AIRCRAFT ACCIDENT REPORT 6/2010

Air Accidents Investigation Branch

Department for Transport

Report on the accident to Grob 115E Tutor, G-BYUT and Grob 115E Tutor, G-BYVN near Porthcawl, South Wales on 11 February 2009

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996

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

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This report contains facts which have been determined up to the time of publication. This information is published to inform the aviation industry and the public of the general circumstances of accidents and serious incidents.

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Department for Transport
Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
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September 2010

The Right Honourable Philip Hammond
Secretary of State for Transport

Dear Secretary of State

I have the honour to submit the report by Mr P E B Taylor, an Inspector of Air Accidents, on the circumstances of the accident between Grob 115E Tutor, registration G-BYUT, and Grob 115E Tutor, registration G-BYVN, at Porthcawl, South Wales on 11 February 2009.

Yours sincerely

Keith Conradi
Chief Inspector of Air Accidents

Contents

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	Air Accidents Investigation Branch
ACP	Air Cadet Publication
AEF	Air Experience Flight
agl	above ground level
AIP	Aeronautical Information Publication
amsl	above mean sea level
AOC 22Gp	Air Officer Commanding 22 Group
ARCC	Aeronautical Rescue Co-ordination Centre
ATC	Air Traffic Control
bhp	brake horsepower
cm	centimetre(s)
CWS	collision warning sytems
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
ELT	Emergency Locator Transmitter
fpm	feet per minute
ft	feet
g	acceleration due to Earth's gravity
GPS	Global Positioning System
HISL	high intensity strobe lights
hrs	hours (clock time as in 1200 hrs)
km	kilometre(s)
LSJ	lifesaving jacket
m	metre(s)
MES	Medical Employment Standard
MHz	megahertz
nm	nautical mile(s)
QNH	altimeter pressure setting to indicate elevation amsl
QRF	quick release fitting
RAF	Royal Air Force
R/T	radiotelephony
SAR	Search and Rescue
SI	Service Inquiry
SSR	Secondary Surveillance Radar
TGO	Training Group Order
UHF	Ultra High Frequency
UTC	Co-ordinated Universal Time (GMT)
UAS	University Air Squadron
UWAS	University of Wales Squadron
VFR	Visual Flight Rules
VHF	Very High Frequency

Aircraft Accident Report No: 6/2010 (EW/C2009/02/02)

Registered Owner and Operator:	VT Aerospace Limited
Aircraft Types:	Two Grob Aerospace 115E Tutors
Nationality:	British
Registrations:	1) G-BYUT
	2) G-BYVN
Location of Accident:	3 nm north-north-west of Porthcawl, South Wales Latitude: 51º 31.5' N Longitude: 003º 43.8' W
Date and Time:	11 February 2009 at 1047 hrs All times in this report are UTC

Synopsis

The accident was reported to the Air Accidents Investigation Branch (AAIB) on 11 February 2009 at 1107 hrs. A field investigation was commenced immediately. A Royal Air Force (RAF) Service Inquiry was also convened, which conducted a parallel investigation. The following inspectors participated in the AAIB investigation:

Mr P Taylor	Investigator in Charge
Mr K W Fairbank	Operations
Mr A Cope	Engineering
Mr S Moss	Engineering
Mr P Wivell	Flight Data Recorders

The two aircraft involved in the accident were based at MOD St Athan near Cardiff and were engaged on air experience flights when they collided in midair. The aircraft were piloted by RAF pilots and each aircraft carried an air cadet as a passenger. The collision occurred in uncontrolled airspace in fine weather, in an area which was routinely used by St Athan based Tutor aircraft.

The investigation identified the following causal factor:

1. Neither pilot saw the other aircraft in time to take effective avoiding action, if at all.

The investigation identified the following contributory factors:

1. The nature of the airspace and topography of the region reduced the available operating area such that the aircraft were required to operate in the same, relatively small block of airspace.

2. There were no formal procedures in place to deconflict the flights, either before or during flight.

3. The small size of the Tutor and its lack of conspicuity combined to make visual acquisition difficult in the prevailing conditions.

4. At various stages leading up to the collision, each aircraft was likely to have been obscured from the view of the pilot of the other aircraft by his aircraft's canopy structure.

Fifteen Safety Recommendations were made by the RAF Service Inquiry (SI) panel. No further recommendations have been made in this report.

1. Factual information

1.1 History of the flights

1.1.1 Introduction

The two aircraft collided at about 3,000 ft agl, whilst conducting air experience flights for two teenage cadets who were members of the Air Training Corps.

1.1.2 Background

The aircraft were being flown by Royal Air Force (RAF) pilots, and each carried an air cadet as a passenger. The pilots were staff members of the RAF's Number 1 Air Experience Flight (AEF), based at St Athan Airfield near Cardiff. Number 1 AEF, along with other AEFs throughout the United Kingdom, exists to provide air experience flying for members of the Air Training Corps and the RAF wing of the Combined Cadet Force. Number 1 AEF was co-located with, and formed part of, the University of Wales Air Squadron (UWAS).

1.1.3 Pre-flight activities

The two pilots arrived at the AEF headquarters building before the start of the day's flying. As was usual practice, they attended the morning meteorological and operational briefings, along with other members of staff and student pilots of the University Air Squadron (UAS). The weather was suitable for the planned flying programme, which involved a mixture of air experience flying for cadets and instructional flying for UAS students. The two Tutor aircraft to be used for the air experience task were G-BYUT and G-BYVN. The two aircraft were, for all practical purposes, identical in appearance, performance and equipment (Figure 1).

The party of air cadets and their adult supervisors had not arrived in time to fly on the first wave of the programme, so the initial cadet flights were re-scheduled for the second wave. In their place, two other staff pilots flew instructional sorties with UAS students. Both aircraft were reported to be fully serviceable on their return; they were refuelled and prepared for the second wave. The pilots who were to fly the cadets were updated on the weather conditions by the unit's Commanding Officer, who had flown one of the first sorties. He advised them that the weather was generally fine, but with slightly more cloud than expected over the airfield, and haze up to about 2,500 ft agl.

Meanwhile, the air cadets had arrived and were being prepared for their flights. This process involved a safety briefing and fitting of safety equipment. It was

Figure 1

Photograph of one of the RAF's fleet of Grob 115E Tutor aircraft

standard practice to fly first those cadets who had not flown before, in case bad weather curtailed flying later in the day. Two such female cadets, aged 13 years and 14 years, were chosen at random to fly first.

Following their pre-flight preparation, the cadets were escorted to the aircraft, and strapped in under the supervision of a member of the ground crew. Meanwhile, the two pilots completed their routine pre-flight inspections and checks.

1.1.4 Flight of G-BYUT

G-BYUT was first to taxi for Runway 26, at 1030 hrs. The pilot was issued a departure clearance by St Athan Air Traffic Control (ATC), which was in accordance with current procedures and was acknowledged by the pilot. The ATC clearance restricted the aircraft to less than 1,500 ft for about 9 nm, until it was beyond the area of controlled airspace around Cardiff Airport (Figure 2).

As G-BYUT taxied, a visiting helicopter joined the St Athan visual circuit for training. The aircraft was held at the runway entry point until the helicopter had flown an approach, after which ATC cleared the aircraft to enter and backtrack the runway (the entry point was about 580 m from the start of the runway). As the helicopter turned downwind, the pilot of G-BYUT was issued takeoff clearance.

The aircraft's track was recorded on Cardiff Airport's Secondary Surveillance Radar (SSR), from soon after takeoff until the point of collision. Once the

Figure 2

Accident location on 1:250,000 scale topographical air chart, showing proximity of Cardiff Airport's controlled airspace (UK Civil Aviation Authority)

aircraft was clear of the Cardiff control area, it commenced a gradual climb to about 3,500 ft, whilst flying towards the M4 motorway, north of Porthcawl. It then turned left onto an approximately westerly track, which took it overhead the Kenfig National Nature Reserve, situated between the motorway and the coast.

The radar recording (which included height information), indicated that the aircraft performed some type of vertical manoeuvre, during which it temporarily climbed to above 4,000 ft. After this it descended again, whilst turning to the left, away from the coastline. As the aircraft's track continued to indicate a left turn, and with the aircraft's track turning through about north, G-BYUT flew into conflict with G-BYVN, which was approaching the same area from the east. A sketch of the approximate flight paths is at Figure 3.

1.1.5 Flight of G-BYVN

The pilot of G-BYVN requested taxi clearance three and a half minutes after the pilot of G-BYUT, and was issued the same departure clearance. As G-BYVN neared the runway, the ATC controller informed its pilot that the helicopter was almost downwind in the visual circuit. The pilot was asked if

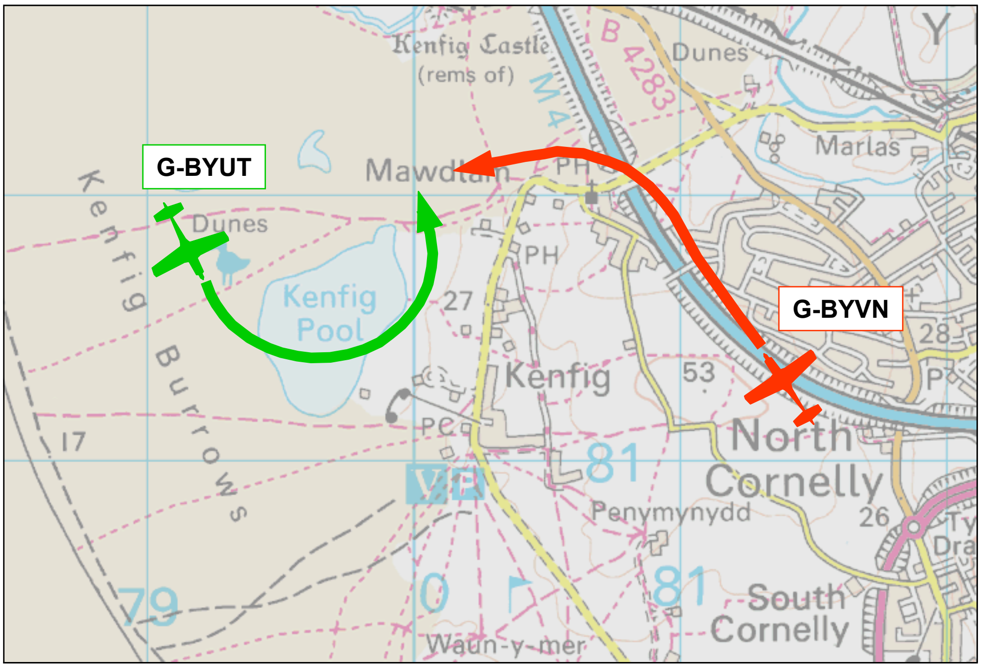

Figure 3

Sketch showing approximate flight paths immediately prior to collision

he could accept takeoff from the runway entry point (ie without backtracking to the start of the runway), to which the pilot said he could. The controller then issued takeoff clearance; G-BYVN taxied onto the runway and took off approximately one minute after G-BYUT.

G-BYVN's outbound route was similar to that of G-BYUT. The horizontal separation between the aircraft reduced to about one and a half miles during the transit to their operating area.

G-BYVN also turned left towards the area overhead the nature reserve, although the pilot started the turn slightly earlier than the pilot of G-BYUT, and at a lower altitude. The aircraft appeared to settle on a steady climbing course, which took it into confliction with G-BYUT.

1.1.6 The collision

The two aircraft collided at about 2,900 ft, with G-BYVN on approximately a westerly heading and G-BYUT closing from the south, probably while still turning to the left. The right wing of G-BYUT struck the aft fuselage of G-BYVN, which detached from the aircraft. The right wing of G-BYUT also detached at, or very soon after, the point of collision. Both aircraft were thus rendered uncontrollable.

Based on eyewitness reports, radar data and physical evidence obtained during the wreckage examination of both aircraft, a 3-D model of the collision was constructed (Figure 4). The figure shows the attitude of each aircraft relative to the other. The precise orientation of the colliding aircraft with respect to the true horizon is less certain, but is believed to be accurately depicted. It should also be noted that the figure only represents a moment in time at the initial point of contact and does not represent the dynamic nature of two moving aircraft colliding.

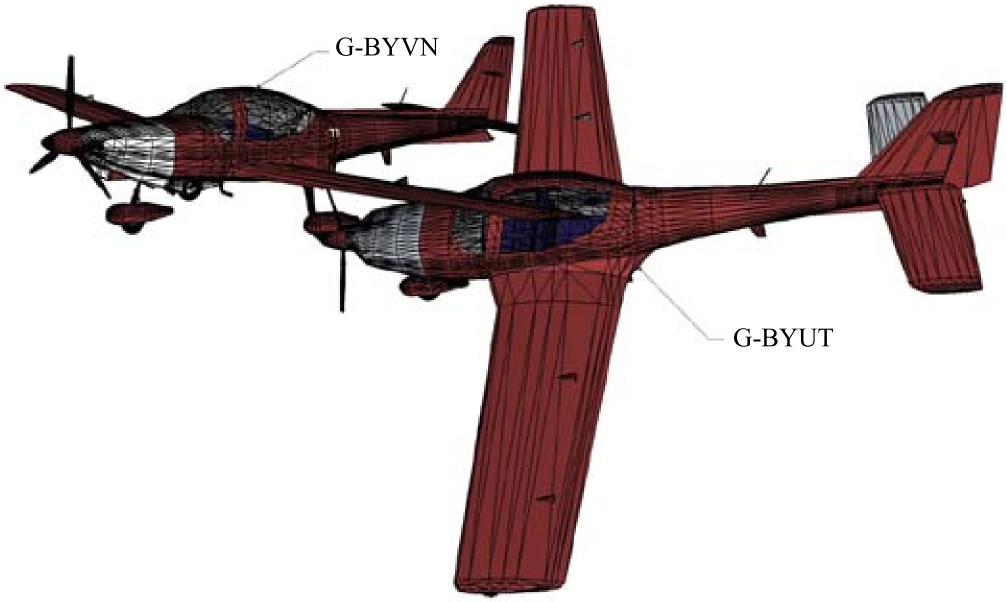

Figure 4

Model of collision orientation

1.1.7 Post-collision

G-BYUT, with its right wing missing, continued in a steepening, descending flight path, and struck the ground in a steep dive, about 500 m to the north of the point of collision. Both occupants sustained fatal injuries.

G-BYVN, with the majority of its aft fuselage and the whole of the tail section missing, also entered a steep dive and struck the ground close to the point of collision. At some point during the descent (but probably in the latter stages, according to eyewitnesses), the pilot separated from the aircraft. The aircraft struck the ground in a steep dive, and caught fire. The pilot's body was found about 23 m from the aircraft wreckage; his parachute had not deployed. The passenger was found still within the cockpit. Both occupants had sustained fatal injuries.

Numerous people on the ground witnessed the collision or subsequent descent of one or both aircraft (a summary of their accounts is at section 1.18 of this report, page 36). The emergency services were alerted immediately and arrived soon afterwards, supported by helicopters of the police, air ambulance and RAF Search and Rescue (SAR) units.

1.2 Injuries to persons

1.2.1 G-BYUT

Injuries	Crew	Passengers	Others
Fatal	1	1	-
Serious	-	-	-
Minor/none	-	-	-

1.2.2 G-BYVN

Injuries	Crew	Passengers	Others
Fatal	1	1	-
Serious	-	-	-
Minor/none	-	-	-

1.3 Damage to the aircraft

1.3.1 Midair impact

1.3.1.1 G-BYUT

The midair collision resulted in the right wing of the aircraft being completely removed at the root, about six inches from the wing/fuselage blend. The wing broke into several pieces, with the largest intact section being the outboard wing and wingtip. All three propeller blades detached at the root. The canopy and windscreen were also disrupted in the collision.

1.3.1.2 G-BYVN

The entire tail section aft of the cockpit area of the fuselage became detached in the initial collision. The tail then broke into numerous small sections, the largest of which consisted of the right horizontal stabiliser, left stabiliser spar and right lower half of the vertical fin. The left main landing gear leg bent under the fuselage and the left main wheel and spat cover detached from the gear leg. The canopy perspex was also disrupted by the collision.

1.3.2 Ground impact

1.3.2.1 G-BYUT

The high-speed, vertical impact with the ground resulted in near total disruption of the airframe. The aircraft impacted nose down, resulting in the fuselage breaking into numerous small sections, the largest of which was the empennage, which remained relatively intact. The left wing, which was still attached to the fuselage at impact, hit leading edge first, again resulting in complete disruption into small sections.

1.3.2.2 G-BYVN

The aircraft hit the ground on the reverse slope of a dune. It impacted inverted and at an acute angle to the slope. This resulted in the removal of the propeller blades some four inches from the root. Some heavy items such as the nosewheel assembly detached and were thrown forward during the impact, but the majority of the wreckage was retained at the initial impact point. Significant further assessment of the damage resulting from the ground impact was not possible, as the majority of the airframe was consumed by the post-impact fire.

1.4 Other damage

There were environmental concerns at both crash sites, particularly as both were located within a nature reserve, which is designated as an area of special scientific interest. The area is also extensively used for recreation purposes by the general public. However, damage to the environment was limited to soil contamination. A significant amount of contaminated soil was removed from both sites after the wreckage had been recovered.

Some of the larger pieces of aircraft structure that detached midair following the collision, notably the tail section of G-BYVN, struck domestic buildings causing limited damage. Although several witnesses close to the point of impact reported taking cover in vehicles due to concerns about falling debris, there were no reports of injuries on the ground.

1.5 Personnel information

1.5.1 G-BYUT

Commander:	Male, aged 63 years		
Location:	Right cockpit seat		
Licence:	Qualified Service Pilot		
Instrument Rating:	Not applicable		
Medical Certificate:	Valid Service medical category Limitations: required to wear corrective flying spectacles		
Flying hours:	Total all types:	3,816 hours	
	Total on type:	427 hours	
	Total last 90 days:	14.5 hours	
	Total last 28 days:	8.6 hours	
	Total last 24 hours:	0 hours	

1.5.1.1 Pilot's background

The pilot of G-BYUT was a RAF Volunteer Reserve officer, having retired from full time RAF service in 2006. He had flown a variety of front-line aircraft types during his military career, including the Phantom and Tornado. He had been flying the Tutor on AEF duties since 2002, and before that had flown the Bulldog aircraft in the same role.

The pilot was reported to be a fit and active individual with a sporting background. He held an appropriate and current Service medical category, which had been renewed on 10 July 2008. The only limitation of his medical category being that he was required to wear corrective flying spectacles. A photograph of the pilot in the cockpit of G-BYUT before takeoff on the accident flight showed that he was wearing his spectacles.

1.5.1.2 Pilot's currency

The pilot flew regularly with the AEF and was very experienced in the cadet flying role. His last supervisory check flight was on 12 August 2008, and his last flying duty before the accident was on 6 February 2009, when he flew two routine AEF sorties.

1.5.1.3 Pre-flight activities

The pilot spent the day before the accident at home. He ate a light evening meal and retired before midnight. He rose at about 0615 hrs on the day of the accident and reported at the AEF in time for the 0830 hrs briefing. He appeared to his colleagues to be fit and well.

1.5.1.4 Passenger

The passenger in G-BYUT was a 14 year old female air cadet. She had recently joined the Air Training Corps and it was her first flight. She was the cousin of the cadet who lost her life in G-BYVN.

1.5.2 G-BYVN

Commander:	Male, aged 24 years	
Location:	Right cockpit seat	
Licence:	Qualified Service Pilot	
Instrument Rating:	Not applicable	
Medical Certificate:	Valid Service medical category	
	Limitations: none	
Flying hours:	Total all types:	222 hours
	Total on type:	92 hours
	Total last 90 days:	30.5 hours
	Total last 28 days:	19.2 hours
	Total last 24 hours:	2.1 hours

1.5.2.1 Pilot's background

The pilot of G-BYVN had completed his RAF training on the Tucano aircraft on 14 November 2008, when he was awarded his flying 'wings'. He was awaiting the start of an advanced flying training course on Hawk aircraft, and had been posted to the AEF at RAF Wyton as a 'holding post' between courses. This was a typical arrangement for qualified pilots between flying courses. The pilot was regarded by his supervising officers as a conscientious and competent pilot, who had been cleared without reservation to fly cadets on AEF sorties.

1.5.2.2 Pilot's currency

The pilot was a full-time holding officer, so was flying the Tutor on AEF sorties on a regular basis. When he joined the AEF it was flying from RAF Colerne whilst work was carried out on St Athan's runway. He underwent an AEF conversion course at Colerne, and also completed familiarisation training at St Athan when the AEF returned there early in 2009. The pilot's previous flying duty was on the day before the accident, when he flew two routine AEF cadet sorties.

1.5.2.3 Pre-flight activities

The pilot kept a room in the Officer's Mess at St Athan. On the evening before the accident, he was engaged in a weekly UAS ground training session at the AEF headquarters. This ended at about 2115 hrs, after which he returned to the Officers Mess. He was not seen in the Mess until the next morning, and it was believed that he had retired to his room straight away. The pilot reported for duty the following morning in time for the 0830 hrs briefing, at which point he appeared to his colleagues to be fit and well.

1.5.2.4 Passenger

The passenger in G-BYVN was a 13 year old female air cadet. She had also recently joined the Air Training Corps and it was her first flight. She was the cousin of the cadet who lost her life in G-BYUT.

1.6 Aircraft information

1.6.1 Leading particulars

1.6.1.1 G-BYUT

Manufacturer:	Grob Aerospace
Type:	115E Tutor T Mark 1
Aircraft Serial Number:	82104/E
Year of manufacture:	1999
Number and type of engines:	One Lycoming AE10-360-B1F
Total airframe hours:	3375 hours
Certificate of Registration:	UK Registered on 30 June 2000
Certificate of Airworthiness:	CS-23C: Aerobatic Category issued by the EASA on 19 November 2008 and expiring on 13 December 2009

1.6.1.2 G-BYVN

Manufacturer:	Grob Aerospace
Type:	115E Tutor T Mark 1
Aircraft Serial Number:	82124/E
Year of manufacture:	2000
Number and type of engines:	One Lycoming AE10-360-B1F
Total airframe hours:	3416 hours
Certificate of Registration:	UK Registered on 30 June 2000
Certificate of Airworthiness:	CS-23C: Aerobatic Category issued by the EASA on 5 June 2008 and expiring on 31 May 2009

1.6.2 Aircraft description

The Grob 115E Tutor is a single engine, lightweight aircraft used by the RAF for elementary flight training. It is constructed predominantly from carbon fibre, has a tapered low wing with two integral fuel tanks, fixed horizontal and vertical stabilisers and conventional flight control surfaces. The dual control columns in the cockpit are connected to the control surfaces by aluminium control tubes and bell cranks. The aircraft is powered by a single 180 bhp piston engine driving a three blade, variable pitch propeller.

The aircraft has a two-seat, side-by-side cockpit layout, with a large, carbon fibre and perspex, sliding canopy. When the canopy is closed against the fixed windscreen, a 'bubble' type cockpit cover is created, but with a T-shaped frame running around the windscreen and down the spine of the canopy. The canopy can be jettisoned in an emergency.

The aircraft has a fixed tricycle undercarriage, with aerodynamic wheel spat fairings. The main landing gear legs are sprung steel, with a conventional oleo nose gear. The aircraft is fully aerobatic and rated from +6g to -3g. The accident aircraft were equipped to RAF standard requirements with conventional gauge instruments, mode A, C, and S transponders and both VHF and UHF radios. They were also fitted with a panel mounted GPS. Although dual control, the instrument layout is designed for the aircraft to be flown from the right seat.

1.6.2.1 Canopy operating and jettison mechanism

In the closed position the canopy seals against the windscreen frame and is locked in place by two spigots on each side of the canopy and a hook which latches onto a bar attached to the top centre position of the windscreen frame.

In normal operation, the canopy is unlocked by moving either the internal or external handle towards the 90° position from closed, causing the hook to release from the bar and rotate 90° to the vertical position under spring tension. This allows the canopy to slide back on carbon fibre rails located on either side of the cockpit and along the top of the rear fuselage.

A red jettison handle, with two integral pins, fits into the mechanism behind the internal canopy release handle (Figure 5). In normal use, the pins prevent movement of the mechanism beyond the 90° (vertical) position of the handle. To jettison the canopy, the red handle is pulled out, allowing the internal handle of the canopy release mechanism to be rotated back a further 80°. This causes the hook to release completely and pulls on three Bowden cables. The cables are attached to pins on the brackets which hold the canopy to the guide rails. When the internal handle is moved to the fully aft position, the pins are pulled out and the brackets released.

The canopy is then moved backwards about 3 cm to release the spigots engaging with the windscreen frame and jettisoned from the aircraft by pushing it up into the slipstream. The RAF's flight manual for the Tutor notes that "*some force may be required*" to do this.

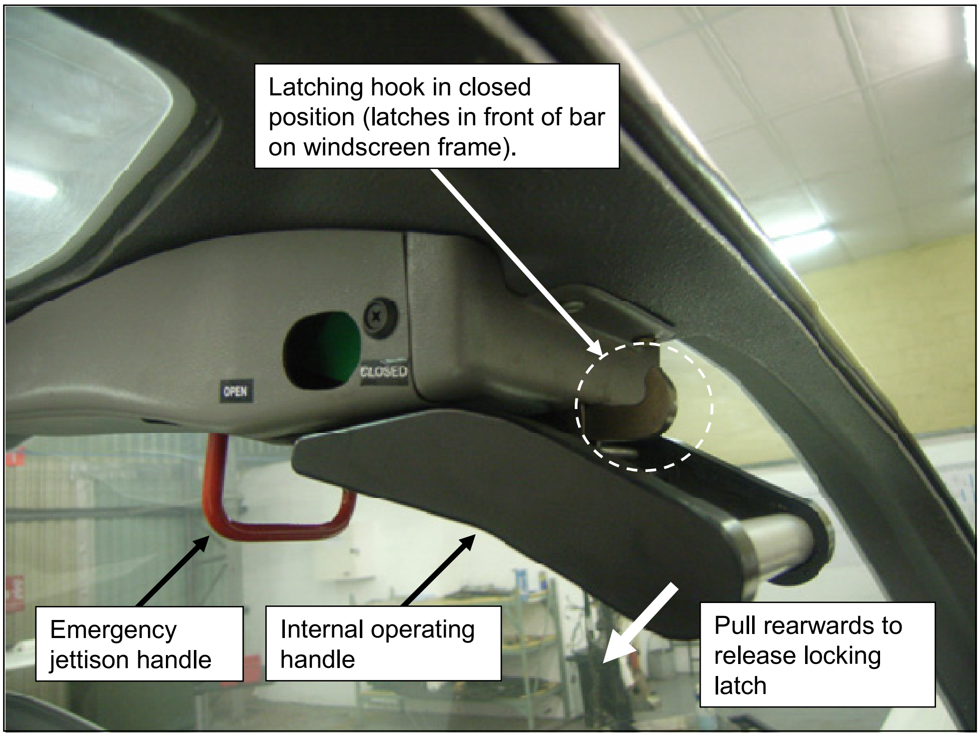

Figure 5

Internal handle in closed position (canopy open), viewed from right

1.6.2.2 Conspicuity

Both aircraft displayed the standard RAF Tutor colour scheme of plain white gel coat, with reflective blue decals across the engine deck, down each side of the main fuselage, on the vertical fin and on each wheel spat. There were also RAF roundels on each side of the fuselage, aft of the cockpit, and on the wings, with squadron badges on either side of the tail fin and standard civilian registration markings (Figure 1).

The aircraft were fitted with white and red high-intensity[1] strobe lights (HISL). Eyewitness accounts identified that the HISLs were switched on prior to takeoff for both G-BYUT and G-BYVN. The aircraft were also fitted with a forward facing white landing light in the nose and standard red and green navigation lights. It was not possible to determine whether these lights were used during the flight, but there was some post-crash evidence to suggest that G-BYVN's landing light was on at the point of impact and a photograph of G-BYUT taken prior to takeoff showed the navigation lights were on. Standard procedure was for the aircraft to fly with the HISLs selected to WHITE and the landing light selected ON.

1.6.2.3 Emergency Location Transmitter (ELT)

Both aircraft were fitted with identical Artex ME406 ELTs. The body of the transmitter was attached to a horizontal bulkhead behind the cockpit, with a co-axial cable running to a rod aerial fitted on the top of the tail boom. The transmitter could be triggered either by a switch on the right-hand side of the instrument panel or by an integral g-switch within the unit.

1.6.3 Aircraft maintenance history

The aircraft were owned and maintained by a private company engaged in a public-private partnership with the RAF. The aircraft were therefore registered on the UK civilian register and subject to EASA and CAA design and maintenance requirements. Investigation of the maintenance records identified that the aircraft were correctly maintained and compliant with all necessary continuing airworthiness maintenance schedules. The aircraft had been flown in the morning prior to the accident flights and no defects had been recorded.

1 Effective intensity of 2,000 candelas.

1.7 Meteorological information

1.7.1 Forecast and actual weather

The aviation forecast from the Met Office showed that a warm front was off the south-western approaches and that an occluded front was over northern England moving south, with the accident area in between the two. The general forecast for Wales and the south of England was for scattered or broken cloud with bases between 2,000 and 3,000 ft. There was also the possibility of isolated areas of scattered or broken low stratus cloud, as low as the surface in places. Visibility was forecast to be generally 30 km, reducing in isolated areas to 3000 m in mist.

At their morning briefing, the pilots were briefed that the visibility was 15 km and forecast to improve to about 25 km, with few or scattered clouds at 3,000 ft. The surface wind was westerly at 8 to 12 kt.

An automated weather report for St Athan at 1020 hrs reported a light north-westerly surface wind, visibility in excess of 10 km and few clouds at 1,100 ft above the airfield. Outside air temperature was +3°C and the QNH was 1018 HPa.

At 1045 hrs the sun was on a true bearing of 153° at an elevation of 21°.

1.7.2 Witness reports

Information from witnesses to the accident and from pilots who flew on the first wave indicated that the weather was generally fine, with little cloud in the accident area.

A police air support helicopter was on scene shortly after the accident and took photographs of the accident area. These included some which showed patches of low stratus cloud obscuring areas of ground further inland, beyond the M4 motorway (Figure 6). The presence of broken low cloud in this area is supported by the account of an eyewitness in the same area who reported seeing one of the aircraft disappear behind cloud prior to the collision, while witnesses more directly below the collision area generally reported no low cloud.

Figure 6

View from accident area looking north-east showing low cloud further inland. Smoke in the foreground is from the G-BYVN crash site

1.8 Aids to navigation

1.8.1 Radar data

1.8.1.1 General

Radar tracks for the two aircraft were captured by the National Air Traffic Service (NATS) area radar at Burrington in Devon, 37 nm from the accident site. They were also captured by Cardiff Airport's SSR, located 16 nm away on the airport. This radar was not normally recorded, but a temporary recording feed had been established for engineering purposes.

The Burrington radar, with an update period of 8 seconds, did not record the aircrafts' tracks below about 2,000 ft agl. The Cardiff radar, with an update period of just under 4 seconds, recorded both aircraft's tracks from just after takeoff. Both radar recordings were analysed by the investigation team. However, the information presented in this report is based on the Cardiff radar which, because of its faster update period and being closer to the accident site, was considered the best available data.

1.8.1.2 Departure from St Athan

G-BYUT appeared on Cardiff radar at 1037:16 hrs, immediately after takeoff while it was still over the upwind end of Runway 26. At 1038:06 hrs, G-BYVN appeared on radar, also while still over the runway, 1.1 nm astern of G-BYUT. As G-BYUT passed Nash Point, the aircraft were flying 1.6 nm apart, with G-BYUT ahead and about 15° to the right of G-BYVN's track. They were both flying level, with the leading aircraft indicating 100 ft lower.

1. 8.1.3 En-route to the accident area

The radar tracks from Nash Point to the accident area are shown at Figure 7, with Mode C altitudes.

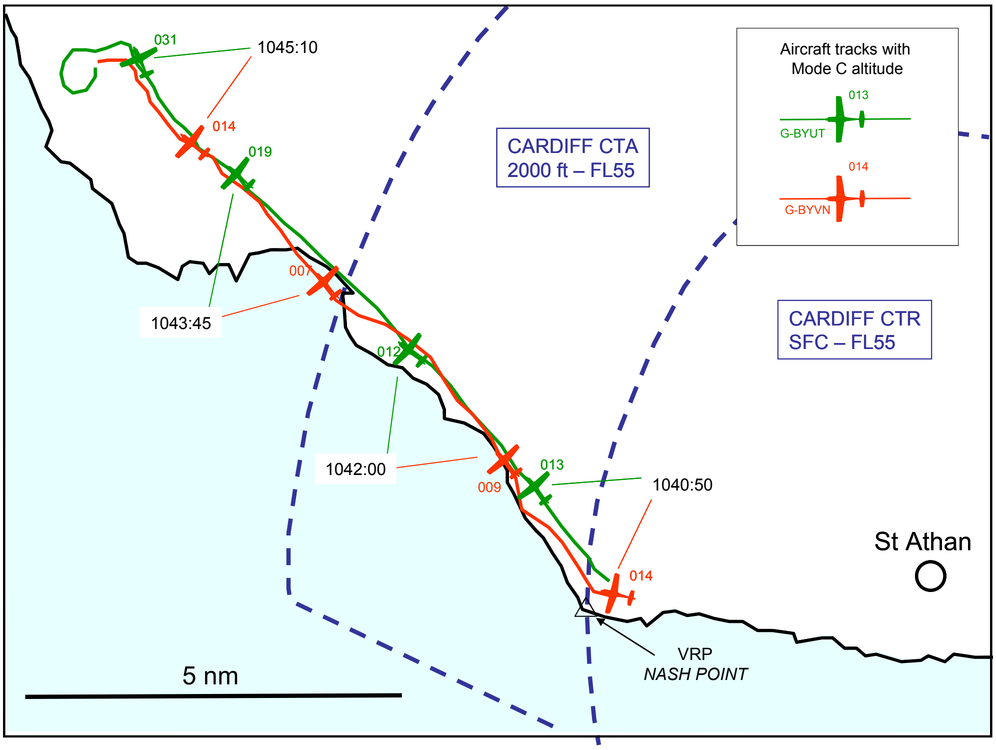

Figure 7

Radar derived sketch of the aircrafts' route to the accident area

1. 8.1.4 The collision

Figure 8 shows that both aircraft climbed on similar tracks as they approached the accident area over the nature reserve, although G-BYVN turned left into the area somewhat further to the south than G-BYUT. When G-BYUT was above 3,000 ft the aircraft flew what was probably an aerobatic manoeuvre, before descending again and entering a turn to the left. As it did so, G-BYVN was approaching from the east; it was below the other aircraft's altitude but still climbing.

Approaching the point of collision, radar returns from G-BYVN ceased. This was most likely due to the limitations of radar in discriminating between targets in close proximity. Given the characteristics of the Cardiff radar and the distance of the radar head from the point of collision, once the aircraft were within two to three hundred metres of each other, there was an increasing chance that the radar would detect only one return. For this reason the last return from G-BYUT shown at Figure 8 is likely to be erroneous, as may be the return before it.

1. 8.1.5 Collision altitude

Based upon available Mode C returns, the collision occurred at a pressure altitude of about 2,800 ft. Corrected for the atmospheric pressure, this equates to 2,940 ft amsl. Ground elevations in the accident area were of the order of 100 ft amsl.

1. 8.1.6 Post-collision

There were several radar returns after the estimated point of collision, over five further radar 'sweeps', or about 20 seconds. Most of the returns were close to the position where G-BYVN struck the ground, with one further to the north. For the reasons given above, some of the returns soon after the collision are probably erroneous, although the last return, showing an indicated 600 ft Mode C altitude, is likely to be a valid return for G-BYVN. Post-collision returns are shown in blue at Figure 8.

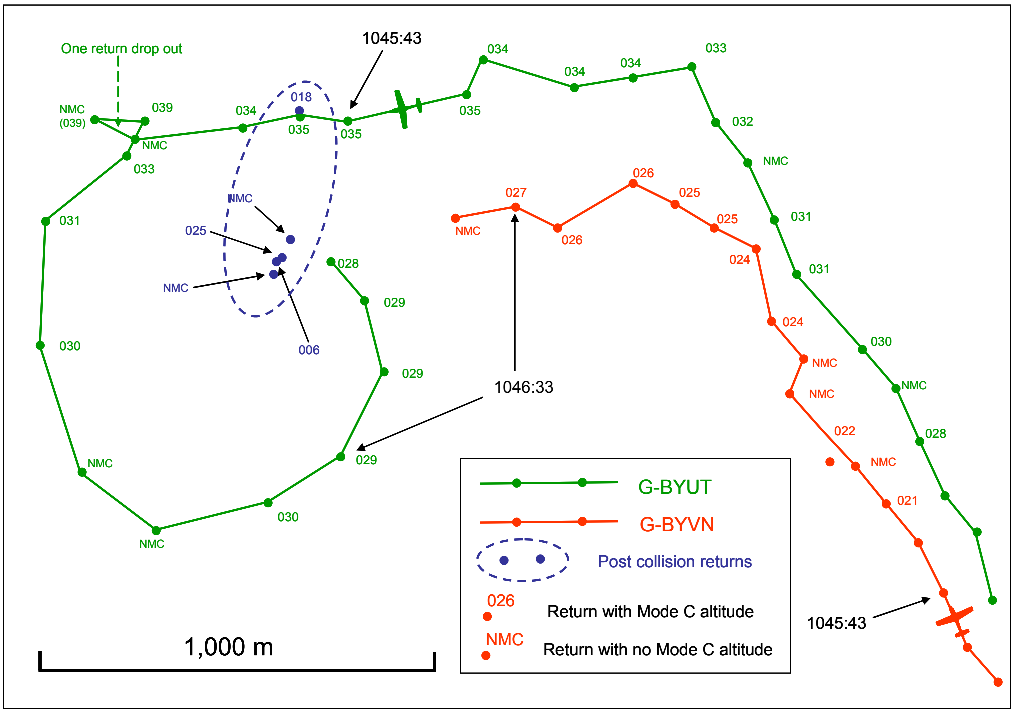

Figure 8

Radar derived sketch of the aircrafts' final flight paths to collision

1.9 Communications

1.9.1 General

Recorded communications data was available in the form of radio telephony (R/T) transmissions between each aircraft and St Athan ATC.

1.9.2 R/T communications

Before taxiing, the pilots of both aircraft made initial contact with St Athan Ground controller on 241.125 MHz. Whilst taxiing to the runway, each pilot was issued with a departure clearance, as previously described, and routine radio checks were carried out.

After takeoff, each pilot remained on the St Athan Tower frequency (240.0 MHz) as far as Nash Point reporting point, where they each reported their position (at 1039:31 hrs and 1040:40 hrs respectively) in accordance with local procedures. Nash Point marked the boundary of the Cardiff control zone at that point (Figure 2), where each pilot changed to the VFR SSR code of 7000, and was passed the Cardiff QNH of 1018 HPa.

The recorded transmissions from each pilot were consistent with normal procedures. After their last routine transmissions at Nash Point, there were no further known transmissions from either aircraft.

1.10 Aerodrome and operating area information

1.10.1 General

St Athan Airfield is about 3.5 nm from Cardiff Airport, and lies within Cardiff's control zone (Figure 2). A local flying zone is established at St Athan, to allow visual manoeuvring in the circuit area without the need for aircraft to contact Cardiff ATC.

1.10.2 Departure procedures

AEF aircraft departing St Athan to the north-west were able to do so under local procedures which did not require their pilots to contact Cardiff ATC. However, if pilots so desired, they could do so and request an air traffic service. Both pilots requested the former type of departure, so did not contact Cardiff.

Procedures governing such movements had recently been revised, in January 2009. Prior to this, pilots were required to establish contact with Cardiff Approach control on departure, at least until they were clear of the Cardiff Zone beyond Nash Point.

1.10.3 Operating area

The accident location was within the normal operating area for the St Athan AEF sorties. This lay to the north-west of Cardiff Airport's control area, between about 10 and 20 nm from St Athan. In practice, the operating area was bounded by the sea to one side[2] and rising terrain a short distance inland. Aircraft could not manoeuvre freely closer than 10 nm to St Athan due to the presence of the Cardiff Zone, and the furthest boundary was limited by the relatively short sortie times (25 minutes) such that aircraft would not normally venture further than the Port Talbot steel works just to the north of the accident area.

The airspace in the area was uncontrolled, and designated as Class G airspace. Aircraft operating in Class G airspace are free to operate without an ATC service, and pilots are not required to maintain contact with ATC or each other (see paragraph 1.18.6, page 41, for a fuller description of Class G airspace).

2 AEF flying regulations prohibited flights with cadets over the sea beyond gliding distance of land.

1.11 Flight Recorders

1.11.1 General

The aircraft were not equipped with flight data recorders or cockpit voice recorders. Neither type of recorder was required by the relevant aviation regulations.

1.11.2 Global Positioning System units

The aircraft were fitted with Filser LX500TR GPS units which were capable of recording aircraft track. The tracks were stored inside the GPS unit on the aircraft using memory devices that required battery power to maintain them.

The memory from the GPS unit fitted to G-BYVN was irrecoverable due to fire damage. The GPS unit from G-BYUT received significant mechanical damage during the accident. The internal battery used to maintain the track memory was held in place with a battery clip. This was broken in the accident and the battery was found loose in the unit so the recording of the track was lost.

1.12 Wreckage and ground impact information

1.12.1 Accident sites

1.12.1.1 G-BYVN: site A

The main wreckage of G-BYVN (identified as site A) was located about 120 m south-west of the estimated collision point. The site was on the reverse slope of a relatively steep sided dune. The aircraft impacted inverted, with the nose of the aircraft pointing downhill. Some heavy items, such as the nose gear had slipped or been thrown down the slope by the impact, but the wreckage was virtually all contained within the dimensions of the aircraft. A significant volume of fuel was thrown forward in the impact and ignited, resulting in a large area of scorching. The wreckage had also been almost completely consumed by a severe post-impact fire. The pilot's body was located about 23 m from the wreckage site.

1.12.1.2 G-BYUT: site B

The aircraft impacted the ground close to vertically and nose down, at the top edge of a relatively large dune, about 400 m north-north-east from the estimated collision point and 470 m from site A. The site (identified as site B) was relatively compact, with the fragmented main fuselage buried down to a depth of about 1.5 m and the sections of tail boom and empennage resting on top. The left wing was almost completely disrupted, but did not scatter and remained laid out alongside the main fuselage debris. A significant amount of smaller items including the remains of the canopy, control rods, sections of lightweight structure and the instrument panel had tumbled or been thrown down the steep slope of the dune and were scattered over an area extending for several tens of metres.

1.12.1.3 Wreckage trail: site C

A considerable amount of structural debris from both aircraft was released by the midair collision. The heavy non-aerodynamic items fell almost vertically from the point of impact, whilst the rest were scattered by the wind in a wreckage trail that gradually decreased in size and quantity but extended some 2 km in total, in a south-easterly direction from the estimated collision point.

1.12.2 Wreckage recovery

Each site was plotted using differential GPS by the MOD Joint Aircraft Recovery Team. The wreckage from each site was marked with the relevant site identifier and recovered to a secure facility for detailed investigation. Items recovered from the wreckage trail that were not associated with either of the main wreckage sites were also GPS plotted, marked with a reference number and site identifier and collected.

1.12.3 Wreckage examination

The wreckage from all the sites was laid out and each aircraft was pieced together as far as possible given the damage incurred. Wreckage from site C (released midair and found in the wreckage trail), which could be positively identified with a specific aircraft was also added to the reconstruction.

1.12.3.1 General

The investigation did not find any evidence of a pre-collision defect or failure in the wreckage of either aircraft.

1.12.3.2 G-BYUT structure

The right wing leading edge displayed significant blue colour transfer onto the white structure. The damage was consistent with an impact at approximately the mid-span position; the surrounding wing structure was fragmented into multiple pieces. The outer section of the wing and wing tip were completely undamaged allowing testing of the navigation and strobe lights, both of which were still serviceable.

Very little windscreen perspex was located within the site B wreckage. However, a significant amount was found in site C. This perspex was broken into relatively small pieces, the majority of which had clean fracture edges. A number of pieces though, displayed evidence of a delamination type fracture, consistent with being struck by a blunt object. No evidence of birdstrike was identified on the fragments. Although the perspex windscreen fragments could not be physically identified to either aircraft, the collision analysis is consistent with the fragments having come from G-BYUT's windscreen.

Forensic examination of the canopy closing mechanism determined that the canopy was most likely unlocked at the point of impact with the ground. It also determined that the emergency handle had not been operated and was in its normal position at ground impact. Very little canopy perspex was located within the main wreckage. A significant amount was found along the wreckage trail, but not sufficient for a complete canopy.

1.12.3.3 G-BYUT propulsion

The majority of all three blades were found in the site C wreckage and identified from serial number records. The blades had been removed at the root, flush with the metal hub into which they were fitted. One of the blades had also been separated across the chord at approximately two thirds span, but the leading edges were undamaged on either side of the break, consistent with it having struck a narrow section structure, such as a main landing gear leg. A section of plastic/carbon covering from a blade root found in site C displayed a rubber smear across it.

The propeller hub displayed significant rubber smearing across two of the blade fixtures. The nose cone was found in the site C wreckage. It was significantly disrupted and displayed evidence of smearing, folding and 'crumpling' which was inconsistent with impact onto soft ground.

1.12.3.4 G-BYUT safety equipment

The quick release fastener on the pilot's seat harness, which had been released, was judged to have been serviceable prior to ground impact. The cadet's harness was still securely fastened at impact. Both parachutes were judged to have been serviceable at ground impact; neither parachute operating handle had been pulled.

1.12.3.5 G-BYVN structure

The majority of the wreckage at site A was consumed in the post-impact fire. However it was possible to identify a significant amount of structure from G-BYVN in the site C wreckage trail.

All the structure of the aircraft from the start of the tail boom rearwards was found unburnt in the site C wreckage. The structure was severely disrupted into small pieces, but it was possible to determine a path of more significant damage in a diagonal line across from the left horizontal stabilizer towards the right side of the tail boom looking forward.

The left main wheel was found in the site C wreckage close to the estimated point of collision. The hub was shattered in a manner that was inconsistent with a fall onto soft ground. The tyre was cut and partially removed from the hub. The remains of the wheel spat cover were also found unburnt in the site C wreckage. The left landing gear leg was burnt with the main wreckage but it had been bent backwards in a manner that was inconsistent with either ground impact or heat damage. The right landing gear leg was undamaged, other than being severely burnt in the fire.

Forensic examination of the canopy closing mechanism determined that the canopy was most likely closed and locked at the point of impact with the ground. It was also determined that the emergency handle had not been used. Some molten perspex was present in the burnt wreckage, but it was not possible to determine how much had been present at ground impact.

1.12.3.6 G-BYVN propulsion

Remnants of the propeller blades were embedded around the engine in the site A wreckage. The blades were removed about four inches from the root and were severely disrupted consistent with having been driven into the ground at the point of impact.

1.12.3.7 G-BYVN safety equipment

The pilot's seat harness was judged to have been serviceable at ground impact before being burnt in the fire; it had been released prior to the ground impact. The cadet's harness was still securely fastened at impact. Both parachutes were judged to have been serviceable at ground impact, neither operating handle had been pulled. Subsequent tests of the pilot's parachute assembly included a controlled deployment using the operating handle, which worked correctly.

1.12.3.8 ELTs

The coaxial cable connecting G-BYUT's ELT unit to the aerial detached from both the base of the aerial and the connector on the unit in the accident, compromising its operation.

G-BYVN's ELT aerial detached from the tail boom structure in the midair collision and remained attached to the ELT unit in the main fuselage via the coaxial cable. Both the aerial and the cable were significantly fire damaged, but still identifiable. The ELT unit successfully triggered and transmitted following the midair collision (see section 1.15), but was completely consumed in the fire following the impact with the ground.

1.13 Medical and pathological information

1.13.1 G-BYUT

The 63 year old pilot of G-BYUT had undergone an RAF service aviation medical on 10 July 2008 and had a normal ECG test on 21 January 2009. He was cleared as 'fit to fly' and cleared all duties within his Medical Employment Standard (MES). He had normal colour vision, with a corrected visual acuity of 6/5 in both eyes. He was seen wearing his spectacles immediately prior to flight, and they were recovered from the aircraft wreckage. The pilot was not on any prescribed medication.

1.13.2 G-BYVN

The 24 year old pilot of G-BYVN was a serving RAF aircrew officer and had undergone an RAF service aviation medical on 27 March 2008. He held a current unrestricted medical category, with normal colour vision and uncorrected visual acuity of 6/5 in both eyes. The pilot was not on any prescribed medication.

1.13.3 Postmortem examinations

Local forensic pathologists carried out postmortem examinations on all four victims of the accident. The conducting pathologist found no obvious evidence of any potentially significant natural disease in either pilot. Toxicological analysis revealed no significant findings in any of the deceased.

1.13.4 RAF Centre of Aviation Medicine report

A report was produced for the AAIB by an aviation pathologist at the Department of Aviation Pathology of the RAF's Centre of Aviation Medicine. The report stated that the crash forces at ground impact were beyond the range of human tolerance and the injuries sustained by the occupants of G-BYUT and the passenger of G-BYVN would have been virtually instantaneously fatal. Similarly, the injuries sustained by the pilot of G-BYVN were commensurate with the forces of a ground impact and were not survivable. The report was unable to rule out the possibility that some of the pilot's injuries may have occurred before he separated from the aircraft.

1.14 Fire

Some eyewitness accounts report that there was a flash as the aircraft collided in the air and that G-BYVN was trailing smoke as it descended to the ground. Although this is not corroborated by all the witness accounts and there are other potential explanations for what the witnesses saw, given the volume of fuel that was released by the compromise of G-BYUT's integral wing tank, this is entirely feasible.

Following collision with the ground, an extensive fire took hold of the G-BYVN main wreckage. The resin used in the composite structure was completely consumed leaving mostly unidentifiable layers of carbon cloth. The aluminium control tubes also melted in the fire, leaving only high temperature resistant metal components such as the engine block, instrument panel, landing gear and canopy release mechanism intact.

The wreckage of G-BYUT did not catch fire after impact with the ground and did not display any evidence of post-collision combustion.

1.15 Survival aspects

1.15.1 Search and Rescue operations

Witnesses at the scene alerted the emergency services within seconds of the accident occurring, and ground based response units were on scene a short time later. It was quickly established that all four occupants of the two aircraft had sustained fatal injuries.

A police helicopter, also based at St Athan, and an air ambulance helicopter were on scene by about 1100 hrs. A Search and Rescue Sea King helicopter was diverted from a training exercise and arrived at the scene at 1115 hrs. The helicopters also assisted with an aerial search for wreckage, some of which had spread a considerable distance downwind from the point of collision.

1.15.1.1 Satellite based alerting system

The ELTs carried by each aircraft were capable of transmitting a signal on the international distress frequency of 406 MHz. The ELT signals were intended to be detected by satellites of the COSPAS/SARSAT system. ELTs using this system are coded with a unique digital signal which identifies the specific aircraft, vessel etc, to which the transmitting device is registered (some transmitters are also capable of encoding position data, derived from on-board equipment). The system employs two separate satellite systems: a geostationary system of satellites in orbit over the equator, and a system of satellites in low-earth polar orbits. The former are capable of detecting ELT signals only, while the latter can compute the position of the transmitting ELT using Doppler processing.

Details of detected ELTs are relayed to ground terminals which pass them to SAR co-ordination centres. In the UK, the Aeronautical Rescue Co-ordination Centre (ARCC) at Kinloss in Scotland, receives this information.

Once activated, the ELT does not transmit continuously but in bursts at about 50 second intervals. The actual repetition period varies randomly between 47.5 seconds and 52.5 seconds, thus ensuring that no two ELTs will continue to transmit at precisely the same time.

The ARCC received notification of detection of a single transmission from G-BYVN's ELT, timed at 1047:30 hrs. There were no further transmissions from G-BYVN, and none from G-BYUT. The signal had been detected by one of the geostationary satellites, but had ceased before coming into coverage of a low-earth orbiting satellite. Consequently, there was no positional data.

1.15.2 Safety equipment

1.15.2.1 Seats and harnesses

The seats in the Tutor are not adjustable, but are designed to be used with cushions of variable thickness to suit the occupant. Each seat is equipped with a safety harness comprising a negative 'g' strap with a quick release fitting (QRF) attached, into which are fitted two lap straps and two shoulder straps (Figure 9).

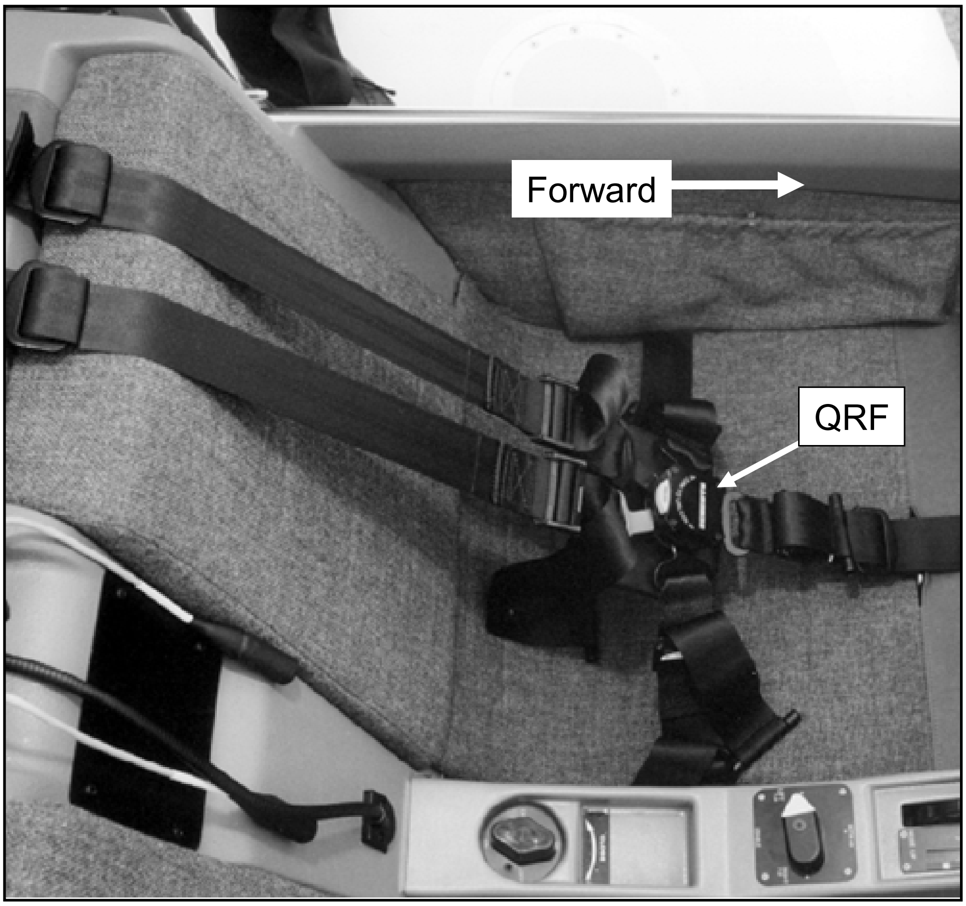

Figure 9

The passenger seat in the Tutor, viewed from above, with safety harness fastened (reproduced from Air Cadet Publication ACP 34)

1.15.2.2 Aircrew equipment

All four aircraft occupants were attired according to standard procedures. The AEF staff pilots wore standard issue RAF flying clothing, including flying suit, boots, gloves and helmet. The cadets each wore RAF flying suits over civilian or uniform clothing, gloves and helmet. Each occupant wore a life saving jacket (LSJ), which was normal at St Athan, being a coastal station. All four aircraft occupants were wearing parachutes, which was standard for RAF operated Tutor aircraft (Figure 10).

Figure 10

Tutor parachute assembly, with operating 'D' ring shown on wearer's right side, in stowed position (left) and being operated.
In the right hand photograph, the subject is wearing an LSJ
(reproduced from *Air Cadet Publication ACP 34*)

1.15.3 Abandonment procedures

RAF flight manual procedures for the Tutor stipulated a recommended minimum height for abandonment from controlled flight of 1,500 ft agl, while the parachute manufacturer specified a minimum operating height of 500 ft agl. However, these figures assume little or no initial rate of decent. In the case of an aircraft "*spinning out of control*", the RAF flight manual advised "*...commence abandonment by 3000 feet agl*".

1.15.4 Crew training

1.15.4.1 AEF staff pilots

AEF pilots were expected to be familiar with the normal and emergency operation of the canopy, as described in the RAF flight manual. Abandonment procedures were practised as 'touch drills' during staff continuation training sorties and check flights.

Although initial and recurrent parachute training was provided to Tutor pilots, this training was at a relatively basic level and its scope depended upon local training facilities. Training ideally included practising drills whilst suspended in a parachute rig, but may on occasions have been limited to static demonstration and discussion.

1.15.4.2 Cadets

Air Cadet Publication ACP 34 contained detailed information about the content and format of AEF operations, including information on the seat harness, parachute and abandonment drills. Additionally, cadets were required to view a training video prior to flight, which covered safety procedures as well as giving general information about the forthcoming flight.

In general terms, in the event of an abandonment becoming necessary, the instruction given to cadets required them to wait for a warning order "CHECK PARACHUTES" by the pilot, who would then jettison the canopy. If it were certain that abandonment was required, the cadet was briefed to expect an executive order "JUMP JUMP" from the pilot.

ACP 34 advised:

> *'As soon as the captain has ordered "Jump Jump", you should release the aircraft safety harness (not your parachute harness!), stand up in the cockpit and dive head first over the side of the aircraft, aiming to clear the trailing edge of the wing. It is vital that you do this immediately the captain has ordered "Jump Jump".'*

1.16 Tests and research

1.16.1 G-BYUT's ELT

The ELT unit from G-BYUT was tested at the manufacturer and found not to operate, though the battery, circuit board and g-switch functioned correctly when tested in a slave unit. The manufacturer determined that the unit had failed to operate due to damage to internal cabling resulting from the unit being subjected to a frontal impact.

1.16.2 Visibility from the Tutor cockpit

1.16.2.1 General

Although the view from the cockpit of the Tutor is excellent compared to many general aviation aircraft, visibility is impaired by a substantial canopy arch and the central canopy spine and locking handle mechanism. Field of View measurements were made by QinetiQ at MOD Boscombe Down. The results showed that significant areas of sky could not be seen with both eyes, even allowing for the limited head movement available with the non-inertial seat belts fitted to the aircraft. This was more noticeable to the pilot's left (looking across the cockpit), where the situation was exacerbated by the presence of a left seat occupant. Although the canopy arch to the pilot's right obscured more of the external scene, its proximity to the pilot made it easier for him to look around it.

1.16.2.2 Flight trials

Members of the RAF Service Inquiry (SI) panel arranged a flight trial to assess whether cockpit obstructions to the pilots' fields of view could have been a factor in the accident.

Two separate trials were flown. The first was arranged so that the sun was in the same sky position relative to the aircraft as at the time of the accident. The second flight was flown over the accident area with aircraft ground tracks arranged to match as closely as possible those of the two accident aircraft.

The findings of the trial are summarised below:

1. With the aircraft flying similar tracks at about one minute separation, it would have been difficult for the pilot of the second aircraft to keep visual contact with the leading aircraft, due in part to the Tutor's relatively narrow profile when viewed from astern.

2. When the lead aircraft flew the vertical manoeuvre seen on radar (believed to be a gentle aerobatic manoeuvre), it would have presented a better target for visual acquisition, but was possibly obscured by the second aircraft's canopy arch at that point.

3. As the lead aircraft started its left turn, its pilot would most probably have been looking in the direction of the second aircraft, but the banked attitude of the lead aircraft could have resulted in the second aircraft being obscured from view by the canopy arch and spine.

4. As the lead aircraft continued turning left, the second aircraft would have come into view in its forward windscreen. Because of the turn, it would have appeared to move from the area of the canopy operating handle (in the upper left of the pilot's forward vision), across the screen towards

the bottom right of it (Figure 11). This would have taken about 14 seconds. For the remaining 10 seconds before the collision, the second aircraft would have appeared to remain approximately stationary in the low right hand area of the windscreen, possibly becoming obscured from view in the last few seconds by the aircraft structure (Figure 12).

Figure 11

Flight trial: forward view from lead aircraft about 10 seconds before collision point. Second aircraft (circled) moving across windscreen from upper left to lower right (RAF Service Inquiry)

Figure 12

Flight trial: forward view from lead aircraft about 3 seconds before collision point. Second aircraft (circled) is in lower right part of windscreen, or may have been obscured from view (RAF Service Inquiry)

5. From the second aircraft, most or all of the leading aircraft's final approach was probably masked by the canopy arch or, in the final seconds before collision, possibly by the cadet in the left seat.

6. In the final seconds before the collision, the lead aircraft would have been approaching the second aircraft from approximately the direction of the sun, making visual detection less likely due to glare (Figure 13).

Figure 13

Flight trial: Looking left from second aircraft towards lead aircraft (circled). Note that camera position is elevated above pilot's eye position; otherwise aircraft would be obscured by left seat occupant's helmet (RAF Service Inquiry)

7. Visual acquisition during the trial had at times been aided by relatively good contrast between the light target aircraft and dark terrain (Figures 11 and 12), but would have been very difficult had the target aircraft been in front of a lighter background such as cloud.

1.17 Organisational and management information

1.17.1 Control of flying

The RAF's Number 1 Elementary Flying Training School, with headquarters at RAF Cranwell in Lincolnshire, is responsible for the fixed wing elementary flying training for pilots of all three UK armed forces, as well as pilots from some overseas countries. It is also responsible for the 14 University Air Squadrons (UASs) at 12 locations, and the 12 AEFs incorporated within them.

The AEFs were established to provide cadets with powered flying experience in an RAF environment. Rules and restrictions pertaining to AEF flights were contained in the RAF's Training Group Orders (TGOs). There was no evidence that either flight had contravened TGOs.

As different locations impose different operating requirements, the UASs and AEFs were able to develop operating procedures best suited to their own local flying environment (whilst remaining in compliance with standing orders controlling general flying operations).

1.17.1.1 Safety action by 1 EFTS

After the accident, the Officer Commanding 1 EFTS sent a memorandum to all UASs and AEFs which contained a list of possible measures which, if not already incorporated locally, were to be implemented by local commanders as their situation allowed. In summary, these measures were:

8. Where an ATC service was available, and flight profiles allowed, AEF flights were to be conducted under an appropriate service.
9. Local landmarks that were likely to be overflown regularly were to be identified as potential choke points and pilots flying over them were to broadcast their position and operating altitude.
10. Operating areas were to be reviewed to identify geographical features which could be used to provide a natural division of available airspace, and flights were, where possible, to be allocated to particular areas.
11. Pre-flight briefings were to include the presence and operating areas of other AEF aircraft.

12. During times of poor visibility due to weather, or when poor weather restricted use of the available operating areas, flying rates were to be reviewed and restricted if appropriate.

1.18 Additional information

1.18.1 Aircraft behaviour post-collision

The Civil Aviation Authority's Flight Test Department was consulted about the likely aircraft behaviour after the collision. Additionally, the RAF SI panel commissioned a study by QinetiQ at MOD Boscombe Down. Information from these sources is summarised below.

1.18.1.1 G-BYUT

G-BYUT would have been flying at about 120 kt. There would have been a strong initial rolling force to the right due to the large amount of asymmetric lift. The aircraft would have continued level for a short time, before entering a gradually steepening dive. The rolling/spiraling motion would have been severe initially, and hence very disorientating for the aircraft occupants, but as speed reduced, the rolling force would reduce with it. Application of aileron to oppose the roll would not have a significant effect, even had it been possible post-collision.

As well as the rolling motion there would have been a yawing motion to the left caused by the unbalanced drag on the left hand side. With the tail surfaces intact, and significant aerodynamic forces at play, the aircraft's motion could have become more spin-like, though with a very nose low attitude because of the significant loss of wing lift. Such a motion would almost certainly have been oscillatory, with variable rates of rotation about each axis.

The aircraft would have been rotating about a new centre of gravity, displaced to the left of the centreline. This may have given rise to unusual centrifugal accelerations, particularly affecting the pilot in the right hand seat.

The time taken for a free falling object to reach ground level without air resistance would have been 14 seconds, and G-BYUT clearly would have descended at a slower rate. However, it is unlikely that it descended at a rate less than 6,000 fpm, which would be typical for a normal spin. Therefore, the probable time between collision and ground impact was estimated as between 20 and 25 seconds, and almost certainly not more than 30 seconds.

1.18.1.2 G-BYVN

G-BYVN would have been flying at about 80 kt. There would initially have been a violent pitch down, which could have continued until the aircraft was inverted. The severity of this pitch down would have been such that the occupants' helmets may well have struck the canopy with some force. The pitching motion would have continued as an inertial moment for a short while, and could conceivably have resulted in the aircraft pitching through 360°.

Wing lift would have reduced rapidly. The aircraft is likely to have gone through a 'fluttering' phase before adopting a steep nose down attitude. Without the lateral stabilising influence of the fin, the wings would have been subject to the effects of sideslip as the aircraft descended. The resulting motion would have been a continually reversing rolling motion, with the aircraft tending to pitch forward then back in the vertical. There would be very little inertia effects and the aircraft would not have had a tendency to spin.

Again, the probable time taken to reach ground level was estimated at between 20 and 25 seconds.

1.18.1.3 Survivability aspects

Both aircraft would have been subject to severely disorientating motions immediately after the collision, with the potential to cause injury to the occupants, particularly in the case of G-BYVN. Unless the occupants of both aircraft were strapped into their seats very securely, it is probable that they would have been displaced, perhaps significantly so, from their normal seated positions.

1.18.2 Military aircrew flying UK registered civilian aircraft

Both aircraft were registered in the UK. Civil Aviation Publication CAP 393, The Air Navigation Order provides for the following exemption for military aircrews flying civil registered aircraft:

> *'A person may act as a member of the flight crew of an aircraft registered in the United Kingdom without being the holder of an appropriate licence if, in so doing, the person is acting in the course of his or her duty as a member of any of Her Majesty's naval, military or air forces.'*

1.18.3 Limitations of visual lookout

Maintaining an effective lookout for aircraft and other hazards is a prime task for a pilot, particularly so when flying in uncontrolled airspace without radar assistance from ATC. However, 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 only a few degrees away from it. 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 that of cells called rods 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 so long as 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 some seconds. An object missed early in the scan may have sufficient time to approach hazardously close or even collide before that area is scanned again by the pilot.

Two aircraft on a collision course maintain a constant relative bearing to each other until the moment of impact. 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 canopy arches or struts until very late. For these reasons pilots are taught not just to look around them but to make positive head movements as they do so.

1.18.4 Tutor conspicuity

1.18.4.1 Prior to service entry

In 1997, before the Tutor entered RAF service, the colour scheme for the aircraft was the subject of extensive discussion both within the RAF and between the RAF and the manufacturer. At that time, an all-black scheme had been identified as providing enhanced overall conspicuity for fast-jet aircraft and, although the test results were thought to be less applicable to slow moving light aircraft, the RAF investigated the feasibility of painting the Tutor all black instead of the manufacturer's all white scheme.

The manufacturer advised that an all black scheme would need to be subjected to an extensive thermal analysis programme and require airworthiness approval[3]. Additionally, the empty weight of the aircraft would be increased, as would through-life costs due to the need to maintain the additional paint scheme.

The conspicuity work undertaken for the RAF had shown that an all white aircraft could be more prominent in certain bright light conditions than an all black one, although the times when these conditions prevailed in the UK were not frequent. There was no advantage over another light colour such as yellow, nor was it beneficial painting the aircraft in different colour blocks, which tended to act in the same way as disruptive pattern camouflage.

The RAF eventually decided to introduce the Tutor in the manufacturer's recommended scheme: all white, with reflective blue 'tick' marks on the fuselage. Additionally, the aircraft was to be fitted with wingtip strobe lights and a permanently illuminated nose landing light.

1.18.4.2 In-service experience

By late 2000 it was clear from in-service experience that the Tutor was difficult to acquire visually in certain conditions, normally when viewed against a light background or in cloud in close formation. In early 2001 a trial was conducted at RAF Cranwell, with two aircraft modified with red wing tips, wheel spats and a red formation line on the wing upper surface. The trial

3 The concern was that the structural integrity of the composite airframe could be affected by heat absorption leading to resin degradation.

concluded that, whilst the additional markings were useful in formation, they did not noticeably enhance overall conspicuity.

1.18.4.3 Collision warning systems (CWS)

Carriage of CWS[4] is mandatory for larger commercial transport aircraft but not for light general aviation aircraft such as the Tutor. However, a number of relatively low cost systems have been developed for general aviation aircraft and gliders. The majority of these systems work by detecting SSR returns from nearby aircraft which are triggered either by a ground station or an aircraft equipped with an interrogating transponder. Consequently, while such a system is very effective in airspace where the carriage and operation of a transponder is required, it is less effective in uncontrolled airspace where non-transponding aircraft would be invisible to the system.

The RAF carried out limited trials of a portable CWS in the Tutor, at a time when various ways of improving the aircraft's overall conspicuity were being considered. Results of the trial were reportedly inconclusive, with concerns being raised about the non-alerting of obvious threats as well as the possibility of an unacceptably high number of alerts in busy airspace. Additionally, there were concerns about the impact of fitting CWS on elementary lookout training. Installation or further trials of CWS were not being actively pursued at the time of the accident.

1.18.5 Eyewitness information

More than 60 witness accounts were obtained, with about half the witnesses providing relatively detailed information. Whilst some saw the collision itself, the majority were alerted by the sound of the collision, or by other people nearby who saw it. In a few cases, witnesses are believed to have unknowingly reported on aircraft that flew without incident on the first wave.

The great majority of witnesses described the two aircraft approaching each other at an angle of 90° or less, and that neither aircraft was manoeuvring significantly prior to the collision, although several witnesses identified that G-BYUT had been turning left beforehand and was travelling faster than G-BYVN.

Initial reports by a small number of witnesses that both aircraft were carrying out aerobatic manoeuvres in close proximity immediately prior to the collision

4 CWS is a generic term describing electronic equipment capable of alerting aircrew to nearby air traffic, in some cases providing advisory avoidance information.

appeared, during detailed questioning, to have been exaggerated, and were not supported by the majority of witnesses nor by radar data.

Most witnesses immediately recognised the catastrophic nature of the collision, with many accurately reporting the contact between one aircraft's wing and the other's rear fuselage, followed by separation of a wing and rear fuselage. Almost all witnesses described the sky as being full of debris after the collision, and many were sufficiently close to the scene to be concerned about it falling on them.

It was clear that neither aircraft was under the control of its pilot after the collision. Most witnesses concentrated their attention on G-BYVN, which had lost its rear fuselage and in most cases was physically the closer of the two. Many described the aircraft exhibiting a short period of extreme instability before adopting a steep nose down attitude and descending quickly. Some described it trailing smoke from an early stage. Those who described G-BYUT reported it as seeming to continue on its flight path initially while rolling or spiralling, before its flight path quickly steepened. It seemed to reach the ground before G-BYVN.

Numerous witnesses reported seeing an object separate from G-BYVN, although not all of them realised at the time that this was the pilot. Witnesses were evenly divided in their opinion of the nature of the pilot's separation; some thought it was a deliberate act, whilst others thought he had been thrown clear by the aircraft's motion. Accounts were not sufficiently detailed or reliable to allow an assessment of whether the pilot could have been attempting to deploy his parachute.

Witness estimates of the height the pilot separated from the aircraft varied significantly. However, it was generally described as being in the latter stages of the post-collision phase, and was after the aircraft had adopted its final, nose low attitude. The lowest estimate was 200 ft. From the combined accounts, it is likely to have been in the latter part of the descent, probably considerably below 1,000 ft agl.

1.18.6 Class G airspace

Airspace over the UK is divided into several classes. The classes, and regulations pertaining to each, are described in the UK Aeronautical Information Publication (UK AIP).[5]

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

The airspace in which the aircraft were operating at the time of the collision was classified as Class G airspace. Class G airspace 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 in Class G airspace are not mandatory. Although pilots are free to seek a deconfliction service from ATC, controllers cannot guarantee to achieve deconfliction minima due to the nature of the unknown Class G air traffic environment.

The UK Aeronautical Information Publication (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.'*

1.18.7 Rules of the Air

Both flights were subject to the Rules of the Air Regulations 2007, made under the Air Navigation Order[6]. Rule 10 of the Regulations dealt with the situation when two aircraft are converging. It stated that:

> *'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.'*

1.18.8 RAF Service Inquiry (SI)

An RAF SI was convened by the Air Officer Commanding 22 Group (AOC 22Gp) RAF, under the provisions of Section 343 of the Armed Forces Act 2006.

In its report[7], the RAF SI panel made a total of 15 recommendations to its convening authority. Certain recommendations are paraphrased below, together with the response by AOC 22Gp.

6 See CAP 393, *'Air Navigation: The Order and the Regulations.'*
7 The Service Inquiry report can be accessed at: www.mod.uk/DefenceInternet/AboutDefence/CorporatePublications/BoardsOfInquiry/

1.18.8.1 Deconfliction

Recommendation:

Measures should be identified and implemented to deconflict flights from all EFT/UAS/AEF units based on unit activity, tasking, ATS availability, local flying area and period of operations.

Response by convening authority:

> *'... new and robust procedures are now in place. The effectiveness of these procedures will be reviewed in due course to establish whether further improvements are possible.'*

1.18.8.2 CWS

… consideration be given to fitting a suitable (collision warning) system to the RAF Tutor aircraft.

Response by convening authority:

> *'...I am aware that such benefits may well be applicable to other aircraft within 22Gp and will direct that the provision of a suitable system be investigated for all aircraft under my command .'*

1.18.8.3 Tutor conspicuity

A review of the previous Tutor conspicuity options and alternative colour schemes should be undertaken to determine what measures to improve the aircraft's conspicuity are technically possible and practical.

Response by convening authority:

> *'A review of Tutor conspicuity options will be conducted to determine what colour scheme is optimal.'*

1.18.8.4 Survival training

RAF Tutor emergency egress and parachute training should be reviewed to ensure motor actions required to jettison the canopy and deploy the parachute are reinforced.

Response by convening authority:

> *'...I have directed that HQ Central Flying School review the egress training for each aircraft type within 22Gp and identify where similar improvements may be made.'*

1.18.8.5 Other recommendations

The SI panel made further recommendations in areas including: lookout training, Service policy on contact lenses, cockpit design of the Tutor and future aircraft, and notification to other airspace users about AEF flights.

2. Analysis

2.1 Aircraft serviceability

The wreckage examination and maintenance record evidence supports analysis from the radar traces and eyewitness accounts that both aircraft were fully serviceable, in controlled flight and under power up to the point of collision. No evidence was found to suggest that mechanical failure of either aircraft was a factor in the collision.

2.2 Collision geometry

Damage observed to the left landing gear of G-BYVN and evidence from the propeller and nose structure of G-BYUT show that these were the initial points of contact in the collision. It is likely that G-BYUT sustained damage to the windscreen and canopy from the landing gear, though this could also conceivably have been caused by debris released at the point of collision. The right wing of G-BYUT, at approximately mid-span, then struck the tail section of G-BYVN, just behind the cockpit, causing both structures to fragment and detach.

2.3 Crashworthiness and survivability

The damage sustained by both aircraft in the collision was incompatible with continued controlled flight of the aircraft.

It is was not possible to determine with any certainty the degree to which the canopy and cockpit area of G-BYUT was compromised in the collision, but this may have had implications with regard to the ability of the occupants to exit the aircraft. Given that the pilot of G-BYVN was not in the aircraft when it hit the ground, yet its canopy mechanism was closed and locked, the canopy perspex must have been compromised, either in the collision or as a result of it. The destruction of evidence by the fire following the ground impact prevented any additional assessment.

The QRF of both pilots' harnesses were undone, implying intent to abandon the aircraft, but successful abandonment for any of the occupants was highly unlikely given the circumstances and time available. It could not be established whether the pilot of G-BYVN had made a deliberate attempt to leave the aircraft when he did or had been thrown from it. Similarly it was not possible to determine why his parachute operating handle had not been pulled, although the chance of a successful parachute deployment from the probable separation height was small.

The lack of available evidence on the effect of the collision on the occupants and the airframe made it impossible to determine what factors prevented them from successfully escaping the aircraft. However, disorientation, incapacitation, overwhelming physical forces, aircraft structural damage or insufficient time, may all have contributed.

The accelerations and forces occurring in the ground impact phase were far in excess of the design capabilities of the aircraft and that which can be tolerated by the human body, making this aspect of the accident unsurvivable.

2.4 ELT

Disconnection of the ELT unit from the antenna on G-BYUT during either the midair or ground impact meant that the signal strength would have been very weak, even if the unit had been capable of transmitting post-impact. The manufacturer's fitting instructions recommend the ELT unit be fitted close to the antenna connection to minimize cable length, thus improving signal strength and reducing vulnerability to damage in a crash. However, the requirements relating to the structural strength and flexibility of the mounting position for the unit are unlikely to be met by the structure that is most suited to the location of the antenna. With the installation used in the accident aircraft this resulted in a compromise location which left the connecting cable vulnerable to damage.

The investigation into the failure of the unit fitted to G-BYUT to transmit a detectable signal also identified wiring failure as the most likely cause. Whilst the impact forces in this accident may have been beyond that which the ELT unit could reasonably have been expected to survive[1], the accident does highlight vulnerabilities in the crashworthiness of the system which are worth taking note of in future development of ELT systems and their certification standards.

2.5 Operating procedures

Both aircraft appeared to have been operating within the applicable rules and regulations. Both pilots were correctly qualified, experienced, in current flying practice and were adequately rested prior to flight. All required pre-flight activities relating to the pilots and cadets were completed and followed a normal sequence. The delay caused by the late arrival of the cadets resulted in both pilot's benefiting from an accurate weather update prior to their flights, otherwise it was not a factor.

1 Based on current design and certification regulatory requirements.

The collision occurred after the two aircraft came into close proximity to each other with neither pilot appearing to have been aware of the fact in time to take avoiding action. The remainder of this analysis therefore concentrates on how the aircraft came to be in such close proximity and why the pilots apparently did not see each other's aircraft in time.

2.6 Operating area

The operating area for the St Athan AEF flights was restricted by a number of factors, some of which were unique to St Athan. These resulted in the AEF flights routinely operating in a relatively small area. There were no specific procedures in place for pilots to deconflict with each other, either before or during flight. The RAF has subsequently recommended that specific deconfliction measures be introduced.

The flights were operating in uncontrolled airspace at the time of the accident, with no requirement for the pilots to be in contact with ATC or to be in receipt of an ATC service. Although Cardiff ATC may have been able to provide a service, this would have been subject to controller workload and without guarantee of deconfliction from other air traffic in the area. However, the RAF subsequently recommended that AEF pilots should seek an ATC service for their flights when it was practical to do so.

2.7 Visual acquisition

The flight trial by the RAF SI panel demonstrated that visual acquisition of the Tutor at the distances involved was sometimes difficult, even for experienced pilots who were alerted beforehand to the other aircraft's presence and approximate position. The aircraft's small size and cross section combined with the all white colour scheme served to make detection particularly difficult from some aspects and against some backgrounds. Although the colour scheme was judged at the time of the aircraft's introduction to offer a reasonable compromise in terms of conspicuity, cost and technical issues, the RAF is to undertake a review of Tutor conspicuity in the wake of this accident.

Although the weather conditions were generally good, the photograph from the police helicopter (Figure 6) showed a layer of low stratus forming slightly inland from the accident area. It is notable that G-BYVN would have been flying against this background as it approached from the east, during the period when the pilot of G-BYUT had most opportunity to detect it. Although the aircraft would have appeared to move across the windscreen of G-BYUT, it would have been moving only slowly against the light coloured background and, thus, probably very difficult to acquire visually. As G-BYUT continued to turn, its pilot's attention would have tended to be in the direction of the turn, and thus not in the direction of G-BYVN's approach.

The pilot of G-BYVN followed G-BYUT to the operating area, although it cannot be sure that he remained visual with it at all times, and he probably lost sight of it some time before the collision. Being relatively non-manoeuvring, the pilot probably had greater opportunity to see G-BYUT than the other pilot did of seeing G-BYVN. However, as the flight test showed, it is probable that obscuration by the aircraft structure and glare from the sun in the latter stages were contributory factors in G-BYVN's pilot's inability to see the other aircraft prior to the collision.

It is probable that neither pilot saw the other aircraft until immediately before collision, if at all. Rule 10 of the Rules of the Air Regulations, which would have required the pilot of G-BYUT to give way in this case, could only function if the pilot had seen G-BYVN beforehand and had time to take appropriate avoiding action.

2.8 Possible distractions

Both pilots were experienced in cadet flying and the sortie profiles were straightforward. As both cadets were flying for the first time, the possibility that the welfare of a cadet may have presented a temporary distraction (due to airsickness or anxiety, for example) to a pilot cannot be discounted. Nevertheless, there was no evidence to indicate that this was the case.

2.9 CWS

Modern lightweight CWS offer potentially significant safety benefits in terms of preventing collisions, although they are not effective against non-transponding aircraft and may be of reduced benefit in busy or rapidly changing traffic environments. Had CWS been fitted to the two aircraft, it may have prevented the collision by warning of the other's presence. However, this is not certain and limited CWS trials undertaken by the RAF in Tutors were inconclusive regarding its effectiveness. In the light of this accident, a further CWS trial was recommended by the SI panel, and has been agreed by the convening authority.

3 Conclusions

3.1 Findings

1. Both aircraft were serviceable prior to the collision.

2. Both pilots were correctly qualified and experienced.

3. The weather was suitable for the proposed flights.

4. All required pre-flight activities had been completed.

5. Neither pilot was in contact with ATC, and was not required to be.

6. Neither aircraft was equipped with an electronic CWS.

7. The primary method of collision avoidance was visual – see and be seen.

8. The physical size of the Tutor, together with its all white colour scheme would have made it difficult to acquire visually in the prevailing conditions.

9. It is likely that each aircraft was physically obscured from the other pilot's view at various times leading up to the collision, thus opportunities to acquire the other aircraft were limited for both pilots.

10. Neither aircraft appeared to take avoiding action.

11. The collision occurred in uncontrolled airspace.

12. The midair collision was catastrophic for both aircraft.

13. Successful abandonment was unlikely in the height and time available.

3.2 Causal factors

The investigation identified the following causal factor:

1. Neither pilot saw the other aircraft in time to take effective avoiding action, if at all.

3.3 Contributory factors

The investigation identified the following contributory factors:

1. The nature of the airspace and topography of the region reduced the available operating area such that the aircraft were required to operate in the same, relatively small block of airspace.

2. There were no formal procedures in place to deconflict the flights, either before or during flight.

3. The small size of the Tutor and its lack of conspicuity combined to make visual acquisition difficult in the prevailing conditions.

4. At various stages leading up to the collision, each aircraft was likely to have been obscured from the view of the pilot of the other aircraft by his aircraft's canopy structure.

4. Safety Recommendations and actions

In view of the wide-ranging recommendations made by the RAF SI panel (Section 1.18), and the responses by the convening authority, no further Safety Recommendations were considered necessary by the AAIB.

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