ACCIDENT

Aircraft Type and Registration:	i) Denney Kitfox, G-TOMZ ii) Cessna F177RG, G-AZTW
No & Type of Engines:	i) 1 x Rotax 912 UL ii) 1 x Lycoming IO-360-A1B6
Year of Manufacture:	i) 2001 ii) 1972
Date & Time (UTC):	23 September 2014 at 0728 hrs
Location:	Near St Neots, Bedfordshire
Type of Flight:	i) Private ii) Private
Persons on Board:	i) Crew - 1 Passengers - None ii) Crew - 1 Passengers - None
Injuries:	i) Crew -1 (Fatal) Passengers - N/A ii) Crew - None Passengers - N/A
Nature of Damage:	i) Aircraft destroyed ii) Damage to engine, propeller, fuselage underside and horizontal tailplane
Commander's Licence:	i) Private Pilots Licence (Medical declaration) ii) Private Pilots Licence (JAA Class 2 medical certificate)
Commander's Age:	i) 46 years ii) 56 years
Commander's Flying Experience:	i) 990 hours (of which approximately 200 were on type) Last 90 days - 36 hours Last 28 days - 4 hours ii) 1038 hours (of which 604 were on type) Last 90 days - 11 hours Last 28 days - 7 hours
Information Source:	AAIB Field Investigation

Synopsis

Two aircraft collided in visual meteorological conditions in Class G airspace; neither aircraft was receiving an ATC service. The investigation concluded that the accident occurred because neither pilot saw the other aircraft in sufficient time to take effective avoiding action.

History of the flights

Denney Kitfox G-TOMZ

The pilot, who owned the aircraft, took off from his private strip at 0752 hrs, and departed on a southerly track towards Sandy Airfield. This was a route he flew regularly, when the weather permitted, as a means of getting to his place of work. He normally flew the route at between 2,000 ft and 4,000 ft, at a speed of between 70 kt and 80 kt. At approximately 0725 hrs he called on the Microlight Common Frequency to inform Sandy Airfield traffic that he was approaching the airfield.

Cessna F177RG Cardinal, G-AZTW

At around 0720 hrs, the pilot of G-AZTW, who was a co-owner of the aircraft, took off from Fowlmere Airfield for Sywell Aerodrome. This was a route he also flew regularly, when the weather permitted, as a means of getting to his place of work. The flight was uneventful until he was approaching the south of St Neots. The pilot reported he was looking out and using ground features to determine he was on track. He was in Class G[1] airspace, and recalled cruising at approximately 2,700 ft, at a speed of 130 kt, and on a heading of approximately 285°. He was listening to the Luton Approach frequency, and his transponder was set to the appropriate 'Listening-out squawk[2]' for Luton.

The pilot recollected suddenly seeing a red light aircraft, with a high wing and a single engine, that he thought was climbing towards him. It was positioned between two and three o'clock, slightly below him, at a distance of 15 to 20 ft. He considered a collision was imminent and instinctively pulled the control column back and turned it to the left. The pilot of G-AZTW thought that the other pilot had not seen his aircraft because G-TOMZ did not appear to have taken any avoiding action.

The pilot of G-AZTW felt and heard an impact, and his aircraft pitched nose-down severely. He applied full aft elevator, but his aircraft did not initially respond. He then transmitted a Mayday call and started to trim the elevator fully back. Using full control input and engine power, he was able to regain limited control of his aircraft. Ahead of him he could see Bedford Aerodrome and, having informed Luton ATC of his intentions, he made a straight-in approach to Runway 26 and landed safely. Although shaken, he was uninjured. After landing he telephoned Luton ATC and provided further details.

G-TOMZ was located shortly afterwards by the emergency services, in a field 2.7 nm to the south of St Neots. The pilot had sustained fatal injuries.

Eyewitness information

An eyewitness was in her garden when she saw an aircraft which appeared to be banking steeply before entering a steep dive. The aircraft started to rotate and the speed of the rotation seemed to increase as it descended, before it disappeared from view behind bushes. The witness saw no other aircraft in the sky at the same time.

Footnote

1 See the section *'Class G airspace', below.*

2 Listening-out Squawk codes, or frequency monitoring SSR codes are allocated for aircraft operating around 10 major UK airfields. AIP ENR 1.6 2.2.5.6 contains the details.

Pilot information

The pilot of G-TOMZ held a Private Pilot's Licence, rated for microlights, originally issued in 1994. The medical declaration[3] was in date and countersigned by a General Practitioner. The pilot was required to wear corrective lenses, and evidence of two pairs of glasses were found in the wreckage. The pilot was in current flying practice as evidenced by the Sandy Airfield Private Flight Log Sheet, which showed he had flown into Sandy Airfield five times during the preceding five weeks.

The pilot of G-AZTW held a Private Pilot's Licence, originally issued in 1986. His Class 2 medical certificate included the limitation that he must wear corrective lenses and he was in current flying practice.

Aircraft information

G-TOMZ

The Denney Kitfox is a two-seat high-wing monoplane with tail wheel landing gear. The aircraft is of tubular alloy, plywood and fabric construction, with a wing span of 9.75 m. G-TOMZ was built in 2001 and was fitted with a Rotax 912 UL engine. The aircraft had a valid Permit to Fly. It was coloured predominantly white with red wings and markings, as shown in Figure 1.

Figure 1

Image of Denney Kitfox G-TOMZ (with kind permission of Peter Olding)

Footnote

3 CAA Official Record Series 4, No 995 allows the medical requirements for a PPL(A) rated for microlights to be met by a pilot's self declaration.

G-AZTW

The Cessna F177RG Cardinal is a four-seat, high-wing monoplane with a retractable tricycle landing gear. It was built in 1972 and was fitted with a 200 hp Lycoming engine. The aircraft had a valid Airworthiness Review Certificate. It was predominantly white with red and blue markings, and had an anti-collision light. Its typical straight-and-level cruising airspeed is around 120 to 140 kt.

Wreckage and wreckage site of G-TOMZ

Most of the wreckage was located in a small area in a stubble field. The vertical and horizontal tailplane were largely intact but the wing and fuselage were severely disrupted. Both the wing-mounted fuel tanks were badly damaged, and there was a smell of fuel. There was no evidence of fire.

Several parts of the right wing were located over 250 m from the main wreckage. The right wing tip fairing, which is red, had white scuff marks. There was a 1.6 m long piece of the alloy leading edge spar tube, one end of which appeared to have failed in overload and the other appeared to have been cut through at an angle of approximately 35°, just inboard of the wing tip.

Damage to G-AZTW

G-AZTW landed successfully at Bedford Aerodrome. There was a 12 cm wide scuff mark on one blade of the propeller, and a 50 cm long dent with red witness marks in the left lower part of the cowling, see Figure 2. Several small pieces of aircraft structure from G-TOMZ were removed from the nose gear door of G-AZTW. There were some scuff marks along the fuselage underside. The landing gear was down, with no evidence of any witness marks that might have occurred had the gear been down during the collision. There was extensive damage to approximately 75% of the underside of the left horizontal tailplane, and a piece of the horizontal tailplane tip fairing was found approximately 500 m from the main wreckage of G-TOMZ.

Figure 2

Images of G-AZTW at Bedford Aerodrome

Assessment of damage to both aircraft

By comparing the damage and the witness marks on both aircraft it appears that the initial impact was between the rotating propeller of G-AZTW and the right wing tip of G-TOMZ. The damage to the lower left of the engine cowling on G-AZTW suggests that the propeller was around the five o'clock position when this occurred. Thus G-AZTW was slightly higher than G-TOMZ at the time of the collision resulting in the damage to the lower fuselage and horizontal tailplane of G-AZTW.

Approximately 40% of the outboard right wing of G-TOMZ was found over a wide area, which suggests that this damage occurred in mid-air. It is likely that the aircraft would not have been capable of normal flight with such damage.

Limitations of lookout

Maintaining an effective lookout for aircraft and other hazards is a prime task for a pilot. It is of particular importance when flying in uncontrolled airspace.

There are limitations in the human visual system that serve to make collision avoidance difficult by visual means alone. The capacity of the human eye to resolve detail is not distributed evenly across the retina. The most central part of the retina is termed the fovea, and is composed only of cones - the light sensitive cells used for day vision. Cones provide high visual acuity, colour vision and contrast discrimination. Although there is good resolving power at the fovea, this ability drops rapidly outside the fovea. Normal visual reflexes adjust the direction of gaze to ensure that the image of an observed object falls on the fovea for optimum resolution. Such vision, sometimes termed 'focal' vision, requires a stable image and the viewer's attention.

Away from the fovea, the density of cones reduces, and the density of rod cells increases. Rods are more sensitive to light than cones, and are used for day, night and low intensity vision. Rod vision is monochromatic and of low acuity, giving only outlines or shapes. It is, however, responsive to movement. It does not require the same degree of attention as focal vision, and is important for spatial orientation and 'flow vision', which gives a sense of speed. Rod vision is sometimes referred to as 'peripheral' vision.

A distant aircraft will be perceptible to a pilot if it is acquired at or near the fovea. As an area of sky is scanned by the pilot, the eye naturally makes a series of jumps, or saccades, with intervening rests. The scene is only interrogated by the brain during the rest periods. A very small object may therefore be 'jumped over' or fall on an area away from the fovea – in either case it will not be detected. Each saccade-rest cycle takes a finite time and a full scan of an area of sky will take several seconds. An object missed early in the scan may approach hazardously close or even collide before that area is scanned again by the pilot.

Two aircraft on a collision course, which are maintaining constant tracks, will maintain a constant relative bearing to each other until the moment of impact. The colliding aircraft will therefore appear in the same place unless the pilot makes a head movement. As the colliding aircraft is not moving relatively, it does not necessarily attract the attention of the peripheral vision system. The rate of increase in retinal size of the approaching aircraft is not linear and the image stays relatively small until very shortly before impact. Additionally, small targets may be hidden behind door frames or struts, or in a blind spot,[4] until close to collision. For these reasons pilots are taught not just to look around them, but to make positive head movements as they do so.

The Australian Transport Safety Bureau (ATSB) explored visual acuity in its research report, 'Limitations of the See-and-Avoid Principle', published in April 1991[5]. The report considered the angular size that the retinal image of an aircraft would have to be before it was identifiable and suggested a threshold of 0.2º, in optimal conditions, up to approximately 0.5º in more realistic sub-optimal[6], conditions.

The effectiveness of visual air-to-air acquisition also depends on the contrast of an aircraft with its background[7]. Increased contrast improves visual acquisition but contrast degrades exponentially with visual range. If contrast reduces to approximately 5% the target disappears. It was not possible to account for contrast during this investigation, so only the size of the target was considered.

In 1983 the FAA[8] issued an Advisory Circular detailing the amount of time it takes for a pilot to recognise an approaching aircraft and execute an evasive manoeuvre. The circular detailed the time taken: to see an object, to recognise it is an aircraft, to become aware it is on a collision course, to decide on the appropriate avoiding action, to make the necessary control inputs and for the aircraft to respond. The publication indicated it could take around 12.5 seconds to complete these actions.

Meteorological information

At the time of the accident, England was under the influence of high atmospheric pressure, with settled conditions and a light south-westerly airflow. There was widespread early morning mist reported, which was clearing to give hazy conditions, and visibility was reported to be approximately 7,000 to 8,000 m. The location of the accident was close to the northern edge of an area of stratocumulus cloud, with a base at approximately 4,500 ft to the south of this. Sunrise was at 0549 hrs and at the time of the accident the sun would have been low in the sky to the south-east. This would have adversely affected into-sun visibility. Under the layer of stratocumulus further south, the sun's position would not have affected visibility. A Met Office aftercast indicated that the wind at 2,400 ft was from 260° at 10 kt.

Footnote

[4] Blind spots are a characteristic of the human eye. The blind spot is located where the optic nerve connects to the eye. If something obstructs one eye's view (such as aircraft structure) the viewed object may be in the remaining eye's blind spot, causing it to disappear.
[5] ISBN 0 642 16089 9 Reprinted November 2004.
[6] With reduced contrast.
[7] Project Report ATC-152. Unalerted air-to-air acquisition. J. W. Andrews 26 November 1991.
[8] U.S. Department of Transportation, Federal Aviation Administration (FAA), Advisory Circular AC 90-48C, Pilots' Role in Collision Avoidance (18 March 1983), Appendix 1.

Recorded information

Recorded radar information was available for both aircraft, with primary and secondary (Mode A and C) recorded for G-AZTW and primary for G-TOMZ. Figure 3 provides the radar tracks of the aircraft. Figure 4 plots the positions of both aircraft commencing at a separation of just over 1 nm, with the relative positions identified at four second intervals and angular sizes of 0.2° and 0.5° when viewed from either aircraft. For clarity, the tracks have been illustrated in Figure 4 rather than the actual radar tracks.

Prior to the collision, G-TOMZ had been maintaining a southerly track of about 180° T at a groundspeed of 64 kt and G-AZTW a track of about 298° T at an altitude of approximately 2,400 ft amsl and at a groundspeed of 118 kt. As the two aircraft approached, they remained on a constant bearing with each other at a closing speed of approximately 157 kt. Assuming a wind from 260° at 10 kt, G-TOMZ would have appeared about 24° to the right of G-AZTW, and G-AZTW would have appeared 50° to the left of G-TOMZ.

Impact is estimated to have occurred at 0728:29 hrs. The main wreckage of G-TOMZ was located approximately 0.15 nm from where the two radar tracks intersected.

Table 1 contains the angular size[9] of each aircraft as they approached each other.

TIME TO COLLISION (s)	RANGE (nm) / (m)	ANGULAR SIZE of G-TOMZ when observed from G-AZTW (º)	ANGULAR SIZE of G-AZTW when observed from G-TOMZ (º)
24	1.05 / 1,940	0.14	0.17
20	0.87 / 1,620	0.17	0.20
17.5	0.76 / 1,420	0.20	0.23
16	0.70 / 1,295	0.22	0.26
12	0.52 / 970	0.29	0.34
8	0.35 / 650	0.43	0.52
7	0.30 / 565	0.50	0.59
4	0.17 / 325	0.87	1.03

Table 1

Angular size from 24 seconds before the collision

Immediately following the collision, G-AZTW descended rapidly for about 16 seconds at an average rate of 1,700 fpm before recovering at about 1,950 ft (see Figure 5). It then climbed to about 2,350 ft before descending to land on Runway 26 at Bedford Aerodrome.

Footnote

[9] This is based on the average of the span, length and height of the aircraft.

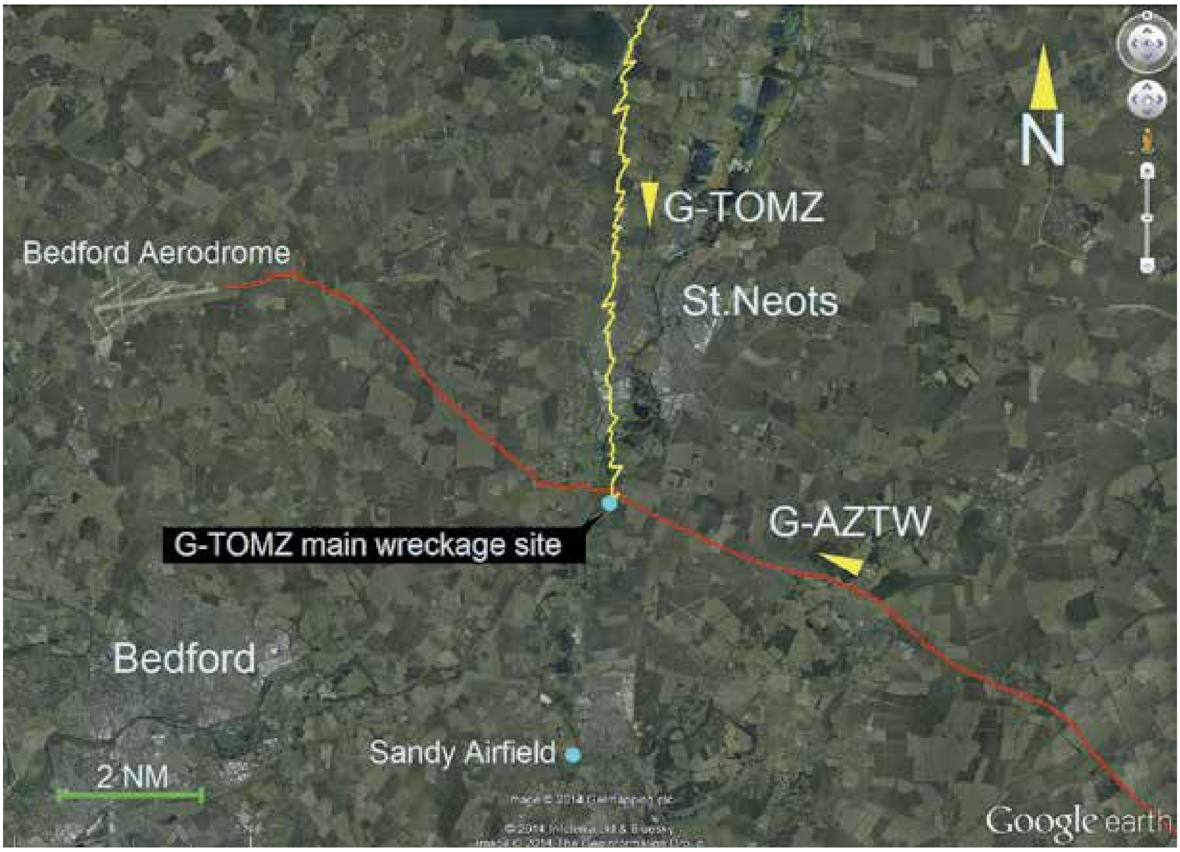

Figure 3
Radar tracks of G-TOMZ and G-AZTW

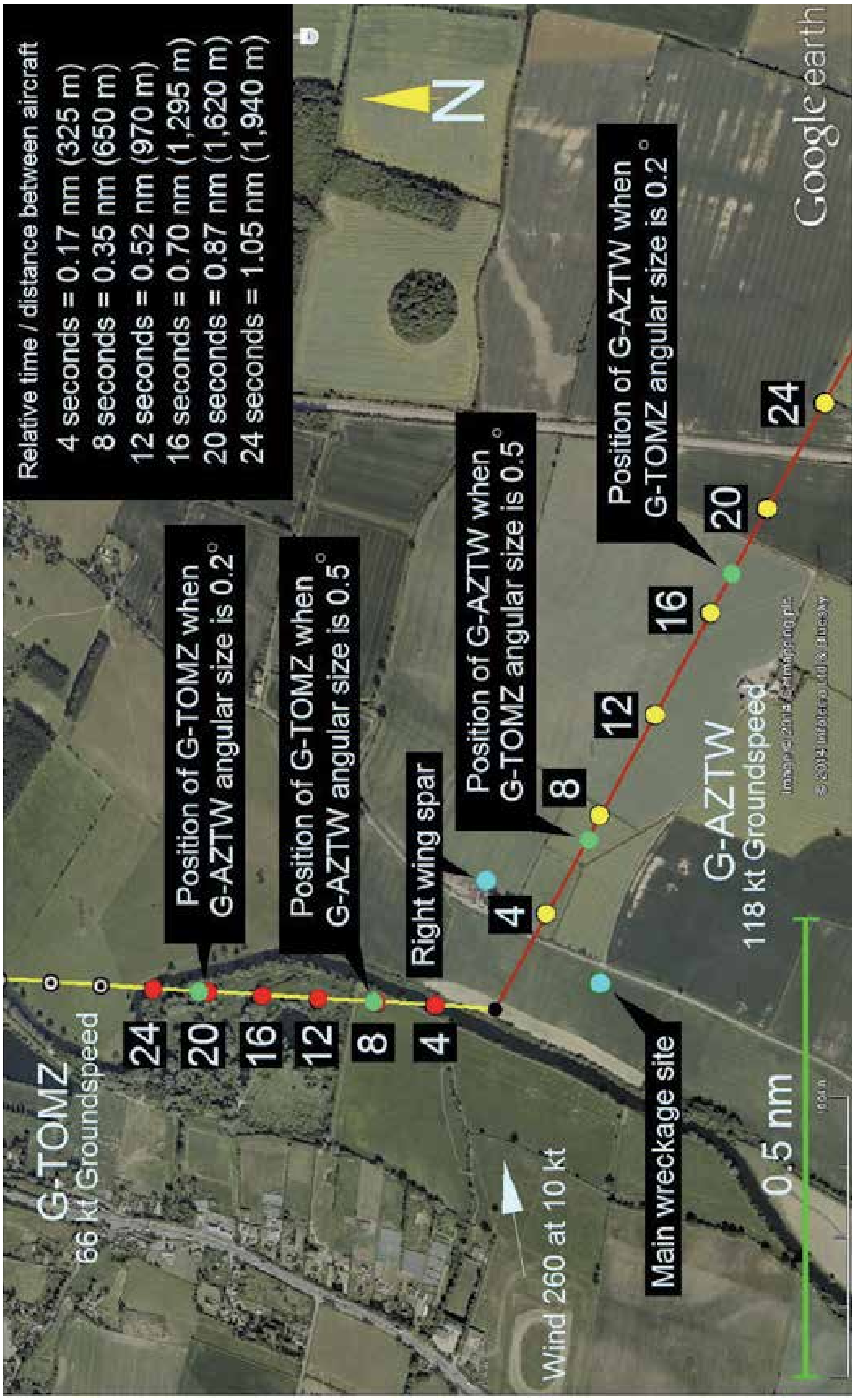

Figure 4
Relative positions of G-TOMZ and G-AZTW prior to collision

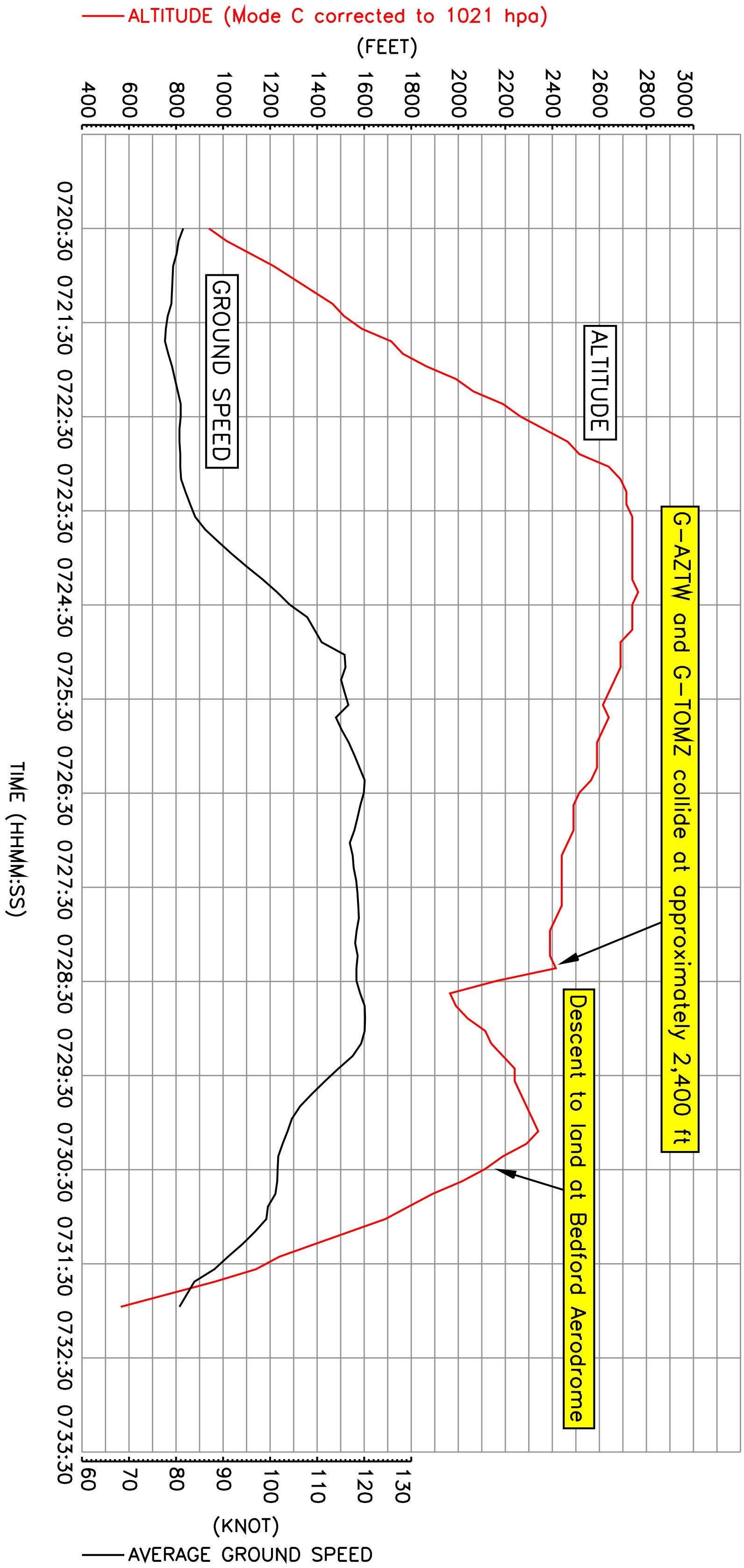

Figure 5

G-AZTW Altitude and groundspeed

View from the respective cockpits

An assessment was made of the likely views that each pilot would have had when looking in the direction of the other aircraft. See Figures 6 and 7. It was determined that G-AZTW had a large door frame to the right side of the cockpit; G-TOMZ had a wingstrut outside the left window.

Figure 6

Pilot's eye view from a F177RG in the direction of G-TOMZ

Figure 7

Pilot's eye view from a Denney Kitfox in the direction of G-AZTW

Medical and pathological information

A post-mortem examination of the pilot of G-TOMZ was carried out by a consultant aviation pathologist. He concluded that the pilot died as a result of multiple injuries consistent with having been caused when his aircraft struck the ground. There were no medical or toxicology factors that may have contributed to the accident.

Class G airspace

Airspace over the UK is divided into several classes, described in the UK Aeronautical Information Publication (UK AIP).[10]

The airspace in which the aircraft were operating at the time of the collision was classified as Class G airspace, which is uncontrolled, and includes all UK airspace which is not either controlled or advisory airspace.

Pilots operating in Class G airspace are not obliged to seek an air traffic service, and ATC instructions to pilots are not mandatory. Although pilots are free to seek a service from ATC, controllers cannot guarantee to achieve de-confliction minima due to the unknown nature of the Class G air traffic environment.

The UK AIP states:

> *'Within Class G airspace, regardless of the service being provided, pilots are ultimately responsible for collision avoidance and terrain clearance, and they should consider a service provision to be constrained by the unpredictable nature of this environment.'*

Rules of the air

The Rules of the Air Regulations 2007 are applicable to flights within the United Kingdom. In respect of powered aircraft, Regulation 9 (3) states:

> *'… when two aircraft are converging in the air at approximately the same altitude, the aircraft which has the other on its right shall give way.'*

Regulation 8(1) states:

> *'… it shall remain the duty of the commander of an aircraft to take all possible measures to ensure that his aircraft does not collide with any other aircraft.'*

Footnote

10 The UK AIP is published by authority of the UK Civil Aviation Authority.

Previous mid-air collisions

The CAA database showed that, in the UK in the 10 years before this accident, there were 22 mid-air collisions resulting in 16 fatalities[11].

Collision avoidance

The primary method of detecting other aircraft in uncontrolled airspace is 'see-and-avoid', where pilots conduct a visual scan to detect other traffic. 'See-and-avoid' can be enhanced by the use of an electronic aid, either air or ground based, to provide range, bearing and (possibly) height information. Such a method is called 'alerted see-and-avoid'. Studies have shown that this method can be eight times more effective[12] than 'see-and-avoid'.

There are several TCAS and non-TCAS aircraft-based electronic aids available, each of which has its limitations. These aids will only provide warnings of other aircraft that are fitted with compatible equipment. A hazard of relying on such electronic aids is that a pilot may concentrate on aircraft that the system has detected to the detriment of looking for other aircraft that do not have the equipment fitted.

The UK Airprox Board (UKAB)[13] has recommended that the CAA should promote the production, and mandate the use of a lightweight transponder. In response, the CAA considered Mode S transponders to be the most appropriate equipment, but following consultation with the aviation community, decided not to mandate their use in uncontrolled airspace. The principal arguments against such transponders are their relatively high power consumption, the cost, and the weight penalty. These arguments are not as strong for equipment such as FLARM[14], which is not utilised by ground-based radars, but intended to alert pilots to nearby aircraft. For such systems to be effective, it would be necessary for all aircraft operating in uncontrolled airspace to be fitted with compatible equipment.

Automatic Dependant Surveillance Broadcasting (ADS-B) collision avoidance trial

Many aircraft already carry transponders that are capable of transmitting GPS sourced positional information via ADS-B. Until recently the CAA required such functionality to be disabled, unless the GPS source was certified. Certified GPS sources have been considered too expensive for the GA community to use.

NATS,[15] is conducting a trial with the AOPA[16], Trig Avionics and Funke Avionics, which uses a non-certified GPS source, connected to a transponder. The aim of the trial is to understand whether the performance of uncertified GPS devices, in conjunction with ADS-B, can be

Footnote

[11] For aircraft under 5,700 kg, a General Aviation Safety Council (GASCo) study over a 26 year period has shown that in the UK 6% of fatalities were caused by mid-air collisions. This compares with almost 25% attributed to loss of control in VMC and 12% caused by controlled flight into terrain.
[12] Unalerted Air-to-Air visual Acquisition Andrews MIT 1991 Project Report ATC-152.
[13] UKAB recommendation 186/05-02.
[14] FLARM is a device that provides a warning, and positional information, of other similar devices it detects in close proximity. FLARM does not increase an aircraft's electronic conspicuity to Air Traffic Service (ATS) providers, unlike mode A, C or S Transponders. More information is available at www.flarm.com
[15] NATS is the UK's national ATS provider.
[16] AOPA Aircraft Owners and Pilots Association, http://www.aopa.co.uk/

used to deliver safety benefits. Possible applications include collision avoidance warnings in the cockpit, enhanced situational awareness, and advanced functions such as synthetic traffic information spoken directly into the pilot's headset.

A supplementary initiative is to introduce a low powered ADS-B transceiver called LPAT (Low Powered ADS-B Transceiver). It is intended that this will be an affordable, lightweight, carry-on device, to provide enhanced awareness of other aircraft.

Analysis

Recorded information indicates that the aircraft approached each other in steady flight, and there was no evidence to indicate that either was in difficulty prior to the collision. The accident occurred in Class G airspace, with neither aircraft in receipt of an ATC service, so the only way to avoid a collision was the use of see-and-avoid techniques. The following factors may have contributed to neither pilot seeing the other aircraft until too late to avoid a collision:

- Each aircraft had little or no relative movement when viewed from the cockpit of the other making them difficult for each pilot to detect.
- Both pilots were navigating visually, so their lookout would have been focussed primarily in the direction they were travelling. The pilot of G-TOMZ was 3.6 nm North of Sandy Airfield and so it's likely his attention was focussed on his arrival into the circuit pattern.
- There was airframe structure in both aircraft that may have prevented the pilots from seeing each other.
- The position of the sun, low in the sky to the south-east, could have made detection of G-AZTW more difficult for the pilot of G-TOMZ.

Research by the ATSB showed that in optimal conditions G-TOMZ might have been visible to the pilot of G-AZTW approximately 17.5 seconds before the collision; G-AZTW may have been visible to G-TOMZ approximately 20 seconds before the collision.

In more realistic sub-optimal conditions, G-TOMZ should have been visible for approximately 7 seconds, and G-AZTW should have been visible for approximately 9 seconds before the collision. FAA research on collision avoidance indicates this would have provided insufficient time for either pilot to take effective avoiding action.

Regulation 9 of the Rules of the Air Regulations, which would have required the pilot of G-AZTW to give way in this case, could only have been complied with if the pilot had seen G-TOMZ in sufficient time for him to take appropriate avoiding action.

'See-and-avoid' is a not a perfect technique for preventing mid-air collisions due to the limitations of the human eye. Technology may provide an affordable enhancement which could reduce the number of mid-air collisions. Until then, whenever possible, pilots should be encouraged to make use of transponders in conjunction with a radar service, and to maintain an active lookout.

Conclusion

The accident occurred because the pilots did not see each other's aircraft in time to take effective avoiding action.