# Air Accidents Investigation Branch

Department of the Environment, Transport and the Regions

# Report on the accident involving RAF Tornado GR1, ZA 330 and Cessna 152, G-BPZX at Mattersey, Nottinghamshire on 21 January 1999

This investigation was carried out in accordance with The Air Navigation (Investigation of Air Accidents involving Civil and Military Aircraft or Installations) Regulations 1986

London: The Stationery Office

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15 March 2000

The Right Honourable John Prescott MP
Secretary of State
for the Environment, Transport and the Regions

Sir,

I have the honour to submit the report by Mr R StJ Whidborne, an Inspector of Air Accidents, on the circumstances of the accident involving RAF Tornado GR1, ZA 300 and Cessna 152, G-BPZX, at Mattersey, Nottinghamshire on 21 January 1999.

I have the honour to be Sir Your obedient servant

**KPR Smart** 

Chief Inspector of Air Accidents

Department of the Environment, Transport and the Regions
Air Accidents Investigation Branch
Berkshire Copse Road
Aldershot
Hampshire GU11 2HH

15 March 2000

The Right Honourable Geoffrey Hoon MP Secretary of State for Defence

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# GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	Air Accidents Investigation Branch	ICAO	International Civil Aviation
AAIT	Air Accidents Investigation Tool		Organisation
AAR	Aircraft Accident Report	IFF	Identification Friend or Foe
ADR	Accident data recorder	JAR	Joint Aviation Requirement
agl	above ground level	km	kilometre
AIC	Aeronautical Information Circular	kt	knot(s)
AIP	Aeronautical Information Publication	LARS	Lower Airspace Radar Service
ALFENS	Automated Low Flying and Flight	LATCC	London Area Terminal Control Centre
	Planning Enquiry and Notification	LFA	Low Flying Area
	System	°M	degrees magnetic
ANO	Air Navigation Order	MHz	Megahertz (frequency)
AOB	Angle of Bank	MLG	Main Landing Gear
AOPA	Aircraft Owners and Pilots	MOD	Ministry of Defence
	Association	MSD	Minimum Separation Distance
ATC	Air Traffic Control	NASA	National Aeronautics and Space
BHAB	British Helicopter Advisory Board		Administration
°C	degree centigrade	NATO	North Atlantic Treaty Organisation
CAA	Civil Aviation Authority	NOTAM	Notices to Airmen
CANP	Civil Aircraft Notification Procedure	PINS	Pipeline Inspection Notification
CVR	Cockpit Voice Recorder		System
CWS	Collision Warning System	PPL	Private Pilot's Licence
DERA	Defence Evaluation and Research	RAF	Royal Air Force
	Agency	SSR	Secondary Surveillance Radar
FAA	Federal Aviation Administration	TBC	Tactical Booking Centre
FIR	Flight Information Region	TCSI	Tornado Combined Safety
FIS	Flight Information Service		Investigation
FOD	Foreign Object Damage	TDA	Temporary Danger Area
FIR	Flight Information Region	TRA	Temporary Restricted Area
FIS	Flight Information Service	TTTE	Tornado Tri-national Training
FJ	Fast jet aircraft		Establishment
GA	General Aviation	UHF	Ultra High Frequency
GASCo	General Aviation Safety Council	UK	United Kingdom
GASIL	General Aviation Safety Information	UKAB	United Kingdom Airprox Board
	Leaflet	UKLF	United Kingdom Low Flying
GPS	Global Positioning System	UTC	Universal co-ordinated time
hrs	TT' (0.4.1 1 1)	VED	Wigned Elight Dules
	Time (24 hour clock)	VFR	Visual Flight Rules
HISL	High Intensity Strobe Light	VHF	Visual Fright Rules  Very High Frequency  Visual Meteorological Conditions

# Air Accidents Investigation Branch

Aircraft Accident Report No: 3/2000 (EW/C99/1/4)

Aircraft 1:

Operator:

The Flight Centre, Gamston Airfield

Aircraft Type:

Cessna 152

Nationality:

British

Registration:

**G-BPZX** 

Aircraft 2:

Operator:

Royal Air Force (RAF)

Aircraft Type:

Panavia Tornado

Model:

GR1

Registration:

ZA 330

Place of Accident:

Near Mattersey, Nottinghamshire

Latitude:

N53.25.0

Longitude:

W000.56.0

Date and Time:

21 January 1999 at 1133 hrs

All times in this report are UTC

#### **Synopsis**

The accident was notified to the Air Accidents Investigation Branch (AAIB) at 1200 hrs on 21 January 1999 and an investigation commenced on the same day. The investigation was conducted under the provisions of the Air Navigation (Investigation of Air Accidents involving Civil and Military Aircraft or Installations) Regulations 1986. The AAIB team comprised Mr R St J Whidborne (Investigator in charge), Mr R J Tydeman (Operations), Mr S W Moss (Engineering) and Miss A Evans (Flight Data Recorders). A Tornado Combined Safety

Investigation (TCSI) was also convened under air force regulations and conducted its own separate investigation.

The Cessna 152, which was based at Gamston Airfield, Nottinghamshire, was conducting a local flight and was most probably engaged in aerial photography. The Tornado GR1, based at RAF Cottesmore was on a routine training flight that included low level flying. The weather was excellent at the time of the accident with good visibility, no cloud and a light westerly wind.

The mid air collision occurred over open ground at a height of 655 feet agl some 300 metres from the western edge of the village of Mattersey, Nottinghamshire. The Cessna pilot, his passenger and both Tornado pilots were killed in the collision. After the collision the Cessna broke up in the air. The Tornado continued on its track but descended into the ground 13 seconds later. The collision initiated the ejection sequence for the front seat of the Tornado and that pilot was ejected from the aircraft but command ejection of the rear seat did not take place. The aircraft disintegrated on ground impact with the rear seat pilot still in his seat.

Eyewitness evidence indicates that before the collision the Cessna had been in a prolonged left–hand manoeuvre when at 1132:25 hrs it collided with the Tornado which was flying at low level on a north-easterly heading.

The following causal factors were identified:

- (i) None of the pilots saw each other's aircraft in time to take effective avoiding action.
- (ii) The Cessna pilot, whilst probably taking aerial photographs, conducted his flight at a height known to be vulnerable to an encounter with a military fast jet.
- (iii) By not using the Civil Aircraft Notification Procedure or informing any ATC agency of his location and intentions, the Cessna pilot degraded the potential of other traffic to locate and avoid him.
- (iv) When conducting operational checks, head down, whilst at low level, the front seat pilot of the Tornado did not detect the Cessna. The rear seat pilot had a limited field of view ahead of his aircraft and would have been unable to detect other aircraft in the forward sector.
- (v) The principle of 'see and avoid' was suspended during a period in which none of the pilots was able to conduct an effective lookout.

(vi) Technology based aids designed to enhance visual detection, such as strobe detectors and Collision Warning Systems, which had been recommended in the light of previous mid air collisions, had not been introduced into service.

Ten safety recommendations have been made as a result of this accident.

#### 1 Factual information

# 1.1 History of the flights

The history of the flights was compiled with the reference to eye witness accounts, data from a hand held Global Positioning System (GPS) in the Cessna aircraft and the Accident Data Recorder (ADR) and Cockpit Voice Recorder (CVR) in the Tornado aircraft. A post flight reconstruction of the Cessna, together with elements of the Tornado, provided information on the geometry of the collision.

#### 1.1.1 The Cessna

The Cessna was based at Gamston Airfield and operated by a flying school that also provided aircraft for private hire. The pilot had booked the aircraft for a local area familiarisation flight. When the pilot arrived at Gamston he requested that the aircraft be refuelled to full and this was accomplished at about 1040 hrs. The pilot completed the signing out procedure in the operations room of the flying school. Earlier that morning he had contacted a colleague who had access to a fax machine and had obtained the local weather for the Gamston area. They discussed this forecast over the telephone. It is not known whether the pilot completed any other planning. He did not notify his intentions to the military through the Civil Aircraft Notification Procedure (CANP), see paragraph 1.17.3.

The pilot and his passenger boarded the aircraft and it took off from Runway 21 at 1110 hrs. After leaving the airfield circuit the pilot did not make radio contact with any other agency and no primary or secondary radar contact was noted by any of the local military or civil radar units. Data from a hand held GPS receiver on board the aircraft indicate that it then flew at 80 to 90 kt towards the north-west to a position 5 km west of Gamston. At 1114 hrs the aircraft entered a left turn 300 metres to the east of the village of Ranby. No further data from the GPS was available.

The aircraft was next seen manoeuvring around the hamlet of Mattersey Thorpe, which is 1 km to the north-west of Mattersey and some 13 km north of Gamston. In the 6 to 8 minute period prior to the accident the Cessna was seen to complete at least 2 orbits to the left at low level. A number of eyewitnesses said that the aircraft behaved as if it was taking aerial photographs. Immediately prior to the collision it was turning to the left with about 30° angle of bank (AOB). The Tornado then appeared from the south—west, flying on a steady heading, and the two aircraft collided.

#### 1.1.2 The Tornado

The Tornado was on a training flight from the Tri-national Tornado Training Establishment (TTTE) which was located at RAF Cottesmore. This flight was the second in a Tornado aircraft for the student pilot. It was planned to commence with a brief introduction to low level flying before pulling up for medium level general handling, a practice diversion and extensive circuit work. The student pilot occupied the front seat and the aircraft captain, an experienced Tornado instructor, occupied the rear seat.

The aircraft took off at 1125 hrs and completed a low level departure from RAF Cottesmore; this was flown at 750 feet on the Cottesmore QFE<sup>1</sup>. The aircraft was planned to enter Low Flying Area (LFA) 6 at 1132 hrs and LFA 11 at 1134 hrs. The aircraft was booked into both LFAs to operate at 500 feet Minimum Separation Distance (MSD). No CANP, Pipeline Inspection Notification System (PINS) or late warnings were in force in either LFA.

After take off the instructor made radio contact with the Cottesmore departure controller who reported no secondary radar response on his radar screen from the aircraft. After leaving the Cottesmore zone the crew contacted Cranwell Air Traffic Control (ATC) who also informed the crew that no secondary radar response was visible on their radar screen and offered a Flight Information Service (FIS). The instructor accepted the FIS and confirmed with the student pilot that the secondary radar transponder (known in the RAF as Identification Friend or Foe (IFF)) was selected to 'ON' and that the correct code was set. The instructor left the Cranwell frequency at 1129 hrs and proceeded on a quiet frequency.

At the same time the crew initiated the pre low level checks, descended to 500 feet MSD and commenced a left turn onto a track of 326° M. At this stage the instructor was reminding the student pilot about steering and map reading techniques with particular emphasis on the need to maintain a good lookout whilst at low level. At 1131 hrs the crew turned right onto a track of 041° M. On this track the aircraft was flying over open, flat terrain with no significant topographical features, obstacles or hazards and with a well defined level horizon. Immediately after the turn, at 1131:30 hrs, the student pilot initiated a routine 'Ops check' of the aircraft and its systems. Towards the end of this check the instructor provided sensor and battery information, which is displayed in the rear cockpit, whilst the student pilot commenced a 15° bank turn to the right to recapture the planned low level track. The student pilot then initiated the last item in the Ops check, which was to check the cabin pressurisation. The cabin pressure gauge, which was about 45 millimetres in diameter, was located on the

<sup>&</sup>lt;sup>1</sup> Barometric pressure at the level of an airfield

environmental control panel situated just outboard of the front pilot's right hip. Whilst the student pilot was checking this instrument the Tornado collided with the Cessna at 1132:25 hrs.

#### 1.1.3 The collision

The collision occurred at a height of 655 feet agl, 300 metres from the western edge of the village of Matttersey, Nottinghamshire. The Tornado was flying at an IAS of 434 kt on a heading of 045°M. Eyewitnesses describe the Cessna in a stabilised turn to the left with about 30° AOB. Its speed is unknown, but was probably close to the cruise speed of 90 kt since this was the pilot's normal method of operation. In the final few seconds of flight the pilot would not have been able to see the Tornado which would have been obscured by the structure of the Cessna. Eyewitnesses report the Tornado going straight through the Cessna with the initial impact just behind the right wing root of the Cessna. Neither aircraft made any alteration to its flight path in the final few seconds and there was no perceived change in the engine noise from either aircraft.

The Cessna pilot and his passenger received fatal injuries in the collision. The aircraft wreckage fell into open ground below the point of collision. Both military pilots received fatal injuries in the collision. The impact also initiated the ejection sequence of the front seat by mechanically removing the main gun sear. The student pilot was ejected from the aircraft and his body came to rest in a field 300 metres beyond the point of collision. The instructor of the Tornado remained in the aircraft, which then commenced a shallow descent and flew into the ground 3 km north-east from the point of the collision. The Tornado disintegrated on impact.

#### 1.2 Injuries to persons

#### 1.2.1 Cessna

	Crew	Passengers	Others
Fatal	1	1	-
Serious	-	-	-
Minor/None	-	-	-

#### 1.2.2 Tornado

	Crew	Passengers	Others
Fatal	2	-	-
Serious	-	-	-
Minor/None	-		-

#### 1.3 Damage to aircraft

Both aircraft were destroyed.

#### 1.4 Other damage

Wreckage from both aircraft came to rest in open agricultural land. There was substantial fuel contamination of the soil in the area of the Tornado wreckage.

#### 1.5 Personnel information

1.5.1 Cessna pilot:

Male, aged 36 years

Licence:

Private Pilot's Licence (Group A landplanes)

Medical certificate:

Class 3 medical certificate with no restrictions.

Valid until 31 July 2002

Certificate of Experience:

Re-issued on 8 November 1998 and valid until

7 December 1999

Total flying hours:

282 hours

(all of which were on Cessna 150/152)

#### 1.5.1.1 Pilot background

The pilot had managed his own aerial photography business for more than 10 years. In 1987 he commenced flying training for a Private Pilot's Licence (PPL) which he completed in September 1997 with a total of 83 hours. Throughout this period he continued to run his aerial photography business and employed other pilots whilst he took the photographs. Once he had gained his PPL he undertook the dual role of flying the aircraft and taking photographs.

Other pilots who had flown with him describe his usual method of operation as flying at the normal cruise speed of about 90 kt with the flaps in the up position. The left-hand window, once opened and with the limiting strap unclipped, would be held open against the underside of the wing by the effect of the slip stream and the photographs would be taken through this aperture. The hand held camera that he used, a Nikon F4, was an auto focus model that required both hands to hold the camera and operate the zoom mechanism; it would normally rest in his lap when not in use.

In February 1998 the pilot joined the flying club at Netherthorpe and routinely used their Cessna 150 for what he described as local flights. Later that year he was seen by a flying instructor from Netherthorpe to be low flying over houses near Sheffield. The chief flying instructor insisted that he undertake another

check ride and warned him about low flying. On 4 July 1998 he was seen loading photographic equipment onto the aircraft prior to flight and later that day he was reported by other club members for low flying over the Fulwood area of Sheffield. He was then banned from flying at the Netherthorpe flying club. The flights recorded in his flying log book indicate that the majority of his flights returned to the airfield of departure and lasted for about two hours. This is an unusual pattern for a private pilot and reinforces the probability that he routinely conducted aerial photography.

On 19 January 1999 the pilot contacted a flying school at Gamston and asked to join their flying club with the intention of hiring their Cessna 152 aircraft. His licence and log book were checked and a proficiency check flight was arranged for the next day. On 20 January 1999 he completed this flight with an assistant flying instructor during which his knowledge of the local procedures and airspace was checked. He was specifically briefed on the availability of RAF Waddington for an FIS and the use of the radar transponder when leaving the circuit in order to increase the conspicuity of his aircraft.

#### 1.5.1.2 Passenger details

The passenger was a male aged 53 years. He had no aviation training or piloting experience and had accepted the offer of the flight in order to enjoy a day out and to provide some company for the pilot. He had previously flown with this pilot on aerial photography flights and had assisted by changing the films in the camera.

#### 1.5.2 Tornado crew

1.5.2.1 Instructor:

Male, aged 35 years, RAF pilot

Medical examination:

2 December 1998

Instrument flight check:

2 July 1998, valid until July 1999

Competency check:

10 February 1998

Total flying hours:

2,250 hours

Total hours on type:

974 hours

Total hours last 30 days:

10 hours

#### 1.5.2.1.1 Operational experience

The instructor had considerable instructional experience and had been instructing on Tornado aircraft at the TTTE for the past 22 months. His previous tour had been as a Tornado pilot on an operational squadron.

1.5.2.2 Student:

Male, aged 25 years, Italian Air Force pilot

Medical examination:

16 November 1998

Instrument flight check:

Not rated

Competency check:

Not yet checked

Total flying hours:

385 hours

Total hours on type:

1 hour

Total hours last 30 days:

1 hour

# 1.5.2.2.1 Operational experience

Prior to joining the TTTE course the student had completed his basic flying training on the SF-260 aircraft in Italy. He then attended the NATO Joint Jet Pilot training course in America where he flew the T37 and T38 aircraft. Having qualified as a military pilot he then flew the MB-339A aircraft in Italy in order to become familiar with military low flying in the European environment. None of these aircraft were equipped with a Head-Up Display (HUD). He had completed the Tornado ground training to a good standard.

#### 1.5.2.3 Flight duties

On the day prior to the accident flight the same crew had flown together and completed the first Tornado GR1 conversion flight for the Italian Air Force pilot. He achieved an average assessment for the sortie with no notable weaknesses. On the day of the accident the crew reported for a met brief at 0800 hrs and commenced planning for the flight at 0830 hrs. At 1010 hrs, before proceeding to the aircraft, the crew conducted an 'outbrief' with the squadron authorising officer and at 1120 hrs, immediately before taxiing, they confirmed with the squadron operations desk that there were no late warnings.

#### 1.6 Aircraft information

#### 1.6.1 Cessna 152

The Cessna 152 was a single engine, high wing monoplane with accommodation for two persons sitting side by side. The pilot normally occupied the left seat, which had a more comprehensive set of flight and navigation instruments. G–BPZX was painted predominantly white with two red horizontal stripes running along the length of the fuselage. In addition to the normal red/green/white navigation lights it was fitted with white flashing strobe lights on each wingtip, a red anti-collision rotating beacon on the vertical fin and a landing light in the engine cowling. It was also equipped with an ATC transponder, which was understood to have been serviceable when the aircraft took off on the accident flight, as were the lights.

Type: Cessna Aircraft Company Model 152

Engine: One Lycoming 0-235-N2C Piston engine

Constructor's Number: 152-85706

Date of Manufacture: 14/02/83

Certificate of Airworthiness: Valid in the Transport Category

(Passenger) until 2 December 2001

Certificate of Maintenance Review: Next due on 13/11/99

Total Airframe hours: 3,725 hours

#### 1.6.2 Tornado

The Panavia Tornado aircraft was a GR1 type fitted with dual controls and bearing the serial number ZA330, it carried a crew of two. The airframe was 'clean' with no external pylons or stores fitted. Painted in overall grey camouflage it displayed High Intensity Strobe Lights (HISLs) above and below the fuselage. The output of these lights is approximately 2,000 candela. The radar system fitted to this aircraft was not designed for acquiring or warning of the presence of other aircraft. It did, however, carry an Identification Friend or Foe (IFF) device that is the military equivalent of the ATC transponder fitted in the Cessna. Although the transponder was believed to be serviceable at the time of departure from Cottesmore, subsequent conversations with ATC suggest that it was not or that it became unserviceable at a very early stage of the flight.

The Tornado was designed for flight at high speed and low level. Amongst its specialised equipment is a HUD. This consists of a transparent screen situated between the pilot and the windscreen onto which are projected the required flight and navigation parameters. This projected information is nominally focussed at infinity thus allowing the pilot to absorb this information whilst looking through the HUD, searching for distant objects, without the need to re-focus the eyes. The pilot can thereby maintain a constant lookout for other aircraft, obstructions and ground objects necessary to the task, with only occasional glances into the cockpit. However, this process ceases when the pilot conducts checks of the aircraft and its systems that require him to direct his attention to instruments within the cockpit.

At 1131:30 hrs the student pilot initiated a routine 'Ops check' of the aircraft and its systems. The instruments that were then checked, their location and the need for the student pilot to look into the cockpit (Head down) or at the HUD (Head up) are described below:

(i)	Fuel total / balance	Right front panel	Head down
(ii)	Fuel sequence /temperature	Right side console	Head down
(iii)	Engine instruments	Right front panel	Head down
(iv)	Altimeter setting	Left front panel	Head down
(v)	Radar height	HUD	Head up

The instructor then provided sensor and battery information which was only displayed in the rear cockpit. During this brief period the student pilot commenced a 15° bank turn to the right to recapture the planned low level track. This track adjustment could have been accomplished using information on the HUD or by reference to a 'head down' instrument. However, only the 'head down' instrument provided cross-track error information and it is therefore possible that both sources were used to re-establish the aircraft on track. Two seconds before the collision the student pilot continued the 'Ops check' by initiating a check of the cabin altitude, this instrument was located at the rear of the right console, by the pilot's right hip, and was thus a further 'head down' check.

# 1.7 Meteorological information

#### 1.7.1 Forecast

The Tornado crew attended a meteorological briefing at 0800 hrs on the morning of the accident.

The Cessna pilot had obtained a telephone brief from a friend who had obtained the local area forecast from the Meteorological Office via a fax machine. He also had the opportunity to study valid meteorological information that was displayed in the flying club at Gamston Airfield when he booked out for his flight.

The low level forecast for all of England on 21 January 1999 for the period 0800 hrs to 1700 hrs was:

Visibility:

12 to 30 km reducing to 3,000 metres in

mist

Weather:

widespread mist south of 55°N before

1200 hrs

Cloud:

scattered cumulus, base 2,000 to 3,000

feet with some localised broken stratus,

base 400 to 1,000 feet

#### 1.7.2 Aftercast

The Meteorological Office, Bracknell prepared an aftercast, for the area of the accident site for 1135 hrs on 21 January 1999. The synoptic situation showed a light westerly airstream established over the area with a mean sea level pressure of 1021 mb.

Visibility:

generally between 8 and 10 km

Weather:

nil

Cloud:

few base 2,000 to 3,000 feet, tops 4,500

to 5,000 feet

Surface wind:

250°/05 kt

Surface temperature:

+6°C

Sun's position:

azimuth 170° (True), elevation 15° 57'

#### 1.7.3 Witness observations

Several witnesses who saw the collision reported the actual weather conditions at the time. They all recalled the weather as being clear, bright and sunny with good visibility. A Tornado crew who flew over the area 15 minutes prior to the accident reported the weather as very good with visibility in excess of 10 km, no low or medium level cloud and a light wind. A civilian pilot who took off from Gamston Airfield 10 minutes after the accident reported no cloud and a visibility in excess of 10 km except into sun at low level.

# 1.8 Aids to navigation

Not applicable.

#### 1.9 Communications

After take off the Tornado crew maintained radio contact with Military Air Traffic Control Units on Ultra High Frequency (UHF) channels. Their initial contact was with the Cottesmore departure controller on frequency 376.57 MHz. After leaving the Cottesmore zone they contacted Cranwell ATC on 250.05 MHz who offered an FIS. When they were clear of all active airfields they selected a nominated quiet frequency for instructional purposes.

The Cessna pilot was cleared to take off by the air-to-ground operator at Gamston on the Very High Frequency (VHF) of 130.475 MHz. Once clear of the circuit the pilot did not make contact with any other agency. Two VHF radios were fitted to the Cessna. Both utilised Light Emitting Diodes to display the frequencies in use or pre-selected. These radios were so badly damaged in the accident that it was not possible to apply electrical power to the units in order to discover what might have been selected. The audio selector box used conventional toggle switches and a rotary selector for the communications set in use. The rotary switch was found in a mid-position between Comm 1 and Comm 2. The toggle switches were destroyed. The rotary switch of the transponder was found to be off.

A Lower Airspace Radar Service (LARS) was available to the Cessna pilot from RAF Waddington on the VHF frequency of 127.35 MHz although the aircraft would need to have been flown at a height above the lower limit of radar coverage and, ideally, to have an active transponder. Alternatively, the pilot could have requested an FIS which would not have been dependent on radar.

#### 1.10 Aerodrome information

Not applicable.

# 1.11 Flight recorders

The Tornado was fitted with an Accident Data Recorder (ADR) which recorded voice and data channels. A transcript of the final 50 seconds from the voice channel is at Appendix A. The data showed that the aircraft took off on a heading of 220° (M) and climbed to a radio height of 900 feet. After one minute it turned first onto a heading of 330° (M) and then onto a northerly heading. The aircraft continued straight and level until three minutes before the collision when it turned left onto a heading of 320° (M) and began to descend. Two minutes before the collision the aircraft started to level at 650 feet radio height.

One minute and ten seconds before the collision the aircraft rolled right onto a heading of 033° (M). The maximum roll attitude during the turn was 65° to the right. The aircraft, which had descended to 550 feet radio height, climbed to 800 feet radio height before descending towards 650 feet radio height. The airspeed was 430 kt. The aircraft remained on a heading of 033° (M) until 14 seconds before impact when it turned onto a heading of 041° (M). The maximum roll attitude during the turn was 17° to the right. The impact occurred at a radio height of 655 feet, and the last recorded airspeed was 434 kt. The aircraft was at a pitch attitude of 3.3°, and a roll attitude of 4.6° to the right. The cabin pressure warning was triggered by the loss of the canopy.

Several parameters were then lost from the recording, including pressure altitude, airspeed, pitch and roll attitude. The aircraft entered a descent as indicated from the radio height and the data ended 13 seconds later. There was no change in the recorded Jet Pipe Pressure or Power Lever setting on either engine, both of which continued to run following the collision.

# 1.12 Wreckage and impact information

A detailed plot of the wreckage of both aircraft was undertaken, particularly in the area below the point of collision. The following is a general overview of the distribution of the wreckage and is intended to assist in understanding the nature of the collision and the degree of damage suffered by each aircraft as a result. There were essentially two distinct debris fields, labelled Site A and Site B at Appendix B. In general Site A comprised almost all of the Cessna wreckage and Site B comprised almost all of the Tornado apart from its windscreen and the canopy glazing, which was found at Site A.

#### 1.12.1 Site A

The major single piece of the Cessna was found just to the south of the main debris trail, which ran in the approximate direction of 045°M. This piece consisted of the complete right wing, engine, propeller and cowling, instrument panel and the right cabin side, including the door, back to the aft edge of the rear window. A section of the cabin floor, including some of the two seat rails, was also present in this portion of the wreckage. The passenger from the aircraft was found close to this latter piece and the pilot was found about 80 metres further to the north-east.

The main debris field comprised almost all of the remainder of the Cessna airframe. The empennage and rear fuselage were found mostly in one piece, together with the upper and lower halves of the fuselage aft of the rear window. The outboard left wing and aileron were also readily identifiable but the remainder of the left fuselage, door and inboard left wing were extremely fragmented. The outboard left tailplane and elevator were also badly disrupted. The right Main Landing Gear (MLG) strut, wheel and the left control yoke were also found in the main debris field. The entire area was liberally strewn with Cessna cockpit transparency fragments.

The contents of the Cessna cabin was distributed about this area, in particular both seats and a number of bags together with photographic equipment and film. Also in the debris were charts depicting an organised and referenced grouping of villages and towns in the area of the crash site and further afield. As the debris trail continued to the north-east, pieces of lighter debris from the Tornado identified largely as radome and canopy fragments started to appear. As the trail approached and crossed the Mattersey/Mattersey Thorpe road, Cessna debris ceased and progressively heavier Tornado pieces prevailed, in particular the left and right windscreen quarterlight panels and the upper left and right switch panels from directly below the glareshield. The clock from the right panel had stopped at 1132 hrs. Helmet fragments belonging to the front-seat Tornado pilot were found as the trail progressed, as were the complete (but badly damaged) windscreen frame and pieces of the front, rear and centre canopy arches. These final pieces appeared to be associated with the ejection of the front-seat pilot, culminating in discovery of the seat itself in woods at the extreme end of the trail. Discovery of several areas of very finely divided pieces of Cessna skin material tended to suggest that this material had been ingested by an engine fan stage and ejected through the by-pass duct.

#### 1.12.2 Site B

Site B displayed the typical characteristics of a fast jet aircraft impacting at a shallow angle and high speed into a ploughed field. An initial, relatively shallow impact crater was followed by a fan-shaped debris throw with the heaviest items (eg wing centre-section and engines) being amongst the furthest items found in a trail stretching some 750 metres. There was some evidence of a slightly right-wing-down attitude at first impact as there was a somewhat smaller indentation slightly to the right of the main crater. Thereafter, the aircraft appeared to have yawed violently to the right, throwing the fin off to the left of the trail whilst the rest of the wreckage tumbled along the surface of the field, completely disrupting the airframe. The body of the rear seat pilot was found in this trail, which was aligned in a similar direction to that of the distribution of Site A, indicating that there had been little, if any, deviation of the Tornado flight path after the collision. The following points were noted:

The fin had suffered little damage from ground impact, but the forward-facing Radar Warning Receiver had detached during the collision and was found at Site A. There was also evidence of impact at the base in the area of the pre-cooler intake. The intake was also amongst the debris at Site A but there was no evidence of scratching from any Cessna debris on the leading edge.

The left mainwheel, tyre and brake disc from the Cessna were recovered from Site B. The associated MLG strut was either not recovered or not identified.

The left engine intake assembly was recovered as an intact unit. Although there was a considerable amount of debris embedded in the ramp and other internal surfaces, this appeared to have come from the forward fuselage of the Tornado itself, and no signs of debris from the Cessna was seen. The intake lip itself was completely clear of damage from substantial debris.

Both engines had suffered Foreign Object Damage (FOD) but much of this had probably occurred during ground impact. Neither bore the classic signs of hot metal spatter on the turbine blades or stators indicative of in-flight FOD ingestion.

Both left and right lower canopy rails were present at Site B.

From the on-site examination of the debris, it was apparent that the collision had completely disrupted the centre fuselage of the Cessna, causing instant fatal injuries to both occupants and destroying the integrity of the aircraft as a whole. The Tornado appeared to have suffered major damage only to the cockpit windscreen and canopy, leading to immediate incapacitation of the crew, certainly fatal in the case of the front seat pilot.

#### 1.13 Medical and pathological information

A post-mortem and toxicological examination was carried out on all four victims. In no case was there any evidence of pre-existing disease, alcohol, drugs or any toxic substance which may have caused or contributed to the cause of the accident. It is apparent that all the occupants received fatal injuries in mid-air at the time of the collision.

#### 1.14 Fire

There were only minor, sporadic fires in areas where fuel had pooled as it came to rest within the Tornado wreckage.

#### 1.15 Survival aspects

The emergency services were alerted by a number of telephone calls from eyewitnesses and the first of these calls was logged at 1134 hrs. The first accident site reported was the field containing the Tornado wreckage and this field was situated on the north-eastern side of the village of Everton. Shortly afterwards a second accident site was reported just to the west of the village of Mattersey. The police arrived at the Tornado site at 1150 hrs and later confirmed that the pilot in that aircraft was dead. The bodies of the two occupants of the Cessna and the student pilot from the Tornado were located at 1201 hrs.

The impact forces suffered by the occupants of the Cessna were well beyond human tolerance and the accident must therefore be considered as not survivable.

The collision with the Cessna removed the front windscreen of the Tornado together with the clamshell canopies above the canopy edge members. Both military pilots received fatal injuries in the initial impact, which also initiated the ejection sequence of the front seat by mechanically removing the main gun sear. The subsequent seat operation and sequencing was normal but, in the absence of any initiating gasses, command ejection of the rear seat did not take place. The student pilot, in the front seat, came to rest in a field approximately 300 metres from the point of the collision. The instructor of the Tornado, in the rear seat, remained in the aircraft which then commenced a shallow descent and flew into the ground 3 km north-east from the point of the collision, the aircraft disintegrated on impact. Following the collision the aircraft was still able to fly but both pilots had been fatally injured and the accident must therefore be considered as not survivable.

#### 1.16 Tests and research

#### 1.16.1 Detection and recognition

Statistics show that the majority of mid-air collisions occur in good weather and good visibility. The problems of the visual detection of another aircraft, and the recognition that it is on a collision course have long been acknowledged and much research has been carried out into ways of avoiding such accidents. The AAIB Aircraft Accident Report (AAR) 2/94 recommended that the Ministry of Defence (MOD) should commission an operational analysis of Fast Jet (FJ) low flying training in the UK to determine whether the use of 'see and avoid' as the primary means of collision avoidance is satisfactory from the point of view of flight safety. The MOD accepted this recommendation and commissioned the Defence Evaluation and Research Agency (DERA) to conduct the analysis and to evaluate various measures that might further enhance flight safety. The executive summary of the study is at Appendix C. The study concluded that the principle of 'see and avoid' in the open Flight Information Region (FIR) below 2,000 feet is generally more than 99% effective in resolving conflictions<sup>1</sup>. At current flying rates (military and civil) this implies an expected collision rate of 0.118 per 10,000 flying hours for military fast jet aircraft and of 0.005 per 10,000 flying hours (by military fast jets) for fast jet/general aviation aircraft. This predicts a random collision between a military fast jet and a general aviation aircraft about once every 6 years.

#### 1.16.1.1 Conspicuity

The study considered the effectiveness of three measures currently available which might enhance conspicuity: high intensity strobe lights (HISLs), forward facing lights and the use of gloss black paint schemes. The use of HISLs, rated at 2,000 candela, on military aircraft was calculated to produce a reduction in the expected collision rate from 2.202 to 1.870 per annum. HISLs are now fitted to all military low flying aircraft. Adding HISLs to all non-sports civil aircraft is estimated to reduce the expected rate of collision rate by a further 0.445 per annum. There is no current requirement for light civil aircraft to be fitted with HISLs. The use of high powered forward facing lights was evaluated by the RAF and, whilst effective, has been found to be viable only on the Hawk aircraft. All RAF training aircraft are now painted black, but fast jet aircraft retain their camouflage paint scheme. Using these conspicuity measures reduces the calculated collision rate by about 49%.

<sup>&</sup>lt;sup>1</sup> The percentage for fast jet/general aviation aircraft conflictions is 98%.

#### 1.16.1.2 Collision Warning System

The study also considered the effect of fitting a Collision Warning System (CWS) to fast jets other than the Hawk and the Tucano. It assumed that all light aircraft were fitted with an operating radar transponder (SSR). The study concluded that a CWS would reduce the collision rate by about 66%. The RAF completed a technology demonstration programme in 1997, which concluded that a transponder based system would be technically feasible for fast jet aircraft. The MOD has since decided to procure a CWS for the Tornado GR4 fleet (an updated variant of the Tornado GR1). The implementation and introduction into service will be dependent upon the selected technical solution but the current planned in The RAF also had a requirement for an airborne service date is 2004. instrumented debrief system and the selected system already incorporated a basic CWS capability. This equipment is expected to be in service in 2002. Unfortunately, this system, once introduced into service, will only detect other similarly equipped aircraft. Therefore, if the Tornado involved in this accident had been carrying such equipment it would not have detected the Cessna, even if, as a pre-requisite, the Cessna's transponder had been selected to 'ON'.

The Civil Aviation Authority (CAA) have also been pursuing the development of a lightweight, battery powered transponder that could be carried in light aircraft, gliders or microlights. A feasibility study has been completed with encouraging conclusions, but component production difficulties for use in a production unit have resulted in further delays to the programme.

#### 1.16.1.3 Strobe detection equipment

The CAA have conducted an extensive study, including field trials, on the development of a strobe detector. This utilises modern optical components to detect the strobe lights fitted to all military and many civil aircraft. An operational evaluation was carried out and confirmed the technical viability and operational effectiveness of the system. The prototype system was evaluated by the RAF with encouraging results. However, it has not yet been possible to manufacture commercially viable products.

#### 1.16.2 Probability of detection

A study to estimate the detectability of each aircraft from the point of view of the other was commissioned from the Centre for Human Sciences at Farnborough. This study is presented at Appendix D. The conclusions of this study are that the nature of the Cessna aircraft's final manoeuvre presented those on board with only a limited opportunity for detecting the Tornado, and it is likely that their attention was confined to ground references during this critical period. The

instructor pilot, in the rear seat of the Tornado aircraft, had an obstructed view in the forward sector and had no opportunity to detect the confliction. Only the student pilot, in the front seat of the Tornado, had any opportunity to detect the confliction. In principle, in the prevailing conditions, a diligent visual scan would have had a moderate probability of revealing the Cessna in time to allow avoiding action to be taken. This principle was undermined by the student pilot's attention to a routine check procedure. Whilst conducting this routine check it is difficult to believe that he was able to give more than scant attention to visual look out. His lack of experience in the use of the HUD probably contributed to his inability to detect the other aircraft. It is also possible that the effects of clutter in the HUD reduced the probability of detection at a critical moment.

#### 1.16.3 Radar coverage

Analysis of the recordings of local military and civil radars failed to show traces of the tracks of either aircraft. It is considered that this was because both aircraft were below the base of primary radar cover and neither aircraft appeared to be using its secondary radar transponder. This device produces an enhanced radar return together with a data tag that can identify a specific aircraft and its altitude. The IFF equipment in the Tornado was identified as being unserviceable immediately after take off. The secondary radar transponder in the Cessna was found to be selected to the 'OFF' position.

# 1.17 Organisation and management information

# 1.17.1 Tornado Tri-national Training Establishment

In 1975 it was agreed that the Tornado flight crews of the RAF, the German Air Force, the German Navy and the Italian Air Force would complete their operational conversion training at a joint facility to be located at RAF Cottesmore. This unit was called the Tornado Tri-national Training Establishment (TTTE). The first course commenced in October 1980 and the TTTE was formally closed on 31 March 1999. During the period from July 1990 until the end of 1998 the TTTE conducted 24,893 hours of low level flying during which time no other low flying accidents have occurred. Foreign military aircraft and their crews are normally subject to a policy of 'reciprocity' under which they are not allowed to fly in the UK at a lower height than applies to RAF aircraft in the country concerned. However, all low level flying training at the TTTE is conducted at 500 feet MSD in order to standardise training techniques and routes. Low flying in the UK by foreign crews, including training at TTTE, accounts for less than 1% of the total activity in the UK low flying system.

#### 1.17.2 Military low flying

In order to fulfil national operational commitments some military aircrew have a requirement to train in the low level reconnaissance and attack roles and such training needs to be undertaken regularly and in a realistic environment. Since 1979 the whole of the UK has in principle been open to low flying and for administrative convenience the country is divided into 19 LFAs, not evidently linked to any geographical divisions on the ground. However, in practice environmental and safety considerations significantly reduce the airspace available. Furthermore, areas around major conurbations are also excluded as is controlled airspace that is required for the protection of the majority of public transport operations. The protection provided to these areas can create choke points which constrain the flow between them. When flying within these constrained areas military aircraft follow established uni-directional flows when below 2,000 feet, in order to reduce the risk of collision. arrangements are published on CAA chart ENR 6-5-2-1 'Areas of Intense Aerial Activity, Aerial Tactics Areas and Military Low Flying System'. Despite the title of this chart it does not depict the Low Flying System.

In the UK military fast jets are considered to be low flying when they are less than 2,000 feet from the ground, water or any object except another aircraft flying in the same formation. The lowest height that a military jet aircraft is normally permitted to fly is 250 feet MSD. However, the majority of low flying takes place between 250 and 500 feet MSD and is invariably carried out on weekdays, during daylight and in good weather. Except in the Highlands Restricted Area, which is set aside on a regular basis for low flying in limited visibility using terrain following radar, all low flying by day is conducted in Visual Meteorological Conditions (VMC). This means that crews must be able to fly by visual reference to the ground. It also requires them to apply the 'see and avoid' principle in order to de-conflict with other aircraft. When flying within the low level system military fast jets are normally limited to 450 kt although speeds up to 550 kt can be authorised for specific purposes.

Details of Military Low Flying in the UK are published in the UK Aeronautical Information Circular (AIC) 82/1996 (Yellow 227); amplification of this information is provided in the General Aviation Safety Sense Leaflet 18A (Military Low Flying) published by the CAA. In these documents the pilots of civil aircraft flying under Visual Flight Rules (VFR) during the working week are specifically advised to:

- (i) Fly above 2,000 feet if possible
- (ii) Avoid particularly, operating in the 250 to 1,000 feet height band

All military low flying sorties are required to be planned and then notified to a central co-ordinating authority which is the Automated Low Flying and Flight Planning Enquiry and Notification System Operations Centre (ALFENS Ops). This unit is located within the military section of the London Area Terminal Control Centre (LATCC (Mil)). Its function is to co-ordinate military low flying sorties but it also provides information on civil aircraft whose flights have been notified in accordance with CANP and PINS, (see paragraph 1.17.3).

As part of its continuing education programme the General Aviation (GA) department of the CAA also conducts an active programme of Safety Evenings at flying clubs around the UK where safety issues, such as the hazard posed by low flying military aircraft, are discussed. Furthermore it publishes a General Aviation Safety Information Leaflet (GASIL) once every two months to further promote specific safety issues relevant to the GA community.

# 1.17.3 Low Level Civil Aircraft Notification Procedure (CANP)

Many flights take place within the FIRs outside controlled airspace and at low levels where a radar service cannot be provided. Collision avoidance must necessarily be based on the 'see and avoid' principle, assisted as far as is possible by information on known activity. Although military aircraft are considered to be low flying when below 2,000 feet MSD it is not practicable to disseminate information on all civil aircraft operating at that height or below. Nevertheless the greatest conflict of interests occurs at or below 1,000 feet where the majority of military low level operations take place and where civil aircraft may be engaged in legitimate activities which might inhibit pilot lookout (aerial photography / crop spraying) or reduce aircraft manoeuvrability (underslung loads). A system exists to collect information on civil aerial activities for distribution to military operators to assist in flight planning. This system is known as the Low Level Civil Aircraft Notification Procedure (CANP).

ALFENS Ops (LATCC Mil) is the central authority for managing information that may affect military low level flying notification. The unit operates a Freephone/Fax line for civilian operators to provide notification of their aerial activities at and below 1,000 feet agl, with an expected duration in excess of 20 minutes at a specified location. The airspace notified under CANP should not exceed an area bounded by a 2 nm radius circle. The intended activities are required to be notified to ALFENS Ops not less than four hours before commencement in order to allow for the timely dissemination of the information to all military users. CANP applications made less than four hours before commencement will still be accepted, however, such applications are less likely to reach all military pilots before they depart on their low level flights. Aircrew of military fixed wing aircraft flying at an IAS greater than 140 kt will avoid areas

reported under CANP either laterally or vertically. During 1998 a total of 1,770 CANPs were notified to the ALFENS Ops but only 22 of these were for fixed wing aircraft. In the previous year 1,515 CANPs were notified but only 61 of these were for fixed wing aircraft.

#### 1.17.4 Mid-air collision statistics

Since 1990 there have been three mid-air collisions between low flying military fast jets and civil aircraft within the UK FIR, including this accident. They are:

29 August 1991

RAF Jaguar TA2 / Cessna 152

Carno, Wales
AAIB Report 2/92

23 June 1993

RAF Tornado GR1 / Bell 206B helicopter

Kendal, Cumbria AAIB Report 2/94

21 January 1999

RAF Tornado GR1 / Cessna 152

Everton, Nottinghamshire The subject of this report.

These have resulted in a total of eight fatalities. No people on the ground have been injured.

Since 1990 there have been four collisions in the UK low flying system between military aircraft and one collision involving a military aircraft and a police helicopter.

The data base maintained by the Safety Data Department of the Safety Regulation Group of the CAA includes details of 13 mid-air collisions between civil light aircraft (including gliders) that have occurred since 1990. These collisions were in Visual Meteorological Conditions (VMC), where the principle of 'see and avoid' applied, and have resulted in 14 fatalities with no people on the ground being injured. Collisions involving aircraft conducting formation flying have not been included nor have collisions between gliders manoeuvring at the start of a competition. It is considered that in both of these instances the aircraft have been deliberately placed close to each other with the full knowledge of the pilots involved.

#### 1.17.5 Airprox statistics

Airprox is the term used whenever a situation existed in which, in the opinion of a pilot or a controller, the distance between aircraft as well as their relative positions and speed were such that the safety of the aircraft involved was or may have been compromised. Whenever an Airprox is reported the circumstances are investigated. Previously, this investigation was conducted by the Joint Airmiss Section. Since 9 November 1998 this function has been performed by the United Kingdom Airprox Board (UKAB), which is a joint CAA/MOD activity. The UKAB comprises civil and military pilots, controllers and operators, from diverse aviation backgrounds, who assess each Airprox case. The purpose of the Airprox assessment process is to determine the causal factors, assess the degree of collision risk inherent in each case and make any appropriate safety recommendations. The degree of risk is assessed in accordance with the International Civil Aviation Organisation (ICAO) guideline and categorised as follows<sup>1</sup>:

Category 'A'

Risk of collision

Category 'B'

Safety not assured

Category 'C'

No risk of collision

Category 'D'

Risk not determined

Records indicate that, within UK airspace, the following Airprox involving military fast jets and civil aircraft occurred at and below 2,000 feet.

Year	<b>'</b> 89	<b>'</b> 90	<b>'</b> 91	<b>'</b> 92	<b>'</b> 93	<b>'</b> 94	<b>'</b> 95	'96	<b>'</b> 97	<b>'</b> 98
Risk A	7	4	4	9	4	2	2	4	5	3
Risk B	10	9	8	11	20	15	9	9	9	6
Risk C	10	11	9	9	21	18	22	11	14	10
TOTAL	27	24	21	29	45	35	33	24	28	19*

<sup>\*</sup>Note: 9 Airprox have not yet been assessed

#### 1.17.6 Relevant regulations

#### 1.17.6.1 Rules of the air

The Rules of the Air Regulations (1996) are set out in Statutory Instrument No 1393 of 1996. The Rules that are relevant to this investigation are presented in Appendix E.

<sup>&</sup>lt;sup>1</sup> ICAO Doc 444-RAC/501/12 Twelfth Edition –1985 Part II paragraph 16.2

#### 1.17.6.2 Aerial work

The definition of aerial work is contained within Article 119 of the Air Navigation (No 2) Order 1995. This Article, covering five pages, is reproduced at Appendix F.

ICAO Annex 6 (Operation of Aircraft) defines aerial work thus: 'An aircraft operation in which an aircraft is used for specialised services such as agriculture, construction, photography, surveying, observation and patrol, search and rescue, aerial advertisement etc.'

Following a mid-air collision between an RAF Jaguar and a Cessna at Carno, Mid Wales on 29 August 1991 the AAIB report (AAR 2/92) drew attention to the UK definition of 'aerial work'. In that accident the Cessna pilot, who held a Private Pilot's Licence (PPL), was engaged in aerial photography. The report referred to Schedule 8 of the Air Navigation Order (ANO) which allows that PPL holders may receive remuneration for flying aircraft under certain circumstances, such as qualified flying instruction, towing a glider and the dropping of parachutists. Aerial photography flights, on which a pilot does not receive direct remuneration for flying the aircraft but does accept a commission from the profits accrued from the sales that he has generated, would seem to fall within an ill-defined area of legislation. The report concluded it was apparent that the UK definition of aerial work was imprecise and required clarification.

AAR 2/92 recommended that the CAA should 're-examine the UK definition of aerial work and ensure that the legislation allows that the activities of operators engaged in aerial photography flights of a commercial nature may be properly and safely regulated. By recognising the activity as aerial work, as opposed to an extension of private flying, a greater measure of regulation should be possible.' The CAA accepted this recommendation and stated that 'the Joint Aviation Authorities have adopted the ICAO definition of aerial work, which includes aerial photography. The Authority will fully support the future development of Joint Aviation Requirements - Operations 2 (JAR-OPS2)<sup>1</sup> which will provide for the safe regulation of the activities of operators engaged in aerial photography flights of a commercial nature.'

In order to establish whether, in these particular circumstances, the Cessna pilot was conducting aerial work the AAIB sought legal advice. The opinion of the legal branch of the CAA was that this was a private flight since no valuable consideration was given or promised for the purpose of the flight.

<sup>&</sup>lt;sup>1</sup> It is intended that JAR OPS 2 will relate to GA operations. It is presently in the discussion phase and no forecast date for the document's promulgation is available.

# 1.17.7 Military / Civil Air Safety Days (MCASD)

For the past five years the CAA and MOD have jointly sponsored and organised MCASD with the aim of improving the mutual understanding of problems which may be encountered in the low level airspace. Most of the safety days have been held at RAF bases where GA pilots enthusiastically accept an invitation to be briefed on fast jet operations and to examine some of the hardware used. Numbers are necessarily limited but it is hoped that those attending pass on the message to others in the GA community.

#### 1.17.8 Aeronautical charts

Following the mid-air collision between an RAF Jaguar and a Cessna at Carno, Mid Wales on 29 August 1991 the AAIB report (AAR 2/92) considered the need for information about military low flying to be depicted on aeronautical charts. It was recommended that 'Military flow directional arrows should be published on civil aeronautical charts and that those RAF stations that operate fast jets should be highlighted'. The CAA accepted the element of this recommendation that related to flow directional arrows. The inclusion of flow arrows on civil charts was agreed by the MOD, and the CAA then considered the mapping implications. The CAA subsequently decided that since these flow arrows already appeared in the AIP the inclusion of them on aeronautical charts was unnecessary.

Following the mid-air collision between an RAF Tornado and a Bell JetRanger helicopter at Kendal, Cumbria on 23 June 1993 the AAIB report (AAR 2/94) once again considered the need for information about military low flying to be depicted on aeronautical charts. The report recommended that 'The MOD and the CAA should arrange for flow directional arrows and choke points of the UKLF system to be published on those topographical charts which are most commonly used by pilots'. This recommendation was not accepted on the grounds that this information was already available in the AIP. Furthermore, it was considered that there were significant differences in operations between day / night, and that major exercises and routine revisions to the system would not be reflected in a chart re-issue cycle. It was considered that there were possible risks involved in publishing this data on topographical charts and therefore the information was to be constrained to the AIP.

In 1998 the UKAB investigated an Airprox involving an RAF Tornado and an unidentified Cessna aircraft. As a result of their investigation the UKAB considered that a risk of collision existed<sup>1</sup>. There was considerable debate amongst the Board's members on the usefulness or otherwise of having the flow arrows from military low level charts incorporated onto CAA topographical

<sup>1</sup> Category 'A'

charts. The Board's view was that the introduction of flow arrows on those maps commonly used by civilian pilots flying at low level would make an important contribution towards safety. This recommendation was made to the Maps and Charts working group of the CAA. The recommendation was rejected on the grounds that this information:

- (a) May cause obstruction and confliction between aeronautical and topographical symbols.
- (b) Could be potentially dangerous as pilots operating in the vicinity of a published arrow may feel encouraged to concentrate in one direction only.
- (c) Inclusion of flow information and choke points would clutter rather than enhance charts.

#### 1.18 Additional information

#### 1.18.1 Emergency restriction of flying

Following an emergency incident on land or at sea the authority controlling the emergency may establish a Temporary Danger Area (TDA)¹. The TDA is established where it is considered essential for the safety of life or property and particularly for the protection of those engaged in search and rescue by inhibiting unauthorised flight within or over the designated area. The establishment of the TDA is promulgated by NOTAM and the emergency controlling authority is the only authority that may grant permission for aircraft to fly within the notified airspace. If a TDA fails to meet the objective or is deemed to be inappropriate for a particular incident further regulations may be introduced which make it an offence to fly within the Temporary Restricted Area (TRA) without the permission of the appropriate controlling authority. Coincidentally, a temporary Military Flying Restriction may be imposed under the authority of the UK Low Flying Handbook.

Following this mid-air collision a TDA was created at 1217 hrs on 21 January 1999. The TDA comprised a circle of 5 nm radius centered at the point of collision (defined by a latitude / longitude) and extended from the surface to 5,000 feet. This was promulgated by NOTAM at 1232 hrs. The NOTAM further requested adjacent ATC units to advise aircraft on their frequencies of the details of the TDA. A TRA for the accident area was then established by NOTAM at 1321 hrs.

<sup>&</sup>lt;sup>1</sup> Details are provided in the UK AIP, ENR 1.1.5 -Airspace Restrictions Danger Areas and Hazards to Flight

Whilst search and rescue operations were taking place in connection with this accident, an unauthorised helicopter flew into the area. The helicopter was identified through its registration as being a Bell 206 helicopter that had taken off from Leeds-Bradford at 1402 hrs. Article 75 of the ANO describes the regulations which may be made by the Secretary of State to restrict or prohibit flying where he deems it necessary in the public interest. The article states that 'it shall be an offence to contravene or permit contravention of or fail to comply with any regulations made hereunder'. Accordingly the Air Regulation Enforcement and Investigation Branch of the CAA interviewed the helicopter pilot who stated that he was unaware of the existence of a TDA or TRA.

#### 1.19 Useful or effective investigation techniques

The airborne impact was modelled using AAIT (Air Accident Investigation Tool), a computer program linking various aircraft crash-analysis codes. The aircraft structural analysis code used is KRASH, a 'hybrid' code developed for FAA/NASA for aircraft ground impact research. KRASH requires a model of the aircraft to be created which comprises a series of lumped mass points linked together by deformable beam elements. The mass points define the weight and inertia properties of the structure and the beams define the strength and ultimate collapse characteristics. Contact springs are attached to selected mass points to represent the crush properties of the lower structure of the aircraft which is likely to contact the ground. In this case the KRASH aircraft model for the Cessna was developed from one already available in AAIT and the Tornado aircraft was modelled as a lumped mass. The speed and orientation of both aircraft at impact was taken from the wreckage analysis and the ADR data available from the Tornado. The program then predicted the motion and deformation of both aircraft during the course of the subsequent simulation. The output was then available to the user as a set of time history plots, 3-D wire frame and through a 'Virtual reality' module a simulation of the impact sequence. The results of these simulations showed that the predicted break-up sequence was generally in accordance with the wreckage analysis. This is because AAIT was primarily designed to investigate ground impacts and, in adapting it to a mid-air collision, certain simplifications and assumptions had to be made. It appears that a more accurate simulation could be developed, but this was outside the scope or the requirements of this investigation. Appendix G shows the relative orientation of the two aircraft at impact.

## 2 Analysis

The civil investigation into this accident was carried out under the provisions of The Air Navigation (Investigation of Air Accidents involving Civil and Military Aircraft or Installations) Regulations 1986. Regulation 4 states: 'The fundamental purpose of investigating accidents under these Regulations shall be to determine the circumstances and causes of the accident with a view to the preservation of life and the avoidance of accidents in the future; it is not the purpose to apportion blame or liability'. The investigation was mainly concerned with the circumstances that resulted in the two aircraft colliding in the open FIR. It also considered those flight safety measures that might prevent further such occurrences. The investigation was not directed towards an examination of military fast jet low flying policy or its effect upon the environment. The House of Commons Defence Committee carried out an examination of Low Flying during the 1989-90 session and its report was published on 28 March 1990.

A Tornado Combined Safety Investigation (TCSI) was convened and conducted a separate investigation in accordance with Service regulations. The AAIB investigation team received full co-operation from the TCSI.

## 2.1 Conduct of the flight

## 2.1.1 Single pilot aerial photographic operation

The Cessna pilot was effectively conducting a single pilot operation since his companion had no aviation training or expertise whatsoever. The pilot was a professional photographer who specialised in aerial photography and who was previously known to have conducted low level aerial photography. Furthermore, the recorded data in his flying log book reinforce the probability that he routinely conducted aerial photography flights. Charts recovered from the wreckage detail an organised and referenced grouping of villages and towns in the area of the crash site and further afield. Moreover, camera equipment and a substantial amount of film were recovered from the crash site. This evidence, together with the description of the flight path of the Cessna prior to the collision, suggests that the pilot of the Cessna was engaged in aerial photography.

When flying as a single pilot and taking aerial photographs with a hand held camera the aircraft would typically be flown at a speed of about 90 kt and at heights down to a minimum of 500 feet agl; in this case the collision occurred at 655 feet agl. Once over an appropriate location the pilot would release the flight controls for a period of 3 to 5 seconds whilst using the camera to take photographs. Flight at the lower levels within uncontrolled airspace requires constant and close attention to the avoidance of collision with other aircraft or

ground based obstructions, ideally this requires a positive and continuous monitoring of the visual scene by the pilot. When the pilot is flying an aircraft and regularly taking photographs with a hand held camera fitted with a large, manually operated, zoom lens he is incapable of maintaining an adequate look out for other aircraft or obstacles. Furthermore, the pilot's ability to cope with a sudden and unexpected event, such as an engine failure, bird strike or turbulence and the associated downdraughts, whilst taking photographs and flying at low level is highly doubtful. A second crew member, allowing for clearly defined responsibilities for the separate tasks of photography and piloting is essential.

Following a previous accident involving a single pilot conducting aerial photography, the AAIB report, published in January 1998, recommended that 'the CAA should consider suitable regulations relating to the conduct of aerial photography of a commercial nature in order to eliminate the dual role of pilot and photographer. (Recommendation 97-53).' The CAA accepted this regulation but added that 'The Authority will make it a condition of any low flying permission relating to the conduct of aerial photography of a commercial nature that a second person is carried to undertake the aerial photography task'. However, since no such permission is required before conducting aerial photography, except in those instances where the pilot seeks from the CAA exemptions from certain provisions of the ANO and Rules of the Air, there is no effective manner in which this safety recommendation is likely to be implemented.

This pilot, operating within the privileges of his licence, was not engaged in flight for a commercial purpose. Nevertheless, the manner in which single pilot, aerial photographic flights are conducted cannot be considered to be safe irrespective of whether they are technically commercial or private flights. It is therefore recommended that the CAA should discuss with GA safety organisations such as: The General Aviation Safety Council (GASCo), The British Helicopter Advisory Board (BHAB) and The Aircraft Owners and Pilots Association (AOPA) the provision of a code of conduct relating to aerial photography. They should also examine the benefits accruing from a trade association or similar body to look after the interests of this particular aerial activity. [Recommendation 99-31]

### 2.1.2 Aerial work

Following a mid-air collision between an RAF Jaguar and a Cessna at Carno on 29 August 1991 the AAIB report (AAR 2/92) considered the existing definition of aerial work in relation to commercial aerial photography. Aerial photography flights, on which a pilot does not receive direct remuneration for flying the aircraft but does accept a commission from the profits accrued from the sales that he has generated, would seem to fall within an ill-defined area of legislation. The report concluded it was apparent that the UK definition of aerial work is imprecise and

requires clarification. In the case of this current investigation it was necessary to seek clarification from the Legal Branch of the CAA thus highlighting the confusion that must exist within the aviation community.

AAR 2/92 contained a recommendation that the CAA should 're-examine the UK definition of aerial work and ensure that the legislation allows that the activities of operators engaged in aerial photography flights of a commercial nature may be properly and safely regulated. By recognising the activity as aerial work, as opposed to an extension of private flying, a greater measure of regulation should be possible.' The CAA accepted this recommendation and stated that 'the Joint Aviation Authorities have adopted the ICAO definition of aerial work which includes aerial photography. The Authority will fully support the future development of Joint Aviation Requirements - Operations 2 (JAR-OPS2) which will provide for the safe regulation of the activities of operators engaged in aerial photography flights of a commercial nature.' At the date of this report there is no forecast date for the introduction of JAR-OPS2. It is regrettable to note that a recommendation which was made in 1992 and which was fully accepted by the CAA has not, at the date of this report, resulted in any effective safety action.

It is therefore recommended that the CAA should revisit its action on the AAIB recommendation 92/09 with a view to introducing into national legislation an appropriate definition of aerial work which should be aligned with both the ICAO definition and that likely to be promulgated in JAR OPS 2 and 4. This work should anticipate the formal adoption of JARs and be completed as soon as possible. [Recommendation 99-32]

## 2.2 Collision avoidance measures

### 2.2.1 Visual detection

Military low flying training is an essential feature of UK national defence policy and requires constant practice by RAF pilots in a realistic environment. Under present arrangements this requires the use of major portions of the UK low level airspace. Civil aviation has an equal entitlement to the same airspace and, because of the gross incompatibility in their operational modes, civil and military airspace users constitute a risk to each other. The risk posed by a fast jet / light aircraft confliction is not easily foreseen and the primary means of avoidance is the 'see and avoid' principle. This requires the pilots to be responsible for the detection of other aircraft and the resolution of conflicting flightpaths. It depends entirely on an effective visual lookout.

In this collision there is clear evidence that the 'see and avoid' principle did not work because, at the material time, the pilots were not using it. The military

aircraft was crewed by two pilots and therefore should have had a more effective visual capability than that considered in the study summarised at Appendix C which based its analysis on a single seat aircraft. However, the instructor's forward field of view, from the rear seat of the Tornado, was substantially reduced by the aircraft structure and equipment, and consequently he would have been unable to provide assistance in the detection of aircraft in the forward sector. The student, whilst a qualified military pilot, was at a very early stage in his training on a new aircraft, using unfamiliar equipment and in a novel environment. The routine checks that he was required to conduct, whilst at low level for a short period of time, necessarily distracted him from the essential task of looking out and compromised the effectiveness of this task. It is normal teaching practice within the RAF that such routine checks should be interspersed with periods dedicated to lookout, particularly whilst at low level. However, the crew of this aircraft would have been better protected had they both been able to monitor the visual scene more effectively. It is therefore recommended that the MOD should examine the content and sequencing of routine checks conducted whilst at low level so as to ensure that they do not compromise the safety of the crew or other aircraft. Future aircraft procurement programmes for similar aircraft (fast jet) should emphasise the requirement for an optimum field of view for both crew members together with automated self-monitoring of the aircraft systems, with the crew only becoming involved in system management following a malfunction. [Recommendation 99-33]

The Cessna pilot's ability to adhere to the principle of 'see and avoid' was severely degraded by his photographic activities. Given his sustained left—hand orbit and the relatively short time during which the Tornado could have been seen by him, his chances of recognising and avoiding the threat were virtually non existent.

# 2.2.2 Training and education

Enhanced flight safety requires the continual need to educate both military and civil pilots in the problems encountered whilst both are operating in the open FIR. For several years the CAA have organised a successful programme of Safety Evenings which are generally held at flying clubs throughout the country. These are highly regarded within the GA community. It is recommended that the CAA should include within this safety promotion programme the following advice to GA operators who plan to use the low level airspace:

- a. Maximum use of ATC Flight Information Services.
- b. The permanent display of all available external lighting.

- c. The routine use of notification procedures.
- d. The routine use of the radar transponder, including height information.
- e. Avoidance of the typical height band used by military low flying aircraft (250 to 1,000 feet).
- f. Avoidance of known concentrations of military low flying activity.

### [Recommendation 99-34]

The Military / Civil Air Safety Days (MCASD), which are organised jointly by the MOD and the CAA, have generated much interest. Such events provide an opportunity for discussion between regular users of the low level airspace. There is a general belief that this dialogue will ultimately improve flight safety although it is not possible to quantify the effect. Although well attended, the resources available, in particular on the part of the MOD, mean that it is only possible to organise an annual event. The target audience is necessarily limited, and includes many that are already familiar with the problems discussed. There is great potential safety benefit in a better understanding of the problems encountered at low level by all airspace users and it is desirable to reach a much larger audience. It is therefore recommended that the CAA and the MOD should together investigate ways in which the concept of the Military / Civil Air Safety Day can be extended. [Recommendation 99-35]

### 2.2.3 Communications

After take off the Tornado crew maintained radio contact with ATC units on UHF channels before selecting a nominated quiet frequency for instructional purposes once clear of active airfields. The sortie was booked into both LFAs that it was planned to transit and thus the traffic was known to ALFENS Ops.

Once clear of the circuit at Gamston the Cessna pilot did not make contact with any other agency although either LARS or an FIS was available from RAF Waddington on a VHF frequency. He had not made use of the CANP process and was undoubtedly 'unknown traffic' within the open FIR. Analysis of the recordings of local military and civil radars failed to show traces of the tracks of either aircraft, most likely because both aircraft were below the base of primary radar cover and neither aircraft was using its secondary radar transponder.

At paragraph 2.2.2 it is recommended that GA pilots should be reminded to use routinely the notification procedures and the SSR transponder. They should also be encouraged to make maximum use of ATC Flight Information Services.

## 2.2.4 Collision warning systems

The problems of visually acquiring conflicting aircraft in a useful time frame, which is the fundamental requirement of 'see and avoid', have been re-stated and discussed in paragraph 2.2.1. The margins available at the present speed of fast jets at low level are such that technological aids may be the only method to further reduce the risk of collision. Such aids will need to cater for the complex requirements of a CWS for military fast jet aircraft, resulting from the military's need for tactical formation flying and manoeuvring within the formation. The CWS system intended for the Tornado GR4 is not planned to be in service until 2004 and even this date is dependent upon the selected technical solution. The CWS capability embedded within the airborne instrumented debrief system selected by the RAF may be able to provide useful warnings to other similarly equipped military aircraft, but it will not warn of the presence of civil aircraft, Meanwhile, the CAA is even if these are equipped with a transponder. investigating the introduction of a lightweight transponder for GA aircraft with one of the original aims being that these will allow an aircraft to be detected by RAF aircraft. With the constraints of limited budgets, conflicting priorities and the prime requirement for operational effectiveness the possibility exists that the MOD could introduce an incompatible CWS system. It is therefore recommended that the MOD should review its planned procurement programmes for a collision warning system to ensure that a compatible system is developed. [Recommendation 99-36]

## 2.2.5 Strobe detection systems

The technical viability and operational effectiveness of a strobe detection system has been demonstrated by the CAA following trials involving the RAF. However, it has not yet been possible to manufacture commercially viable products because of the complexity of the system. If this remains the case then it may be that other systems, which rely on other technologies, might be more suitable. It is therefore recommended that the CAA should review the status of its strobe detector programme against the background of other technologies that might assist pilots in preventing collisions in the air. [Recommendation 99-37]

# 2.3 Flight planning

The Tornado crew planned their flight carefully and in accordance with all relevant service regulations.

#### 2.3.1 CANP

The pilot of the Cessna chose not to notify his intentions under CANP. However, his actual flight profile was well outside the geographical and temporal requirements of this procedure. Indeed, it is probably for this reason that fixed wing aircraft feature so rarely in the CANP notifications and this particularly applies to those conducting aerial photography (see paragraph 1.17.3). If the CANP procedure is to encompass fully fixed wing GA aircraft then the notification criteria will have to be revised, notwithstanding the adverse effect on the planning considerations for military fast jet caused by an increased number of notifications. It is therefore recommended that the CAA and MOD should review the criteria under which GA operators may notify their intentions to ALFENS Ops using CANP. The aim should be to expand the scope of the procedure so as to encourage and facilitate wider use of the procedure by those GA operators both seeking and needing the protection afforded by the procedure within the capability of military fast jet operations to guarantee avoidance. [Recommendation 99-38]

### 2.3.2 Aeronautical charts

Although the Cessna pilot was familiar with the local area there was no information available on his aeronautical chart to highlight the probability of an encounter with low flying military aircraft. There are areas at low level where the flightpaths of these aircraft are constrained leading to the creation of unidirectional flows and choke points. These flow arrangements are published on CAA chart ENR 6-5-2-1 'Areas of Intense Aerial Activity, Aerial Tactics Areas and Military Low Flying System'. However, this 1:1,000,000 scale chart is published in one of four large manuals that constitute the UK Aeronautical Information Publication (AIP). It would be more practical and useful if this information was to be portrayed on those charts most widely used by GA pilots (1:500,000 and 1:250,000 topographical).

Both the MOD and the CAA accepted the first AAIB recommendation relating to flow arrangements and choke points, but the CAA subsequently decided that the portrayal of them on aeronautical charts was unnecessary. Since then similar recommendations made by both the AAIB and the UKAB have been rejected for different reasons. The MOD offered to make information relating to flow arrangements and choke points available in 1992 and in the interests of flight safety this information should be readily available to GA operators. It is therefore recommended that the CAA should reconsider their responses to AAIB Recommendations 92-08 and 94-02 and arrange for suitable charts to show those concentrations of military low flying aircraft that are brought about by the constrictions placed upon the UKLF system. The charts should depict flow arrows and choke points. Particular attention should be paid to a suitable scale

and the ready availability of charts likely to be in widespread use by GA operators. [Recommendation 99-39]

#### 2.4 The collision

The collision between the low flying fast jet and the slow speed, low flying light aircraft occurred at a height of 655 feet agl in uncontrolled airspace where both aircraft were being operated in accordance with their relevant regulations. The collision occurred in excellent weather, in good visibility, over relatively flat terrain and with neither aircraft operating under positive radar control. Both aircraft were operating below the base of primary radar and would only have been identified on radar via the secondary radar transponder. However, this equipment was apparently unserviceable on the Tornado and was selected to 'OFF' in the Cessna. The radar system fitted to the Tornado was not designed for acquiring or warning of the presence of other aircraft. Thus, at the time of the collision the only recognition of a potential hazard available to the pilots was by visual detection. 'See and avoid' were the collision avoidance criteria in effect at the time.

It is clear from the cockpit voice recording of the Tornado crew that neither pilot saw the other aircraft prior to the collision. The student pilot was conducting routine checks that necessarily distracted him from the task of looking for other aircraft. The field of view of the instructor, in the rear seat, was significantly degraded in the forward sector by aircraft equipment and consequently he had very little chance of seeing any aircraft directly ahead of him.

Immediately prior to the collision there was no noticeable alteration in the flightpath or engine noise of the Cessna. The Cessna pilot was most probably engaged in aerial photography and his attention would therefore have been directed towards photographic opportunities in the hamlet that he was orbiting. The passenger did not have the experience to allow him to acquire visually an aircraft flying fast at low level. It is therefore probable that neither occupant of the Cessna saw the other aircraft.

Strict interpretation of the Rules of the Air required the Cessna to give way to the Tornado because the latter aircraft was on the Cessna's right. Conversely, the Tornado was the overtaking aircraft and therefore it should have kept out of the way of the other aircraft by altering course to the right. Moments before the aircraft had been nearly head on to each other thus requiring both to give way by altering their course to the right. In attempting to apply the Rules of the Air a sighting of the other aircraft is an essential pre-requisite for avoidance and there is no evidence that such a sighting occurred. Moreover, with such a rapidly

changing spatial relationship precise consideration of the 'right of way' rules is inappropriate.

## 2.5 Emergency restriction of flying

Following the accident an associated TDA was created at in order to protect those engaged in search and rescue operations (see paragraph 1.18.1). Details of the TDA were promulgated by NOTAM at 1232 hrs and a TRA was established, also notified by NOTAM, at 1321 hrs. Nevertheless, a civil helicopter flew over the accident site without the necessary ATC authority.

With the growth in the number of media organisations, competing for early information and photographs, it is likely that the commercial pressures upon pilots to violate TDAs in such a manner will increase. This demonstrates both the difficulty in making available information about TDAs and TRAs within a short time scale, and the consequent potential risk to search and rescue operations. This will inevitably lead to a greater exposure to risk of the personnel conducting the search and rescue activities. It is therefore recommended that the CAA should consider how best to ensure the effective promulgation and enforcement of TDAs. [Recommendation 99-40]

## 2.6 Summary

The collision between the aircraft occurred in uncontrolled airspace where both aircraft were being operated in accordance with their relevant regulations. The collision occurred in excellent weather, in good visibility, over relatively flat terrain and with neither aircraft operating under positive radar control. 'See and avoid' was the collision avoidance principle in effect at the time but in this instance the concept failed.

The Cessna pilot, operating as a single pilot, was most probably engaged in taking aerial photographs using a hand held camera; this type of operation is inherently unsafe. The Cessna was orbiting directly in front of the Tornado for a period of some 25 seconds. However, the probability of the Tornado crew acquiring it visually increased only with the passage of time, since in the early stages the 'target' would have been barely detectable. The Cessna would have been identifiable only in the last seven seconds before impact. The instructor in the rear seat had no opportunity to see the Cessna and the student pilot was engaged in routine checks that, from time to time, caused him to direct his attention within the cockpit. For periods when there is no effective lookout by the pilots of aircraft, which are on a collision course, the principle of 'see and avoid' is suspended.

The 'see and avoid' principle may be enhanced by improved conspicuity measures, technology based warning systems and improved notification/information procedures for users of the low level airspace. Recommendations relating to the latter two aspects, which had been made following previous military/ civil mid-air collisions, remained unimplemented at the time of this accident.

## 3 Conclusions

## (a) Findings

#### The Cessna

- (i) The Cessna pilot was properly qualified to conduct a private flight, which included the taking of aerial photographs. He was not licensed to engage in aerial work.
- (ii) There was no evidence of any medical factors which may have caused or contributed to the accident.
- (iii) The Cessna was airworthy immediately prior to the collision.
- (iv) The Cessna pilot was in a prolonged left-hand orbit around a hamlet and his attention was still probably directed at his photography task. In the final few seconds of flight he would not have been able to see the Tornado which would have been obscured by the structure of the Cessna.
- (v) The secondary radar transponder in the Cessna was selected to 'OFF' thereby denying ATC units any information about its position.
- (vi) The Cessna pilot neither chose to notify his flight in accordance with the CANP nor did he use the lower airspace radar service that was available from RAF Waddington. He therefore placed himself in the category of 'unknown traffic', albeit in the open FIR.

#### The Tornado

- (vii) The Tornado crew was correctly briefed, suitably qualified, medically fit and operating in accordance with their regulations.
- (viii) The Tornado was airworthy immediately prior to the collision.
- (ix) Neither Tornado pilot saw the Cessna prior to the collision.
- (x) The Identification Friend or Foe (IFF) in the Tornado may have been unserviceable thereby denying ATC units any information about its position.

(xi) Following the collision the Tornado aircraft was still able to fly, however, both pilots had been fatally injured in the mid-air collision. The accident must therefore be considered as not survivable.

# Collision avoidance in the low level airspace

- (xii) In the circumstances of this accident, involving such a rapidly changing spatial relationship, the 'right of way' rules are inappropriate. Particularly so since the sighting of the other aircraft is a pre-requisite for avoidance under these criteria.
- (xiii) With the exception of the Highland Restricted Area, the rest of the open FIR in the UK is not set aside for exclusive use by either military or civil aircraft. Civil aircraft and military aircraft are both entitled to operate in such airspace in accordance with their own operating regulations.
- (xiv) The collision occurred in excellent weather, in good visibility, over relatively flat terrain there were no environmental restrictions on an early sighting by either aircraft.
- (xv) There are limits to the effectiveness of 'see and avoid' using purely visual acquisition methods. Deconfliction may be enhanced using other methods such as geographic and temporal separation. Recognition and traffic acquisition may be augmented by technological means including electronic alerting devices and optimum paint and lighting schemes.

## Safety issues

- (xvi) The regular and sustained use of a hand held camera by a pilot who is operating an aircraft single handedly is inherently unsafe.
- (xvii) A study has shown the principle of 'see and avoid' to be effective in resolving confliction on over 99% of occasions, the principle is severely degraded during those unavoidable periods when pilots are required to look inside the cockpit, thereby suspending their own lookout.
- (xviii) The incorporation of the ICAO definition of 'aerial work' into UK legislation, which the AAIB recommended in 1992, has not been achieved. If the ICAO definition had been adopted it would have been possible to exercise better regulatory supervision of aerial photography of a commercial nature. This could have ensured that single pilot operations always required carriage of a second person to undertake the aerial photography task.

- (xix) Two recommendations made by the AAIB following previous civil / military collisions in 1991 and 1993 which called for information about military low flying to be depicted on civil charts have not been implemented.
- (xx) The emergency restrictions to flying established shortly after the accident had occurred was not effective in preventing unauthorised penetration of the area by a helicopter.

# (b) Causal factors

The following causal factors were identified:

- (i) None of the pilots saw each other's aircraft in time to take effective avoiding action.
- (ii) The Cessna pilot, whilst probably taking aerial photographs, conducted his flight at a height known to be vulnerable to an encounter with a military fast jet.
- (iii) By not using the Civil Aircraft Notification Procedure or informing any ATC agency of his location and intentions, the Cessna pilot degraded the potential of other traffic to locate and avoid him.
- (iv) When conducting operational checks, head down, whilst at low level, the front seat pilot of the Tornado did not detect the Cessna. The rear seat pilot had a limited field of view ahead of his aircraft and would have been unable to detect other aircraft in the forward sector.
- (v) The principle of 'see and avoid' was suspended during a period in which none of the pilots was able to conduct an effective lookout.
- (vi) Technology based aids designed to enhance visual detection, such as strobe detectors and Collision Warning Systems, which had been recommended in the light of previous mid-air collisions, had not been introduced into service.

# 4 Safety recommendations

The following recommendations are made:

4.1 The CAA should discuss with GA safety organisations such as: The General Aviation Safety Council (GASCo), The British Helicopter Advisory Board (BHAB) and The Aircraft Owners and Pilots Association (AOPA) the provision of a code of conduct relating to aerial photography. They should also examine the benefits accruing from a trade association or similar body to look after the interests of this particular aerial activity.

### [Recommendation 99-31]

4.2 The CAA should revisit its action on the AAIB Recommendation 92-09 with a view to introducing into national legislation an appropriate definition of aerial work which should be aligned with both the ICAO definition and that likely to be promulgated in JAR Ops 2 and 4. This work should anticipate the formal adoption of JARs and be completed as soon as possible.

## [Recommendation 99-32]

4.3 The MOD should examine the content and sequencing of routine checks conducted whilst at low level so as to ensure that they do not compromise the safety of the crew or other aircraft. Future aircraft procurement programmes for similar aircraft (fast jet) should emphasise the requirement for an optimum field of view for both crew members together with automated self-monitoring of the aircraft systems, with the crew only becoming involved in system management following a malfunction.

### [Recommendation 99-33]

- 4.4 The CAA should include within its safety promotion programme the following advice to GA operators who plan to use the low level airspace:
  - a. Maximum use of ATC Flight Information Services.
  - b. The permanent display of all available external lighting.
  - c. The routine use of notification procedures.
  - d. The routine use of the radar transponder, including height information.
  - e. Avoidance of the typical height band used by military low flying aircraft (250 to 1,000 feet).
  - f. Avoidance of known concentrations of military low flying activity.

### [Recommendation 99-34]

4.5 The CAA and the MOD should together investigate ways in which the concept of the Military / Civil Air Safety Day can be extended.

[Recommendation 99-35]

4.6 The MOD should review its planned procurement programmes for a collision warning system to ensure that a compatible system is developed.

[Recommendation 99-36]

4.7 The CAA should review the status of its strobe detector programme against the background of other technologies that might assist pilots in preventing collisions in the air.

[Recommendation 99-37]

4.8 The CAA and MOD should review the criteria under which GA operators may notify their intentions to ALFENS Ops using CANP. The aim should be to expand the scope of the procedure so as to encourage and facilitate wider use of the procedure by those GA operators both seeking and needing the protection afforded by the procedure within the capability of military fast jet operations to guarantee avoidance.

[Recommendation 99-38]

4.9 The CAA should reconsider their responses to AAIB Recommendations 92–08 and 94-02 and arrange for suitable charts to show those concentrations of military low flying aircraft that are brought about by the constrictions placed upon the UKLF system. The charts should depict flow arrows and choke points. Particular attention should be paid to a suitable scale and the ready availability of charts likely to be in widespread use by GA operators.

[Recommendation 99-39]

4.10 The CAA should consider how best to ensure the effective promulgation and enforcement of TDAs.

[Recommendation 99-40]

R StJ Whidborne
Inspector of Air Accidents
Air Accidents Investigation Branch
Department of the Environment Transport and the Regions

January 2000