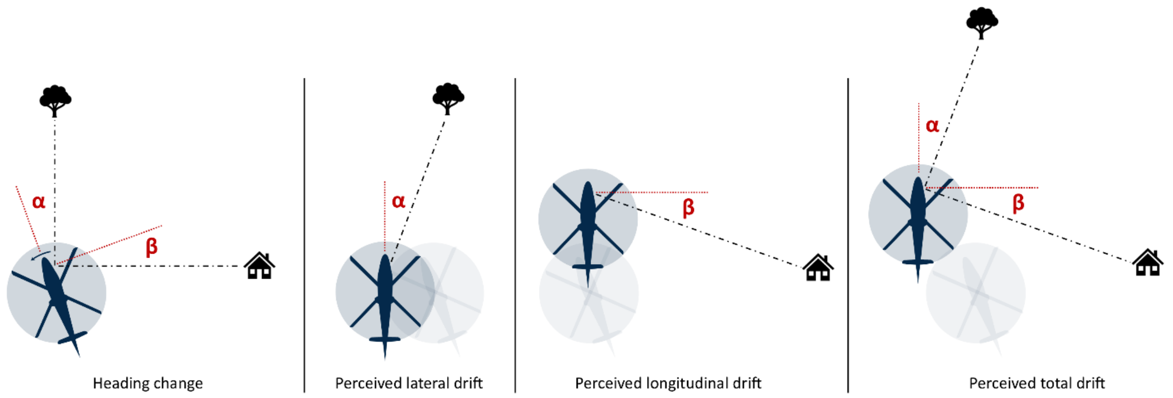


Figure 19
Heading change perceived as positional drift

Visually acquiring suitable markers at night is challenging unless they are lit, there is sufficient cultural or environmental lighting (eg moonlight on a clear night) for objects to be easily seen with the naked eye or the pilot is using a night vision device. In conditions of limited visibility, such as when relying on illumination from a helicopter's external lights, pilots are more likely to pick a single identifiable ground feature close to the cockpit to use as their primary hover reference. The downward sightline from the pilot's eyes to the feature means that, if it is maintained in the same relative position when lifting, the helicopter will naturally move up and rearwards as the pilot maintains that fixed sightline (Figure 20). Without an adequate distant lateral marker any consequential rearward movement is more difficult to detect visually. The investigation heard that, at night on an unlit site, a searchlight beam directed to a close-in reference 30-60° either side of the helicopter's nose offers greater opportunity to detect rearward drift than one directed straight ahead.

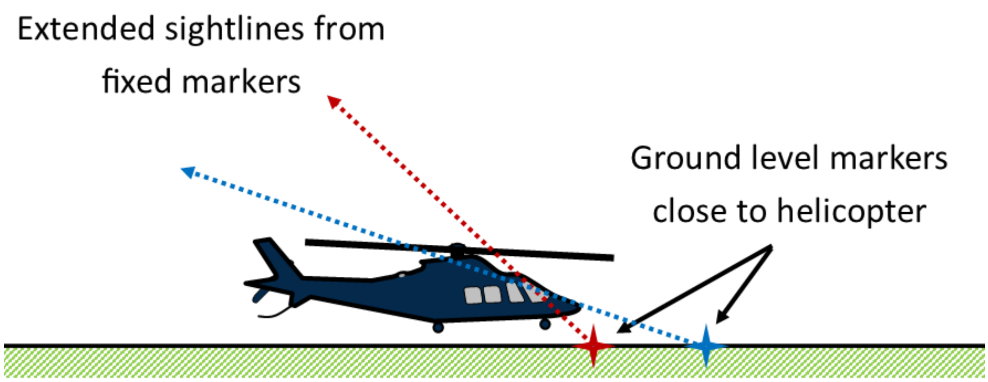


Figure 20
Extended sightline from close-in ground level markers

At the time of departure on the accident flight, it was dark with overcast cloud and little cultural lighting other than that from the lodge's windows. The pilot was not using a night vision device and the portable HLS lighting system had not been deployed.

Analysis

Aircraft serviceability

Extensive inspection and examination of the helicopter, component level testing and examination of maintenance records was undertaken to determine if there were any technical factors that were causal or contributory to the accident. The extensive damage to the helicopter was determined to be due the impacts during the accident sequence. While end-to-end testing of systems such as the fuel system was not possible, the manufacturer analysis of key components such as the FCC, FCU and DAU showed that the aircraft systems were functioning correctly prior to the accident. The maintenance records showed that the helicopter had been correctly maintained. The investigation concluded that the helicopter was serviceable at the time of the accident.

NCO and OM compliance

The reported cultural misunderstanding regarding the status of 'private' flights, those conducted on behalf of owners flying in their own aircraft, led to the helicopter being flown outwith the OM restrictions for Estimated HLSs. The legacy term 'private flights' is no longer used by the regulator; such flights now fall under the remit of Part NCO. For those elements of the accident flight which took advantage of the less-restrictive Part NCO regulations, the associated enhanced protections established in the OM were not in place, negating safety barriers that might have prevented the accident.

To reduce the opportunity for future confusion amongst its pilots over the applicability of OM restrictions for any flight being undertaken, as a safety action:

> The operator had amended their OM, flight documentation, and aircraft technical log sector record pages, to provide greater clarity on who, operator or owner, holds the duty of care and regulatory compliance oversight responsibility for the flight, or series of flights, being undertaken.

Flight tasking and planning

G-RAYN's tasking for the 1 November series of flights was generated in response to the helicopter owner's request for return flights for five passengers between Lisvane and LEA2. The operator's ground operations staff followed their normal processes, using their planning tool to validate task feasibility before accepting the request. The OMA required planners to consider day/night implications and the suitability of landing sites '*during the quotation process*.' Both LEA2 and Lisvane were listed as Estimated HLSs in the CLSD and, therefore, night operations at them were not permitted by the OMA. The departure from LEA2 was scheduled for 1630 hrs, 15 minutes before sunset. The evening arrival and departure at Lisvane were planned to occur at night.

A departure from LEA2 before 1715 hrs would have been classed as a daytime takeoff, and thereby compliant with the OMA day-only restriction on Estimated HLSs. The tasking documentation generated for the pilot did not include sunset times, neither did it outline any contingency planning considerations for a delayed departure from LEA2.

While Lisvane had been surveyed in 2017 and approved for day and night flights, incomplete transfer of data to the extant (2019) version of the CLSD meant the survey details were not included in the accident pilot's tasking documentation. The discrepancy between the 2019 CLSD's Estimated HLS categorisation for Lisvane and its '*Day + Night*' status had not been resolved in the intervening period leading up to 1 November 2022. On both versions of the CLSD, the reported dimensions of the landing site were less than the OMA-specified minima of 110 m x 60 m for a night HLS.

The CLSD entry for LEA2 was potentially ambiguous regarding day/night status.

While the pilot was aware of the sunset time at LEA2, he was under the misapprehension that the OMA allowed him to depart from LEA2 at night because he was operating a non-revenue, private flight. The OMA specifically stated that no deviation from CAT criteria could be applied to night HLS operations, regardless of flight category.

The operator has since undertaken to work with the developer of the planning tool to explore the possibilities for further exploiting the tool's capabilities for increasing operational oversight and providing additional information to pilots through enhanced tasking documentation.

> As a safety action, the operator had issued additional instructions to their pilots regarding the process for updating site entries and were working with the planning tool's developer to align the CLSD management protocols and templates to their requirements.

Decision making and commercial pressure

The existence of the OMA derogations for certain aspects of non-revenue operations and contradictory entries in the CLSD contributed to the pilot's misinterpretation of company regulations. Believing he could waive the day-only restriction, as the scheduled 1630 hrs departure time approached, the pilot saw no need to hurry the passengers. They did not apply pressure on him to delay the flight. While not an explicit factor in this accident, commercial and customer pressure is an unavoidable element of corporate helicopter operations. The operator had established procedures to alleviate pressures on individual pilots, whereby difficult conversations with customers would be the responsibility of duty managers. The judgement of when to refer to a duty manager was subjective, rather than objective. Inevitably, successful operations delivering client satisfaction require a flexible and proactive approach by pilots in command who are directly responsible for delivery of an expected level of service. Continually exposed to this operational environment, the danger is that pilots become acclimatised into an excessively 'can do' mindset where the balance of what is possible versus what is appropriate becomes tilted toward a more risk-tolerant approach.

The operator declared an intent to review the scope and suitability of training for handling commercial and customer pressure currently provided as part of its recurrent CRM syllabus.

TEM

The investigation found that, while TEM was included in the CRM training syllabus for the operator's flight crew, the level of understanding of how it could be used to best effect was not fully appreciated across the organisation.

While the pilot identified weather and delays as holistic threats for the flight from LEA2 to Lisvane, a more effective TEM strategy would have focused on the specific threats for each phase of the flight. For the accident flight takeoff, significant threats were the degraded visual environment coupled with a lack of HLS lighting, the presence of trees behind and relatively close to the helicopter, and the westerly wind blowing toward the trees. These combined threats gave rise to the potential error of an inaccurate hover leading to reduced separation from the treeline. The investigation considered that had the pilot been habituated to employing TEM in a more focused way he might have been more effective in identifying and proactively mitigating the takeoff threats.

The operator declared an intention to issue enhanced guidance to their personnel on the implementation of TEM, from initial planning by ground operations staff through to sector-level considerations for pilots. The intent would be to include guidance for both single and multi-pilot operations as well as suggested mitigations for known general threats. Once codified within the OM and the SMS, the policy would be referenced during training, checking and auditing activities.

Accident flight departure

Having flown into the site during the day, the pilot was aware of the presence of trees to the east of the landing site. To meet the OMA intent of operating to PC1 standards whenever possible, he planned for a vertical Category A departure as a precaution against engine failure. While night had fallen when he took off, the pilot assessed that he had sufficient visual references to safely conduct the intended departure manoeuvre. He described using light from the lodge's windows as his lateral marker and establishing a forward visual reference with the aid of the controllable searchlight.

As the helicopter lifted into the hover, the lodge's windows would have been in the helicopter's approximate 3 o'clock position, in line with the pilot's shoulders. Having turned into wind, the chosen lateral markers would have become more difficult to see, the pilot needing to look back over his shoulder to see the lights, approximately 30° behind his shoulder line (Figure 21). The lights' change in relative position would have made it harder to discriminate between real and apparent drift, degrading their usefulness as markers. As the helicopter translated rearwards the lights would have appeared to move closer to their original orientation in the pilot's 3 o'clock position.

Figure 21

Representation of pilot's sightline to lodge windows during departure (image © 2023 Getmapping plc)

During the time from lift off until the pilot committed to the climb the helicopter's attitude rose to 6° nose-up and G-RAYN was already moving rearward toward the trees before the attitude stabilised at approximately 7° nose-up. While the pilot reported having a "vague, but usable, horizon" ahead, he had not intended to use, nor appreciated, the amount of nose-up attitude selected. That the attitudes flown were similar to those used to generate the rearward trajectory for the earlier departure from Lisvane, indicates the external references available to the pilot were insufficient for accurate visual assessment of the helicopter's pitch attitude. G-RAYN's rearward drift was consistent with that predicted by the manufacturer's performance modelling based on the helicopter's recorded nose-up attitude and CG[32]. The investigation considered that, in twisting to look at the lodge lights, the pilot may have inadvertently applied increased rearward pressure on the control column, contributing to the higher than intended nose attitude.

The investigation also considered it likely that, having the searchlight beam directed ahead of the helicopter made it more difficult to assess rearward movement by reference to sightline shift from a close-in marker. Having the searchlight beam directed 30-60° right, rather than straight ahead, could have aided detection of longitudinal drift. Training to depart from an unlit HLS might have helped the pilot avoid these pitfalls, nonetheless, the operator's chosen mitigations were to prohibit night operations at Estimated HLSs and to stipulate a minimum lighting standard for Surveyed sites. Following this accident, the operator intended to investigate the potential for pilots to practise night takeoffs, with environmental lighting conditions "near to official dark" in a flight simulator where one is "available and capable of this training."

Footnote

32 Albeit modelling weight set to MTOW limit of 3,175 kg.

Survivability

The specific crashworthiness features introduced on the AW109SP appeared to function well. There was no fuel leak and no post-crash fire and the structural integrity of the main crew and passenger compartments were not breached. This reduced the severity of risk and protected crew and passengers against more severe or even lethal post-accident consequences in what was considered a survivable accident.

The pilot had not delivered a passenger safety brief for either flight and had not confirmed that all passengers had fastened their seatbelts prior to the departure from Lisvane or on the accident flight. Most, if not all, of the passengers were unrestrained on the accident flight. The investigation did not have data to support a detailed analysis of how the wearing of seatbelts would have affected the injuries sustained by the passengers during the accident sequence.

Ensuring that passengers are appropriately briefed and seated with harnesses secure is a regulatory obligation placed on aircraft commanders. Following this accident, the operator undertook to review different methods of delivering passenger briefings and any training that might be required to support a change in methodology.

> The operator had taken specific safety action to remind pilots that, irrespective of a passenger's previous flying experience or status, safety briefings and a check of seatbelt/ harness security must be carried out for every flight, as per the OM.

Weight and balance

Although not a causal factor, G-RAYN was above the RFM MTOW limitation of 3,175 kg when it took off on the accident flight. It had also been above the MTOW limit when it departed Lisvane that morning. While he reported for duty ahead of his nominated check-in time, the pilot was distracted by the unanticipated conversation with his bereaved colleague and had not opened a tech log entry for the day's flying.

No auditable WB calculations for the day's flying were provided to the investigation. Data from the software navigation application on the tablet device the pilot was using for the flight showed that the WB function had not been accessed on any of the sectors. The application remained set at its default parameters, which would have generated a CG warning if checked.

Using the tablet-based software navigation application's WB function or completing the tech log SRP loadsheet prior to each sector could have been a barrier to the aircraft taking off above MTOW.

While the OMA required the SRP loadsheet to be completed for all flights, this requirement was not always complied with for NCO flights. One instance of the SRP loadsheet being incorrectly calculated was found in the tech log recovered from the aircraft.

Exporting acceptable sector fuel ranges, as automatically calculated in the planning tool, to the pilots' tasking paperwork could have been another barrier against MTOW exceedances resulting from excess fuel on board. The investigation was not able to resolve the discrepancy between the pilot's recollection of the weight of fuel on board at takeoff and the physical quantity recovered from G-RAYN at the accident site. Data recovered from the helicopter indicated that its fuel displays would have been showing a combined total of just above 400 kg as G-RAYN lifted from LEA2.

> In December 2022, the operator issued an internal Flying Staff Instruction to remind all pilots that the load sheet section of the technical log sector record page must be completed for every sector on all flights, including NCO. They also amended the default WB configuration in the pilot's software planning application and undertook a review of representative fuel burn rates to be used for flight planning purposes.

SMS

The risk of night off-airfield landings had been identified as one of the operator's top risks in their SMS. There was no explicit mention of the risks associated with night off-airfield takeoffs but in many regards the risks could be directly read across. The operator commented that they had been unable to find an authoritative guide to the specifications for, and procedures for using, a NATO-T lighting array.

> Safety actions taken by the operator to further manage the risk of night off-airfield night operations were as follows:
>
> - A new Integrated Management System was developed to improve operator processes for the management of hazards. This included a new generic risk assessment for off-airfield night operations that explicitly covered both night landings and night takeoffs.
> - In November 2022 an FSI was issued to re-iterate the requirements for night off-airfield operations. This was subsequently incorporated into the OM.
> - Deployable lighting sets were procured for use on flights where there was an identifiable risk of an unscheduled night takeoff resulting from a delay to the planned programme.
> - Landing site risk was added as an additional criterion in the OM pre-flight risk assessment tool, with night off-airfield operations attracting the highest risk factor loading.

Training

ORO.FC.202(b) did not explicitly mandate that pilot recurrent checks should contain an element of night flying but did require such checks to be conducted '*in an environment representative of the operation*.' The regulator's interpretation was that for operators undertaking night flying operations, '*an environment representative of the operation*' would include night flying elements.

The operator had not inferred from ORO.FC.202(b) that their instrument rated pilots were required to undergo any form of recurrent night proficiency training or checking. The accident pilot held a valid IR and none of his recurrent proficiency checks on the AW109 type included an element of night flying. The pilot could not recall having been trained or checked as proficient to operate from an unlit HLS at night during his employment with the operator.

The operator's Safety Action Group had identified a training need for operations utilising its contracted portable HLS lighting system but an illness-related delay meant the planned training had not been completed before the accident occurred.

> The operator took safety action to instigate an annual night flying training programme for all its onshore charter pilots (employees and contractors). The programme's syllabus specified theoretical training on night procedures and site surveys as well as a flying element to include night takeoffs and landings using a NATO-T lighting array. The first iteration of this training programme was conducted in November 2022.

Conclusion

The accident resulted from the undetected rearward transition of the helicopter into a stand of trees during a planned vertical departure at night from an unlit HLS. No causal or contributory technical factors with the helicopter were discovered.

The investigation identified several barriers that were either breached or not present which might have prevented this accident. Contradictory and potentially confusing CLSD entries and differing requirements for CAT and non-revenue flights, combined with colloquial legacy terminology, offered an opportunity for misinterpretation over the applicability of the OMA restrictions at the HLSs being used on the day.

Opportunities were also missed during the planning process to anticipate and develop proactive mitigation strategies for delays to the published flight schedule. There was an air gap of information where data such as sunset time and acceptable sector fuel loads were available in the operator's planning tool but not presented to the pilot. Distraction and time pressure contributed to the pilot not completing auditable WB calculations which could have alerted him to the potential for MTOW exceedances. Offloading planning tasks from pilots to the planning tool could have reduced their pre-flight workload, thereby releasing capacity in a time-pressured operation.

The pilot could not recall having been trained to takeoff from an unlit HLS but judged there to be sufficient lighting for his intended departure. Even with the helicopter's external lights to aid vision, the "vague horizon" and lights from the lodge windows proved inadequate visual reference for the pilot to detect unintentional rearward drift during the climb. The pilot's focus on delivering the expected service to the clients, despite the challenges posed by a night departure from an unlit site, was indicative of an insidious acclimatisation to risk engendered by long term exposure to the nature of commercial and corporate charter operations.

Acclimatisation to risk is not the sole purview of pilots. For owners and frequent flyer passengers, or those focused on time pressures, it is tempting to see safety briefings and seatbelts as an unnecessary encumbrance. Nonetheless, it is important that all parties realise an aircraft commander is under a legal obligation to ensure passengers are appropriately briefed and have their harnesses secure for all takeoffs and landings. A shared understanding of this obligation is key to expectation management in this regard.

Effective TEM could have provided an additional safety barrier for the accident flight.

Safety Actions

Following the accident, the operator took the following safety actions. They:

- Amended their Operations Manual, flight documentation, and aircraft technical log sector record pages, to provide greater clarity on who, operator or owner, holds the duty of care and regulatory compliance oversight responsibility for the flight, or series of flights, being undertaken.
- Issued additional instructions to their pilots regarding the process for updating company landing site directory entries and are working with the planning tool developer to align the directory management protocols and templates to their requirements.
- Reminded pilots that, irrespective of a passenger's previous flying experience or status, safety briefings and a check of seatbelt/harness security must be carried out for every flight.
- Issued an internal Flying Staff Instruction to remind all pilots that the load sheet section of the technical log sector record page must be completed for every sector on all flights.
- They also amended the default weight and balance configuration in the pilot's software planning application and undertook a review of representative fuel burn rates to be used for flight planning purposes.
- Developed a new Integrated Management System to improve operator processes for the management of hazards. This included a new risk assessment for off-airfield night operations that explicitly covered both night landings and night takeoffs.
- Issued a Flying Staff Instruction in November 2022 to re-iterate the requirements for night off-airfield operations.
- Procured deployable lighting sets for use on flights where there was an identifiable risk of an unscheduled night takeoff resulting from a delay to the planned programme.

- Instigated an annual night flying training programme for all its onshore charter pilots (employees and contractors). The programme’s syllabus specifies theoretical training on night procedures and site surveys as well as a flying element to include night takeoffs and landings using a NATO-T lighting array. The first iteration of this training programme was conducted in November 2022.
- Added landing site risk as an additional criterion in the OM pre-flight risk assessment tool, with night off-airfield operations attracting the highest risk factor loading.

Published: 18 April 2024.

Accident

Aircraft Type and Registration:	1) Ventus-2CT, G-KADS 2) E1 Antares, G-CLXG
No & Type of Engines:	1) 1 Solo Kleinmotoren Gmbh 2350 piston engine 2) 1 Lange Flugzeugbau EA 42 electric engine
Year of Manufacture:	1) 2012 (Serial no: 231) 2) 2019 (Serial no: 89E58)
Date & Time (UTC):	17 August 2023 at 1356 hrs
Location:	Melton Mowbray, Leicestershire
Type of Flight:	1) Private 2) Private
Persons on Board:	1) Crew - 1 Passengers - None 2) Crew - 1 Passengers - None
Injuries:	1) Crew - 1 (Fatal) Passengers - N/A 2) Crew - None Passengers - N/A
Nature of Damage:	1) Aircraft destroyed 2) Damage to right wing and wingtip missing
Commander's Licence:	1) Sailplane Pilot's Licence 2) Sailplane Pilot's Licence
Commander's Age:	1) 67 years 2) 78 years
Commander's Flying Experience:	1) 2,760 hours (of which 458 were on type) Last 90 days - 138 hours Last 28 days - 82 hours 2) Approx 2,500 hours (of which 188 were on type) Last 90 days - 18 hours Last 28 days - 6 hours
Information Source:	AAIB Field Investigation

Synopsis

During a gliding competition flight, both gliders entered a thermal just to the south of Melton Mowbray at a similar height. Although the gliders were initially on opposite sides of the thermal, changes in the angle of bank of both gliders brought their flight paths into conflict and they collided. The pilot of G-CLXG was able to land his glider safely and was uninjured but the tail of G-KADS was severed in the collision and the glider descended out of control. The pilot was fatally injured.

The British Gliding Association (BGA) took action to raise awareness regarding the increased risk of midair collisions in gliding competitions.

History of the flight

Both gliders were taking part in a competition being held at Husbands Bosworth gliding centre. The competition took the form of a multi-day event with a different route and task set daily for the participants. Both the pilot of G-CLXG and the pilot of G-KADS had significant experience in gliding and fixed wing flying. Both had flown numerous competitions before and had operated in many different environments.

On the day of the accident the task consisted of a multi-leg route with turning points. G-CLXG launched first at 1236 hrs with G-KADS following a minute behind. The task took the gliders north-northeast from Husbands Bosworth towards a turning point just north of Melton Mowbray before routing south to the next point close to Oxford. Both gliders completed the first leg and were en route to the second turning point when the accident happened (Figure 1).

Figure 1
Location of the accident ©Google 2024

Having left the first turning point the pilot of G-CLXG entered a thermal just south of Melton Mowbray at 1352 hrs to gain some height for his onward flight. As he could see there was already a glider in the same thermal, he joined turning in the same direction (left) as that glider. He had completed two turns in the thermal when the pilot of G-KADS also joined the thermal at 1354 hrs and at approximately the same height. The pilot of G-KADS also made his turns to the left to match the manoeuvring of the other gliders in the thermal. G-KADS was positioned between the 5 o'clock to 7 o'clock positions relative to G-CLXG. The aircraft remained in these relative positions for three complete turns in the thermal.

As the pilot of G-KADS began a fourth turn in the thermal he increased his angle of bank and therefore his turn rate. Shortly afterwards the pilot of G-CLXG began the process of leaving the thermal once he had completed the fourth turn by starting to decrease his bank angle and therefore rate of turn. As a result, G-KADS turned inside the path of G-CLXG and this brought the two flight paths into conflict as both were at around the same height. The two gliders collided at 1356 hrs at an altitude of 2,900 ft amsl with the right wing of G-CLXG severing the tail of G-KADS. G-KADS began to tumble out of control and struck an area of rough ground between houses in the southern area of Melton Mowbray. The pilot was fatally injured. The pilot of G-CLXG initially intended to abandon his glider but found he had sufficient control and was able to land in a field. The right wing of G-CLXG was damaged and the right winglet and outboard flaperon[1] were missing. The pilot of G-CLXG was uninjured.

Accident site

G-KADS

The glider, minus the tail and a section of the rear fuselage, struck the ground in a grass field beside a housing estate on the southwest edge of Melton Mowbray (Figure 2). The rear fuselage and tail fell to the ground 450 m to the west of the main accident site, in an open area of vegetation.

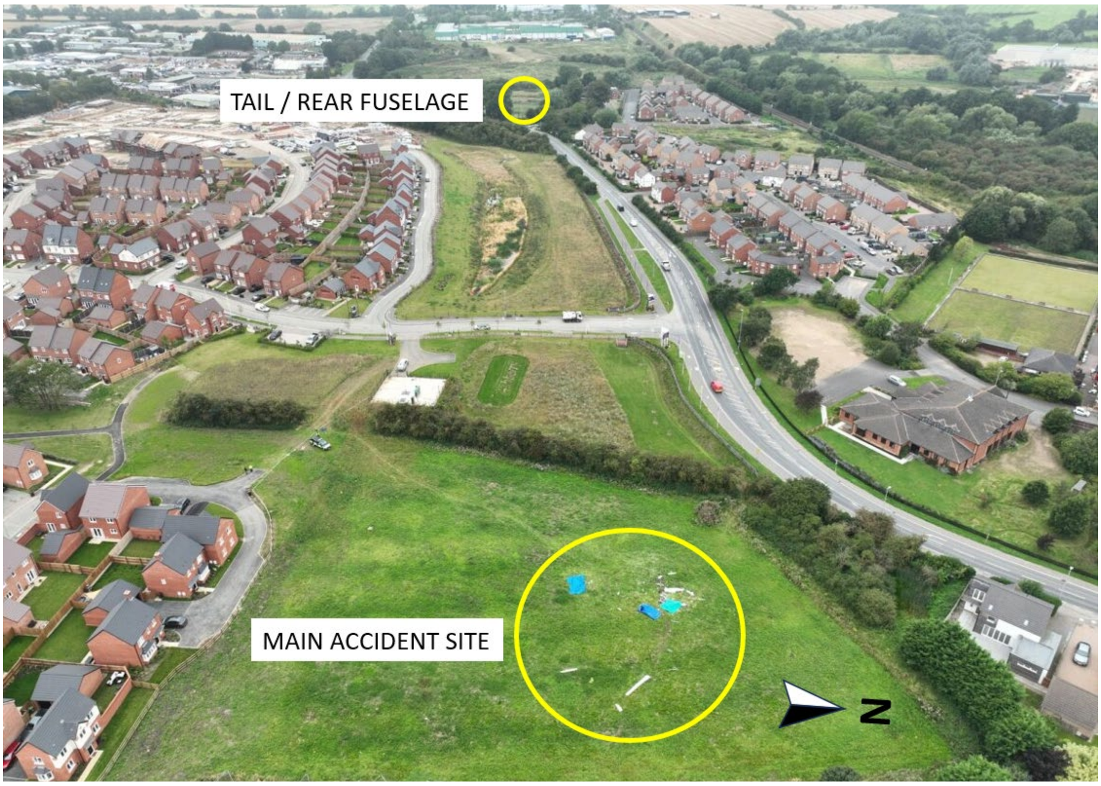


Figure 2
G-KADS accident site

Footnote

1 A flaperon is a trailing edge control surface combining the roll-control function of an aileron with the increased lift function of a flap.

The glider struck the ground at high speed in a nose-down, left wing low attitude. The impact was not survivable, and the glider was destroyed. Examination of the wreckage identified that the airbrakes were open at impact, although it was not possible to determine whether they had opened in flight due to the collision impact on the airbrake mechanism, or by pilot action. The landing gear was up. Deformation of the canopy latching mechanism showed that the canopy was latched closed at impact. The pilot's four-point seat harness was fastened, and his parachute had not been used, with the ripcord present in an undeployed condition. The glider's fuel tank was found punctured with no fuel present, and no fire had occurred.

G-CLXG

G-CLXG landed in a grass field 1.4 nm southeast of the G-KADS accident site. The glider was mostly intact apart from the right winglet and outermost section of right flaperon which were missing and not subsequently recovered (Figure 3).

Figure 3
G-CLXG after the field landing

G-CLXG's right wing was damaged between 1.6 m and 3.5 m outboard from the wing root due to the impact with G-KADS' rear fuselage. The upper and lower wing skins were torn and delaminated, and the flaperon control surface at the trailing edge had split open due to rearward deflection of the wing (Figure 4). The right flaperon moved in response to movement of the control column through the flaperon inboard and outboard drive arms, which were undamaged. The battery compartment access panel in the lower wing skin was missing, the battery pack was not damaged and the powerplant battery management system did not indicate that any faults were present.

Figure 4
Damage to G-CLXG's right wing

The outer right wingtip, adjacent to the missing winglet and flaperon section, was damaged with paint cracking at the leading edge and large areas of delamination of the lower wing skin from the foam core material. There were no witness marks present on these damaged areas indicating that this damage had not been caused by direct contact with G-KADS during the collision but was due to the wing's structural response when the collision occurred.

Recorded information

G-KADS

Several items of substantially damaged avionics were recovered from the wreckage of G-KADS including a lxnav LX9070 moving map and task planner.

The non-volatile memory from these units was, in part, recoverable but none of the recovered data pertained to the accident flight.

G-CLXG

G-CLXG was fitted with a lxnav LX9000, a very similar unit to the LX9070 fitted to G-KADS, but with a smaller display. As G-CLXG was able to successfully land, the integrated flight logger was downloaded for the incident flight. The flightpath for G-CLXG is shown below in Figure 5.

FLARM devices

The LX9070 fitted to G-KADS and the LX9000 fitted to G-CLXG both incorporated FLARM transceivers; FLARM is an electronic system designed to alert pilots to a potential collision.

FLARM units use GPS position and barometric data to accurately position themselves and they transmit this information to other FLARM units within range. This information is then processed by an algorithm within each FLARM unit to predict any potential conflicts with other nearby FLARM equipped aircraft. FLARM does not only consider how close another aircraft is but whether its flight path presents a threat of collision. It provides the pilot with the location and the threat level of other aircraft, based on time to collision, but offers no solution for avoidance. It is up to the pilot to locate the other aircraft visually and to take action to avoid a collision.

The use of FLARM devices is common on gliders, which don't always carry conventional ATC transponders. These transmissions can be received by suitably configured receivers on the ground, processed and then re-transmitted to provide other airspace users with an awareness of glider activity. The AAIB, using data from one such service provider, was able to retrieve the position information transmitted by G-KADS and this is shown, alongside the flightpath of G-CLXG, in Figure 5 as both gliders manoeuvred in the thermal.

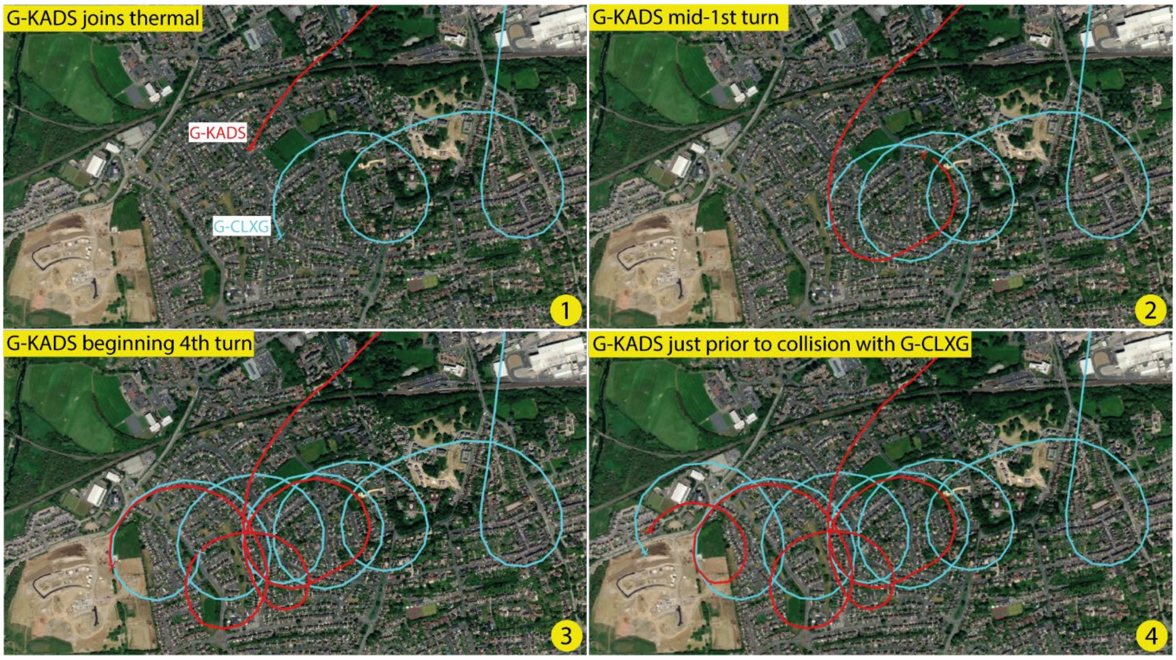


Figure 5

Flightpaths of G-KADS and G-CLXG in a thermal prior to the collision
© 2022 SeeYou software by Naviter

Both gliders had models of FLARM that integrated into large LCD navigation displays in the cockpit. The models fitted to both gliders work with three levels of alert:

- Low alarms: For distant FLARM targets (13-20 seconds before possible collision).
- Medium alarms: For distant FLARM targets (7-12 seconds before possible collision).
- High alarms: For very close FLARM targets (0-6 seconds before possible collision).

The equipment allows the pilot to select various options for the FLARM warnings including which levels of warnings are displayed, how the warnings are displayed and whether an audio tone sounds. There is an option for a voice annunciation and the pilot is able to cancel or silence the warnings for up to a minute in flight. The manufacturer of the units recommends that for competition flying the warning threshold is either set to Medium (only alerting for medium or high risk) or High (only alerting for high risk) because otherwise too many warnings may be triggered. The scale of the navigation screens can also be adjusted to meet the requirements of the pilot at that point in flight.

The pilot of G-CLXG had not changed the default factory settings of his FLARM and it was therefore set to show warnings at the Low setting (showing all warnings low, medium and high). The investigation could not establish what settings the pilot on G-KADS had on his FLARM.

FLARM log

The FLARM units fitted to G-KADS and G-CLXG were both PowerFLARM which have a greater detection range and reception capability from a wider range of electronic conspicuity devices than standard FLARM.

Examination of the flight log downloaded from G-CLXG, showed the presence of encoded FLARM status messages. These were analysed by the manufacturer, FLARM Technology AG, and this showed that G-KADS was detected by G-CLXG's FLARM, prior to G-KADS joining the thermal that G-CLXG was established in.

It was also possible using historic data for G-KADS and G-CLXG to show that both FLARM installations had good coverage and detection range, with no significant blind spots.

FLARM modelling

FLARM Technology AG were also able to model the expected performance of both gliders' FLARM installations. They concluded that both units would have provided 4-5 seconds of warning prior to the collision if the alerts on each individual device had been correctly configured and not supressed. The modelling also made certain assumptions about each device's quality of radio coverage and the veracity of the source data used for the modelling.

Witnesses

There were several other gliders around the area in which the collision occurred. Whilst none of these pilots saw the collision, they did see both aircraft in the thermal. Other pilots reported that the thermals that day were relatively weak due to the strength of the wind but that the day was perfectly good for the task they were to fly. They reported that the cloud base did mean that the gliders were compressed into a relatively small height band when they were in a thermal.

A witness on the ground saw the collision and reported that one glider seemed to be slightly above the other one but that they were on the same trajectory, turning left. The witness saw the two gliders collide and heard what was described as an "almighty bang." The witness described that the tail of G-KADS came off immediately and fell straight down with the aircraft then tumbling forward, nose first. The witness lost sight of G-KADS as it descended.

Aircraft examination

The recovered parts of G-KADS' fuselage were reassembled (Figure 6). This showed that G-CLXG's right wing had struck the fuselage from below, in an upwards direction. The rudder cables, fin ballast tank dump cable and elevator pushrod had failed in overload and the pitot-static system tubes were severed.

Figure 6

Detached section of G-KADS' rear fuselage and fin

Survivability

The pilots of both gliders were wearing parachutes. Examination of the canopy release mechanism of G-KADS showed that no attempt was made to jettison the canopy. It is possible that the pilot was rendered unconscious by the collision or that the forces on him due to the motion of the glider once it lost its tail meant he could not make any attempt to abandon the aircraft before it struck the ground. The time between the collision and G-KADS striking the ground was around 18 seconds.

Aircraft information

G-KADS

G-KADS was a single-seat glider with a wingspan of 18 m. The annual maintenance check was completed on 31 January 2023 and the glider had a current Airworthiness Review Certificate. The glider was equipped with a retractable powerplant consisting of a two-cylinder piston engine and five-bladed propeller which stowed in the fuselage when not in use. It was constructed from composite materials and was painted white, with the registration markings and competition number 'KS' painted in purple. It did not have any high-contrast paintwork and was not fitted with a strobe system.

G-CLXG

G-CLXG is a single-seat powered glider with a wingspan of 20 m, equipped with an electric powerplant permitting the glider to self-launch as an alternative to launching by aerotow. The powerplant runs on lithium-ion battery packs mounted in the wings, between the leading edge and the main spar. The annual maintenance check was completed on 7 April 2023 and the glider had a current Airworthiness Review Certificate. It was constructed from composite materials and was painted white, with the registration markings and competition number '895' painted in dark blue. It did not have any high-contrast paintwork and was not fitted with a strobe system.

View from the cockpits

All gliders have blind spots where the pilot cannot see. These are most often the 45° segment behind the pilot and a 45° segment below. There may also be areas which are obscured by the aircraft canopy frame although both G-KADS and G-CLXG were modern gliders with good visibility and a single piece canopy/windscreen.

External lighting

Neither glider was equipped with anti-collision lights or strobes, nor were they required to be. Gliders have not traditionally been fitted with external lights as most were not flown outside of daylight hours. Older lights were also often heavy and had significant power requirements which could not be met by a glider. Modern light-emitting diode (LED) technology offers a low weight and very low power alternative. There are systems available for gliders offering very bright lights in both red and white, which can be fitted to improve visibility of the glider to other pilots. These systems can also be integrated with FLARM, changing the strobe flash rate and/or colour if a FLARM warning is triggered.

Meteorology

An aftercast showed that there was an area of high pressure over Scandinavia and a low-pressure system over the Atlantic to the west of the UK. There were no frontal systems affecting the area with generally south-easterly winds and good visibility. There were some scattered clouds in the area although these were breaking up and the sky was largely clear. The sun was in south southwest and was 50° above the horizon meaning it was relatively high in the sky. Reports from other pilots flying in the area of the collision reported that where there was cloud, the base was around 3,000 ft agl.

Organisational information

Glider soaring

A thermal is an upward current of warm air and glider pilots will use thermals to gain height. They will circle around the centre of a thermal as they attempt to climb. Once pilots have found a thermal, to gain the best lift they need to find and remain in the centre, this may involve increasing or decreasing their radius of turn. Pilots may have differing ideas as to the location of the centre of the thermal and therefore where the best lift may be found. With gliders in a competition flying the same or very similar routes, it would not be uncommon for there to be several gliders all entering and climbing in the same thermals along the route.

BGA guidance

The BGA Soaring Protocol[2] describes the safety protocols to be used when soaring. The protocol had been developed through many years of experience and accident/incident analysis. The protocol does not replace the need for pilots to obey the rules of the air or the Air Navigation Order.

The protocol suggests that when joining a thermal, a pilot should circle in the same direction as those already established, that the entry into the thermal should be planned so as to retain continual visual contact with other aircraft at or near the entry height and that established gliders have right of way. Once in the thermal the protocol emphasises that lookout is paramount and that pilots should not neglect it to look inside at the cockpit. Pilots are advised to maintain visual contact with the other gliders and to position so that the other pilots can also see them. One glider should never turn inside another glider at a similar level as to do so may risk reducing their separation. If a pilot turns inside another glider, there can be a period in which neither pilot can see the other glider. The protocol recommends that should a pilot lose visual contact with a nearby glider then then safest action would be to leave the thermal.

Competition flying

The BGA describes competition flying as an important part of gliding. Competitions offer pilots the chance to fly alongside like-minded people, compare their skills, learn from others as well as to enjoy some social activities and meet others from around the country. Events can last from a single day to multiple flights over a two-week period. Many glider pilots enjoy taking part in competitions both at their home airfields and when visiting others.

BGA gliding competitions are organised in accordance with the BGA '*Rules for Rated Competitions*'[3]. This document contains the rules and procedures for organisers and competitors to follow. Pilots need to be familiar with the contents of the rulebook as well as any local rules and procedures for the airfield they are flying from. The competition day begins with a briefing where topics such as the weather, the tasking for the day, airspace and any safety issues that might have occurred are covered. The rulebook also contains a requirement for a pilot safety committee to be formed, which can review any reported safety or flying standards infractions and take action as required up to and including escalating safety concerns to the competition director. The BGA also has an extensive section on its website on managing flying risks[4] including a section on flying in glider competitions.

Competition flying motivates pilots in ways that can be subconscious. Motivations can be different for different pilots with some enjoying the overall experience, rather than comparing

Footnote

2 https://members.gliding.co.uk/library/safety-briefings/soaring-protocol/ [accessed October 2023].
3 https://members.gliding.co.uk/library/competitions/bga-competition-rules/ [accessed February 2024].
4 https://members.gliding.co.uk/safety/managing-flying-risk-index/ [accessed February 2024].

themselves against others, whilst others are keen to perform well and test themselves. Competitive flying can bring with it an increase in risk with some pilots taking perhaps greater risks than they might do outside of that environment. Pilots may observe such behaviour or actions of other pilots and assess them as safe and acceptable.

Competitions also bring large numbers of gliders together in one area, often flying the same routes and using the same thermals. This means the safety advice contained in the BGA Soaring Protocol is essential risk mitigation for all the pilots.

Midair collision statistics

The investigation analysed all midair collisions that occurred in UK airspace in the period between 2003 and 2023. In this period, 39 collisions between 78 aircraft were identified (a table listing the collisions is provided in Appendix 1), of which 15 involved one or more fatalities to the aircraft occupants. No collisions involved a commercial air transport aircraft, and no person on the ground was injured because of a collision. The types of aircraft involved were identified and divided into the following four categories:

- General Aviation (GA) – A powered aircraft or rotorcraft with a maximum takeoff mass less than 5,700 kg.
- Glider.
- Tug – A light single-engine piston aircraft engaged in aerotowing operations when the collision occurred.
- UAS – An unmanned aerial system, either a model aircraft or a drone.

The collisions were grouped according to the type of aircraft involved (Figure 7). The number of fatalities to aircraft occupants in each collision is listed, as is whether any of the aircraft were involved in a competition at the time.

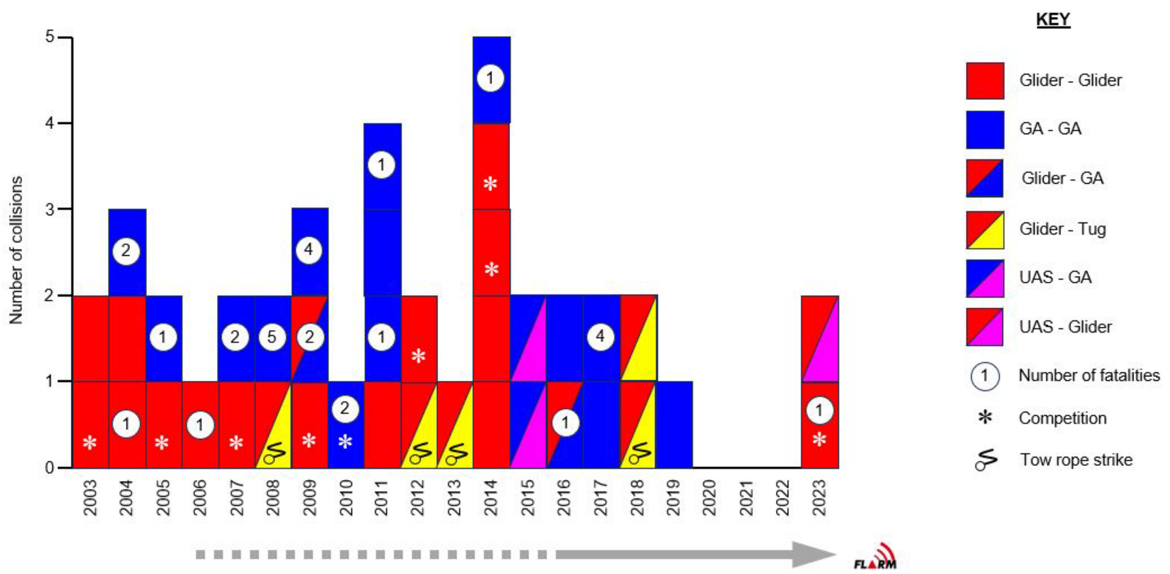


Figure 7

Chart of UK midair collision events, 2003-2023

There were 15 collisions between gliders in the period, three of which involved a fatality. Eight collisions occurred between gliders participating in a competition. Of the 30 gliders involved, 18 landed safely and 12 crashed. Ten pilots were able to parachute to safety following a collision. Analysis of flight recorder files showed that, in 2022, gliding competitions accounted for 8.5% of all glider hours flown in the UK.

The introduction of FLARM to the UK glider fleet began in approximately 2006 and a large proportion of the fleet was equipped by 2016. The collision between G-KADS and G-CLXG was the first collision between gliders to have occurred since 2014. It is only the second collision in the UK known to have occurred where both gliders were equipped with FLARM.

Other information

Pilot experience

Both the pilot of G-CLXG and the pilot of G-KADS had significant experience in gliding and fixed wing flying. Both had flown numerous competitions before and had operated in many different environments.

See and avoid

The primary means of avoiding other aircraft is using the see-and-avoid principle. This relies on the pilot seeing another aircraft, identifying it as a threat or not, and taking action to avoid any conflict if required. In 1991 the Australian Transport Safety Board completed a research study into the limitations of the see and avoid principle.[5] Although the work is over 30 years old, the limitations identified are still applicable today. The report outlined that there are limitations in the human visual and information processing system which can reduce the effectiveness of the process. These limitations are not a lack of skill or effort on behalf of the pilot but reflect the very fact that pilots are human. The BGA also provides a comprehensive summary of the principals and limitations of lookout.[6]

For see and avoid to be an effective barrier to a collision the pilot must ‘see’ the threat. Seeing the threat can be compromised by the effectiveness of the pilot’s visual scan, by the field of view from the cockpit, by how the target stands out against the background, whether the pilot is engaged with other tasks which are taking attention away from the scan, and by psychological factors such as whether the pilot is expecting to see an aircraft in that area. Seeing an aircraft behind you can be challenging as the view may be partially or totally obscured by structure, and it requires a significant physical effort to shift the head and upper body to look effectively behind. Gliders tend to be predominantly white which can provide a poor contrast against a light background such as the sky. Whilst gliders often have large wings in proportion to their size, their wings are often long and thin with the overall effect that gliders often present a small target for others to spot.

Footnote

5 https://www.atsb.gov.au/publications/1991/limit_see_avoid [accessed November 2023].
6 https://members.gliding.co.uk/wp-content/uploads/sites/3/2017/08/1-5-LOOKOUT-2017.pdf [accessed November 2023].

Whilst electronic systems such as FLARM can provide the pilot with timely information on collision risks with other equipped aircraft they can only be an aid to a pilot lookout. The BGA states that:

> *'Pilots are reminded that whilst electronic collision warning equipment can enhance pilots' awareness by providing most useful warnings, such equipment cannot and must not replace a good systematic visual lookout scan.'*

Reaction to alerts

It is possible that pilots who experience repeated alerts or alarms from aircraft systems can begin to disregard or pay less attention when they sound even if those alerts are genuine. When a number of gliders are flying around the same area it is possible, especially with the alert level set at low (alerting for low, medium and high threat traffic), that the FLARM alerts and aural tones may be triggered in the cockpit repeatedly. In combination with the possibility of repeated alerts, if the pilot believes that they have the aircraft around them in sight, they may not make use of the information being presented by FLARM inside the cockpit.

Thermalling whilst close to other gliders can generate a high workload for the pilot which can mean that FLARM information is not prioritised. The pilot may be trying to gain altitude, trying to keep the other gliders in sight as well as adjusting the angle of bank to stay in position. The natural constraints of processing capacity within the brain can mean that the pilot awareness of FLARM alerts during periods of high workload is limited.

The pilot can also experience startle when an unexpected FLARM alert sounds in the cockpit especially if this alert is indicating another glider is very close. The pilot may respond rapidly by looking all around for the intruding aircraft without any particular focus on the area being indicated by the FLARM.

Analysis

The pilots of G-KADS and G-CLXG were taking part in a gliding competition. Having flown to the first turning point, both gliders were circling in the same thermal to the south of Melton Mowbray. After a number of turns in the thermal, the two gliders collided with the right wing of G-CLXG severing the tail of G-KADS. The pilot of G-CLXG was able to land his glider in a field nearby but the pilot of G-KADS was fatally injured when the glider struck the ground. Although the pilot of G-KADS was wearing a parachute, there was no attempt to abandon the glider. This could have been due either to the forces on him from the motion of the glider after the tail was lost or if he was rendered unconscious in the collision.

Visual contact

As the two gliders approached the point of collision G-KADS was slightly above G-CXLG and behind. The geometry of this meant that it is likely that neither glider was visible to the other with G-KADS sitting either partially or completely in the rear blind spot of G-CLXG, and G-CLXG sitting in the blind spot below G-KADS. The position of the sun would also have increased the difficulty for the pilot of G-KADS in seeing G-CLXG as during the final part of the flight G-KADS would have been pointing into the sun with G-CLXG ahead. As both the gliders were white with a small cross section, they may also have been challenging to spot against any white cloud in the vicinity.

Although both aircraft were equipped with FLARM, the alerts did not prevent the two aircraft colliding. FLARM can provide pilots with an excellent picture of the aircraft around them, but it remains an aid to see and avoid rather than the sole source of avoidance.

Competition risk

Competitions provide opportunities for pilots to mix with others within the sport as well as to test their skills within the community. They often place a larger number of gliders within a geographic area than normal flying and this can present a higher risk. Analysis of midair collisions over the period 2003 – 2023 showed that more than half the collisions between gliders occurred during gliding competitions, despite competitions accounting for approximately 10% of the overall gliding activity. The nature of a competition itself can also generate a desire to beat others, which carries with it subtle internal pressure to reduce safety margins more than might be the case in other flying. This pressure can be felt differently by different pilots.

BGA Soaring Protocol

The BGA Soaring Protocol is a document detailing the methods for joining, remaining in and leaving a thermal whilst soaring. The protocol is clear that pilots should never turn inside another glider whilst in a thermal as to do so risks both gliders losing sight of each other and increases the risk of a collision. In this accident, the separation between the gliders reduced due to G-KADS turning inside G-CLXG. It is not possible to know why the pilot of G-KADS did this, or if he lost sight of the other glider before doing so. This, combined with the pilot of G-CLXG starting to reduce his bank angle to leave the thermal, brought the gliders into conflict and the collision occurred.

Collision risk and electronic conspicuity

The introduction of FLARM to the UK glider fleet has coincided with a significant reduction in the number of collisions between gliders, including a nine-year period[7] where no such collisions occurred. Whilst the statistical sample size is small, it is likely that the additional situational awareness provided to glider pilots by FLARM has been a significant factor contributing to the decrease in collisions.

Conclusion

The pilots of G-KADS and G-CLXG were taking part in a gliding competition and had entered a thermal to the south of Melton Mowbray to gain some height. After several turns in the thermal, the pilot of G-KADS increased his rate of turn and started to turn inside G-CLXG. This reduced the separation between the two gliders and the geometry was such that it is

Footnote

[7] 2 September 2014 to 16 August 2023.

likely that neither glider was visible to the other. As G-CLXG then began to reduce his rate of turn to leave the thermal, the two gliders came into conflict as they were at the same height. A collision occurred in which the tail of G-KADS was severed. The pilot of G-KADS was fatally injured when the glider struck the ground.

The BGA Soaring Protocol contains clear guidance on thermalling and the dangers of turning inside another glider, which can reduce the separation between aircraft and the effectiveness of the see-and-avoid principle.

Safety action

The following safety action was taken by the BGA:

- The BGA has updated the *'Managing Flying Risk – Flying in Gliding Competitions'* section of their website.
- The BGA is to deliver a midair collision safety campaign, in the spring of 2024, aimed at pilots taking part in gliding competitions.
- The BGA is monitoring an initiative from FAI[8] International Gliding Commission which is evaluating a 'proximity monitoring tool' for evaluation of logger traces to identify unusually close proximity between gliders, as an aid to post-flight safety debriefs. If the tool proves to be useful, the BGA plans to adopt it for UK gliding competitions.

Footnote

[8] Fédération Aéronautique Internationale, the world governing body for air sports.

Appendix 1

#	Date	Aircraft	Reg	Location	Fatalities	AAIB accident number	Notes
1	11/08/2003	LS4 glider & Libelle glider	BGA4189 & BGA1630	Didcot	0	-	Collision in a thermal at 4,000 ft during competition. Both landed safely.
2	04/09/2003	ASW-27 glider & Discus glider	BGA4338 & BGA4092	Near Lasham	0	-	Collision in a thermal at 3,000 ft. Both pilots baled out.
3	26/04/2004	Skylark 4 glider & Ventus ct glider	BGA1116 & BGA3259	Near Lasham	1	EW/C2004/04/03	Collision at 4,000 ft during local flying. Skylark pilot baled out.
4	06/07/2004	Robinson 22 & Hybred 44XLR	G-LIDS & G-MTJP	Welham Green	2	EW/C2004/07/02	Collision at 1,200ft. Robinson 22 landed safely.
5	22/7/2004	Grob 103C glider & Vega T65C glider	BGA3574 & BGA2716	Lasham	0	-	Collision occurred on final approach, below 300 ft. Both landed safely.
6	18/12/2005	Cessna 152 & Eurostar EV-97	G-BNXC & G-GHEE	Moreton-in-Marsh	1	EW/C2005/12/01	Collision at approximately 1,000 ft. Eurostar landed safely.
7	26/7/2005	ASW-20 & Janus	BGA3419 & BGA4210	Lasham	0	-	Collision prior to task start during a competition. Both landed safely.
8	02/10/2006	ASW-19 & SF-27	BGA3752 & BGA3934	Sutton Bank	1	EW/C2006/10/02	Collision at 1,500 ft during local flying. SF-27 pilot baled out.
9	16/12/2007	Luscombe 8E & PAC750XL	G-AKUI & ZK-KAY	Rugely	2	EW/C2007/12/02	Collision at 2,000 ft. PAC750XL landed safely
10	14/7/2007	DG-600 & ASW-28	BGA4966 & BGA5161	Southam	0	-	Collision in a thermal during competition. Both landed safely.
11	17/08/2008	Cessna 402 & KR-2	G-EYES & G-BOLZ	Coventry	5	EW/C2008/08/05	Collision on approach path at 3 nm. Both aircraft crashed.
12	29/7/2008	PA-18 tug & ASK-21	N/K & N/K	N/K	0	-	Tug aircraft towrope struck K-21 during aerial photography. Both landed safely.
13	11/02/2009	Grob Tutor & Grob Tutor	G-BYVN & G-BYUT	Porthcawl	4	EW/C2009/02/02	Collison at 2,900 ft. Both aircraft crashed.
14	14/06/2009	Grob Tutor & Cirrus glider	G-BYXR & G-CKHT	Benson	2	EW/C2009/06/04	Collision at 4,200 ft. Cirrus pilot baled out.
15	28/7/2009	Antares 18S & Ventus 2ct	D-KAIB & G-EVII	Wittering	0	-	Collision in a thermal during competition. Both landed safely.
16	04/09/2010	Vans RV-4 & Mooney M20J	G-MARX & G-JAST	Isle of Wight	2	EW/C2010/09/01	Collision at 700 ft during an air race. RV-4 landed safely.
17	04/07/2011	Vans RV-6A & Diamond DA-40	G-RVGC & G-CEZR	Shoreham	1	EW/C2011/07/01	Collision in visual circuit at 1,100 ft. DA-40 landed safely.
18	10/07/2011	P-51D & AD-4N Skyraider	D-FBBD & F-AZDP	Duxford	0	EW/C2011/07/02	Collision during airshow 'break' manoeuvre. Skyraider landed safely.
19	18/12/2011	Taylorcraft & Pitts S2C	G-BVXS & G-IICI	Leicester	1	EW/C2011/12/01	Collision in the visual circuit at 1,000 ft. Pitts landed safely.
20	5/8/2011	K-21 glider & K-13 glider	N/K & N/K	Lasham	0	-	Collision in a thermal at 1,200 ft. Both landed safely.
21	23/07/2012	DG-100G glider & LS-7 glider	G-CKMG & G-CGBY	Newmarket	0	-	Collision in a thermal at 2,000 ft during competition. LS-7 landed safely.
22	30/5/2012	Rallye tug & LS-7	N/K & N/K	N/K	0	-	Tug aircraft overflew landing LS-7. Both aircraft landed safely.
23	18/05/2014	Discus glider & Arcus glider	G-CFFT & G-JKRV	Gransden Lodge	0	-	Collision in a thermal at 2,600 ft. Discus pilot baled out.
24	15/07/2014	ASW-19 glider & Mosquito glider	G-DDZG & G-DDUB	Portmoak	0	-	Collision during ridge soaring at between 1,600 and 2,000 ft. ASW-19 pilot baled out.
25	26/07/2014	Discus glider & LAK17 glider	G-IDER & G-CKOI	Little Paxton	0	-	Collision in a thermal at 4,000 ft during competition. Discus pilot baled out.
26	01/09/2014	Grob 103 glider & Cirrus glider	G-CJOG & G-CHRL	Aboyne	0	-	Collision at 4,000 ft prior to task start during a competition. Both Grob 103 pilots baled out.
27	5/10/2013	PA-25 tug & Discus	N/K & N/K	N/K	0	-	Descending tug aircraft towrope struck Discus in a thermal. Both landed safely.
28	23/09/2014	Kitfox & Cessna 177RG	G-TOMZ & G-AZTW	St. Neots	1	EW/C2014/09/03	Collision at 2,700 ft. Cessna landed safely.
29	05/04/2015	Pioneer 300 & model aircraft	G-OPFA & UAS	Upton-on-Severn	0	EW/G2015/04/12	Collision at 630 ft, Pioneer 300 landed safely.
30	30/04/2015	DR400 & model aircraft	F-GSBM & UAS	Shoreham	0	EW/G2015/04/27	Collision in visual circuit between 600-800 ft. DR400 landed safely.
31	30/09/2016	PA-28 & PA-28	G-CCZV & G-BZBS	Near Elstree	0	EW/G2016/09/23	Collision at 2,000 ft. Both landed safely.
32	04/12/2016	Cessna 150L & SZD-51 glider	G-CSFC & G-CLJK	Leicester	1	EW/C2016/12/01	Collision at 2,300 ft. Cessna landed safely.
33	23/09/2017	P-51D & P-51D	G-SHWN & G-BIXL	Duxford	0	EW/C2017/09/05	Collision during airshow formation flight. Both landed safely.
34	17/11/2017	Guimbal G2 & Cessna 152	G-JAMM & G-WACG	Waddesdon	4	EW/C2017/11/02	Collision at 1,030 ft. Both aircraft crashed.
35	08/06/2018	DR400 tug & K21 glider	G-LGCC & G-CFYF	Dunstable	0	EW/G2018/06/07	Collision at 900 ft. Both landed safely.
36	04/08/2018	DR400 tug & SZD-55	N/K & G-CHHR	Dunstable	0	-	Tug aircraft towrope struck SZD-55 canopy. Both landed safely.
37	23/06/2019	Cessna 172 & Fuji FA-200	G-HAMI & G-BXGV	White Waltham	0	AAIB-25830	Collision, both landed safely
38	17/08/2023	Ventus 2cxt glider & Antares E1 glider	G-KADS & G-CLXG	Melton Mowbray	1	AAIB-29483	Collision in a thermal at 2,300 ft during competition. Antares landed safely.
39	07/10/2023	T21 glider & UAS	WB924 & UAS	Dunstable	0	AAIB-29662	Collision at 100 ft during landing, T21 landed safely.

Published: 25 April 2024.

Accident

Aircraft Type and Registration:	VA-1X, G-EVTL
No & Type of Engines:	8 Equipmake HTM-1900 electric motors
Year of Manufacture:	2022 (Serial no: 1)
Date & Time (UTC):	9 August 2023 at 0715 hrs
Location:	Cotswold Airport (Kemble), Gloucestershire
Type of Flight:	Experimental flight test
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to right wing, fuselage, landing gear and engine pylon
Commander's Age:	60 years
Commander's Flying Experience:	More than 4,300 hours (of which 3 were on type) Last 90 days - 6 hours Last 28 days - 0 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was being flown by a remote pilot on a test flight at 30 ft agl when a propeller blade detached from the electric propulsion unit 3 forward motor due to a failure of the adhesive bond between the propeller blade sheath and spar. Large out-of-balance loads generated by the blade release caused structural failure of the right inboard pylon, resulting in damage to the aircraft's wiring harnesses. This caused a loss of thrust from motors 4 and 7. Whilst the aircraft's flight control system was able to maintain a level attitude, the high rate of descent caused by the loss of vertical thrust resulted in substantial damage to the aircraft when it struck the ground.

The aircraft manufacturer was, at the time of the accident, in the process of introducing a blade design that, amongst other things, eliminated the bonding failure mode that caused the blade release. The manufacturer's investigation identified 36 product and process improvements resulting from findings of the investigation.

History of the flight

G-EVTL was in the second phase of its test flying having completed the initial tethered phase. The accident flight was the twenty-second flight of the programme. The aim of the test was to look at one engine inoperative performance during out of ground effect hover. The aircraft was being flown remotely under the CAA Specific Category[1].

Footnote

[1] CAA Cap 722 Unmanned Aircraft System Operations in UK Airspace – Policy and Guidance http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=415 [Accessed September 2023].

Routine checks were completed, and the aircraft set up according to the test card. At 0712:16 hrs aircraft flight mode was selected, and all the electric propulsion units (EPUs) began idling. At 0714:25 hrs G-EVTL completed a normal vertical takeoff with all EPUs operating. Once the aircraft was stable in ground effect, the remote pilot shutdown EPU1 in accordance with the test card. At 0714:40 hrs the remote pilot then began a gentle climb to 30 ft agl. The test card required the aircraft to be stable at this height for 10 seconds before proceeding with the flight. This was completed and the remote pilot began a gentle acceleration towards 7 kt ground speed (GS). At 0715:47 hrs, as the aircraft speed passed 2-4 kt GS, a loud 'pop' was heard, and a propeller blade was released from EPU3.

The resulting imbalance caused the structural failure of the right inboard pylon (pylon 3). Despite EPU1 restarting automatically the aircraft was unable to maintain height and at 0715:50 hrs it struck the ground on the left edge of the runway with a vertical descent rate of 19.45 ft/sec. During the impact the right wing failed outboard of pylon 3, the nose gear collapsed and there was other structural damage. There were no injuries and no damage to any third party.

Figure 1

Pylon 3 failure following the release of a propeller blade from EPU3
(courtesy of manufacturer)

Aircraft description

G-EVTL is an Electric Vertical Takeoff and Landing (eVTOL) prototype with a carbon fibre composite structure, fixed tricycle landing gear, V-tail and a high wing. In its configuration for this test the aircraft had a maximum takeoff mass of 3,737 kg and could be flown with a pilot onboard or remotely.

Flight control system (FCS)

The aircraft was fitted with three Flight Control Computers (FCCs). The FCCs communicate EPU speed commands and tilt position commands (as well as their associated monitoring), over Controller Area Network (CAN) data buses. There were six CAN buses in total (two for each EPU and two for each tilt system) with each CAN bus consisting of two wires each. Part of this monitoring included the position of each EPU tilt mechanism.

Propulsion system

The aircraft is fitted with eight EPUs, each driving a propeller, with four on the wing leading edge and four on the trailing edge. The forward EPUs are numbered 1 to 4, from left to right, and the rear EPUs are numbered 5 to 8, also from left to right. The leading edge EPUs drive five-bladed, fixed pitch 'Generation 1' carbon composite propellers and each has a tilt mechanism allowing a variation of propeller angle between 0° and 100°, where 0° is straight ahead and 90° is vertically upwards. The forward EPU propeller blades comprise an external sheath that is adhesively bonded, with an expanding adhesive film, to a carbon fibre spar fixed to the propeller hub.

The trailing edge EPUs are fixed vertically upwards and drive four-bladed, fixed pitch composite propellers.

Each EPU consists of a three-phase motor, an inverter and a thermal management system. Three-phase cables connect the motor to the inverter; the inverter is fed both high voltage (HV) power for drive and low voltage (LV) power for control. Each EPU is connected to two independent and redundant CAN buses, used for motor control and monitoring.

Power for the propulsion system is provided by multiple battery subpacks located within the fuselage. Each battery subpack consists of lithium-ion cells connected together to provide HV DC power. An HV power distribution unit (PDU) then transfers this power to the EPUs.

The aircraft has a dualLV systems to power all onboard systems.. Power can be supplied to the system from the main aircraft LV battery, an external power socket or from DC-DC converters connected to the propulsion battery subpacks.

The landing gear is designed to accommodate sink rates of up to 10 feet per second without damage.

If the aircraft is being piloted remotely the pilot stands behind a remote cockpit with a wraparound screen, electronically displayed cockpit instruments and a control unit. The flight tests included a second pilot who maintained visual contact with the aircraft while the commander was in the remote cockpit. A Telemetry station and engineering team were live monitoring the aircraft status, in close proximity to, and in communication with the pilot remote cockpit.

Accident site

The aircraft hit the southern edge of Runway 26 in a level attitude with the right mainwheel on the paved runway surface and the left mainwheel and nosewheel on the grass. The right wing had broken at the inboard pylon but remained attached to the aircraft by wiring harnesses. Two propeller blades had detached from EPU3, with the blade sheath that separated in flight coming to rest 50 m from the aircraft, at its seven o'clock position. A section of blade spar that had also released came to rest close to where the sheath had landed. A second blade had detached during the ground impact as EPU3's propeller was still rotating when the aircraft touched down.

Figure 2

G-EVTL after the accident

Operator's accident response

Following the accident the operator carried out its pre-prepared emergency response plan, led by the lead flight test engineer. This plan had been practiced as a 'desk exercise' prior to commencement of the flight test programme. The initial actions involved ensuring the airfield RFFS was responding to the accident, quarantining the aircraft and associated data recordings and informing the AAIB and the operator's incident command group.

The RFFS arrived promptly and as no fire had occurred and no occupants were present, monitored the aircraft with a thermal camera in order to detect any overheating of the aircraft's batteries.

The aircraft's high voltage insulation monitoring system had detected a short circuit between the high voltage system and the airframe structure, but it was not apparent where the fault was located. The second remote pilot, dressed in appropriate personal protective equipment and accompanied by a high voltage-trained 'hook man' approached the aircraft to shut down the electrical systems. This included turning the high voltage system to OFF, to which the system responded as expected by opening the battery contactors to disconnect the high voltage system from the propulsion batteries. An ethernet cable was connected to the aircraft to allow direct laptop connection for system troubleshooting.

The left fuselage access panel was removed and the HV insulation fault was isolated by removal of a connector on the PDU. The battery pack voltages and temperatures were monitored over an immediate three-hour period and no abnormal behaviour was observed, allowing aircraft recovery to proceed. The damaged section of the right wing was cut free and the aircraft was recovered to the operator's hangar for further examination.

Aerodrome information

Aircraft testing was being conducted at Cotswold Airfield (Kemble) where special arrangements had been made to safeguard the area as well as G-EVTL. Untethered test flights were planned for outside the airfield's operating hours, but with both air traffic and airport fire services available. The risk assessment and CAA approval for the test had required a sterile area around the runway which included a significant safety margin. This area was reserved for G-EVTL operations at the time of the tests. The aircraft, including released propeller blade, remained well inside this area throughout the flight and subsequent accident.

Aircraft examination

Pylon 3 had failed in overload due to high out-of-balance loads caused when the EPU3 propeller blade released, allowing the forward section of the pylon to initially rotate vertically upwards under residual propeller thrust. This movement damaged the wiring harnesses where pylon 3 was attached to the wing front spar, severing the CAN bus C1 and C2 wiring. Low voltage wires providing power and return feeds to the EPU3 inverter were open circuit within a connector, due to cable strain. Damage to the high voltage wiring consisted of phases U and W pulling out of their connectors at the EPU3 motor and phase V pulling out of its connector to the inverter, with electrical arcing damage between the cable and the connector body.

The nose landing gear had collapsed and the left main landing gear oleo remained fully compressed. A number of skin-to-frame fasteners had pulled through the fuselage skin around the right main landing gear upper fitting. The right wing had failed in downward bending overload at the inboard pylon station.

The blade sheath that released during flight showed evidence of poor bonding between the sheath and the blade spar (Figure 3). Most of the adhesive remained attached to the internal sheath surface with very little present on the blade spar.

Figure 3

Released propeller blade including failed spar-to-sheath adhesive bond (lower three images, viewed in direction 'A')
(courtesy of manufacturer)

In the days following the incident, routine system monitoring identified one battery subpack exhibiting a greater than expected self-discharge rate. All the battery subpacks were purposely deep discharged as a precaution, rendering them inert, allowing safe removal from the airframe and for detailed inspections to occur.

Recorded information

The aircraft was fitted with a comprehensive data recording system, designed for the flight test campaign. This included an on-board recording system, and lower-rate telemetry data which was recorded off-aircraft. Data was recovered from both locations and allowed the manufacturer to perform a detailed post-flight analysis.

The recording system included video cameras which captured the propeller blade release and subsequent aircraft damage and descent. Post-flight review of the data confirmed that there were no data indicators that could pre-empt the propeller blade release.

Aircraft performance

The aircraft manufacturer spent a significant amount of its investigation on the aircraft performance after the rotor propeller blade release. The aircraft was designed to be able to continue to operate with one EPU inoperative, so the investigation focussed on the root cause of the propeller blade failure as well as the aircraft response following the failure of the propeller blade.

Once the blade released, there was a short delay before the aircraft systems detected a problem with EPU3. The rpm demand was then reduced to zero and the propeller rpm gradually reduced. After loss of EPU3, for the first second, the flight control laws assumed a higher than actual rpm for EPU3 as the EPU shutdown was instigated by the EPU, not the FCS. With this assumed higher rpm, to maintain control, the system reduced rpm on EPUs 4 and 8 for one second.

Detection of EPU3 failure led to the successful re-activation of EPU1. However, the subsequent movement of pylon 3 caused significant damage to the aircraft wiring and impacted the aircraft system response.

Two of the six CAN buses were severed completely and video footage showed a spark from around EPU3 caused by the high voltage power cables being damaged. Another CAN bus exhibited an intermittent connection, causing loss of the tilt position of EPU4 to the FCCs. With loss of tilt position, EPU4 rpm command was reduced to zero as designed.

In addition, the FCC lost CAN bus contact with EPU7, probably due to an inverter reset. As the FCC had lost contact with EPU7, it assumed zero rpm for this EPU as per design.

Despite the re-activation of EPU1, the damage to the aircraft wiring meant the system did not command sufficient thrust to the remaining EPUs to allow the aircraft to continue to hover, although it was successful in maintaining the aircraft in an approximately level attitude during the descent.

Meteorology

Conditions were described as ideal for this test flight with light winds from the south-west (240° 2-4 kt). Some early low cloud had lifted by the time the aircraft was prepared for the flight.

Analysis

Failure sequence

The failure of the adhesive bond between the EPU3 propeller blade sheath and spar allowed the sheath to translate radially outwards, increasing the bending load on the blade spar which caused the outer section of the spar to fracture and separate. The loss of the blade whilst the propeller was spinning at 1,200 rpm generated large out-of-balance forces, causing the structural failure of the forward section of pylon 3.

The upward rotation of the broken section of pylon 3, due to the remaining thrust from EPU3 whilst its propeller continued to rotate, damaged the aircraft's wiring harnesses. This resulted in the loss of thrust from EPU4 and EPU7. With the remaining vertical thrust insufficient to sustain the aircraft in a hover, it descended vertically whilst the flight control system retained a level pitch and roll attitude. The aircraft struck the ground at a rate of descent approximately twice the limit descent velocity that it was designed to withstand, leading to structural damage to the right wing, landing gear and fuselage.

Cause of the blade release

The released propeller blade was operating within its normal rpm and loading levels when it detached, without any increased vibration or foreign object impact prior to release. The blade sheath detached due to failure of the adhesive bond between the blade sheath and spar. Stress analysis performed by the manufacturer showed that only 5% of the spar-to-sheath bond area was required to retain the sheath at the centrifugal loading condition when the bond failed. It is therefore likely that progressive degradation of the bond occurred during operation prior to the blade release.

The manufacturer inspected two other similar propeller blades from its spares pool using CT scanning. Voids were widespread in the bond line in both blades, as were variations in the shape of the blade spar cross section. A review by the manufacturer determined that the blade structural design, and the relevant manufacturing control, quality assurance processes and verification programme were contributory factors to the blade release.

Safety action

As a result of this accident, the manufacturer has taken the following safety actions:

- The remaining 'Generation 1' propeller blades were withdrawn from use and, subject to a satisfactory inspection, will only be used for ground testing.
- The manufacturer was in the process of introducing a new 'Generation 2' propeller blade when the accident occurred that, amongst other things, eliminated the bonding failure mode that caused the blade release.
- Having completed its internal accident investigation, the manufacturer identified 36 product and process improvements. These include improvements in quality control, supplier qualification, design and verification processes, flight control laws, CAN bus architecture and the routing of wiring harnesses.

Conclusion

The blade released from EPU3 was caused by a failure of the adhesive bond between the propeller blade sheath and spar. It is likely that defects introduced in the bond when the blade was manufactured grew progressively larger during the blade's operational service to the point that the remaining bond area was insufficient to retain the blade under normal operating loads.

Large out-of-balance loads generated by the blade release caused structural failure of the right inboard pylon, resulting in damage to the aircraft's wiring harnesses. This caused a loss of thrust from motors 4 and 7. Whilst the aircraft's flight control system was able to maintain a level attitude, the high rate of descent caused by the loss of vertical thrust resulted in substantial damage to the aircraft when it struck the ground.

The manufacturer identified the propeller blade's structural design, the manufacturing controls, quality assurance processes and verification programme as contributory factors to the blade failure. It was, at the time of the accident, in the process of introducing a revised propeller blade design that, amongst other things, eliminated the bonding failure mode which caused the blade release.

The manufacturer's investigation identified 36 product and process improvements resulting from findings of the investigation.

Published: 2 May 2024.

AAIB Correspondence Reports

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

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

The accuracy of the information provided cannot be assured.

Serious Incident

Aircraft Type and Registration:	AW169, G-KSSC
No & Type of Engines:	2 Pratt & Whitney Canada PW210A turboshaft engines
Year of Manufacture:	2017 (Serial no: 69061)
Date & Time (UTC):	11 October 2023 at 1605 hrs
Location:	Bearsted Common, Maidstone
Type of Flight:	Emergency Services Operation
Persons on Board:	Crew - 2 Passengers - 2
Injuries:	Crew - None Passengers - None Others - 1 (Minor)
Nature of Damage:	No damage reported
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	2,860 hours (of which 873 were on type) Last 90 days - 42 hours Last 28 days - 14 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During the final approach to a Helicopter Emergency Medical Service (HEMS) landing site, the rotor downwash from the helicopter moved an unsecured ground cover on a cricket pitch. The cover struck a bystander on the leg causing a minor injury.

Safety action was taken by the operator to amend its Operations Manual to include enhanced guidance for pilots on helicopter downwash.

History of the flight

The crew of G-KSSC was tasked as a HEMS asset to attend an incident in Maidstone, Kent. On arrival at the area, the incident scene was identified by the presence of emergency response vehicles on the ground, already attending to the casualty. The crew discussed potential landing sites and concluded that a field containing a cricket pitch, approximately 80 m to the west of the emergency responders, provided the best option.

The crew assessed the field and established that its size, approximately 80 m by 120 m, was more than sufficient to use as a HEMS landing site[1]. The crew decided on an approach track that avoided the cricket pavilion and some residential properties to the north-east of the pitch (Figure 1). This also allowed the approach to be conducted largely into wind, which was from the south-west. The crew noted that there were pedestrians at the northern end of the field and some ground covers protecting the playing surface, but the main pitch area was clear. They elected to use a helipad profile approach with a committal height of 180 ft agl to provide sufficient clearance from surface obstructions.

On the final approach to land, when passing abeam the pavilion, the crew noticed that two previously unseen members of the public had appeared at the north-eastern edge of the cricket square, near the pavilion. The pilot flying stopped the descent at a height of approximately 160 ft agl to minimise the effect of the rotor downwash and extended his aiming point further into the area. As the crew established the helicopter in a hover at about 40 ft agl, one of the medical crew in the cabin noticed that the ground covers had rolled from their original position. The pilot flying decided to continue with the landing as any additional manoeuvring would risk blowing the covers further. After landing, the helicopter was shut down.

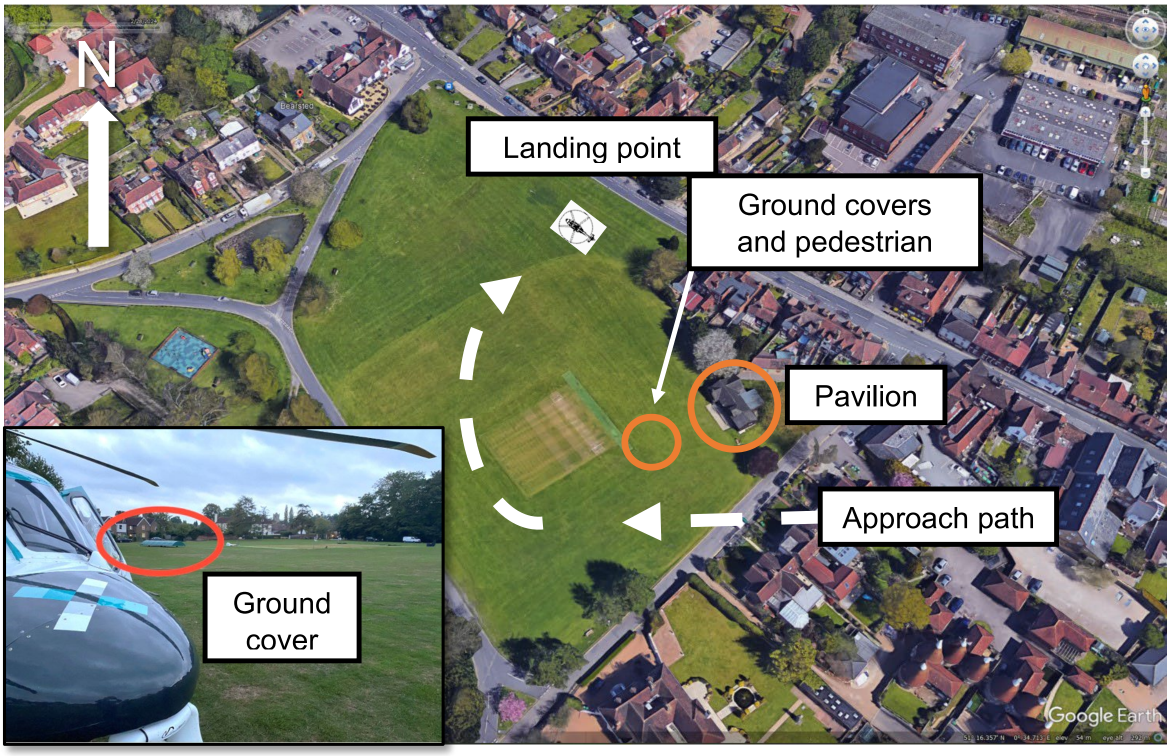


Figure 1

The cricket pitch and surrounding field

Footnote

[1] The dimensions for a HEMS landing site must be big enough to provide adequate clearance from all obstructions. This means that by day, it should have a minimum size of at least twice the largest dimension of the helicopter when the rotors are turning. For the AW169 this is 30 x 30 m.

On exiting the helicopter, bystanders alerted the medical crew to a lady who had been injured by one of the ground covers. While the medical crew responded to the primary incident they had been dispatched for, the pilots attended to the injured lady to render first aid. They established that she had suffered a cut to her leg when one of the ground covers rolled towards her, striking her. The lady was then triaged at the scene by a Critical Care Paramedic and subsequently conveyed to hospital.

On investigation, the pilots found that the covers were mounted on wheels which were equipped with brakes. The brakes had not been applied and the covers were moved easily.

Aircraft information

The speed of the downwash produced by a helicopter is a function of weight, air density and rotor diameter. The rotor downwash reaches its maximum velocity between 1.5 and 2 times the rotor diameter below the helicopter, then reduces as it disperses outwards (sometimes referred to as 'outwash'). For the AW169 with a maximum takeoff weight of 4,800 kg, the velocity of the downwash can be in the order of 46 kph (29 mph). At a distance of 30 m from the helicopter, the velocity of the downwash is still in the order of 38 kph (24 mph), but this can be influenced by terrain features, buildings or other substantial objects.

The regulations

Guidance for the conduct of HEMS flights is provided in the Guidance Material to SPA.HEMS.100(a) *Helicopter Emergency Medical Service (HEMS) Operations* in UK Regulation (EU) No.965/2012[2]. Regarding the '*HEMS Philosophy*', it notes that at a HEMS operating site, risk to third parties should be '…*as low as reasonably practical; when additional controls are not economically or reasonably practicable'.* Also that, '…*potential risk must only be to a level proportionate to the task'.* The task of a HEMS flight is to preserve life.

The operator

The operator's Risk Register contained an entry for unprepared landing sites, noting that,

> *'Aircraft Downwash may cause stones, loose crops, fences, branches to become detached and endanger the aircraft, third party public and surrounding buildings and vehicles.*
>
> *Consequence: Aircraft damage or third party injury is possible due to debris created by downwash in smaller more confined unprepared landing sites'.*

Key mitigations to this risk were:

- The Operational Conversion Course and line training that concentrates on landing site selection and the hazards involved in operating to unprepared landing sites.

Footnote

[2] UK Regulation (EU) No.965/2012, 'Air Operations', CAA, 2024. Available at GM1 SPA.HEMS.100(a) Helicopter emergency medical service (HEMS) operations (caa.co.uk) [accessed April 2024].

- HEMS Operating Site Procedures published in the Operations Manual, including the process for the conduct of a detailed airborne site survey.
- All pilots conducting an annual line check.

Operations Manual

The operator's Operations Manual contained a general reference to rotor downwash, particularly the effect on other aircraft in close proximity. However, it did not contain detailed guidance on the effects of downwash at HEMS landing sites but required pilots to be '*acutely aware of the effects of their downwash when selecting HEMS landing sites*'.

Flight safety information

In November 2021, the operator published an internal Flight Safety Circular to address downwash incidents. It provided a comprehensive summary of rotor downwash and reflected on how to plan operations at a landing site to anticipate and minimise the hazard. The circular stated that:

> *'This is especially important when operating within hostile congested areas and forms part of the HEMS pilot tool kit; running through a dynamic risk assessment based on the landing areas available and the aviation risk being proportional to the task.'*

Incident review

The operator conducted an internal review of the incident and concluded that:

> *'Additional guidance on downwash risk diameter, effect of wind, downwash funnelling, FOD most at risk of disturbance, and features likely to dissipate downwash would assist a pilot in assessing the risk posed when considering a particular landing site'.*

Analysis

The crew performed a comprehensive airborne survey of the intended landing site and identified potential hazards surrounding the cricket pitch. They selected an approach track and landing profile to avoid surface obstacles and overflying bystanders. When the threat of people appearing close to the final approach path was recognised, the pilot flying stopped descending and extended his aiming point further into the field to minimise the effect of the downwash on them. However, even at 160 ft above the surface, there was sufficient downwash to move the ground covers which did not have their wheel brakes applied.

Guidance material provided by the CAA that outlines the 'HEMS Philosophy' requires that risk to third parties should be *'as low as reasonably practical*; *when additional controls are not economically or reasonably practicable',* and that '*potential risk must only be to a level proportionate to the task'.*

HEMS operations are inherently reactive and time sensitive. Due to the urgency involved, it is often impractical to provide formal site security measures to control access to third parties at landing sites. This risk is acknowledged, and HEMS operators are required to manage it by striking a balance between the helicopter's unique abilities to land close to an incident scene, thereby increasing the chances of saving lives, and ensuring the safety of bystanders on the ground.

The operator had established mitigations to manage the risks associated with downwash at unprepared landing sites but noted in an internal review of the incident that '*additional guidance*' would '*assist a pilot in assessing the risk posed when considering a particular landing site'.* Consequently, on 10 April 2024, the operator took the following action:

Safety Action

The operator published a Flying Staff Instruction (FSI) to provide enhanced guidance to pilots on the awareness of downwash and links to industry guidance material and resources for additional study. The FSI was incorporated into the Operations Manual.

Conclusion

The serious incident happened when a ground cover, moved by downwash from the approaching HEMS helicopter, struck a bystander in the leg. The cover was mounted on wheels equipped with brakes, but the brakes had not been applied. Downwash can be a significant risk, especially when operating in an urban environment.

Accident

Aircraft Type and Registration:	Aerosport Scamp, G-BOOW
No & Type of Engines:	1 Volkswagen 1834 piston engine
Year of Manufacture:	1988 (Serial no: PFA 117-10709)
Date & Time (UTC):	10 February 2024 at 1344 hrs
Location:	Near RAF Mona, Anglesey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - Serious Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	4,876 hours (of which 2 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft suffered a partial loss of power shortly after takeoff from Runway 04 at RAF Mona. Full power was briefly regained before the engine then stopped. The pilot was unable to reach the airfield or a suitable field, and carried out a forced landing into trees during which the aircraft was destroyed and the pilot sustained a serious injury. The cause of the power loss was not identified.

History of the flight

The pilot was making his fourth flight in the aircraft, which had recently undergone a major restoration. He intended to fly a series of four right-hand circuits from Runway 04 and the weather conditions were good. Pre-flight checks on the aircraft were normal and there was no contamination visible in the fuel sample drained from the fuel tank. The engine ran smoothly once started, and a test of the carburettor heat system showed a small rpm drop when selected, indicating that it was working.

The aircraft took off from Runway 04 but as it reached approximately 400 ft agl, the engine rpm decreased significantly, with some rough running. The pilot lowered the nose to maintain 65-70 kt airspeed, during which the aircraft descended to 300 ft. As he prepared to make a forced landing in a field beyond the end of Runway 04, the engine returned to full power without intervention from the pilot.

With the engine now producing power, the pilot decided to fly a tight right-hand circuit which he considered would also provide the opportunity to land downwind on Runway 22 if necessary. As the aircraft entered the downwind leg, at 600 ft agl, the engine power decreased to idle with significant rough running. The pilot lowered the nose below the horizon and, being too low to reach the airfield, selected a field to land in. He felt the aircraft stall with a right wing drop and he pitched the aircraft further nose down to recover, however he was now too low to reach his selected field. The engine then stopped. With a residential area ahead and a high rate of descent, he picked an open area of gardens with a line of trees to land in and intentionally stalled the aircraft into the tree line. The aircraft slid sideways from the trees, coming to rest on its right side (Figure 1). The pilot sustained a fractured wrist and some minor injuries. While he was wearing a helmet which provided some protection, the pilot sustained a minor head injury

Figure 1

G-BOOW accident site (used with permission)

Aircraft examination

The engine was examined by the pilot after the accident. All four cylinders had good compression and the crankshaft rotated freely. The oil level was normal and there was no sign of any electrical arcing of the ignition system, although it was not possible to perform any testing of the ignition. The fuel tank had been drained during the aircraft recovery and fuel was present in the tank.

Pilot's comments

The pilot commented that the loss of engine power may have been due to carburettor icing. He noted that the Aerosport Scamp is a high-drag, low-inertia light aircraft with a relatively small margin between the climb speed of 65 kt and the stall speed at 47 kt, and that the airspeed decayed quickly following the loss of power. He was not experienced on this type of aircraft and he stated that it was likely he experienced some 'startle effect' following the loss of engine power, during which the airspeed decayed.

He stated that as a commercial pilot, he had received upset prevention and recovery training (UPRT) which was reinforced during regular proficiency checks. He considered that this assisted his quick reaction in lowering the nose when the aircraft stalled, which probably prevented a more serious accident, as having regained control he had some additional time to decide where to set the aircraft down.

Analysis

The aircraft's engine suffered a partial loss of power after takeoff, after which it briefly produced full power before it then stopped. The changes in the available power, combined with the aircraft's low altitude and its relatively rapid deceleration following a loss of power created a challenging decision making environment for the pilot. As the cause of the power loss was not identified, it was not possible to state whether prompt application of carburettor heating may have improved the performance of the engine.

A recent AAIB report[1] highlighted the hazards associated with partial power loss. In addition to three safety recommendations made in the report, it also highlighted the importance of briefing emergencies prior to takeoff in helping to anticipate the decision making process.

The pilot's prompt recognition and response to the aircraft's stall allowed for a greater degree of control over the aircraft's flight path and time to decide where to land, which probably contributed to a less severe outcome that might have otherwise occurred.

Conclusion

The cause of the engine failure was not determined. Contributory factors to the resulting accident were a challenging decision making process due to the partial power loss and proximity to the ground, and the pilot's inexperience with the relatively high-drag, low-inertia aircraft type.

Footnote

1 Grumman AA-5, G-BBSA (publishing.service.gov.uk) [accessed April 2024].

Accident

Aircraft Type and Registration:	De Havilland Canada DHC-6-300 Twin Otter, VP-FBC
No & Type of Engines:	2 Pratt & Whitney PT6A-27 engines
Year of Manufacture:	1982 (Serial no: MSN787)
Date & Time (UTC):	23 January 2023 at 1600 hrs
Location:	E322, Mount Lymburner field location at the north-west end of the Ellsworth Mountains, Antarctica
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to fairing around the landing gear, and upper and lower forward bulkhead
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	5,438 hours (of which 3,223 were on type) Last 90 days - 174 hours Last 28 days - 58 hours
Information Source:	Aircraft Accident Report Form submitted by the commander

Synopsis

On departure from an unprepared landing site the nose landing gear of the aircraft struck a small ice ridge. Once airborne, the commander noticed that attitude information was misaligned and there was some minor disruption within the cockpit near the rudder pedals. He diverted to an unmanned landing site nearby where he assessed the damage. Considering that the aircraft was safe to fly he flew the aircraft to a field station, two hours flight time to the north.

On landing at the field station, further damage was found to have occurred to the nose fairing around the landing gear and the lower bulkhead forward of the cockpit.

History of the flight

In support of polar research in the Antarctic, the commander was tasked to take a field team to a new location, designated Station E322 (Mount Lymburner), at the north-west end of the Ellsworth Mountains, in Ellsworth Land, Antarctica. He was accompanied by a field guide; a second aircraft with an engineer on board was tasked to follow-on a few hours later.

The commander assessed the weather at the location as "good" and briefed the task. A nearby unmanned fuel depot with a prepared landing surface, named Castle, was nominated as a diversion.

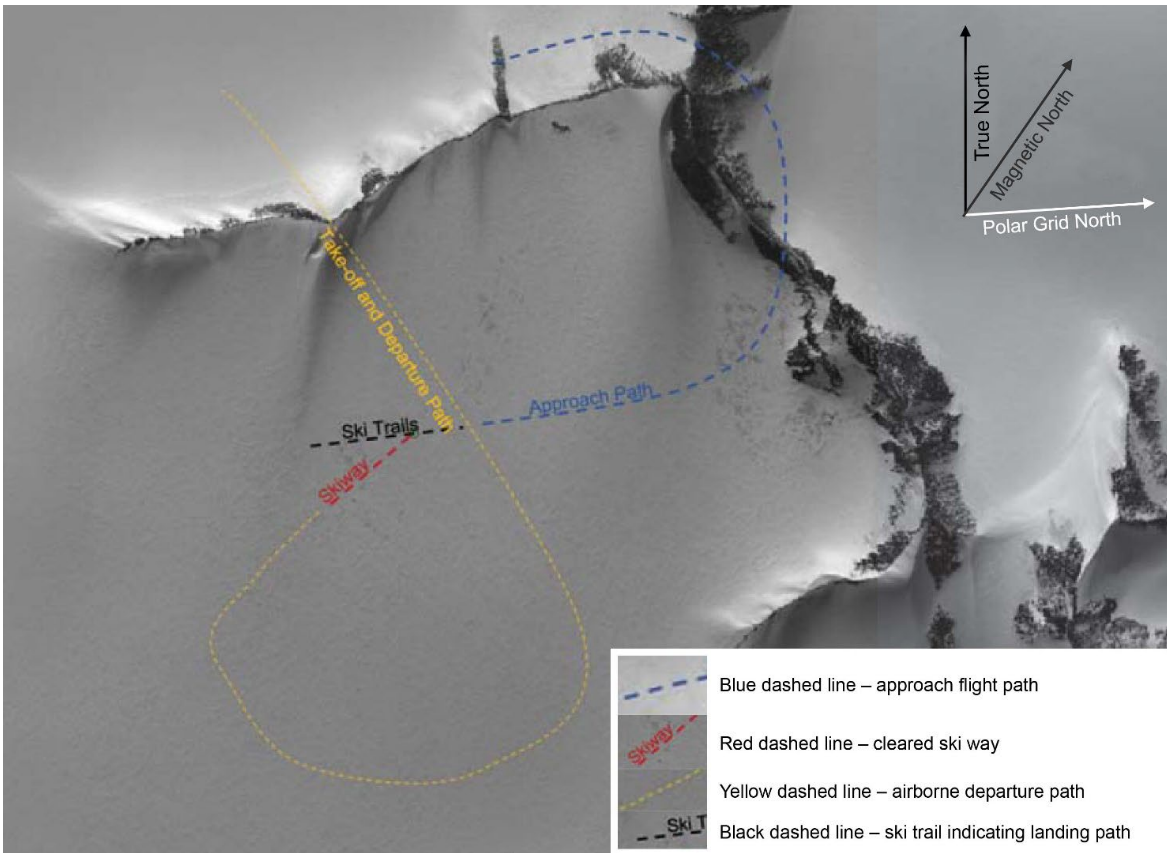


Figure 1

Station E322 location beside Mount Lymburner, Ellsworth Mountains (Google Earth)

On reaching Station E322, he assessed it in accordance with the company's operating procedures and identified landing and takeoff routes away from the ridge on a plateau (Figure 1). The commander flew a steep approach through a col and assessed the surface by flying a "trail"[1] before making a further approach to land. The aircraft landed without incident.

The direction of the ice ridges (also known as sastrugi[2]) was more apparent when on the ground. Consequently, the commander prepared a skiway[3] of 800 m, about 20° off the direction in which he had landed but in line with the direction of the sastrugi (Figure 2), for the following aircraft to land. He marked the skiway with bamboo poles.

Footnote

1 A trail involves flying along the length and in the direction of the intended landing run by touching down the skis of the main landing gear onto the surface but keeping the nose off the surface with the weight of the aircraft borne by the wing.
2 See sub-section on Sastrugi.
3 A skiway is a snow strip marked by flags and the surface prepared to prevent the potential for damage to aircraft during takeoff or landing. This is achieved through the removal of sastrugi and use of other measures such as visual markers.

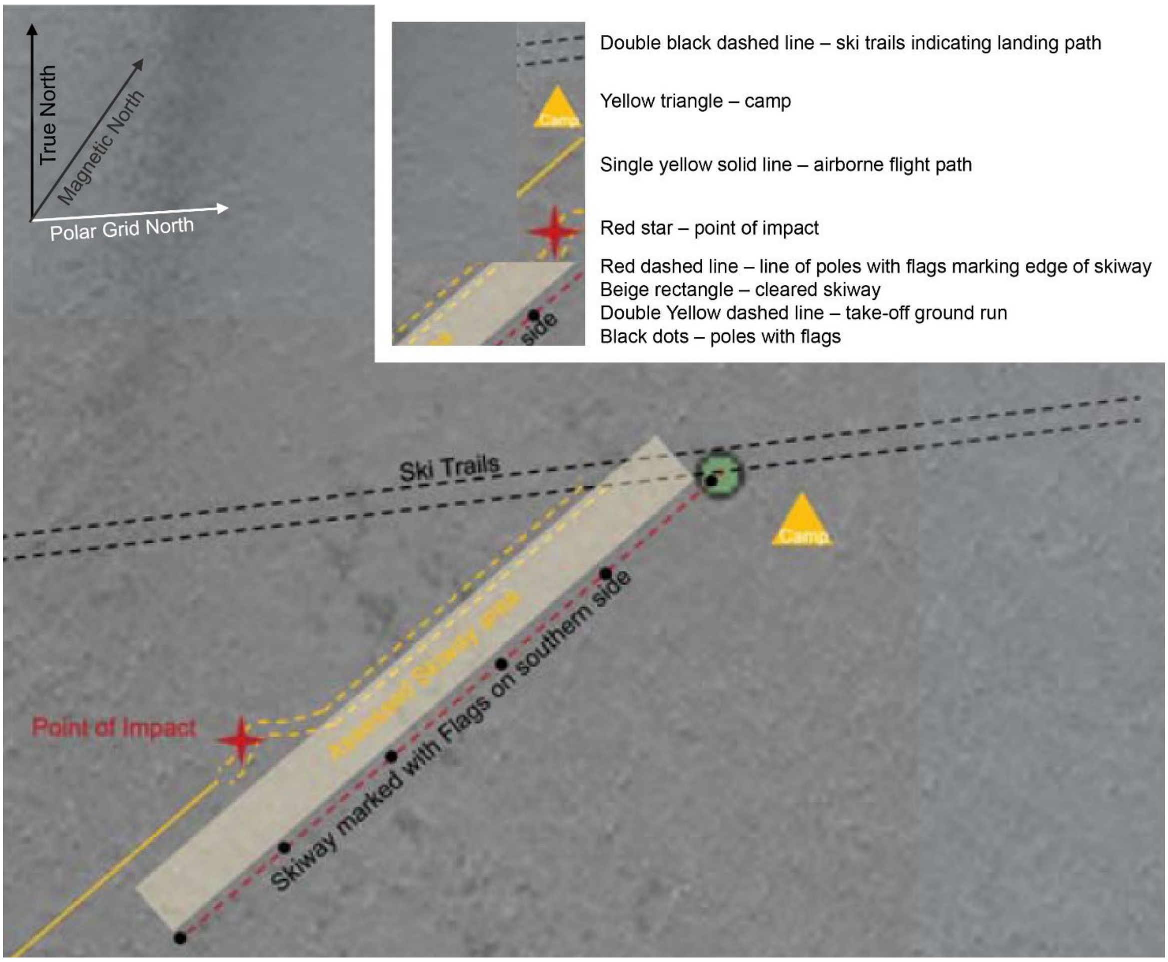


Figure 2

Station E322 landing site with ski trails and cleared skiway shown (© Google Earth)

The commander stated that, while he would normally depart using the same trail made when landing, he elected to depart using the skiway. He reported that almost at the point of rotation during takeoff, he felt the right ski sink, pulling the nose of the aircraft to the right. Although he tried to correct this using differential power and rudder, a large impact was felt on the nose ski; it was at this point the aircraft became airborne. The field guide subsequently told the operator that he considered the impact unremarkable.

On completion of the after takeoff check list, the commander noticed that the standby artificial indicator showed a 40° bank while the aircraft was level and that attitude indication of the No 1 primary flight display seemed slightly off alignment. He also noticed that the covers around the rudder pedals were dislodged.

Considering his diversion options, the commander determined that, although he had sufficient fuel to return to the ice runway at Sky Blu field station, it would not be sufficient to ensure the aircraft landed with fuel remaining above the mandatory minimum reserve. He was also concerned about having sufficient fuel in uncertain and rapidly changeable weather conditions. Following a low-speed handling check, the commander therefore elected to land at Castle, which had a known smooth prepared surface, where the current weather was known to be good and there was fuel.

After an uneventful landing, the commander assessed the damage to the aircraft. He considered that no major structures were compromised, and that the aircraft was safe to fly. While the follow-on aircraft may have provided further support from the engineer on board, the commander was conscious that the location was very remote and unsupported and that any need to secure the aircraft would require personnel to stay on-site. Consequently, he determined that the best option was to fly a single sector back to Sky Blu where there was infrastructure to support personnel and access to engineering support. He did not consult the chief pilot on this decision. He refuelled the aircraft and flew it back to Sky Blu without further incident. Upon landing, the engineer based at Sky Blu confirmed damage to the forward bulkhead and the fairing around the nose landing gear.

Station E322 and other operator sites

The landing site at Station E322 was an unprepared location beside Mount Lymburner on the north-western tip of the Ellsworth mountains, about 260 nm to the south-west of Sky Blu (Figure 3). The surface consisted of compacted snow forming an ice shelf. The commander reported that the trail indicated a hard surface but with small sastrugi and that the landing run felt like landing on a rough grass airfield.

The fuel depot called Castle, at latitude 76°55' S, has a skiway and is about 40 nm from E322. It is unmanned with minimum stocks of fuel. The commander commented that its location was extremely remote and subject to strong katabatic winds and temperatures below minus 40°C.

Sky Blu field station is situated in Eastern Ellsworth Land. It has a blue ice[4] runway, up to 1,200 m long and 50 m wide permanently marked by flags. The camp is manned during the summer, including a licensed engineer. Facilities consist of a large semi-permanent hut, tents, and weather monitoring equipment. There is an ice cavern garage for storage of equipment. Its purpose is to provide supplies, fuel, and people in support of "deep field" operations to the interior of the Antarctic.

Rothera air facility is the largest research station and the main base for the air unit. It is situated in the south-east of Adelaide Island on the Antarctic peninsula and acts as the main airbridge to and from Antarctica. It is about 900 nm to the site at E322.

Footnote

4 A blue ice runway is a naturally occurring strip of ice that is kept smooth and snow-free for wheeled landings.

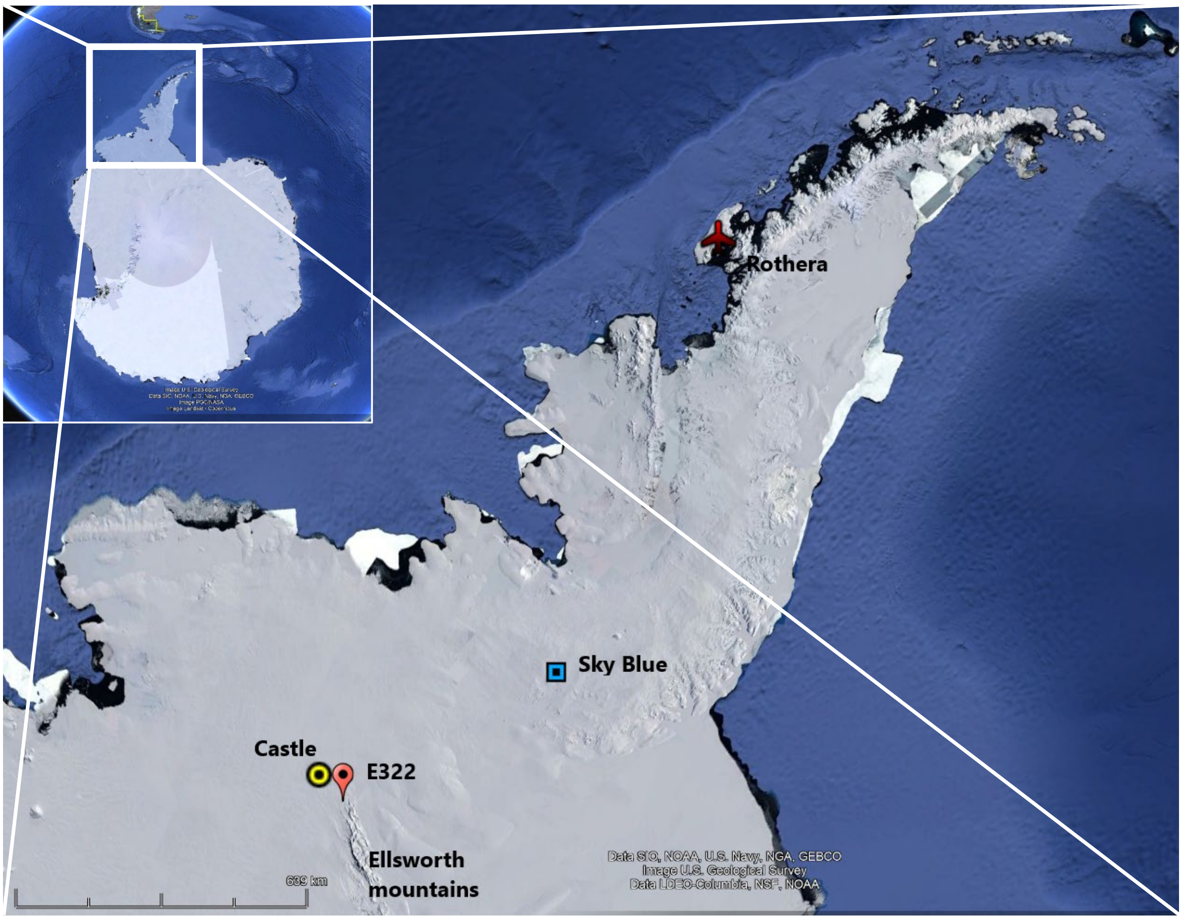


Figure 3

Ellsworth land showing station E322 and other operator sites (© Google Earth)

Aircraft examination

On landing at Castle, the commander inspected the aircraft and assessed the damage to the external nose gear and surrounding aircraft skin (Figure 4), nose baggage bay, avionics and hydraulic bays. He checked the flying controls, including the rudder and elevator, of which the pulleys are attached to the forward bulkhead at station 60. While he determined that this bulkhead looked torn and buckled, he determined all the flying controls were undamaged and there were no control restrictions. The engine nacelles and main landing gear also appeared undamaged.

Figure 4
Damage to aircraft skin around the nose gear (photo taken after landing at Sky Blu)

On landing at Sky Blu, the aircraft was inspected by a licensed engineer who confirmed damage to the upper and lower forward bulkhead at station 60 (Figure 5). The commander noted that the damage appeared to be worse than he had observed at Castle.

Figure 5
Station 60 upper bulkhead damage (photo taken after landing at Sky Blu)

The type certificate holder issued a Repair Engineering Order for a temporary repair to the nose and bulkhead structure, allowing a ferry flight with a maximum of two cycles and eight flying hours.

Aircraft information

The twin turboprop De Havilland Canada DHC-6-300 Twin Otter (DHC-6) is a short takeoff and landing utility aircraft with a high wing and fixed tricycle landing gear. The version operated in Antarctica is wheel and ski-equipped for operation on snow, ice and other types of hard runway.

Figure 6

DHC 6-300 Twin Otter with ski landing gear (image courtesy of the operator)

Station 60 forward bulkhead

The forward bulkhead at station 60, to which the nosewheel landing gear is connected, separates the nose compartment from the flight compartment. The operator and commander stated that this area is known to be liable to damage in the event of an impact on the nosewheel landing gear.

Meteorology

The weather forecasting for the task was based on satellite pictures and on model data but without any observation on the ground from a Met Office operational forecaster. The commander reported that, at the time of the accident, visibility at the landing site was unlimited, with a few high-level clouds and good contrast. The sun was just above the horizon in the south-west, and the winds were calm. The Antarctic summer ends and the winter begins in March.

Communications

High Frequency (HF) radios are the primary means of communication between aircraft and Rothera. Two HF systems are installed on each aircraft. Manned remote locations also have access to an HF system, but it is not routinely monitored. Each aircraft also carries two satellite phones, which cater for voice calls and provide text messaging facilities.

The operator reported HF transmissions and reception were "generally good in the region" but that the satellite phone coverage was "patchy", and calls could be broken "like a bad mobile call" where only every other word is heard.

Personnel

The commander had flown in excess of 2,000 hours in command on type and was working towards a Part 66 engineering licence. The operator recognised that the commander had considerable polar flying experience combined with strong technical knowledge of engineering, the aircraft and its structures.

Survivability

The operator's procedures recognised that many factors, including weather or technical issues, might affect the transport of loads to a new field site. It stated that:

> *'…the first load into the field must contain all the necessary equipment to live comfortably and safely in the field.'*

It provided a list of equipment that must be placed on the first aircraft to a site. The commander stated that the safety equipment provided was designed for the Antarctic summer. He observed that it was sufficient to be able to survive, though not in comfort for any length of time.

Commander's decision-making

The commander stated that, following his examination of the damage, he assessed the aircraft as safe to fly. He was concerned about the remoteness of the location with its extreme environment and the challenge of bringing engineering support to recover the aircraft before the end of the Antarctic summer. Conversely, Sky Blu offered a safer location for the personnel and support, including a licensed engineer for the further recovery of the aircraft to Rothera.

Organisational information

The operator

The aircraft operation is part of a research-driven organisation for polar science and operations. It is responsible for providing safe and effective airborne logistics and science capability in support of UK and collaborating nations' science activity, primarily in Antarctica.

The DHC-6 is one of the operator's two types and operates in the Antarctic from October through to March each year. Landing on unprepared snow sites using ski landing gear, it transports people, fuel, skidoos, sledges, food and scientific equipment to remote camps, to lay depots and stockpile fuel for field science parties.

Operator investigation

The operator's own safety investigation found that the accident occurred because the aircraft's ground roll diverged from the cleared skiway and struck a sastrugi.

The investigation indicated that other pilots would have reacted in the same or a similar way if presented with the same scenario. It found that whilst the pilot had considered the potential for damage occurring on the subsequent takeoff or landing, he may not have considered the potential for further damage occurring during the cruise phase.

The commander expressed that it would have been difficult to explain a nuanced and complicated situation over the satellite phones and that decisions made remotely may have been less effective. Consequently, the operator considered there was a strong psychological barrier to communicating with engineering and management personnel.

The investigation also highlighted the tension between keeping the risk to personnel within tolerable levels and the need to protect high value assets while reducing the exposure of personnel to an extremely hostile environment. The operator recognised that there could be rare occasions where decision-making would require a balance to be struck between safety and airworthiness compliance. It concluded there may be circumstances in which it would be appropriate to fly a damaged aircraft if this minimised the exposure of personnel and assets to immediate risks, or if it was required to meet international obligations for the protection of the Antarctic environment. The operator commented that *'some degree of flexibility may be required if an engineering fix is available but cannot be achieved at a remote site…'* but '… *if necessary, assets would be abandoned if the risk to personnel, or the cost of recovery (financial, environmental, human effort) is too great to bear.'*

The operator reviewed:

- The barriers (perceived or actual) to open communication between pilots and management.
- The existing risk assessment process and communication channels for occurrences which result in damage to aircraft in remote locations.
- The level of autonomy required and accepted by pilots and management in certain circumstances regarding in-field / dynamic decision-making.
- The existing processes and practises in place for new sites including a review of training.

As a consequence, the operator adopted the use of low orbit commercial satellites for communications which has improved their quality and reliability.

It has developed a 'field checklist' to guide the decision-making process to recover damaged or unserviceable aircraft from remote locations, defining the process of assessment and the level at which decisions should be made.

It established that existing processes and training for new sites were *'sufficient and satisfactory*'.

Additionally, during the annual review of operations for 2023, the operator held discussions with pilots on remote decision-making, levels of autonomy for commanders and the confidence with which commanders had the confidence to raise safety concerns. These discussions are to be repeated in the annual review of operations in 2024.

Other information

Sastrugi

Sastrugi, or zastrugi[5], are small ice features which resemble frozen waves formed by erosion of snow by wind. They are found in polar regions, and are distinguished by upwind-facing points, resembling anvils, which move downwind as the surface erodes. When landing at an unprepared landing site in Antarctica, Sastrugi are a key threat.

Site recce

The operator's procedure in its field operations manual for the setting up of a skiway stated that it should be aligned with the prevailing wind direction, 500 m long and 30 m wide marked by black flags along one longitudinal edge every 50 m, and with contrast bags placed in each of the four corners. It also stated that large sastrugi would need to be flattened, and both thresholds should be clear of obstructions with any camp positioned more than 200 m away.

National regulations

Antarctic regulations and permits require the operator to take all necessary actions to remove the aircraft in order to meet its obligations under the Antarctic treaties to minimise the potential for environmental impact and damage. However, the operator stated it is also implicitly recognised:

> *'That recovery may not be possible in all circumstances, particularly if the process of removing it is more damaging than leaving it in situ. Therefore, should an aircraft not be in a position to be flown but personnel are recoverable, its location, ease of retrieval, cost (in terms of to the environment – carbon footprint, etc), carriage of D[angerous] G[oods] (inc. fuel), and so on, should all be considered in the round.'*

Footnote

5 The word comes from the Russian and means 'small ridges'.

Operational control

The operator is authorised to conduct general aviation operations and is required to comply with the rules laid down in Overseas Territories Aviation Requirements (OTAR) 125. OTAR 125.55 states:

> *'The pilot-in-command shall have responsibility for operational control.*
>
> *Note: Operational Control is the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of the flight.'*

The operator's air operations manual (AOM)

> *2.1.2 Flight Authorisation*
>
> *All flights must be approved and authorised by the Chief Pilot. …. If changes from the scheduled flights are required, with the exception of flights for the purpose of saving life or other emergency, further authorisation must be sought before making the flight. …. Whenever an [mandatory occurrence report] MOR or [occurrence report] OR is required which relates to an aircraft operational error on the part of the flight crew and/or significant technical fault the flight crew are required to gain approval from the Chief Pilot before operating any company aircraft.'*

Commander's responsibilities

The operator's AOM permits a commander to deviate from its own procedures for the purposes of saving life or in an emergency. It further defined the scope of the commander's authority and responsibilities and authority with the focus on safety. It stated:

> *'2.3.4 Responsibility for Flights*
>
> *The responsibility for a flight, once authorised by the Chief Pilot, devolves to the PIC before departure….*
>
> *In flight, the final authority as to the disposition of his aircraft rests with the PIC who shall responsibly co-operate with operational and maintenance personnel. He shall base any decision on all aspects of the operational requirements and consequences regarding the aircraft, its passengers/cargo, and crew paying particular attention to safety.*
>
> *When the PIC accepts the aircraft…, he acknowledges he… will conduct the flight in accordance with the rules and regulations as described in the [operator's] AOM and any other National Regulations if more restrictive. He may deviate from any regulations in the interest of safety. Such a deviation must be reported using the Mandatory Occurrence Reporting procedure as described in this manual.'*

Analysis

The accident occurred during the ground roll of the takeoff run at a new unmanned deep field site as a result of the aircraft diverging from the skiway that the commander had previously cleared. Once airborne, on noticing some flight instruments were misaligned, together with some disruption to the cockpit structure, the commander decided to land at a nearby unmanned fuel depot to inspect for damage. Assessing the aircraft was safe to fly and conscious of the hostile environment and remote location, he made the decision to fly to a field site where there was better on-site protection and support for the crew and the aircraft.

Detection of Lateral movement

The cause of the aircraft diverging from the cleared skiway could not be determined. The conditions in the Antarctic, with its absence of topographical features, monochrome landscape and low contrast environment, can make it difficult to detect lateral movement.

The operator sought to mitigate this threat by marking the skiway with flags down one edge and contrast bags placed at each of the four corners. It has reviewed its procedures for preparing a skiway and considered that they were '*sufficient and satisfactory'*.

Decision to fly to Sky Blu

The commander was faced with either remaining at the location with its extremely hostile environment and the concomitant risks and challenges or flying the damaged aircraft to a field site with better engineering support and protection for personnel.

The commander had extensive experience in polar aviation operations. He was also able to draw upon his technical knowledge of the aircraft. He assessed the aircraft was safe to fly and decided that it was safer to fly to a field site about two hours flight time away, where there was better support.

Operational control

The operator had procedures for the exercise of operational control, requiring authorisation from the chief pilot '*with the exception of flights for the purpose of saving life or other emergency'*. The commander, faced with the team remaining in a remote and hostile location, acted within his authority in accordance with OTAR125.155 and the operator's AOM to act in '*in the interests of safety*'.

Communication with management

The commander highlighted a strong psychological barrier to communicate the situation with management. This arose from the difficulty he perceived he would encounter to relay the nature of the situation by satellite phone and his concern that any decisions made remotely may have been less effective.

The operator, while considering the communication channels to be adequate, acknowledged that effective communications were a very real barrier. This psychological barrier would probably have been exacerbated by the commander's awareness of the remoteness and extreme environment of the location and the consequence for personnel and the aircraft.

However, the decision not to discuss the situation with management missed the opportunity to discuss the situation with others including the potential threat of further damage occurring to the aircraft during the cruise phase of the subsequent flight.

Operator actions

The operator has developed a process to guide decision-making and escalation to management to promote effective decision-making at the right level according to the circumstances. It also reviewed its processes for preparing a skiway and the training for ski landing and taking off.

Conclusion

The accident occurred during the ground roll of the takeoff run as a result of the aircraft diverging from the skiway at a new unmanned site. The reason for the aircraft diverging from the cleared skiway could not be determined. However, the environmental conditions may have contributed to a loss of visual acuity by the commander.

The commander found himself in a situation with a genuine concern for risk to personnel. Drawing upon his engineering and technical knowledge of the aircraft, he assessed it was safe to fly, and decided to fly to a field site where there was better environmental protection and support for both personnel and the aircraft.

He considered that involving others, who were remote from the situation, in the decision-making process, may have resulted in a less optimum outcome. However, the decision not to communicate with management about the situation missed the opportunity to discuss the situation with others including the potential threat of further damage occurring during the cruise phase of the subsequent flight.

The operator recognised that there could be rare occasions where safety would take priority over airworthiness compliance, and it may occasionally be appropriate to fly a damaged aircraft if this minimised the risk to personnel and assets, or if it was required to meet international obligations for the protection of the Antarctic environment.

Safety actions

The operator took the following safety action:

> It adopted the use of low orbit commercial satellites for communications, which improved quality and reliability.
>
> It developed a 'field checklist' to guide the decision-making process when recovering damaged or unserviceable aircraft from remote locations. It would only be used in circumstances where the non-routine protection of life, assets or the environment conflicted with defined and well-established airworthiness and engineering requirements.

It reviewed existing processes and training for new sites and established that they were 'sufficient and satisfactory'.

During the annual review of operations for 2023, it held discussions with pilots on remote decision-making, levels of autonomy for commanders and the confidence they had to raise safety concerns. These discussions would be repeated in the annual review of operations in 2024.

Accident

Aircraft Type and Registration:	Extra EA 300/L, G-OLAD
No & Type of Engines:	1 Lycoming AEIO-540-L1B5 piston engine
Year of Manufacture:	2007 (Serial no: 1270)
Date & Time (UTC):	17 January 2024 at 1145 hrs
Location:	Northrepps Aerodrome, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Both mainwheels detached on landing leading to landing gear detachment, lower fuselage, engine and propeller damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	21,404 hours (of which 64 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and follow-up enquiries by the AAIB

Synopsis

On landing, both mainwheel assemblies detached from their axles. The fasteners attaching both axles to the landing gear leg failed due to the nuts being pulled from the attachment bolts. When the axles were last refitted, the axle attachment bolts were re-used.

The aircraft manufacturer is taking safety action across all applicable aircraft maintenance manuals to include an additional prominent instruction to fit new bolts when refitting the axles.

History of the flight

The pilot was conducting a familiarisation flight in the Extra 300, having flown over 60 hours on the Extra 200 series. The flight comprised three circuits and landings on grass Runway 22 at Northrepps followed by some local flying. Upon returning to the airfield the pilot landed approximately half way along the displaced threshold, and immediately after touchdown the main landing gear collapsed. The propeller struck the ground and the aircraft came to a halt at the left side of the runway.

Accident site

Witness marks in the grass surface appeared to show that the right tyre was initially not turning upon touchdown and that the right mainwheel assembly detached before the left mainwheel assembly (Figure 1).

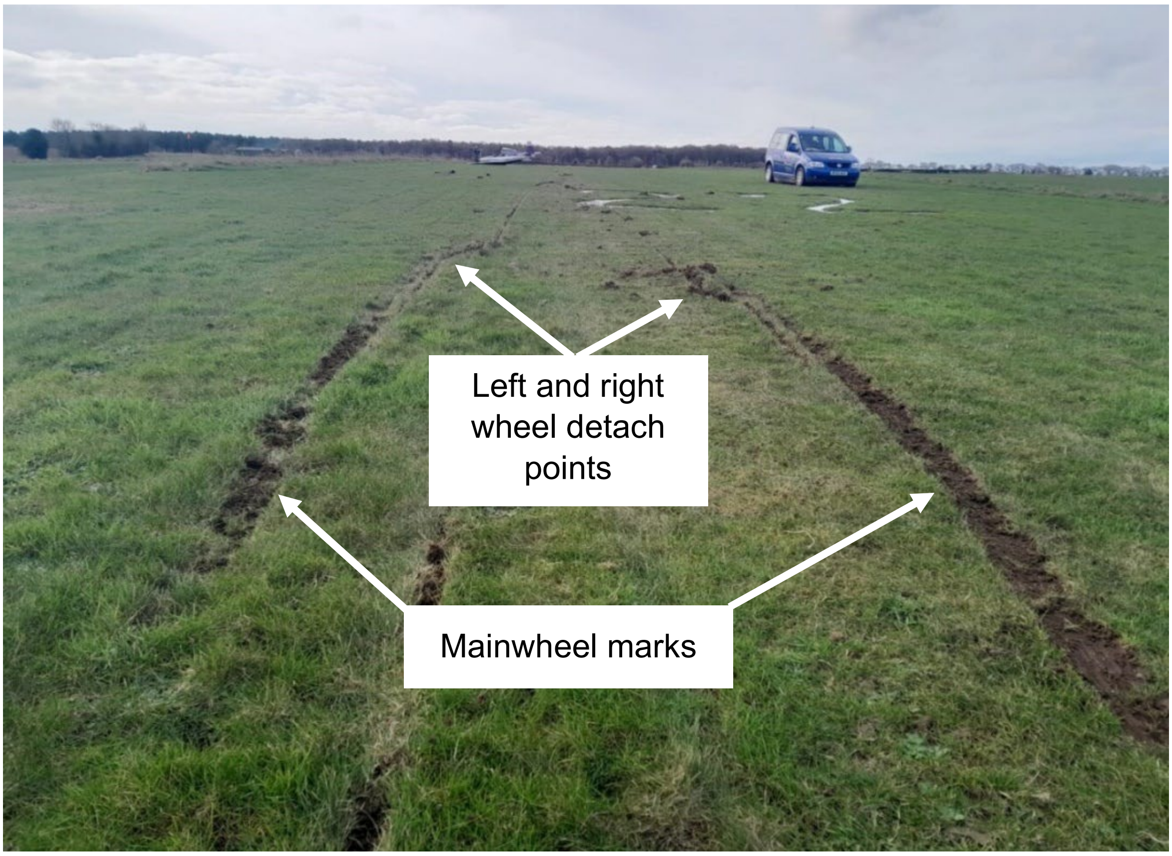


Figure 1
Runway witness marks

Aircraft examination

Both mainwheel assemblies detached from the landing gear leg, which then bent back underneath the fuselage. The maintenance organisation tasked with recovering the aircraft found that both main wheels turned freely. The four axle attachment bolts on each wheel were bent and the threads were stripped (Figure 2). None of the eight axle bolt nuts were recovered.

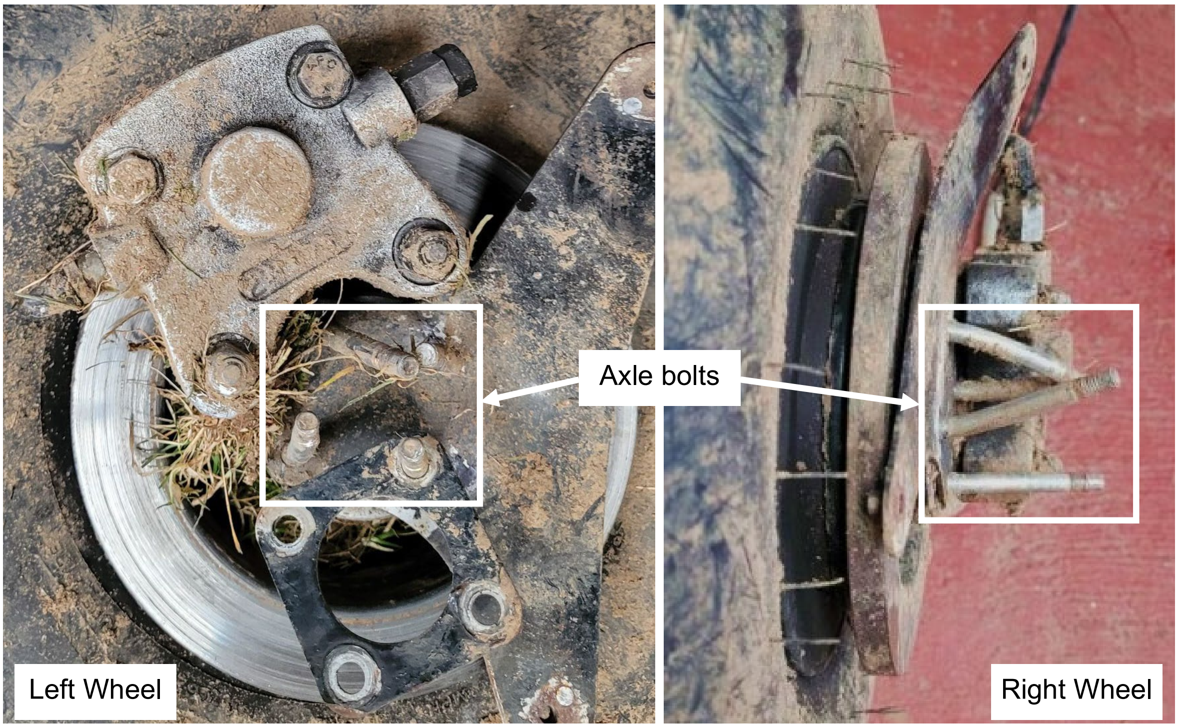


Figure 2
Damaged axle attachment bolts

Maintenance history

A new main landing gear leg assembly was fitted to G-OLAD in May 2022, 111 hours prior to the accident. During the replacement process the axles were refitted using the existing attachment bolts with new nuts. The aircraft maintenance manual used was at Revision 11, dated 2019.

Previous occurrence

AAIB investigation EW/G2010/04/05[1] into a similar failure of axle fasteners on an Extra EA 300 aircraft could not determine the cause of failure but concluded that it is possible to damage the axle attachment bolt threads when the axles are removed and refitted. This damage could then lead to the fasteners failing during normal landing loads.

Safety recommendation 2010-046 was made to the Extra Aircraft Company, and the EA 300/L maintenance manual was amended[2] at Chapter 32-10-03, step 4 of wheel axle removal/installation to include *"Use new nuts and bolts."*

A prominent instruction was also added to Revision 1, Chapter 32-10-00 Landing Gear of the maintenance manuals for the 300/SC, 300/LT and 300/LC models (Figure 3). This is not present in the maintenance manual for the 300/L aircraft.

Footnote

[1] AAIB investigation to Extra EA 300 G-SIII, https://assets.publishing.service.gov.uk/media/54230283e5274a1314000b29/Extra_EA_300__G-SIII_10-10.pdf [accessed 14 February 2024].

[2] Revision 10, 26 October 2015.

IMPORTANT	New bolts are to be used when the wheel axles are replaced or refitted.

Figure 3

Excerpt from EA300/LT Maintenance Manual, Chapter 32-10-00
(Used with permission)

Analysis

The damage to the axle attachment bolts is consistent with side forces having been applied to the tyres, and the nuts being pulled from the bolt threads under load. The pilot noted that this aircraft routinely experiences firm landings and heavy braking at Northrepps due to the 615 m runway length. However, neither the pilot or passenger felt this landing was heavier than normal, and both confirmed their feet were clear of the brakes.

Witness marks on the runway show it is likely that the surface in the displaced threshold was soft. This can increase both the landing gear leg flex and the tendency for the aircraft to dig in upon touchdown, introducing higher loads into the main landing gear assembly that may not be felt by the passengers. It was not possible to determine the cause of failure of the fasteners, but it is possible that if there was pre-existing damage to the bolt threads it could lead to failure of the fasteners under normal landing loads.

The axle attachment bolts had been reused when the axles were refitted 111 hours previously. The manufacturer's maintenance manual used included the instruction in Chapter 32-10-03 to use new bolts when refitting axles due to the possibility of damaging the bolt threads. The manual did not include the additional instruction in Chapter 32-10-00 that is present in the manuals of some new aircraft models, which presents an additional opportunity to highlight the requirement to use new bolts.

Extra Aircraft is taking safety action to add the prominent instruction to Chapter 32-10-00 of the maintenance manual for all related models at their next revision.

Conclusion

The axle attachment fasteners of both wheels failed due to the nuts being pulled from the bolts under load. It is possible the bolt threads had been damaged during the axle removal and refitting process when the bolts were re-used. The version of the manufacturer's maintenance manual used for the process specified to use new axle attachment bolts.

Serious Incident

Aircraft Type and Registration:	UAS Prion Mk3
No & Type of Engines:	1 Parallel-twin-120cc engine
Year of Manufacture:	2023 (Serial no: 3-0021)
Date & Time (UTC):	6 March 2023 at 1352 hrs
Location:	West Wales Airfield
Type of Flight:	Private - Test & Evaluation
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose gear, boom, fuselage and right wingtip
Commander's Licence:	N/A
Commander's Age:	26 years
Commander's Flying Experience:	166 hours (of which 166 were on type) Last 90 days - 7 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the operator.

Synopsis

The aircraft was operating at West Wales Airport when the remote pilot observed the engine had stopped. The aircraft had lost all electrical power but continued to fly briefly before disappearing behind a hedge. The aircraft landed a short distance beyond the south-western edge of the airfield. It sustained minor damage; there was no damage to property or injuries to people.

The operator has taken two safety actions.

History of the flight

The operator was conducting the second of two flights to complete validation of the aircraft's autopilot.

The plan involved the aircraft taking off from West Wales Airfield (WWA); operating in visual line of sight (VLOS) within the air traffic zone (ATZ), and beyond visual line of sight (BVLOS) below 3,000 ft amsl within 1.8 km of the remote pilot (RP), all within danger area D202D.

The RP conducted the takeoff at 1215 hrs and handed control of the aircraft to the RP station operator (RPSO).

A number of tests were conducted to validate the autopilot and flight control systems. At 1350 hrs the RP observed that the engine had stopped, with the aircraft 1,000 ft agl over the centre of the airfield and routing along the northern edge of Runway 25. He informed the RPSO that he was taking control by saying "my bird" to which the RPSO acknowledged "your bird". However, the RP then advised the RPSO that he was not able to gain control; the RPSO then attempted to regain control but without success.

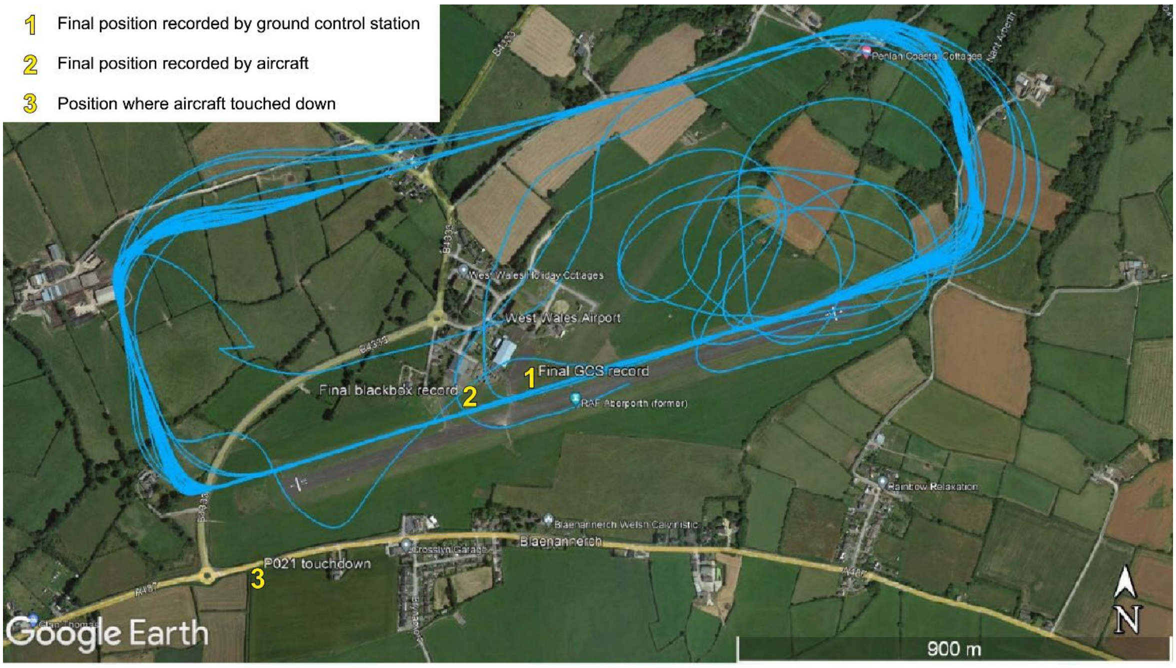


Figure 1
Track of UAS Prion during accident flight

The RPSO advised ATC of the situation. Meanwhile, the aircraft continued further along the direction of Runway 25 for about 30 seconds before turning right and circling, then disappearing from the RP's sight beyond a hedge (Figure 1).

Accident site

The aircraft was found just beyond the south-western end of the airfield to the east of the A487/B4333 roundabout. It had landed on its wheels but suffered damage to the nose gear, right wingtip and fuselage. There was no damage to property or injuries to people.

Aircraft information

The Prion Mk3 is a fixed wing monoplane with a 4-stroke petrol engine, which uses an electronic fuel injection system and an electric alternator generator. It has a maximum takeoff mass of 55 kg with up to a 4.5 m wingspan and is 3 m in length. The airframe remains visible to the naked eye within a flight envelope of 1,000 m lateral distance up to an altitude of 1,000 ft agl.

Electrical power provision and distribution

The Prion MK3 uses ground power prior to engine start. Once the engine has started, power is supplied by an on-board alternator generator. In the event of the generator failing, there is an emergency lithium polymer battery, which will continue to power the systems for a minimum of two hours (calculated at 20°C). This battery is tested for charge before each flight and is continuously charged by the alternator generator while the engine is running.

There is a warning system fitted to ensure this battery is connected before flight. The field crew could monitor the charge status of the emergency battery using the flight telemetry system, if selected for display.

After flight, the aircraft is connected to ground power, which also charges the emergency battery.

Aerodrome information

WWA is a licenced aerodrome situated at Aberporth on the west coast of Wales and lies within the danger area D202D, where extensive UAS activities occur.

Organisational information

Operator safety case

For flights within WWA under extended visual line of sight (EVLOS) rules, the aircraft was to remain within 2,000 m lateral distance from the RP up to an altitude of 1,000 ft agl.

The operator safety case considered a number of scenarios. This included the loss of aircraft flight control and telemetry systems during flight, engine failure and flyaway. The emergency response plan for a flyaway recognised that the cause could be the result of total systems failure wherein, with the *'more dramatic failure of the autopilot, the aircraft will likely ditch.*'

The mitigations put in place for flyaway included the use of pre-flight checklists to assure system functionality, together with the use of buffer zones for flights operating under VLOS/EVLOS and segregated airspace when operating under BVLOS. The buffer zone applied to operations within an ATZ was established at 500 m horizontal 500 ft vertical separation from the edge of the ATZ.

There was no specific scenario that considered total loss of electrical power.

Operator investigation

The operator's post flight investigation determined the accident occurred as a result of the total loss of electrical power. This occurred on the second flight of the day once the emergency battery became discharged, resulting in loss of flight control, communication with both the RP and the RPSO and the shutdown of the engine. Consequently, the aircraft glided to the point it touched down.

The investigation established that the alternator generator system was not delivering power nor charging the emergency battery because of an incorrect wiring connection which had not been identified during assembly. Prior to the accident, the wiring for each airframe was unique. The operator has since standardised the schematics and wiring across the fleet. It also identified that the field crew had not selected the option on the flight telemetry system to enable them to monitor the voltage of the back-up battery.

The investigation established that the powerplant had been changed the previous day, but that validation of the performance of the alternator generator system had not been carried out. It identified that the fault existed for the first flight of the day which lasted only 35 minutes but which, consequently, did not fully deplete the emergency battery. The fault was not identified prior to the second flight since the emergency battery was charged by the ground power connection prior to flight, preventing the pre-flight check from identifying that the emergency battery charge had been depleted during the first flight.

The operator identified that the after-flight check list was missing a check of the emergency battery status prior to the aircraft being connected to the ground power. It also improved the engine monitoring graphical interface flight telemetry system (Figure 2) to include voltage indication of the emergency battery to allow its charge status to be monitored in flight. This would indicate if the alternator generator system was faulty.

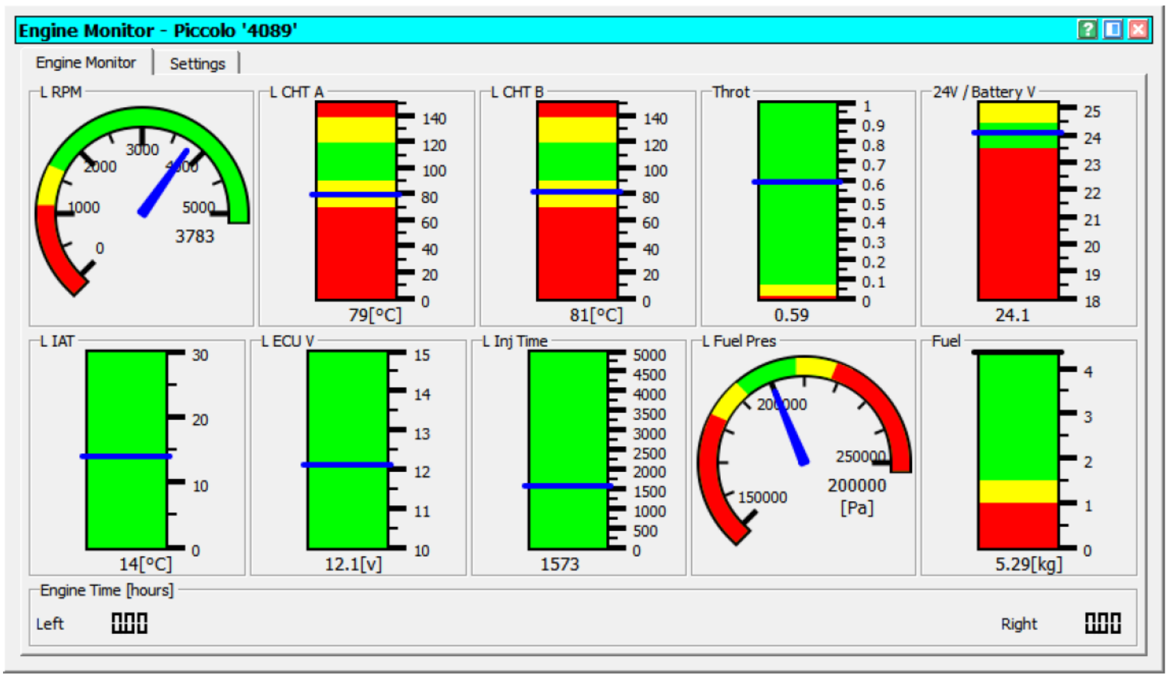


Figure 2

Engine monitor with emergency battery voltage (top right) indication

Analysis

The flight was conducted within the confines of the WWA ATZ and consequently the aircraft remained in sight of the RP at all stages up to the final moments when it disappeared behind the hedge.

The accident occurred once the emergency battery had become depleted of all charge. This resulted in the loss of communications by the RPSO, and the RP followed by the loss of propulsion.

The mitigations of a buffer zone helped limit the risk of escalation of the consequences of total loss of power. However, while the operator recognised the consequences of a total systems failure, it had not explicitly considered total loss of electrics within its safety case.

The management of the threat of loss of electrical power was ineffective since the means by which the field crew could identify a malfunction of the alternator generator system had not been enabled. Additionally, assurance of the serviceability of the system through a check of the charge status of the emergency battery during pre-flight was ineffective since there was no check of its charge status prior to connection of ground power post flight.

Conclusion

The aircraft suffered the total loss of electrical power as a result of the malfunction of the alternator generator to maintain the charge of the emergency battery and deliver power to the systems. This was the consequence of an incorrect wiring connection. The means to provide warning to the field crew of an alternator generator malfunction was not selected in the flight telemetry system. Further, the pre-flight check of the charge status of the emergency battery was not an effective means of establishing the alternator generator system was functioning properly.

Safety action

The operator has taken the following safety action.

- The operator has standardised the wiring and schematics across the fleet.
- The operator has amended their after-flight check list to establish the charge status of the emergency battery, prior to the connecting of ground power to the aircraft, as a means to verify the functionality of the power generation and charging system.
- The operator has included voltage indication of the emergency battery in the engine monitoring graphical interface to indicate alternator generator system performance.

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only investigations reviewed: March - April 2024

27 Jul 2023 **Magni M24C** **G-GTFB** Newborough Nature Reserve, Anglesey

The pilot reported that while flying near the coast the gyroplane became sheltered from the prevailing headwind behind some sand dunes and lost airspeed. The pilot applied full power and pitched nose down, but there was insufficient height to recover the flight path. He flared the gyroplane to reduce its rate of descent before it struck the ground, but it sustained substantial damage.

14 Oct 2023 **CZAW SportCruiser** **G-JAYZ** Ford Farm Airfield, Nottinghamshire

On returning to the airfield, after there had been a heavy rainfall, there was a lot of water on the grass surface. The pilot reported that he taxied too fast at the end of the runway after landing, and the wheels locked when he applied the brakes. The aircraft continued to move forward and slid down an embankment into a hedge where one of the composite propeller blades and the the left wing were badly damaged.

13 Jan 2024 **X'Air Hawk** **G-CGCV** Palmer Moor Airfield, Derbyshire

Following a brief reduction in engine performance, the pilot made a precautionary return to the airstrip. On short final, he heard a "bang" and felt the aircraft vibrating. Being high on the approach, the pilot aimed for a ploughed field beyond the runway on the other side of a road. Just before touchdown, the left wing dipped, and the aircraft landed heavily. The pilot considered that carburettor icing may have caused the earlier reduction in engine performance, but the cause of the bang was not determined at the time this report was published.

20 Jan 2024 **Beech 35** **G-NEWT** Field near Murcott, Oxfordshire

The aircraft was being flown home following its annual maintenance. On approach the engine failed to respond. Despite selecting the fuel tank which the pilot believed to be full, the engine did not respond so he executed a forced landing. Investigation by the maintenance organisation found that the old type fuel selector handle had been inadvertently re-fitted such that the fuel would have been selected from a tank that was close to being empty.

4 Mar 2024 **Quik GT450** **G-CFWN** Darley Moor Airfield, Derbyshire

The aircraft veered to the left during a crosswind touchdown. As the pilot tried to correct the heading, the aircraft flipped onto its side.

Record-only investigations reviewed: March - April 2024 cont

8 Mar 2024 **Eurofox 3K** **G-RONK** Private strip, near Ashford, Kent
The aircraft took off from a private grass strip. The aircraft's nose rose unexpectedly, the right wing stalled at a height of about 20 ft and the aircraft struck the ground in a field near the runway; the pilot was uninjured.

17 Mar 2024 **Piper PA-24-250** **G-ARYV** Field near Leicester Airport
Shortly after departing from Runway 22 at Leicester, G-ARYV's engine started to misfire and moments later it stopped. The pilot turned toward Runway 33 to attempt a forced landing but could not reach it. The aircraft landed short of the runway, striking some rubble and sustaining significant damaged in the process. Neither occupant was injured. The pilot considered that either carburettor icing or possible mismanagement of the fuel system caused the engine to stop.

29 Mar 2024 **Cessna 152** **G-TALA** Welshpool Aerodrome, Montgomeryshire
The aircraft bounced during landing and on the subsequent touchdown the nose landing gear broke off, the aircraft tipped forward and the propeller struck the runway.

14 Apr 2024 **Zlin Z.526F** **G-EHZT** Boston Aerodrome, Lincolnshire
The pilot intended to cycle and then lower the landing gear whilst downwind to land at Boston Aerodrome, but inadvertently left the gear up. The aircraft landed wheels up, damaging the propeller and shock loading the engine.

14 Apr 2024 **Zenair CH 601HD** **G-ZAIR** Priory Farm Airfield, Tibenham, Norfolk
Following a normal approach to land, the aircraft unexpectedly dropped from about 4 ft to the ground resulting in a heavy landing. The pilot considered that the accident was due to windshear.

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

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

Published November 2018.

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

Published March 2020.

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

Published May 2021.

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

Published September 2023.

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

Published November 2023.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

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

Air Accidents Investigation Branch