ACCIDENT

Aircraft Type and Registration:	1) Cessna 152, G-WACG 2) Guimbal Cabri G2, G-JAMM
No & Type of Engines:	1) 1 Lycoming O-235-L2C piston engine 2) 1 Lycoming O-360-J2A piston engine
Year of Manufacture:	1) 1982 (Serial no: 152-85536) 2) 2017 (Serial no: 1185)
Date & Time (UTC):	17 November 2017 at 1201 hrs
Location:	Near Waddesdon, Buckinghamshire
Type of Flight:	1) Training 2) Training
Persons on Board:	1) Crew - 2 Passengers - None 2) Crew - 2 Passengers - None
Injuries:	1) Crew - 2 (Fatal) Passengers - N/A 2) Crew - 2 (Fatal) Passengers - N/A
Nature of Damage:	Both aircraft destroyed
Commander's Licence:	1) Commercial Pilot's Licence 2) Airline Transport Pilot's Licence (H)
Commander's Age:	1) 27 years 2) 74 years
Commander's Flying Experience:	1) 419 hours (of which around 400 were on type) Last 90 days - n/k hours Last 28 days - 19 hours 2) 25,000+ hours (of which n/k were on type) Last 90 days - n/k hours Last 28 days - n/k hours
Information Source:	AAIB Field Investigation

Synopsis

The Cessna 152 and the Cabri G2 helicopter collided in mid-air when both were engaged on training flights. They were operating in Class G airspace[1] and neither aircraft was receiving an ATC service. The opportunity for the occupants of either aircraft to see the other was limited because, although they were in proximity for some time, they were both following a similar track and were not in each other's field of view.

Work is ongoing, led by the CAA, to promote the development and use of compatible Electronic Conspicuity (EC) aids to help mitigate the well-known limitations of 'see and avoid'.

Footnote

1 A brief description of UK airspace can be found at: https://www.nats.aero/ae-home/introduction-to-airspace/ [Accessed 21 September 2018].

© Crown copyright 2018

The flying club which operated G-WACG has issued an Instructor Notice to highlight the importance of maintaining an effective lookout throughout flight, and the need to carry out a regular change of heading during a prolonged descent, to check that the area ahead is clear.

History of the flights

Cessna 152, G-WACG

During the morning of the day of the accident, the instructor completed a training flight in G-WACG with another student. The signing out sheet at the flying club indicated that the detail had comprised Exercise 7.2 (best angle of climb, cruise climb, climbing with flap) and Exercise 8.2 (effect of power, speed and flap on descent).

The accident flight, about one hour later, was the instructor's second instructional flight of the day. The flight was recorded on the club signing out sheet as Exercise 7.1 (best rate of climb) and Exercise 8.1 (glide descent).

At 1138 hrs the student requested taxi clearance for a local flight. The aircraft was instructed to taxi to holding point A3 (Figure 1) and later, at 1146 hrs, G-WACG was given clearance to take off from asphalt Runway 24.

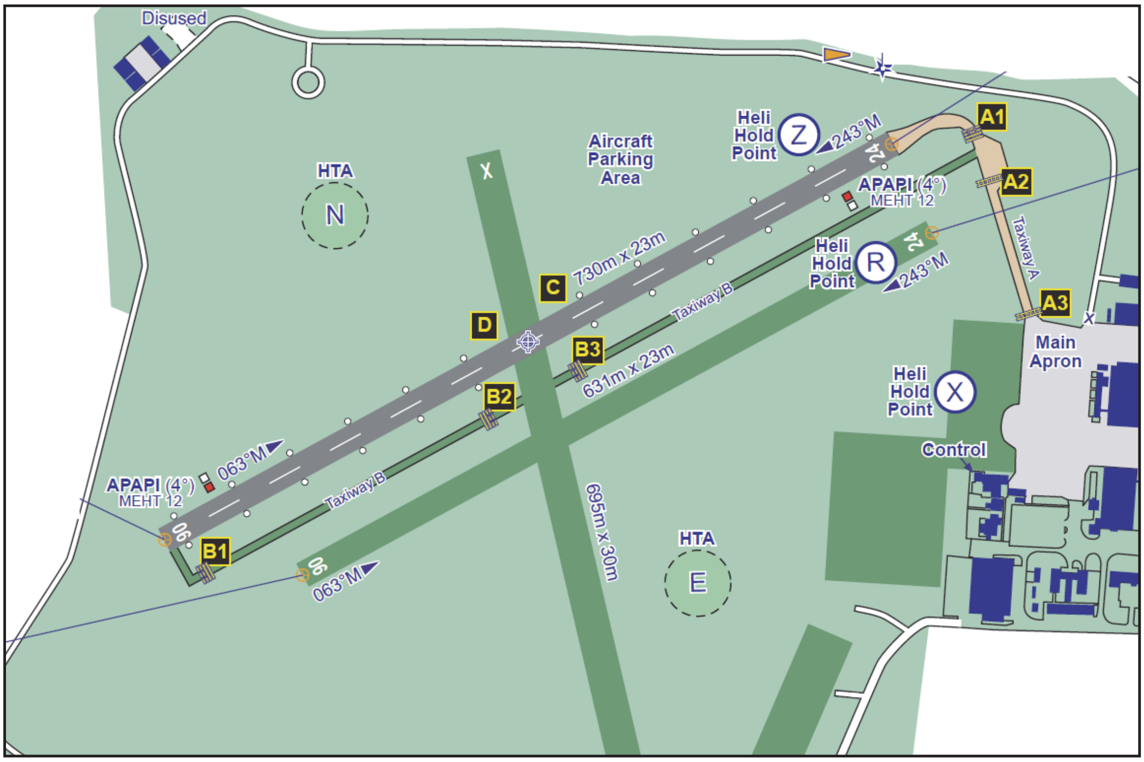

Figure 1

Wycombe Air Park/Booker, location of runways and holding areas

G-WACG took off and climbed steadily up to an altitude of 2,000 ft before turning on course to the local training area northwest of the aerodrome. At 1150 hrs G-WACG confirmed with Wycombe Tower that they had left the circuit area; there were no further radio communications from the aircraft. G-WACG reached 4,000 ft, turned left onto a steady north-westerly course and then commenced a sustained descent which continued until the point of collision. The collision occurred 14 minutes after takeoff from Wycombe.

A more detailed description of the relative positions of the two aircraft throughout their flights is provided in the recorded data section of this report.

Guimbal Cabri G2, G-JAMM

The instructor had completed one training detail in G-JAMM during the morning of the day of the accident; a navigation exercise in the local area to the north-west of Wycombe, routing via Silverstone and return. The second detail was planned as a repeat navigation exercise with a different student, so it is likely that the accident flight was intending to follow a similar track (Figure 2).

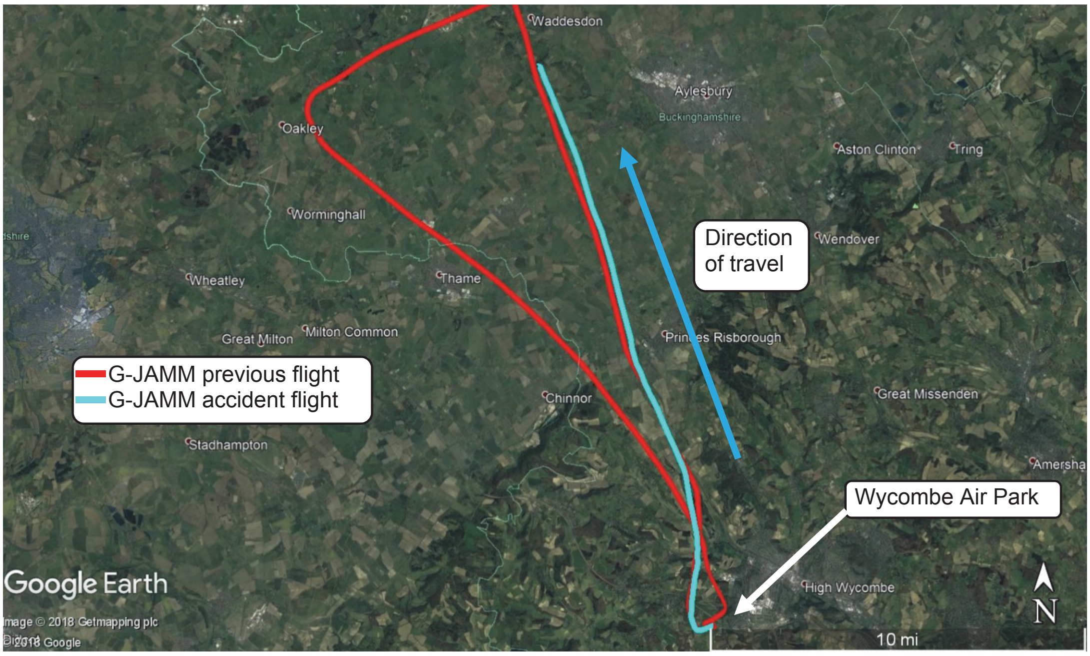

Figure 2

Radar-derived tracks of G-JAMM on 17 November 2017
(First flight red, accident flight blue)

At 1145 hrs G-JAMM was cleared to lift and taxi to holding point 'X' and subsequently to holding point 'R' to hold short of Runway 24. As G-JAMM was waiting at 'R', G-WACG took off from Runway 24. G-JAMM was then cleared to cross Runway 24 to helicopter training area 'N'. G-JAMM departed at 1147 hrs, climbing initially to the south-west, before turning north and then north-west on track to Silverstone. The instructor in G-JAMM advised Wycombe Tower they were leaving the circuit to the north; there were no further radio communications from the helicopter. G-JAMM climbed to and maintained an altitude of around 1,500 ft amsl until the point of the collision.

Witness information

There were no witnesses to the flight paths of the two aircraft before the collision.

One witness, about 0.5 nm to the south-west, saw the two aircraft immediately before the collision in close proximity, estimated at around 20 m apart. He described both as flying fairly low and observed that "the plane was gliding down slightly" and the helicopter "was directly underneath the plane and seemed to be rising underneath it."

Recorded information

The position of each aircraft and Mode C/S altitude information throughout the flights was recorded by four NATS[2] radar heads. In addition, a number of ADS-B receivers recorded G-JAMM's position and altitude; the data was provided to the AAIB by NATS.

The recorded altitude from the aircrafts' transponders used a pressure datum of 1013 hPa. This has been corrected to the reported QNH on the day of 1029 hPa and all altitudes quoted in this report are amsl.

The period when G-JAMM and G-WACG collided was recorded on all four of the radar heads, the closest to the accident site being Bovingdon radar, 16 nm to the south-east. This recorded altitude and position every five seconds. Heathrow and Stansted radars, which were further away, recorded position every four seconds and the aircrafts' tracks from all radars were similar. On the accident flight and the earlier flights, both aircraft were squawking 7000, the conspicuity squawk.

Accident flights

G-WACG

G-WACG was fitted with a transponder which was transmitting aircraft pressure altitude to the nearest 100 ft (ie ± 50 ft). NATS radar first recorded G-WACG at 1147:02 hrs just after takeoff from Runway 24. The aircraft tracked on the runway heading for approximately 2 nm, climbing to 2,000 ft before turning 90° to the right towards the Stokenchurch Mast (Figure 3).

At the mast, G-WACG turned to a heading of approximately 015°, descended briefly to 1,430 ft before commencing a climb at 1154:43 hrs. This climb continued over the next 3 minutes 49 seconds, to a maximum altitude of 4,130 ft. This altitude was maintained for approximately 13 seconds before the aircraft began descending at 1158:44 hrs. Approximately seven seconds later, G-WACG turned left onto approximately 340°T.

G-WACG remained on this approximate track throughout the descent, which continued for the next two minutes and seven seconds, at which point the recorded altitude was 1,530 ft. The average vertical speed for this descent was -1,228 ft/min and radar-derived groundspeed ranged between 79 kt and 85 kt. Primarily due to the accuracy of the radar

Footnote

2 NATS is the UK national Air Navigation Service Provider (ANSP).

© Crown copyright 2018

data, but also its sampling rate, it was not possible to ascertain whether or not shallow turns were performed before or during the descent.

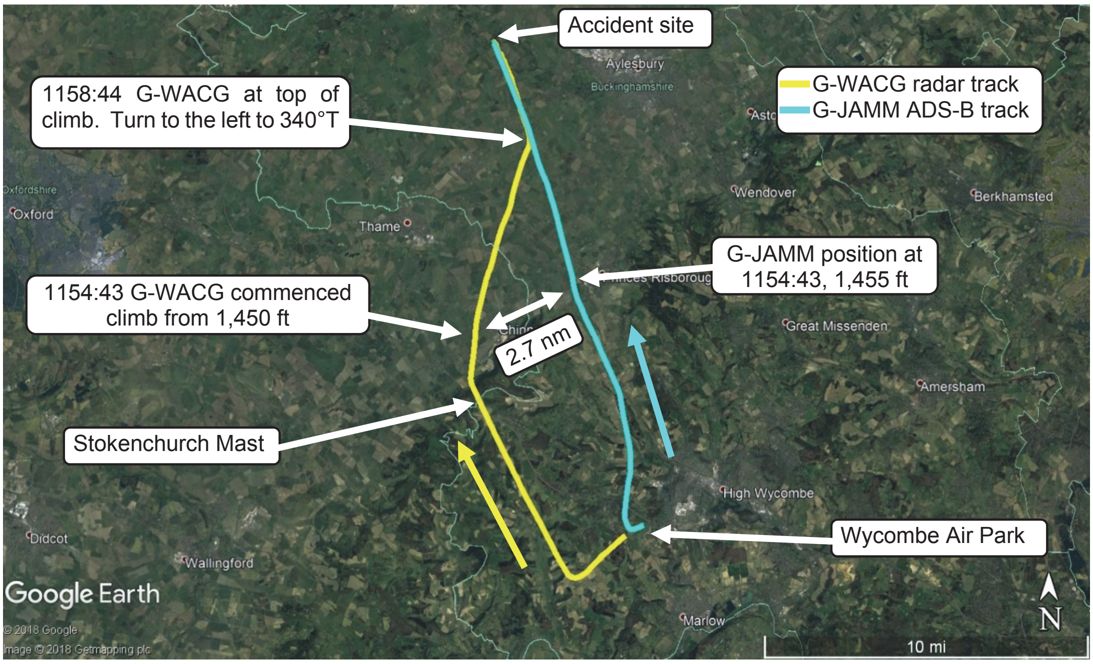

Figure 3

G-WACG and G-JAMM position information

G-JAMM

G-JAMM was fitted with a Garmin GTX335 Mode S transponder. This device not only responded to radar interrogation but also periodically transmitted ADS-B out[3], allowing the helicopter's position, derived from an internal GPS, to be received and recorded by appropriate equipment. The transmissions also included pressure altitude to the nearest 25 ft. As GPS position tends to be more accurate than radar-derived position, the recorded ADS-B data has been used in this report for G-JAMM.

G-JAMM was first recorded at 1147:04 hrs when it was on the ground at Wycombe. After takeoff, the helicopter turned to the right, climbing to approximately 1,500 ft, initially heading north before turning on to a track of approximately 340°T (Figure 3). Throughout the remainder of the flight, the altitude varied between 1,380 ft and1,555 ft and groundspeed between 60 kt and 73 kt.

Relative positions

Recorded positions of both aircraft commenced within two seconds of each other during departure from Wycombe. At this time, G-WACG was airborne at approximately 730 ft amsl, just beyond the end of Runway 24; G-JAMM was on the ground.

Footnote

3 Automatic Dependant Surveillance-Broadcast (ADS-B) – a surveillance technology which allows aircraft to transmit GPS position, pressure altitude and other parameters.

© Crown copyright 2018

During the first six minutes of flight, the distance between the aircraft increased up until the point where G-WACG turned to the right at the Stokenchurch Mast. Just prior to G-WACG commencing its climb, the aircraft were at a similar level, approximately 2.7 nm apart with G-WACG slightly behind and to the left of G-JAMM (Figure 3).

As G-WACG climbed, the tracks converged. When G-WACG then turned to track 340°T, the recorded positions show both aircraft following an almost identical path over the ground, albeit initially separated by over 2,500 ft vertically. At 1159:10 hrs, G-WACG, with a higher groundspeed, was approximately 0.5 nm behind G-JAMM and 1,950 ft above. A minute later, G-WACG was 750 ft above and approximately 1,000 ft behind. The vertical and horizontal separation progressively reduced to the point of the collision (Figure 4).

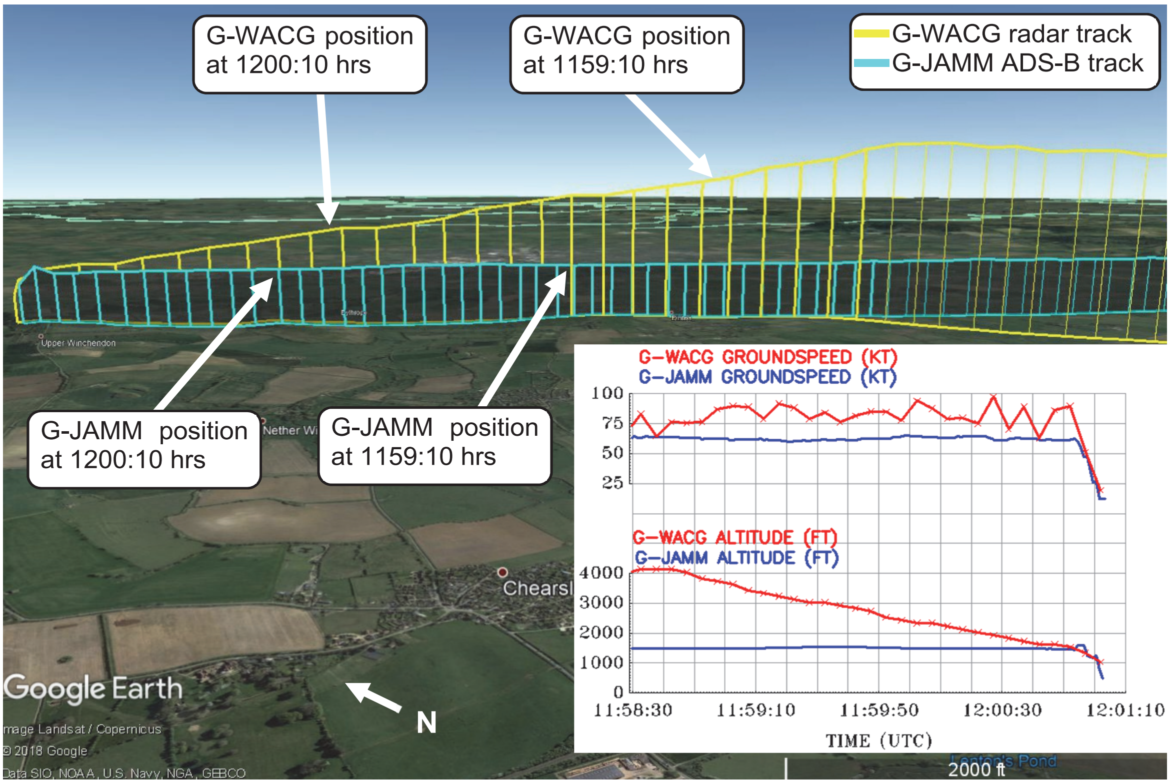

Figure 4

G-WACG and G-JAMM position information, looking to the north-east

The exact time and location of the collision could not be established due to the altitude resolution and the sampling rate of the radar. At 1200:45, G-WACG was at 1,630 ft, approximately 175 ft above G-JAMM. At 1200:53, G-WACG's recorded altitude was 1,500 ft and G-JAMM's was 1,455 ft. Just after this, the recorded radar altitudes of both aircraft started to decrease.

The final recorded radar position for G-WACG was at 1201:02 hrs, at 1,030 ft. The ADS-B recording from G-JAMM continued until 1201:03 hrs. Following the collision, some of the ADS-B altitude data was unreliable, but the final recorded altitude was almost at ground level. The accident site elevation was approximately 450 ft amsl.

Accident site

Both aircraft came down in the grounds of Waddesdon Estate and there was a debris trail approximately 300 m in length in a direction of approximately 312ºM. There were five areas of interest (Figure 5) and, apart from area 1, the wreckage from both aircraft was contained within an area of woodland.

Figure 5
Key areas of interest (area 1 highlighted in grey)

Debris recovered from area 1 consisted of small, lightweight items that were identified to be from the right wing of G-WACG. This included the navigation light, sections of fibreglass from the wingtip and parts of the right aileron and outer wing skin. Paper pages from a Cessna Pilot Operating Handbook were also recovered from this area. The aircraft's empennage, including both elevators and the rudder, was found in area 2.

G-WACG's fuselage and wings were found in area 4, having come to rest upside down opposing the direction of travel. There was no evidence of fire. The right wingtip and approximately 0.6 m of the outboard section of the right wing were missing. The right mainwheel was found adjacent to the wreckage, having broken off its axle; the nosewheel and left mainwheel remained attached to the fuselage. The leading edge of the right wing

© Crown copyright 2018

showed compression damage across its span caused by multiple impacts with the trees but the left wing was less damaged. The flaps were up.

The wreckage of G-JAMM was found mainly in area 3. It had come to rest upright, in the direction of travel and it had sustained considerable damage when it struck and descended through the trees. Some components, including the right door and fragments of the windscreen, were found several metres from the main wreckage. Most of the composite fuselage had been consumed by a post-crash fire and one of the main rotor blades was missing. The two rotor blades that remained in-situ were extensively damaged but unburnt. The tail boom and tail rotor remained attached but the structure was badly disrupted. The main rotor blade that had detached from the helicopter was found in area 5.

The wreckage was recovered to Farnborough for detailed examination and analysis by the AAIB.

Aerodrome information

Both aircraft were based at Wycombe Air Park/Booker (WAP). WAP is a busy general aviation airfield with fixed wing, rotary and gliding activity. A single asphalt runway is orientated 24/06 and there are two grass runways. Gliders use an open grass area on the south side of the aerodrome; there are designated training areas and holding points for helicopters north and east of the runways.

Communications

WAP Air Traffic Control (ATC) operates on frequency 126.55 MHz, callsign 'Wycombe Tower'. The communications are recorded and a copy of the recording was provided to the AAIB. On the morning of the accident the frequency was busy; between 1137 hrs and 1225 hrs there were multiple simultaneous/overlapping transmissions. G-WACG and G-JAMM each contacted ATC to request taxi clearance respectively and their exchanges continued until departure from the Aerodrome Traffic Zone. Neither aircraft advised ATC of a change to another frequency and no evidence was found of either aircraft having contacted any other Air Traffic Service.

Airspace

The area where the collision occurred is in Class G airspace. NATS publication '*Introduction to Airspace*[4]' advises:

> *'In class G airspace, aircraft may fly when and where they like, subject to a set of simple rules. Although there is no legal requirement to do so, many pilots notify Air Traffic Control of their presence and intentions and pilots take full responsibility for their own safety, although they can ask for help.'*

Footnote

4 https://www.nats.aero/ae-home/introduction-to-airspace/ [Accessed 21 September 2018].

© Crown copyright 2018

The United Kingdom Aeronautical Information Publication (AIP) states:

> *'Within Class G airspace, regardless of the service being provided, pilots are ultimately responsible for collision avoidance….'*

Civil Aviation Publication (CAP) 1434 and CAP 774 provide guidance to pilots on the types of Air Traffic Service that are available within Class G airspace. A 'Basic Service' relies on pilots avoiding other traffic unaided by a controller; the Air Traffic Service provider is not required to monitor the flight. A 'Traffic Service' is surveillance-based, whereby the controller provides specific surveillance-derived traffic information to assist pilots in avoiding other traffic.

The area to the north-west of WAP, where many training flights operate, is partly covered by Farnborough North Lower Airspace Radar Service (LARS), Figure 6. Farnborough LARS provides Air Traffic Services outside controlled airspace to pilots flying under or around the London Terminal Manoeuvring Area. The type of service available depends upon the request made by the pilot and the capacity of the unit. The 'Farnborough LARS Guide' published online by NATS includes the following note:

> *'Please note that Farnborough cannot provide a TS[5] below an altitude of 1,500 feet due to radar performance.'*

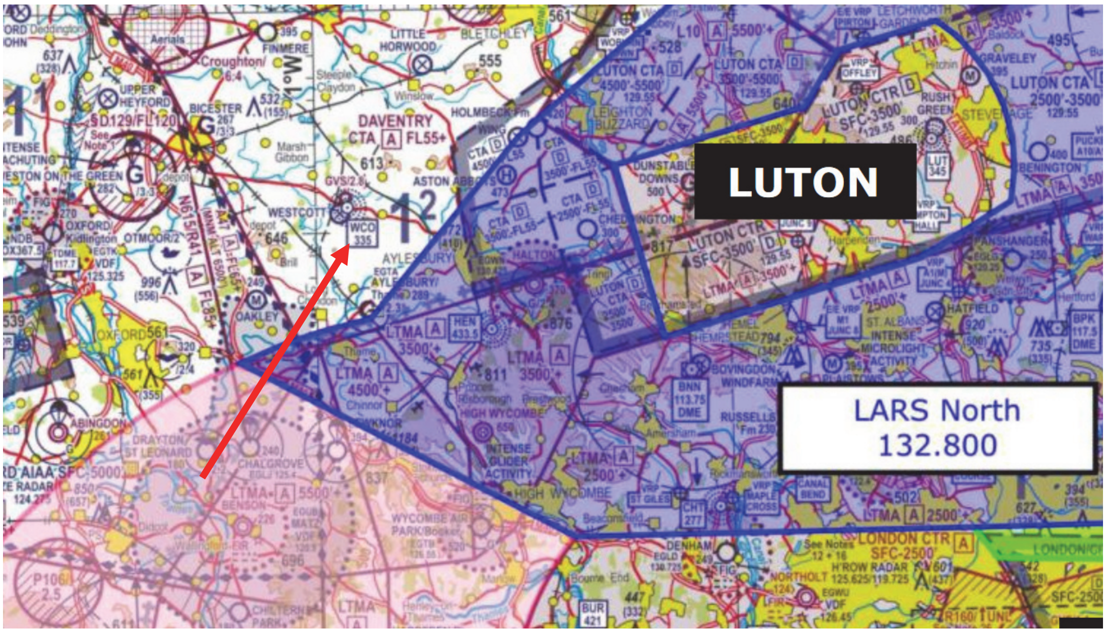

Figure 6

Accident location (indicated by arrow) relative to Farnborough LARS North

The area to the west of the Farnborough North LARS boundary is covered by Brize Norton LARS. London Oxford Airport is also radar equipped and pilots flying in the vicinity may call Oxford Approach; a Listening Squawk of 4517 is utilised for flights in the vicinity who may not wish to call ATC but want to highlight their position.

Footnote

5 (TS) Traffic service.

The Future Airspace Strategy VFR Implementation Group (FASVIG) published online a '*Register of VFR Significant Areas*'[6] which includes an overlay facility for display on Google Earth. This document provides information on areas of significant general aviation activity but also on traffic densities for gliding and paragliding activity. The collision occurred in the zone named the Brize Norton-Heathrow-Luton Gap, information on flying training activity within this area is reported:

> *'Intensive private and commercial licence training area for Oxford, Wycombe, White Waltham and other airfields/airstrips in the area, plus helicopter training from RAF Benson.'*

Aircraft information

Cessna 152

The Cessna 152 is a two-seat, single-engine, high-wing aircraft, popularly used for flying training. It has dual flying controls and the student normally occupies the left seat, which is equipped with a more comprehensive set of instruments. The aircraft has a fixed tricycle landing gear and conventional flying controls actuated by metal control rods and cables. The aircraft is of semi-monocoque construction meaning that an element of its structural integrity is derived from its outer skin. Exhaust gases from the engine pass through a muffler assembly before being discharged overboard. The muffler has a shroud around the outside, which forms a heating chamber for carburettor heat and cabin heater air; exhaust gases are not mixed with cabin air.

The aircraft has a normal cruise speed of 90 kt to 100 kt and a best glide speed of 60 kt. The rate of descent at idle power and 60 kt is around 650 fpm to 750 fpm. At higher airspeeds the rate of descent increases. While descending at idle power it is recommended to warm the engine periodically by applying power for a few seconds.

Information defining the pilot's field of view from a Cessna 152 is limited to basic angular data from the manufacturer that is '*approximate based on eye location for an 85th percentile human male.*' Nevertheless, the data was sufficient to explore the opportunities for seeing the helicopter.

G-WACG was manufactured in 1982 and had accrued 14,180 flying hours. It had a valid Certificate of Airworthiness and a 50-hour scheduled check was completed on the day of the accident. There were no outstanding faults recorded.

G-WACG was painted predominantly white with a light blue underbelly and a red stripe along the length of the fuselage side, Figure 7. It was fitted with red, green and white navigation lights, a red anti-collision beacon on the vertical fin and a landing light in the engine cowling beneath the propeller spinner.

The technical log indicated that 80 litres (21 USG) of fuel was onboard prior to takeoff.

Footnote

6 http://docs.fasvig.info/Projects/MAS01/20170930-MAS01-0002-FASVIG-VSA-V2.pdf [Accessed 21 September 2018] This document has not been endorsed by the CAA.

Figure 7

G-WACG in the colour scheme when the accident occurred
(Photograph used with permission)

Guimbal Cabri G2

The Guimbal Cabri G2 is a two-seat helicopter with a single piston engine. It has dual controls and is flown from the right seat.

The field of view from the Guimbal Cabri G2 is predominantly forwards and sideways; rearward visibility is severely restricted because of the engine and main rotor gearbox.

The main rotor has three blades with a diameter of 7.2 m, turning in a clockwise direction when viewed from above. The nominal rotor speed is 530 revolutions per minute, which equates to approximately 26 blade passes per second, or about 0.04 seconds between blades. The helicopter has a shrouded tail rotor with a diameter of 0.6 m.

G-JAMM was manufactured in 2017 and had accrued 160 flying hours. It had a valid Certificate of Airworthiness and a 50-hour check was completed in November 2017. There were no outstanding faults recorded.

G-JAMM was painted predominantly metallic red with the upper and rearmost section of the tail boom being white (Figure 8). The main rotor blades were painted light grey with yellow tips.

The aircraft technical log indicated that 68 lbs (30 kg) of fuel was onboard prior to takeoff.

© Crown copyright 2018

Figure 8

G-JAMM in the colour scheme when the accident occurred
(Photograph used with permission)

Aircraft examination

G-WACG

Debris recovered from area 1 was identified to be from the outer section of the right wing including parts of the aileron, wingtip and navigation light. Two-dimensional reconstruction of the outboard section of the wing identified multiple cuts in the trailing edge and aileron. Distortion adjacent to the cuts showed that the wing had been struck from underneath and the angle between one of the cuts and the wing upper surface was measured to be approximately 110º.

The rear empennage had separated from the aircraft in flight. Examination showed a single cut through the upper half of the fuselage, the dorsal fin and the elevator UP control cable. The cut was approximately 56° to G-WACG's vertical axis and originated on the right side of the aircraft. The lower half of the fuselage was buckled and distorted with numerous tears along the rivet lines and through the skin. The flying control cables in this lower section of the fuselage had broken due to overload.

The flying controls showed no evidence of any disconnects prior to the collision. Examination of the exhaust and shroud assembly found no evidence of any pre-existing cracks or damage.

© Crown copyright 2018

G-JAMM

The tail boom and tail rotor assembly had been extensively damaged but there was no evidence they had been struck by the main rotor blades or any part of G-WACG.

The post-crash fire consumed most of the composite fuselage and the extent of the damage prevented a full assessment of the flying controls.

Damage to the main rotor blades showed evidence of multiple hard object impacts and anti-corrosive compound from the internal structure of the Cessna had been transferred to the blades. The fracture face of the detached blade showed evidence of a failure in overload. Witness marks and damage on the blade indicated that it struck the rear fuselage of G-WACG.

Meteorology

The weather conditions were clear with good visibility. A photograph of the inflight conditions taken by a pilot of another aircraft operating in the area ten minutes before the accident and travelling in the same direction as the accident aircraft is shown at Figure 9.

Figure 9

En route weather conditions at location of accident
(Photograph used with permission)

© Crown copyright 2018

Pilot information

The Cessna instructor had been flying for seven years and instructing for one year, all at the same flying club. He held a Commercial Pilot's Licence with instructor rating and a current Class 1 medical certificate with a 'VDL' endorsement that required corrective lenses be worn and a spare set carried.

The Cessna student pilot was enrolled on an Air Transport with Commercial Pilot Training university course. He had recorded a total of three hours of flight time; the accident occurred on his fifth flight. He held a Class 1 medical certificate.

The helicopter instructor's logbook was not available for the investigation. He is reported to have flown in excess of 25,000 hours and was an experienced instructor. He held a Commercial Pilot's Licence (Helicopter) with a Class 1 medical certificate (not valid for single crew flying[7]) and held a type rating for the Cabri Guimbal helicopter.

The helicopter student held a Civil Aviation Authority of Vietnam Airline Transport Pilot's Licence with an endorsement for the Cabri G2 helicopter and a Class 1 medical certificate. He had completed 23 hours of training on the Flight Instructor Course.

Medical information

A carboxyhaemoglobin (COHb) level of 50% is considered to be the fatal threshold for a fire death and a level of 30% is considered to be incapacitating. Symptoms for a COHb level of 20% include; slight headache, fatigue and breathlessness. More serious symptoms, including significant shortness of breath, impairment of vision during exercise and general performance decrement, generally occur with rapid onset at levels of COHb around or above 25% to 35%. COHb is excreted through the lungs and the half-life is considered to be 4 to 5 hours[8].

Post-mortem examinations were carried out on the occupants of both aircraft. The post-mortem reports indicated that cause of death was multiple injuries in each case. A toxicological report noted an elevated level of COHb of 24% for the instructor in G-WACG; the COHb for the student was less than 5% (normal for a non-smoker). The report concluded that the elevated level of 24% suggested that the instructor may have survived for a short period after the accident.

It was noted in the investigation that, although all four pilots held Class 1 medical certificates, the post-mortems revealed that the instructor in G-JAMM and the student in G-WACG both showed signs of significant coronary disease.

The accident was not considered to be survivable.

Footnote

[7] The helicopter student was qualified as a pilot on the Guimbal Cabri G2.

[8] Aviation Toxicology in Aviation Medicine 3rd Edn. Eds Ernsting, J. Nicholson, A. Rainford, D. Butterworth-Heinemann 2000.

© Crown copyright 2018

Organisational information

The flying school operating G-WACG was conducting a programme of pilot training as part of a university course towards a BSc degree in Air Transport with Commercial Pilot Training. The student pilot was enrolled on the course.

Since the accident, the flying club who operated G-WACG have carried out a comprehensive internal review of their operating procedures and published Instructor Notice 001-2018 which highlights the importance of maintaining an effective lookout throughout flight and includes the information:

> *'With particular reference to exercise 8(1) and 8(2), but applicable whenever descending is taking place, pilots should avoid commencing a descent wings-level, or maintaining a prolonged straight descent. At the commencement of the descent and at regular intervals during the maintenance of the descent (every 500 feet or so) the aircraft heading should be changed sufficiently to clear the airspace below.'*

The WAP Aerodrome Operator's Safety Committee met in January 2018. It was agreed that a common approach between operators based at the aerodrome towards the adoption of Electronic Conspicuity (EC) aids would be beneficial. Research was undertaken into the existing equipment fitted to operator's aircraft and to other available solutions. At the next meeting of the committee, in April 2018, it was decided that an effective system that would work with a significant number of aircraft was not yet available and that, in the interim, a procedural review should be undertaken to facilitate the flow of traffic in and out of the Aerodrome Traffic Zone.

Tests and research

A research study '*Helicopter Rotor Conspicuity*' conducted in 2004 by The Centre for Human Sciences, QinetiQ, explored the potential enhancement to visual conspicuity afforded by different main rotor blade colour schemes. The study acknowledged there was a particular challenge presented by helicopters, especially when viewed against the low reflectance terrain background typical of a rural area.

Following a series of tests using model helicopters the study concluded that there was a significant advantage to be gained from a colour scheme where a rotor disc contained whole blades of markedly different contrasting colours. The report noted:

> *'Contrasting whole blade schemes proved superior to uniform grey, uniform white, spiral and annular schemes throughout. The best results were obtained when white and black blades were together; the benefits were substantial in comparison with uniform schemes and appeared across a wide range of background reflectances.'*

Other information

Lookout technique

The European Aviation Safety Agency (EASA) Part-FCL – Subpart C provides a syllabus of flight instruction for a Private Pilot's Licence (PPL) and includes the note: '*Each of the exercises involves the need for the applicant to be aware of the needs of good airmanship and look-out, which should be emphasised at all times*.' Specific details concerning the use and interpretation of the syllabus is the responsibility of the National Licensing Authority, in the UK this is the Civil Aviation Authority (CAA).

CAA Safety Sense Leaflet 13, '*Collision Avoidance*'[9] provides comprehensive guidance on the importance of lookout for pilots operating under Visual Flight Rules (VFR). It includes information on physical limitations of the human eye and on visual scanning techniques. Training for the Private Pilot's Licence also includes advice to pilots on the importance of lookout and guidance for lookout technique.

Elementary Flying Training for the Royal Air Force has been conducted on the Grob Tutor aircraft. The associated Tutor Training Manual introduces the 'work cycle' approach of *Lookout-attitude-instruments* for all phases of flight. It also provides guidance, specific to each training detail, on lookout technique. The advice given for the Glide Descent is:

> *'Lookout. As always lookout, is vital. Before descending you must ensure the area ahead, behind and below the aircraft is clear. When in the descent, you will see that the flightpath ahead is obscured under the aircraft's nose and so, in a long visual descent, you will be taught to clear this area in a gentle weave similar to that used in the climb.'*

The United States Federal Aviation Administration issued an Advisory Circular '*Pilots' Role in Collision Avoidance*' (AC No: 90-48D[10]) in June 2016 highlighting the importance of lookout. Section 4.3.1 Pilots' Responsibilities advises that:

> *'Pilots should: During climbs and descents in flight conditions which permit visual detection of other traffic, execute gentle banks left and right at a frequency which permits continuous visual scanning of the airspace about them.'*

See and avoid

CAP 1391[11] published by the CAA states:

> *'Aircraft operating under Visual Flight Rules (VFR) in Class G (uncontrolled) airspace are not required to carry or use a radio, transponder or, other EC system, or communicate with Air Traffic Control. Instead, pilots and other airspace users*

Footnote

9 http://publicapps.caa.co.uk/docs/33/20130121SSL13.pdf [Accessed 21 September 2018].
10 https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_90-48D_CHG_1.pdf [Accessed 21 September 2018].
11 https://publicapps.caa.co.uk/docs/33/CAP1391_E2_APR2018.pdf [Accessed 21 September 2018].

© Crown copyright 2018

> *rely on visual scanning to detect and avoid other traffic: this is known as the "see and avoid" principle. Visual scanning can however be affected by a variety of issues including: environmental conditions, aircraft design, pilot training and the limitations of the human eye.'*

A research report by The Australian Transport Safety Board (ATSB)[12] entitled '*Limitations of the See-and-Avoid Principle*', first published 1991 but still pertinent today, states:

> *'Numerous limitations, including those of the human visual system, the demands of cockpit tasks, and various physical and environmental conditions combine to make see-and-avoid an uncertain method of traffic separation.'*

The report concludes that *'the see-and-avoid principle in the absence of traffic alerts is subject to serious limitations*' and that reliance on '*see-and-avoid*' as a means of traffic separation should be minimised.

The United States National Transportation Safety Board (NTSB) issued a Safety Alert '*Prevent Midair Collisions: Don't Depend on Vision Alone -- Augment your reality to help separate safely'* (SA-058 November 2016[13]). This is aimed at encouraging pilots to adopt the use of available technology to assist them in the detection of other aircraft.

Collision avoidance systems

In addition to the see and avoid concept, a number of systems are available to enhance a pilot's mental picture of the traffic situation. These devices are collectively referred to as EC which the CAA defines in CAP 1391 as:

> *'Electronic Conspicuity (EC) is an umbrella term for a range of technologies that can help airspace users to be more aware of other aircraft in the same airspace. It includes transponders and radios. At the most basic level, aircraft equipped with an EC device effectively signal their presence to other airspace users, turning the 'see and avoid' concept into 'see, BE SEEN, and avoid'.'*

When an aircraft is fitted with a transponder, position can be determined by a radar head interrogating this transponder and using the response to calculate distance and direction from the radar head. Depending on the transponder fit, the radar head can also receive a 4-digit octal identifier (Mode A), altitude (Mode C/S) and/or a unique 24-bit identifying address[14]. This unique address enables an aircraft to be identified from a database of information (registration, aircraft type etc). If a transponder is equipped with an extended squitter and a GPS input, it can also transmit ADS-B out; a system designed to allow position, altitude and other information to be periodically transmitted without the need for radar interrogation.

Footnote

[12] https://www.atsb.gov.au/publications/2009/see-and-avoid/ [Accessed 21 September 2018].
[13] https://www.ntsb.gov/safety/safety-alerts/Documents/SA_058.pdf [Accessed 21 September 2018].
[14] State of Registry assigns each aircraft a unique 24-bit identifying address.

© Crown copyright 2018

Transponders with extended squitters are not prevalent in general aviation aircraft largely due to cost and in some cases power and size constraints. A device capable of ADS-B out does not have to be part of a transponder but, if it is, this enables the transponder's Mode S and ADS-B transmissions to be synchronised.

ADS-B traffic information can be received and displayed in a number of ways including on some flight planning and navigation software.

Both G-JAMM's and G-WACG's transponders transmitted their pressure altitude and aircraft ident of 7000. In addition, G-JAMM was Mode S and extended squitter equipped, transmitting its 24-bit aircraft identifying address and ADS-B out. Neither aircraft was equipped with an EC device that could receive and display ADS-B data to its pilots.

Although both aircraft were fitted with EC aids, neither could receive relative position and altitude information for each other. Consequently, the pilots of both aircraft relied on 'see and avoid' for collision avoidance.

Development of EC systems

In April 2018, the CAA published the second edition of CAP 1391 '*Electronic conspicuity devices.*' This document represented the outcome of a CAA-led initiative to define a standard for low-cost EC devices for light aircraft. The document stated that the CAA:

> *'…viewed ADS-B extended squitter technology as the most practical solution, due to the possibility of lower transmit power levels leading to lower power consumption, lower costs and the potential for interoperability with other ground and air users.'*

A standalone EC device containing an extended squitter separates it from the transponder which can reduce its cost, size and complexity.

By defining this standard, the aim is to encourage manufacturers to adopt this common standard and develop low-cost solutions for general aviation pilots to implement on a voluntary basis. This would allow pilots to enhance their situational awareness, providing additional cues to a visual scan.

CAP 1391 requires EC devices to have a Declaration of Capability and Conformance which is granted by the CAA. At the time of writing, seven devices had been granted declarations which are all listed on the CAA website[15]. These devices operate using 1,090 MHz which is a frequency which lies within the aviation protected spectrum. However, the CAP also prohibits simultaneous use of separate transponder and ADS-B out EC devices to ensure coordination of transmissions; thus, if a transponder is in use, the separate EC device must be switched off.

Footnote

[15] https://www.caa.co.uk/General-aviation/Aircraft-ownership-and-maintenance/Electronic-Conspicuity-devices/ [Accessed 21 September 2018].

Additional devices are also available which do not conform to the CAP1391 standard and so are not listed by the CAA, but they are widely used and have been shown to be effective in some circumstances. The frequencies used are not within the aviation protected spectrum and, if these devices do not transmit ADS-B out, the aircraft's transponder can be used at the same time.

Sense and avoid

The integration of Unmanned Aerial Systems (UAS) into civilian airspace provides additional challenges in collision avoidance. Some of these systems already use 'sense and avoid'[16] technology, but at present their effectiveness is limited in terms of detection range and closure rate. Future developments in this field may be applicable to manned aircraft.

Previous accidents and incidents

The United Kingdom Airprox Board collates and analyses information on all reported UK Airprox events and publishes an annual report[17]. Every event is attributed a risk rating and the effectiveness of identified safety barriers in avoiding a mid-air collision is also assessed. For 2016, 'see and avoid', outside of controlled airspace, was attributed a weighting of 20% as a safety barrier. Analysis of 71 events, in all airspace[18], indicated that 'see and avoid' was only fully effective in 35% of cases and partly effective in 49%.

In September 2017, the AAIB reported on a fatal mid-air collision which occurred in December 2016[19] in Class G airspace. Both aircraft were fitted with a type of EC aid but differing technologies meant that they did not communicate with each other. Since then the wider fitment and use of EC devices and the adoption of a common standard has been promoted by the CAA through the publication of CAP 1391.

Industry activity

Electronic Conspicuity Working Group (ECWG)

In 2009, the AAIB investigated a fatal mid-air collision in Class G airspace between a Grob G115E and a glider. The report[20] made Safety Recommendations to the CAA regarding EC and, as a consequence, the ECWG was set up in 2014. This Group consists of a number of industry representatives, who continue to meet to progress the development of EC.

CAA

While CAP 1391 defined the CAA's preferred EC standard, it also noted that further work was required on the subject. Since CAP 1391, the CAA has engaged in a number of trials including one investigating the effects of simultaneous use of a transponder and a separate

Footnote

[16] The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action.
[17] http://www.airproxboard.org.uk/uploadedFiles/Content/Standard_content/Analysis_files/Book%2032-final.pdf is the report for 2016 [Accessed 21 September 2018].
[18] Both controlled and uncontrolled airspace.
[19] https://www.gov.uk/aaib-reports/aaib-investigation-to-szd-51-1-junior-glider-g-cljk-and-cessna-150l-g-csfc [Accessed 21 September 2018].
[20] https://www.gov.uk/aaib-reports/5-2010-g-byxr-and-g-ckht-14-june-2009 [Accessed 21 September 2018].

© Crown copyright 2018

EC device, both operating on the same frequency. The outcome of this trial is due towards the end of 2018 which the CAA will use to focus the next stage of progressing EC devices, including whether the restriction on simultaneous EC device and transponder usage is required to continue.

EASA

In November 2017, the EASA published the European Plan for Aviation Safety (EPAS) 2018-2022. Part 5.5.4 focusses on 'Preventing mid-air collisions' and includes:

> ***'SPT.089 European Safety Promotion on Mid-air collisions and airspace infringement:***
>
> *Develop and implement a pan-European Safety Promotion campaign on preventing airspace infringement and reducing the risk of MAC* [Mid-Air Collisions] *including awareness of airspace complexity and the use of technology such as ADS-B out.'*

The EASA has requested that the CAA and EUROCONTROL[21] consider the similarities and differences in their current approaches to general aviation surveillance. This activity is currently underway; the CAA has reported that they consider *'an ADS-B solution with across Europe buy in is achievable.'*

Analysis

Communications and airspace

Air Traffic Services are available in the area of the accident but the location is on the boundary of several different providers, thus, an aircraft manoeuvring on a typical training flight within the accident area would probably need to keep changing frequencies. External communications can create an additional distraction and increase the workload during an instructional flight, which may be why neither instructor attempted to contact an Air Traffic Service other than 'Wycombe Tower'.

The collision was outside of the promulgated area for Farnborough North LARS and was below their 1,500 ft amsl altitude restriction for provision of a Traffic Service. The busy airspace and restricted radar coverage in the area was such that any of the possible service providers would probably only have been able to offer, at best, a Basic Service.

Collision

As neither aircraft was electronically conspicuous to the other, the only available method of collision avoidance between the two aircraft was 'see and avoid.' There are considerable and well understood limitations to 'see and avoid' and there was no evidence to suggest that the occupants of either aircraft had seen each other in time to avoid the collision.

Footnote

[21] EUROCONTROL is a European organisation for the safety of air navigation.

© Crown copyright 2018

G-WACG was descending from above G-JAMM on a similar course and gaining ground. The planned exercise was 8.1 Glide Descent, however, G-WACG was descending at a higher average rate of descent and airspeed than would be expected for a best angle glide, so it is possible that a higher airspeed was used, with a corresponding increased rate of descent. The angle at which the aircraft were closing was such that neither was in the field of view of the other, until perhaps a few moments before the collision.

G-WACG

The damage sustained by G-WACG indicated that the initial contact with G-JAMM was between the right wing of the aircraft and the main rotor blades of the helicopter. The number of cuts and their orientation indicated that the wing was struck from underneath by multiple rotor blades that were retreating ie travelling aft. Without precise attitude data it was only possible to determine the relative geometry of the two aircraft, and the cuts in the wing suggested that G-WACG was slightly ahead of G-JAMM immediately before the collision. The angle between one of the cuts and the upper surface of the wing indicated that the relative angle between G-WACG and the helicopter's rotor blades was approximately 110°. This suggests that one or both aircraft may have been manoeuvring immediately prior to the collision and the possibility of sudden evasive action cannot be discounted.

Following the initial impacts on the right wing, G-WACG was struck by a single rotor blade that cut through the upper half of the rear fuselage, passing from right to left at an angle of approximately 56° to G-WACG's vertical axis. The blade cut through the elevator UP control cable, which is routed through the upper half of the rear fuselage. The empennage, including both elevators and the rudder detached because of the combined effects of aerodynamic loading and the loss of structural integrity. The aircraft could not sustain controlled flight following the loss of the empennage.

Examination of G-WACG identified no evidence of any flying control disconnections that were not attributable to the accident, indicating that the aircraft was controllable prior to the collision.

G-JAMM

G-JAMM was severely damaged in the accident and post-crash fire. It was not possible to examine the flying controls in their entirety but the radar data showed no evidence of anything untoward prior to the collision and the crew did not report any anomalies. The damage sustained during the collision and the loss of a main rotor blade would have rendered the helicopter uncontrollable.

Witness marks on the detached rotor blade indicate that this was probably the blade that struck the rear fuselage of G-WACG.

See and avoid

Fixed wing aircraft with forward mounted engines have a restricted view ahead and below the flightpath. As a consequence, to see into the blind spots and to determine that the area

© Crown copyright 2018

into which it is descending is clear, an aircraft would have to be manoeuvred, generally by conducting a series of shallow turns.

Radar data indicated that, when G-WACG was 1,950 ft above G-JAMM, it was only 0.5 nm behind it. A simple assessment indicates that, if G-WACG was straight and level with zero pitch angle at 2,000 ft above G-JAMM, it would have to have been at least 1.9 nm behind for the pilot to have had any opportunity of detecting a possible conflict without additional manoeuvring (Figure 10). In the absence of a turn, the pilot would need to have pitched the aircraft at least 24° nose-down to have had any chance of observing the helicopter. The situation, whereby additional manoeuvring would have been required by G-WACG to bring the helicopter into view, would have persisted up to the point of collision.

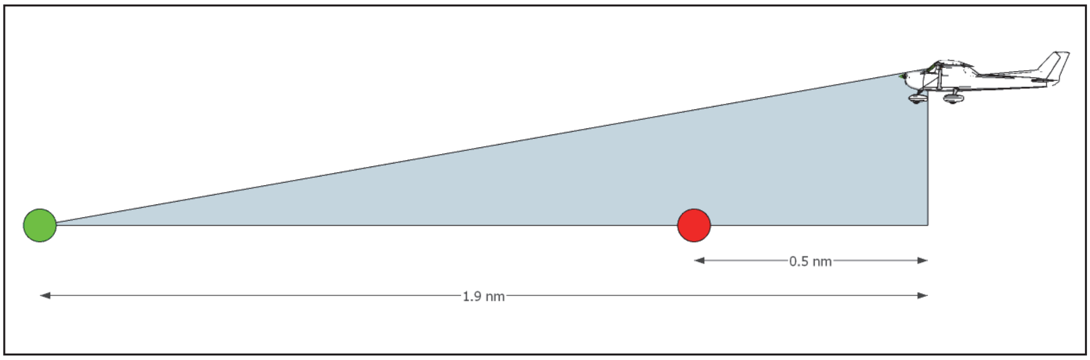

Figure 10

Forward visibility from G-WACG
(grey area is obscured from vision,
red circle indicates the radar position of G-JAMM,
green circle indicates the minimum distance at which
G-JAMM would have been visible)

The limitations of radar data are such that it was not possible to determine whether the pilots in G-WACG carried out any additional manoeuvring. Even if they did bring the helicopter into their field of view the chance of seeing it would have been limited; the conspicuity of a small helicopter against an unreflective background such as open fields and trees, is very low. The main rotor blades were of a uniform grey colour with yellow tips and would have been very difficult for the pilots of G-WACG to see against the land surface.

It would have been impractical for the pilots of the helicopter, in which visibility to the rear is obscured, to search the area behind them.

It is widely acknowledged that 'see and avoid' has a limited effectiveness in the prevention of mid-air collisions. The opportunity for a pilot to see another aircraft may be enhanced by the adoption of a good and regular scanning technique, as well as manoeuvring the aircraft regularly to clear unsighted areas. Similarly, the visual conspicuity of aircraft may be improved by high-visibility paint schemes, lighting and, specifically for a helicopter, by having one rotor blade of a contrasting colour.

© Crown copyright 2018

Despite these possible enhancements a more effective method of collision prevention is likely to be through compatible EC aids on all aircraft which could draw a pilot's attention to the presence of other aircraft.

Medical aspects

The investigation noted from the toxicological analyses that that there was an elevated level of COHb for the instructor of G-WACG. This remains unexplained. The different levels between the two occupants and the evidence of the undamaged exhaust system indicate it was not as a result of an aircraft exhaust entering the cabin. Other possible explanations for the discrepancy are exposure to carbon monoxide (CO) prior to flight, exposure to CO post-accident and sample quality.

Exposure prior to flight is considered unlikely given the probable elapse of at least several hours since exposure, together with the rate of half-life decay of 4 to 5 hours. These factors would require the COHb to have been at a level considered to be incapacitating and clearly discernible to self or others in the period leading up to the accident flight. Also, there is no evidence to suggest an incapacitating exposure to CO in the one hour before the accident flight as the effects would have been apparent prior to commencement of that flight. It is more likely therefore that the exposure was as a result of a short survival period post-accident, as concluded in the toxicological report.

Although not identified at their respective Class 1 medical examinations, one pilot on each aircraft suffered from a medical condition which could have resulted in a sudden incapacitation. However, given the circumstances, it is unlikely that it was a factor in this accident.

Medical aspects were not considered to have been a factor in the accident.

Ongoing CAA work

The CAA work to help prevent the number of mid-air collisions in GA aircraft in uncontrolled airspace primarily involves the promotion of EC. The results of the simultaneous transponder and EC use trial will provide a useful insight to those who wish to fit a CAP 1391 EC device alongside their transponder. A number of EC-specific CAA activities are underway on which the CAA will report with a view to progressing the uptake of EC devices.

The operators based at Wycombe Air Park/Booker have agreed that a common approach towards the adoption of EC aids would be beneficial but recognise the current absence of an effective system that would work with a significant number of aircraft.

Conclusion

The geometry of the flight paths was such that the opportunity for the occupants of the two aircraft to 'see and avoid' each other was very limited. The damage sustained to each aircraft was such that neither could continue in controlled flight.

It is not known whether shallow turns were made during G-WACG's descent from 4,000 ft and G-JAMM's main rotor paint scheme would not have enhanced visual conspicuity when viewed from above.

© Crown copyright 2018

As the separation between the two aircraft gradually reduced over several minutes, the use of compatible EC devices could have improved situational awareness such that avoiding action could be taken.

CAP 1391 defines a standard for EC, using ADS-B out, which has been adopted by some manufacturers. Other manufacturers have created and sold cost-effective devices, using a different standard and frequency, which are widely used and can be operated at the same time as the aircraft's transponder. With a growing uptake in EC devices, interoperability between systems and frequencies is vital to ensure its success in preventing mid-air collisions.

Safety action

Following previous Safety Recommendations, work is ongoing, led by the CAA, to promote the development and use of compatible Electronic Conspicuity (EC) aids to help mitigate the well-known limitations of 'see and avoid'.

The flying club which operated G-WACG has issued an Instructor Notice to highlight the importance of maintaining an effective lookout throughout flight, and the need to carry out a regular change of heading during a prolonged descent, to check that the area ahead is clear.