AIRCRAFT ACCIDENT REPORT 2/94

Air Accidents Investigation Branch

Department of Transport

Report on the accident involving Royal Air Force Tornado GR1, ZG 754 and Bell 206B JetRanger III, G-BHYW at Farleton Knott near Kendal, Cumbria on 23 June 1993

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

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Department of Transport
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5 May 1994

The Right Honourable John MacGregor
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr R StJ Whidborne, an Inspector of Air Accidents, on the circumstances of the mid-air collision between RAF Tornado GR1, ZG 754 and Agusta Bell 206B JetRanger III, G-BHYW that occurred at Farleton Knott near Kendal, Cumbria, on 23 June 1993.

I have the honour to be
Sir
Your obedient servant

K P R Smart
Chief Inspector of Air Accidents

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K P R Smart
Chief Inspector of Air Accidents

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	-	Air Accidents Investigation Branch
AAR	-	Aircraft Accident Report
ADR	-	Accident data Recorder
AIC	-	Aeronautical Information Circular
AIP	-	Aeronautical Information Publication
AIS	-	Aeronautical Information Service
ALFENS	-	Automatic Low Flying Enquiry and Notification System
ANO	-	Air Navigation Order
AOC	-	Air Operator's Certificate
ASI	-	Airspeed Indicator
ATC	-	Air Traffic Control
AWR	-	Air to ground Weapons Range
ATIS	-	Automatic terminal Information Service
BASI	-	Bureau of Air Safety Investigation
CAA	-	Civil Aviation Authority
CANP	-	Civil Aircraft Notification Procedure
CAP	-	Civil Aviation Publication
CCF	-	Coordinated Control Function
CVR	-	Cockpit Voice Recorder
CWS	-	Collision Warning System
DRA	-	Defence Research Agency
DUA	-	Dedicated User Area
FDR	-	Flight Data Recorder
FJ	-	Fast Jet (major portion of flight >300 kts IAS)
GA	-	General Aviation
HISL	-	High Intensity Strobe Lights
IAM	-	Institute of Aviation Medicine
ICAO	-	International Civil Aviation Organisation
JAS	-	Joint Airmiss Section
JAWG	-	Joint Airmiss Working Group
JSP	-	Joint Service Publication
LATCC	-	London Air Traffic Control Centre
MATZ	-	Military Air Traffic Zone
MATS	-	Manual of Air Traffic Services
mb	-	millibars
MHz	-	Mega Hertz
MOD	-	Ministry of Defence
MSD	-	Minimum Separation Distance
NATS	-	National Air Traffic Services
nm	-	nautical miles
NOTAM	-	Notice to Airmen

OM	-	Operations Manual
PAPI	-	Precision Approach Path Indicator
PINS	-	Pipeline Inspection Notification Procedure
QNH	-	Corrected mean sea level pressure
SRA	-	Surveillance Approach Radar
TBC	-	Tactical Booking Cell
TCAS	-	Traffic Alerting and Collision Avoidance System
TDP	-	Technology Demonstrator Programme
UHF	-	Ultra High Frequency
UKLFB	-	UK Low Flying Handbook
UTC	-	Co-ordinated Universal Time
VHF	-	Very High Frequency
VMC	-	Visual Meteorological Conditions

Air Accidents Investigation Branch

Aircraft Accident Report No: 2/94 (EW/E93/6/1)

Aircraft: 1

Registered Owner and Operator:	Lakeside Helicopters Limited
Aircraft Type:	Agusta Bell 206B JetRanger III
Nationality:	British
Registration:	G-BHYW

Aircraft: 2

Operator:	Royal Air Force (RAF)
Type:	British Aerospace (BAe) Tornado
Model:	GR1
Registration:	ZG 754
Place of Accident:	Farleton Knott, near Kendal, Cumbria
Date and Time:	23 June 1993 at 1049 hrs

All times in this report are UTC

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) at 1225 hrs on 23 June 1993 and an investigation began the same day. The AAIB team comprised Mr R StJ Whidborne (Investigator in Charge), Mr D S Miller (Operations), Mr S W Moss (Engineering) and Miss A Evans (Engineering). An RAF Board of Inquiry was also convened under Service Regulations.

The Bell 206B JetRanger III helicopter, which was based at Edinburgh, Scotland, was engaged on an aerial pipeline inspection flight. The Tornado GR1, based at RAF Bruggen,

Germany, was one of a pair of Tornados on a routine low level training flight in transit from the east coast weapons ranges, via the Lake District, to RAF Leuchars in Scotland.

The collision occurred over open ground at a height of 380 feet agl, some 500 metres to the north west of the higher ground of Farleton Fell, close to Dove House farm near Kendal. After the collision the helicopter, with its tail rotor and boom severed aft of the horizontal stabiliser, entered a series of spiral turns before descending out of control. The helicopter pilot and passenger were killed on impact with the ground. The Tornado, although substantially damaged, diverted to the BAe airfield at Warton and landed without further incident.

Immediately before the accident the JetRanger had carried out one left-hand orbit at an estimated height of 300 feet above ground level (agl) and at a speed of 40 kt overhead some engineering sub-contractors working close to the pipeline. Eyewitness evidence indicates that the JetRanger had just rolled 'wings level' onto a northerly heading when, at 1049 hrs, it was struck by the Tornado which was flying low level on a north westerly heading at a speed of 450 kt.

The report identifies the following causal factors:

(i) Neither pilot saw the other aircraft in time to avoid the collision.

(ii) Incompatibility of operational modes and the unsuitability of the 'see-and-avoid' principle in these circumstances failed to ensure the necessary separation.

(iii) There were no routine procedures, such as CANP, or facilities, such as CWS, to inform either pilot about the presence of the other aircraft prior to the impact.

Five safety recommendations were made on 28 September 1993 and a further five are made in Part 4 of this report.

1 Factual Information

1.1 History of the flights

1.1.1 JetRanger

The Agusta Bell 206B JetRanger III was owned and operated by an Edinburgh based helicopter company with contracts for three major UK chemical suppliers to conduct, on a regular basis, routine aerial inspections of their UK pipeline networks. Inspections of the UK Ethylene pipeline from Stanlow to Grangemouth were carried out in accordance with the powers conferred on the Health and Safety Executive (HSE)[1]. The inspections, which were carried out fortnightly, over a three day period, were conducted at heights mainly between 300 feet and 700 feet agl and at a speed of approximately 60 kt. Pipeline superintendents, representing the responsible chemical company, accompanied the pilot on each flight to act as an observer.

At 0730 hrs the helicopter pilot left Standish and transited to Barton Airfield landing at 0736 hrs to collect the pipeline superintendent for that day. Prior to departure from Barton the pilot made a brief visit to Lancashire Aero Club, where meteorological and navigational information was displayed, to pay his landing fee and 'book out' for the first stage of the flight to Blackpool. There was no requirement for him to notify the relevant authorities of his exact route, timings or operating heights as the flight would be operating outside controlled airspace and in accordance with the operator's low flying exemption.

At 0805 hrs the pilot and observer, occupying the right and left-hand seats respectively left Barton Airfield and flew the usual route via Runcorn, St Helens, and Skelmersdale. They passed to the west of Preston maintaining routine radio contact with the Air Traffic Control (ATC) units at Liverpool and Warton. Where the route crossed the M55 motorway they departed from the pipeline and flew directly to Blackpool Airport arriving at 0936 hrs. The helicopter was then refuelled and the pilot and observer had some light refreshments.

At 1019 hrs the helicopter took off on the next phase of its inspection, following the pipeline which runs parallel to the M6 motorway, displaced approximately 5 kms to the west, and crossing the motorway at Junction 33. The pipeline then routes northbound parallel with the motorway displaced approximately 1 km to the east. Just to the south of Junction 36 the pipeline routes close to the motorway and alongside the Lancaster canal, approximately 500 metres west of the higher ground of Farleton Fell.

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1 In accordance with sections 20 and 23 of the Pipe-lines Act 1962 as amended by the Pipe-lines Act (Repeals and Modifications) Regulations 1974.

Three engineering sub-contractors, working in this area, knew that the pipeline was to be surveyed by helicopter and, at approximately 1050 hrs, they saw the helicopter as it approached from the south. They reported that the weather at the time was 'clear, sunny and fine with good visibility, enough to see the Lake District hills'. The helicopter appeared to be flying at its normal survey height and, as it approached the working party, it circled their position in a left-hand orbit so that the observer could have good sight of the ground and the work being carried out.

The ground workers stopped working, waved, and were able to see clearly the face of the observer who was waving back. Having completed the orbit the helicopter rolled out in a level attitude at about 300 to 400 feet and proceeded northbound. Moments later it was hit by the Tornado.

1.1.2 Tornado

The Tornado GR1 was engaged on a routine low level training flight intending to land at RAF Leuchars, Scotland. At 0944 hrs on Wednesday 23 June 1993 it departed RAF Bruggen to fly as No 2 of a pair of Tornados on a sortie involving various bombing profile manoeuvres using either the Donna Nook Air-to-ground Weapons Range (AWR) or Cowden AWR on the east coast of the UK. With the range work complete the crews planned to carry out a low level attack transit flight landing at RAF Leuchars to refuel, before returning to RAF Bruggen later that day.

The outbound and return flights to RAF Leuchars had been planned the previous day by the formation lead crew and a crew nominated to fly as No 2 of the pair but which, for administrative reasons, comprised a different captain on the day of the accident (see paragraph 1.5.2.3). The Notices to Airmen (NOTAMs), Civil Aircraft Notification Procedures (CANP) and navigational warnings for the route were checked during this initial planning stage and again the following morning prior to their briefing.

The aircraft had planned to take off as a pair but a minor technical problem delayed the No 2's departure. Approximately 15 minutes after his leader, the No 2 aircraft, now fully serviceable and with its anti-collision lights selected on, departed and transited at high level towards the UK east coast bombing ranges. As the Donna Nook AWR was not available, due to other traffic, the No 2 aircraft proceeded direct to Cowden range and joined up with his leader.

With their range work complete the pair set out on the low level portion of the flight to RAF Leuchars with the No 2 flying on the leader's left. During the initial transit the two aircraft maintained a lateral separation of about 4,000 metres. The

formation then turned left towards Kendal and in doing so the No 2 changed sides and flew on the leader's right. At this stage of the flight the pilot reported that visibility at low level was excellent.

The first significant turn along the route was to be to the right, around the town of Kendal. The navigator of the No 2 aircraft, reminded his pilot of this track change three minutes before the turn. At this point the Tornado crews were following a route parallel with the A65 trunk road displaced approximately 3 nm to the south. As they approached the high ground of Farleton Knott the pilot of the No 2 aircraft decided to fly tactically by following the A65 valley passing to the north of the high ground of Farleton Knott. This put him on a slightly converging course with his leader who was displaced approximately 4,000 metres to the south and who flew to the south of Farleton Knott. As he entered the valley the pilot of the No 2 aircraft, now surrounded by high ground, lost sight of his leader and concentrated on ensuring that the track ahead was clear. He had to climb initially to avoid a flock of birds but soon resumed his normal height above ground level (below 600 feet with 250 feet MSD). As he reached the end of the valley he satisfied himself that the area ahead was clear. Still on a converging course with his leader and knowing that they were soon to initiate a turn, he looked to the left for the other aircraft. The navigator, in the rear seat and whose forward vision is normally restricted by aircraft equipment, was concentrating his lookout to the right towards the Kendal area where the chart showed an active hang glider site. The pilot reported that, as he glanced to his left, there was a loud bang. Presuming that his aircraft had suffered a bird strike and, noticing significant damage to the radome, the pilot immediately assured the navigator that he still had control of the aircraft and initiated a climb.

Numerous eyewitnesses saw the accident but few saw the Tornado before it hit the JetRanger. None of them noticed any sudden change in attitude or flight path of the helicopter or Tornado to suggest any attempt to avoid a collision. Neither crew of either Tornado saw the helicopter before or after the accident. The navigator of the No 2 aircraft did, however, see something impact the pilot's right quarter light and a blur disappearing down the right wing.

1.1.3 The collision

The collision occurred at a height just below 400 feet agl with the Tornado flying at a ground speed of 440 kt on a heading of 304° and the helicopter flying at a speed estimated to be 60 kt on a heading of 036°. Following the impact, which severed the tail boom of the helicopter just aft of the horizontal stabiliser, several witnesses saw light debris fall from the helicopter as it entered a series of three descending spirals to the right before stabilising at about 150 feet. It then fell vertically to the ground in an upright attitude.

After the impact the No 2 Tornado, assisted by the pair leader, diverted to the BAe airfield at Warton. The aircraft had suffered damage to the right engine, right-hand engine intake and considerable damage to the nose section. The right-hand engine had caught fire but had extinguished itself. During their single engine diversion to Warton the crew of the No 2 aircraft had to rely on the leader for speed and height information as their flight instrumentation had been damaged in the impact.

The Tornado landed without further incident. When the crew examined their aircraft they discovered metal fragments embedded in the nose section. It was only at this time that they realised they had been involved in a mid-air collision with another aircraft.

1.2 Injuries to persons

		Crew	Passengers	Others
1.2.1	JetRanger			
	Fatal	1	1	-
	Serious	-	-	-
	Minor/None	-	-	
1.2.2	Tornado			
	Fatal	-	-	-
	Serious	-	-	-
	Minor/None	2	-	

1.3 Damage to aircraft

JetRanger: Destroyed

Tornado: Substantially damaged (Category 3)

1.4 Other damage

Minor damage to farm boundary hedgerow.

1.5 Personnel information

1.5.1	Bell 206B Pilot:	Male, aged 37 years
	Licence:	Airline Transport Pilot's Licence (Helicopters and Gyroplanes), Instructors Rating
	Medical Certificate:	A Class 1 Medical Certificate, with a condition that the holder must wear correcting spectacles, issued on 10 March 1993 and valid until 30 September 1993
	Certificate of Test:	Re-issued on 31 March 1993 and valid until 30 April 1994
	Total flying hours:	4,868
	Total hours on type:	343

1.5.1.1 Operational experience

The pilot was hired by the helicopter company on a freelance basis and had been flight checked in March 1993 by the company Chief Pilot, and Line checked in May 1993 by a company training captain. The pilot had flown pipeline inspection flights for the company on seven previous occasions and was assessed as being competent to act as pilot by day for public transport operations on all operational tasks including powerline and pipeline patrols.

1.5.1.2 Flight duties

On Monday 21 June 1993, after a working weekend, the pilot departed Edinburgh on the three day inspection programme flying for 2 hours and 35 minutes on the pipeline route between Grangemouth and Teesside. The following day he flew south-westwards for 3 hours from Teesside via Liverpool to Standish near Wigan where he spent a quiet night with friends. On 23 June 1993 the pilot was tasked with inspection of the UK Ethylene pipeline from Stanlow, near Liverpool, to Grangemouth. Combined refuelling and rest stops were planned, at Blackpool and Carlisle, as the helicopter headed northwards along this route.

1.5.2 Tornado crew

1.5.2.1	Captain:	Male, aged 25 years. RAF pilot
	Medical examination:	23 April 1992
	Instrument flight check:	22 March 1993, valid until March 1994
	Competency check:	19 April 1993
	Total pilot hours:	718
	Total hours on type:	421
	Total hours last 30 days:	22
1.5.2.2	Navigator:	Male, aged 28 years. RAF Navigator
	Medical examination:	30 March 1993
	Instrument flight check:	Not applicable
	Competency check:	24 November 1992, valid until November 1993
	Total flying hours:	1,047
	Total hours on type	831
	Total hours last 6 months:	72

1.5.2.3 Flight duties

On the day of the accident the original pilot of the No 2 aircraft was delayed on other duties and was replaced, late in the morning. Although the crew composition was changed the replacement (accident) pilot, who had flown a similar sortie profile earlier in the week, was well briefed and had sufficient time to acquaint himself with the sortie contents. Before walking to the aircraft a squadron flight commander informed the pilot that there were no late navigational warnings and confirmed with him that he had had sufficient time to prepare for the flight and was confident to undertake the task.

1. 6 Aircraft Information

1.6.1 Agusta Bell 206B JetRanger III

The helicopter was a single turbine-engined machine of conventional arrangement comprising a two-bladed main rotor and two-bladed tail rotor. It could carry a maximum of five persons and was normally flown from the right-hand seat.

Type:	Agusta Bell 206B JetRanger III
Engine:	1 Allison 250 C20 turboshaft
Constructors Number:	8043
Date of Manufacture:	1968
Certificate of Registration:	Lakeside Helicopters Ltd [2]
Certificate of Airworthiness:	Transport Category (Passenger). Expiry date 8 June 1996
Certificate of Maintenance Review:	8 June 1994 at 11,059.55 hours
Total Airframe hours (at accident):	approximately 11,110
Maximum total weight authorised:	3,200 lb
Estimated weight at time of accident:	2,480 lb
Centre of Gravity at time of accident:	within approved limits

The helicopter's predominant colour was white with dark metallic grey stripes sweeping rearwards to the tailboom. A red/white High Intensity Strobe Light (HISL) was fitted above the cabin on top of the engine oil reservoir and heat exchanger fairing to the rear of the main rotor assembly. Normal white strobe lights were fitted at the tip of each horizontal stabiliser.

The aircraft's technical documentation showed that it had been maintained to the approved Light Aircraft Maintenance Schedule as required by the Certificate of Airworthiness. There were no relevant Carried Forward Defects listed in the Technical Log.

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2 The company ceased trading shortly after the accident.

1.6.2 Tornado

The Panavia Tornado aircraft involved in the accident was a GR1 model bearing the serial number ZG 754 and carried a crew of two. It was fitted with an external 1,500 litre fuel tank on each of its inboard wing pylons and another on its right-hand fuselage pylon. Stores were attached to each of the outboard wing pylons and the left fuselage pylon. Painted in overall grey/green camouflage, it displayed anti-collision lights[3] above and below the fuselage. The radar system fitted to this aircraft was not intended to be used for acquiring or warning of the presence of other aircraft.

1.7 Meteorological information

1.7.1 Forecast

The lead crew and the navigator of the No 2 Tornado attended a weather briefing at 0730 hrs on the morning of the accident. The crews repeated the weather briefing late in the morning, during the main sortie briefing, for the benefit of the replacement No 2 pilot.

The helicopter pilot had the opportunity to study valid weather information, which was displayed at Barton Airfield, when he booked out his flight.

The low level forecast for Scotland and northern England on 23 June 1993 for the period 0600 hrs to 1200 hrs with little change forecast until 1800 hrs was:

Visibility:	30 km, reducing to 7 km in isolated areas in the east
Cloud:	Broken cumulus and stratocumulus, base 2,500 feet and scattered altocumulus base 12,000 feet
Surface wind:	North westerly light
Temperature:	+13°C

1.7.2 Aftercast

An aftercast was prepared by the Meteorological Office, Bracknell for the area of the accident site at 1055 hrs on 23 June 1993. The synoptic situation showed a light and unstable north westerly airstream established over the Lake District with a mean sea level pressure of 1,017 mb.

Visibility: 30 km or more

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3 Approximate light output of 400 candela.

Weather:	Nil
Cloud:	Scattered cumulus base between 2,000 and 2,500 feet with scattered, occasionally broken, strato-cumulus base around 4,000 feet.
Surface wind:	300°/07 kt
Temperature:	+14°C
Sun's position:	azimuth 146° (True), elevation 55° 17'

1.7.3 Witness observations

Several witnesses who saw the accident reported on the actual weather conditions at the time. The engineering sub-contractors reported that the weather was 'clear, sunny and fine with good visibility, enough to see the Lake District hills'. One witness, an experienced balloon pilot, described the weather as 'bright conditions with approximately 30 km visibility and broken cloud at about 3,500 feet'.

1.8 Aids to navigation

Not applicable.

1.9 Communications

The helicopter pilot maintained routine radio contact with ATC units en route on Very High Frequency (VHF) frequencies. On departure from Blackpool Air Traffic Zone (ATZ) the controller advised the pilot that a Lower Airspace Radar Service (LARS) was available from Warton Radar. One minute later the pilot contacted Warton Approach Radar, on 124.45 MHz, stating that he was 'JUST OUTBOUND FROM BLACKPOOL RESUMING THE LOW LEVEL PIPELINE THREE HUNDRED AT INSKIP...WE'LL BE RESUMING NORTHBOUND TRACK BACK TOWARDS EDINBURGH'. By 1024 hrs the pilot reported to Warton that he was 'ON THE PIPELINE WORKING OUR WAY NORTHBOUND'. The controller replied 'THANK YOU, KEEP A GOOD LOOKOUT'. At 1041 hrs the pilot made an attempt to communicate with Warton which was unsuccessful, probably because of his low altitude and so he changed to the London Flight Information frequency of 134.7 MHz. No transmissions from the pilot were recorded on this frequency.

The Tornado crew maintained routine radio contact where possible with Military Air Traffic Control Units on Ultra High Frequency (UHF) channels throughout their transit flight to the east coast bombing ranges. Whilst operating as a pair the Tornados maintained contact with each other on their common air-to-air UHF

frequency, changing to the appropriate airfield frequency only as they transited through various Military Air Traffic Zones (MATZ).

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

1.11.1 Replay of Flight Recorders

There was no Cockpit Voice Recorder or Flight Data Recorder fitted to the JetRanger and neither was required to be fitted. The Tornado carried a Sperry SCR200 Accident Data Recorder (ADR) with combined voice and data recordings consisting of one track of audio information and 3 tracks of flight data each of one hour duration. The track allocation was as follows:

Channel 1	Audio
Channel 2	Data #1
Channel 3	Data #2
Channel 4	Data #3

The ADR was replayed by the Aircraft & Armament Evaluation Establishment at Boscombe Down and a copy of the audio and flight data was passed to the AAIB.

The method of operation of the recorder results in the most recently recorded data track being synchronised to the audio. Data is recorded in a one second frame where a status word is located at the start of each second followed by 127 data words; the position of the collision can therefore be determined accurately in relation to the recorded data. The collision occurred at 1049 hrs UTC exactly (to within ±2 seconds, timing related to the ATC tapes). At this point there was an audible bang, which was probably the sound of initial impact of the Tornado with the JetRanger. There was no indication from either crew on the audio track that they had seen the JetRanger before or after the collision.

1.11.2 Interpretation of Data

Appendix A Figure 1 shows selected parameters from the ADR, beginning 40 seconds before the collision. The Tornado was on a compass heading of 297°, at 455 kt airspeed and at a recorded barometric altitude of between 400 and 500 feet, based on 1,013 mb, which corresponds to between 510 and 610 feet above mean sea level. The resolution of the barometric altitude is 128 feet.

About 30 seconds before impact the Tornado rolled to the right onto a heading of 304°, and then left gradually onto 301°. After impact the Tornado pitched up and climbed as indicated by the radio height.

Appendix A Figure 2 shows a expanded plot of these parameters in the area of the impact at 1049 hrs UTC. At 5 seconds before impact the Tornado rolled from 22° left wing down to an approximate wings level attitude just prior to the collision. The roll continued and reached 6.4° right wing down at impact, with a pitch attitude of 2.6° nose up. The compass heading was 303°, the recorded radio height was 381 feet. The pitot/static information was lost after impact as the probe was damaged. The right-hand engine began to run down after the collision as shown by the recording of the HP rotor speed.

The ground track of the Tornado was derived from the recorded data assuming a wind of 300°/7 kt. The exact position of the collision was not known, but from the distribution of the wreckage on the ground an approximate position for the collision is marked on Appendix A Figure 3, which also shows the estimated track of the Tornado up to that point and the ground contours in the area. The position on the ground where most of the wreckage from the JetRanger landed is also shown. Appendix A Figure 4 shows this in a three-dimensional view, with height calculated from the Radio Height corrected for the ground level below the estimated track.

1.12 Wreckage and impact information

1.12.1 Helicopter

The wreckage of the helicopter lay in the yard of Dove House farm at map reference SD 541818, some 10 metres from outbuildings. Most of the aircraft was in this one location apart from the tail boom approximately aft of the horizontal stabiliser which was not in evidence. The aircraft had descended at a high rate almost vertically into the ground while rolled slightly to the right in a level pitch attitude. The tail boom had fallen across a hedgerow and thus the in-flight damage was not overlaid by ground impact disruption. The relative lack of damage to the main rotor blades indicated that they had very little rotational energy at impact.

Most of the missing structure was located approximately 130 metres to the south of the main wreckage in a trail of some 250 metres length running roughly south east/north west. Virtually all the light airframe structure was here together with the tail rotor blades. There was no sign of the heavier mechanical parts such as the tail rotor gearbox, hub or blade grips. Later examination of the damage to the Tornado resulted in recovery of a substantial proportion of the gearbox (see

following paragraph), and the tail rotor shaft with about 30% of the crown gearwheel was found some days later about 4 miles further along the track of the Tornado. The blade grips and hub were not found but may have been in the canal or rough uncultivated ground to the west of the identified wreckage trail.

The HISL selector switch was found in the 'HISL white' position. Since this is an unguarded switch it is not certain that this was a pre-impact position but it is consistent with the expected selection. During the course of the subsequent examination at the AAIB at Farnborough it was possible to check the operation of the HISL by applying power to the circuit and it was found to operate normally in both the white and red selections. The smaller strobe lights fitted to the extremities of the horizontal stabilisers had been broken by impact but their electronic unit housed in the fuselage was serviceable.

Although most of the wreckage found at the site was from the helicopter, some debris from the Tornado was found amongst the wreckage trail. There were identifiable pieces of the plastic radome and sections of skin panel from the right engine intake, including the navigation light fitted in this location.

1.12.2 Tornado

The Tornado was examined at the BAe factory at Warton, Lancashire. The most obvious sign of impact with the helicopter was the badly damaged radome which had been disrupted along its upper right side and the pitot probe was bent downwards. Pieces of the helicopter tail rotor gearbox mounting structure and the casing itself were found embedded in the radar components in this area.

A fairing over the refuelling probe was torn and there was a heavy scrape on the right side windscreen and frame. Further aft there were panels torn out of the outer skin of the right engine intake lip where an object appeared to have burst through from the inside. These were the skin panels found at the accident site. There were also heavy impacts on the right wing inboard leading edge slats and 'nib' fairing with a heavy gouge on the inboard pylon. The airframe had received many more minor scratches and impacts from light debris.

The most serious damage had resulted from debris that had been ingested into the right engine some of which had destroyed all the stages of the compressor. Much of the IP and HP compressor and the turbine section had burnt away. Some of this debris had been ejected forwards after contact with the LP1 compressor blades and had punched a hole in the intake duct just forward of the engine front face.

All the debris recovered from the engine and from behind the intake duct comprised parts of the helicopter tail rotor gearbox and the majority of this component was thus accounted for.

1.12.3. Collision parameters

First contact was made with the Tornado pitot probe piercing the relatively light fairing around the helicopter tail rotor gearbox. The gearbox had torn open the radome and struck its aft lip known as 'the skirt'. This latter impact detached and disrupted the gearbox and tail rotor, the heavy components of which were then ingested into the right engine intake. It would appear that some substantial parts, possibly the blade grips, burst through the side of the intake whilst most of the gearbox itself was ingested by the engine. The helicopter's light vertical fin structure had wrapped around the upper fuselage of the Tornado, striking the canopy.

As the impact sequence progressed the helicopter tailboom, already truncated with the loss of the tail rotor gearbox, received a further impact from the right wing leading edge of the Tornado, removing more of its structure and damaging the horizontal stabiliser. The helicopter's pitch attitude was level and the two aircraft were at right angles to each other.

With the light northwesterly wind at the time of the accident and the low height at which the collision occurred, it was concluded that the actual point of collision was approximately above the centre of the wreckage trail (map reference SD 540816), with lighter debris being blown back towards the south east and heavier items being thrown to the north west.

1.13 Medical and pathological information

A post-mortem and toxicological examination was carried out on the pilot of the JetRanger. No evidence was found of medical factors which might have caused or contributed to the accident.

The pilot and navigator of the Tornado were interviewed by the Deputy Senior Medical Officer of RAF Bruggen on the day after the accident. Both had had a good night's rest before the flight and showed no signs of being unwell within the preceding 24 hours.

1.14 Fire

Although the fuel tank of the helicopter was ruptured on impact with the ground there was no fire. The right engine of the Tornado suffered a titanium fire but this extinguished itself moments after the collision.

1.15 Survival aspects

A police officer who witnessed the accident alerted the emergency services shortly after 1049 hrs and they arrived on the scene at 1109 hrs to find that the pilot and observer had sustained fatal injuries on impact with the ground.

The decelerative forces experienced by the pilot and observer of the JetRanger were well beyond human tolerance. The seat belt and diagonal torso strap of the pilot remained intact although there was gross distortion of the cabin area. The lap portion of the observer's harness became detached at the outboard end due to airframe distortion on impact.

1.16 Tests and research

1.16.1 Visual detection and collision recognition

In order to assess the probability of detection in the circumstances of this accident, advice was sought from the Principal Psychologist of the Institute of Aviation Medicine (IAM). His report, which is at Appendix B, concludes that the circumstances of this accident illuminate the general problem of collision avoidance. Given the difficulty of detecting small aircraft, a fast jet (FJ) pilot needs to sweep his forward sector about every five seconds (including head movements to clear canopy obstructions) in order to have a reasonable chance of avoiding conflicts. This is difficult enough without the other demands on his attention at low level including navigation, terrain avoidance, station keeping and aircraft systems management. The pilot of a slow moving aircraft needs to scan an even wider area.

Analysis of the contour map and the Tornado ADR data indicate that the relief features of Farleton Knott and Farleton Fell did not obscure either pilot's view of the other aircraft for a significant time before the collision. The estimated probability of the Tornado detecting the JetRanger indicates that the latter was effectively invisible until about 17 seconds before the collision. However, the cumulative probability of detection was minimal until about five seconds from impact. At impact minus 7 to 5 seconds the probability of detection would rise sharply; as long as obscuration did not play a part. The Tornado, having better

contrast and being a larger target, would have been in principle somewhat more detectable.

It is possible to enhance the conspicuity of aircraft by a suitable choice of paint scheme and by the addition of sufficiently bright lights. Lights considerably brighter than the existing HISLs, which are of at least 2,000 candela (cd), are currently being considered. Collision warning systems would enhance the effectiveness of visual lookout, particularly if fitted to civil as well as military aircraft. These are, however, unlikely to prove a complete solution unless employed in combination with improvements in aircraft conspicuity.

1.16.2 Summary of Australian Bureau of Air Safety Investigation research report

Investigations carried out by the Australian Bureau of Air Safety Investigation (BASI) into mid-air collisions that occurred in Australia in the late 1980's, drew attention to the deficiencies of the 'see-and-avoid' concept for air traffic separation. As a consequence, the BASI made an evaluation of the practicality of the 'see-and-avoid' principle in controlled and uncontrolled airspace. The report on their research, which was published in April 1991, is at Appendix C. It refers to international research of this problem and highlights concisely some serious limitations of the 'see-and-avoid' principle.

While 'see-and-avoid' undoubtedly prevents many collisions, the principle is far from reliable. Numerous limitations, including those of the human visual system, the demands of cockpit tasks, and various physical and environmental conditions combine to make 'see-and-avoid' an uncertain method of traffic separation. Cockpit workload and other factors reduce the time that pilots spend in traffic scans. However, even when pilots are looking out, there is no guarantee that other aircraft will be sighted. Most cockpit windscreen configurations severely limit the view available to the pilot which is frequently interrupted by obstructions such as window-posts which totally obscure some parts of the view and make other areas visible to only one eye. Window posts, windscreen crazing and dirt can act as 'focal traps' and cause the pilot to focus involuntarily at a very short distance even when attempting to scan for traffic. Direct glare from the sun and veiling glare reflected from windscreens can effectively mask some areas of the view.

Visual scanning involves moving the eyes in order to bring successive areas of the visual field onto the small area of sharp vision in the centre of the eye. The process is frequently unsystematic and may leave large areas of the field of view unsearched. The contrast between an aircraft and its background can be significantly reduced by atmospheric effects, even in conditions of good visibility.

An approaching aircraft, in many cases, presents a very small visual angle until a short time before impact. Even when an approaching aircraft has been sighted, there is no guarantee that evasive action will be successful. It takes a significant amount of time to recognise and respond to a collision threat and an inappropriate evasive manoeuvre may serve to increase rather than decrease the chance of a collision.

The BASI report concluded that unalerted 'see-and-avoid' had a limited place as a last resort means of traffic separation at low closing speeds but was not sufficiently reliable to warrant a greater role in the air traffic system. It was considered that many of the limitations of 'see-and-avoid' were associated with physical limits to human perception, however there was some scope to improve the effectiveness of 'see-and-avoid' in other areas such as conspicuity and improved anti-collision lights.

1.16.3 Collision Warning System

To assist in the deconfliction of military aircraft involved in high speed low level training operations the Ministry of Defence (MOD) are funding development of an airborne electronic Collision Warning System (CWS). It is expected that CWS will also provide collision warning information on civil aircraft with suitable transponding equipment.

An aircraft installed system interrogates other aircraft which are equipped with ATC transponders using mode 'A' or 'C'. The specification calls for its use in low-level operations only, detecting potential threats out to a range of 20 nm, 60° either side, 10° below and 20° above the nose of the aircraft. The ability to interrogate five targets simultaneously is specified and the system should be able to deal with closure rates of up to 1,000 kt with an accuracy of bearing information in the order of ± 15°. By acquiring range and bearing information the system will calculate a collision threat in time and distance. This will produce two types of threat alert. Type 1 will give a warning of closing traffic inside 15 seconds to collision. Type 2 will give a warning of closing traffic inside 5 seconds to collision, and warning of 'pop-up' traffic inside 2 nm. Having been alerted to the threat the pilot will take the necessary action to avoid a collision.

The CWS requirement is currently at the stage of a Technology Demonstrator Programme (TDP) involving flight trials of the equipment throughout most of 1994. A progress report is to be issued in December 1994. The results of the TDP, along with policy and economic considerations, will determine the future of the programme.

A civil system known as the Traffic Alerting and Collision Avoidance System (TCAS), which is already in use and is mandatory equipment in some large civil aircraft operating in certain ATC environments, is considered unsuitable for military FJ operations. It resolves conflictions by advising manoeuvres in the vertical plane and this would be inappropriate at low level.

1.16.4 Electronic strobe detection

Just as HISLs and other lights are designed to enhance conspicuity so pilots' ability to detect such lights visually may be augmented by the use of an electronic detection device. A study had been funded by the CAA to review the possibilities offered by modern optical components to detect Xenon strobe lights fitted on military and many private aircraft [4]. The type of system envisaged would be two sensors, probably installed above and below the fuselage to provide the maximum field of view, linked to a display/audio warning in the cockpit. Initial results indicate that it may be feasible to develop a practical system using innovative design at a cost that might be attractive even to light aircraft operators and progress reports are awaited.

1.17 Additional information

1.17.1 Military low flying

The RAF has a continuing requirement to train its pilots in the low level reconnaissance and attack roles. Before 1976 specific areas within the UK were designated as areas available for military low flying. These areas were joined by designated low flying corridors known as link routes, however, since 1979 the whole of the UK is in principle open to low flying but in practice environmental and safety restrictions halve the airspace available. Conurbation and the airspace designated for flights which are conducted under positive ATC control at all times are excluded. For administrative convenience, the country is now divided into 19 Low Flying Areas (LFA), not evidently linked to any geographical divisions on the ground.

In the UK, military FJs 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 at which a military jet is normally permitted to fly is 250 feet MSD. Foreign military aircraft are 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. For example German aircraft may not operate in the UK below their national limit of

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4 CAA Project Code: No 9.3; Title: Conspicuity; Objectives: Improved visibiltiy of airborne hazards.

1,000 feet agl which also applies to RAF aircraft operating in Germany. Low flying by foreign aircraft accounts for less than 2% of the total activity in the UK Low Flying System.

About 80% of FJ low flying training takes place between 250 and 500 feet MSD and is carried out on weekdays, during daylight and in good weather. Except in the Highland 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 in Visual Meteorological Conditions (VMC), that is pilots must be able to fly by visual reference to the ground. Details of Military Low Flying in the UK are published in UK Aeronautical Information Circular (AIC) -AIC 89/1993 (Yellow 107) and in the RAC Section of the UK Aeronautical Information Publication (AIP). Chart RAC 5-0-1.1 is a chart showing Areas of Intense Aerial Activity (AAIA), Aerial Tactics Areas (ATA) and detail of the Military Low Flying System. It is intended that this chart will include the flow structure which was recommended in Aircraft Accident Report (AAR) 2/92 on the mid-air collision at Carno, Powys in August 1991 [5].

Nearly all low flying sorties are required to be planned and then notified to a central co-ordinating authority, normally the London Air Traffic Control Centre (Military) Tactical Booking Cell (TBC) at West Drayton. This centre co-ordinates military low flying sorties and also provides co-ordination with civil aircraft whose flights have been notified in accordance with the Civil Aircraft Notification Procedures (CANP) and Pipeline inspection Notification System (PINS) (see paragraph 1.17.3).

The organisation and control of military low flying and its co-ordination with civil aviation is under constant review and the TBC anticipate the use of a new Automated Low Flying Enquiry and Notification System (ALFENS). This computerised system will speed up communications and provide up to date information on the UK low flying system at all FJ operating bases. It is expected to become operational in Spring 1995.

1.17 2 Civil low flying

Aircraft are not normally permitted to fly closer than 500 feet to any person, vessel, vehicle or structure [6]. In order to operate to a height as low as 300 feet agl, the helicopter operator had been granted by the CAA an exemption to the normal rules. This exemption permitted helicopter flights down to 300 feet agl when within a horizontal distance of 300 feet from the pipelines to be inspected.

5 AAR 2/92 Recommendation 92-8

6 Article 69 of the Air Navigation Order 1989 Rules of The Air Regulations 1991 Section II para 5 (1) (e)

Typically such exemptions require that helicopters are to be fitted with a white HISL of at least 2,000 cd intensity. The JetRanger was fitted with a red/white HISL which was selected on 'HISL WHITE' at the time of the accident. After the accident, on 28 September 1993, the AAIB made a recommendation that the CAA should circulate a notice to AOC [7] holders involved in aerial surveys recommending that where practical they operate in the height band 500 feet to 700 feet thus providing a degree of vertical separation from high speed low flying military aircraft which will generally operate below 500 feet. [Recommendation 93-47].

On 17 August 1993 the CAA (Flight Operations Inspectorate) wrote to all helicopter AOC holders describing additional safety measures proposed as a result of this accident. The letter stated:

> '.....with effect from commencement of operations on 23 August 1993, pipe-line inspections will be flown in the height bracket 500-700 feet above ground level, with 600 feet agl optimum. The RAF have confirmed that 80% of their fast jet low flying traffic will pass below 500 feet, thus in theory a measure of vertical separation for safety purposes will have been established. It is appreciated that pilots of pipe-line patrol helicopters will still have to descend below 500 feet for closer inspection of faults and so on: this practice will continue to be authorised by an easement from Rule 5 (1) (e) obtainable from this inspectorate. Pilots will have to exercise normal airmanship in carrying out a conscientious clearing turn prior to any descent into the possible military operating height band, and should return to their 600 feet as rapidly as possible.'

The letter also gave advance notice of an AIC which was published on 21 October 1993 confirming these arrangement and introducing the new procedure of PINS (see paragraph 1.17.3 below). The CAA also publishes a Safety Sense Leaflet on Collision Avoidance which gives advice to civil pilots, including advice on correct scanning techniques.

1.17.3 Notification Procedures (CANP and PINS)

Although military aircraft are considered to be low flying when they are below 2,000 feet agl, it is not practicable to disseminate information on all civil aircraft operating at that height or below. The greatest risk of collision exists at or below 500 feet agl where much of the low level military operations take place. Since 1974, following a collision between an RAF Phantom FJ and a Piper Pawnee crop spraying aircraft, the system of Low Level Civil Aircraft Notification Procedure (CANP) has been available to civil operators. This gives civil aircraft

7 Air Operators Certificate required for public transport undertakings

engaged in aerial work within 2 miles of a datum and for a duration in excess of 20 minutes operating below 1,000 feet agl the opportunity to notify their presence to military operators who will then arrange to avoid the notified area. The procedure, which is voluntary, is fully described in the United Kingdom Air Pilot (UK AIP), Rules of the Air and Air Traffic Services (RAC) 3-10-1. Commercial agricultural aviation operators are required to use CANP, whenever appropriate, under the terms of their Operations Manuals and Aerial Application Certificates.

Pipeline and power line inspection flights by helicopters were originally included in this procedure but there was considerable difficulty in providing, at the necessary notice, sufficiently accurate times and positions for aerial survey activities. Following a trial by the principal operator at the time, and with the full agreement of the British Helicopter Advisory Board (BHAB), such inspection flights were excluded from the system in 1984.

After the accident AAIB Recommendation 93-48 was made on 28 September 1993 and was that:

> 'The Civil Aviation Authority should introduce a system of area notification of information to military crews involved in low flying training that provides the timely distribution on civil aerial activity relating to the surveying of pipelines in the UK.'

In response it was agreed by CAA (NATS - Airspace Policy) and the operators of aerial survey flights that a system of notification such as CANP was essential (refer to AAIB Safety Recommendation 93-48 and AIC 156/1993 (Yellow 126)). A new procedure to cater for the particular needs of pipeline inspection flights was devised. Known as the Pipeline Inspection Notification System (PINS), details of the system are published in an Aeronautical Information Circular (AIC) which is reproduced at Appendix D.

Recommendation 93-49 was also made on 28 September 1993 and was that:

> 'The Ministry of Defence (RAF), in consultation with the Health and Safety Executive and the known energy providers, should obtain for crews involved in low level flying training suitable briefing material on the location and routes of the major pipelines within the UK. The briefing material should include any known frequency of routine inspections with provision for any variations to be notified by the operators.'

Since the accident this briefing material has been provided by MOD.

1.17.4 Volume of aerial survey flights

An estimate of pipeline survey flights, which are conducted on a random weekly or fortnightly basis and subject to suitable weather conditions, gives a maximum of 147 hours per week flown by a maximum of 13 helicopters. Other statistics indicate an annual total of pipeline inspection flights of some 6,000 hours.

1.17.5 Volume of military low flying

The following table shows estimated number of low flying sorties flown during the period 1987 to 92:

Year:	1987	1988	1989	1990	1991	1992
Sorties:	146,500	151,000	144,000	141,000	127,400	131,450

Of these totals about two thirds were flights by FJs [8] and one third other aircraft including helicopters. On any week day there may be as many as 600 military low flying sorties planned. On 14 October 1991 HM Government announced that, due to proposed changes in the structure of the armed forces, low flying flights over the UK by military jets would be progressively reduced by about 30% on the 1988 baseline figures over the following three years.

1.17.6 Mid-air collision statistics

The database maintained by the Safety Data Analysis Unit of the Safety Regulation Group, CAA, includes details of mid-air collisions involving UK civil powered light aircraft (see Appendix E). From May 1977 until June 1993 there have been 30 mid-air collisions in UK airspace. In these there were 26 fatalities with no injuries to persons on the ground.

Excluding collisions in the circuit, formation aerobatics, air-to-air photography and other close proximity manoeuvres, there were only seven random collisions in the UK open FIR. Three of these occurred between military and civil aircraft. These were:

a. 29 February 1984 - USAF A10 / Cessna 152, Hardwick, Norfolk.

b. 29 August 1991 - RAF Jaguar T2A / Cessna 152, Carno, Wales.

c. 23 June 1993 - RAF Tornado GR1 / Agusta Bell 206B JetRanger III, Farleton Knott, near Kendal, Cumbria.

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8 A Fast Jet is defined as an aircraft whose major portion of flight is in excess of 300 kt IAS.

The remaining four involved civil aircraft only and occurred between 1,800 and 3,300 feet.

1.17.7 Airmiss statistics

Whenever an airmiss is reported by one or both of the pilots involved, the circumstances are investigated by the Joint Airmiss Section (JAS), a section of NATS which is a joint civil/military air traffic organisation. Once the evidence has been assembled by JAS it is discussed by the Joint Airmiss Working Group (JAWG) who assess the degree of risk inherent in each occurrence. The degree of risk is assessed in accordance with the International Civil Aviation Organisation (ICAO) guide lines and categorised as follows:

Category 'A' - Actual risk of collision

Category 'B' - Possible risk of collision

Category 'C' - Other reports with no assessed risk of collision

JAS maintains a data base of all airmisses and, after the JAWG assessment, each airmiss is coded under a wide range of parameters including aircraft types, the location and geometry of the incidents, passing distance, degree of risk and cause. The database was interrogated to provide details of all airmisses during a three year period between low flying military and civil GA aircraft at 2,000 feet and below. The figures for 1990 are for 6 months from June to December. The figures for 1993 are for 6 months from January to June. The statistics are for Category 'A' and 'B' risks only.

Year	1990 (6 months)	1991	1992	1993 (6 months)	Total
Category 'A'	5	5	3	0	13
Category 'B'	6	19	11	6	42

1.17.8 Relevant legislation

1.17.8.1 The Rules of the Air Regulations 1991

The Rules of the Air Regulations 1991 are published in full in Section 2 of the Air Navigation Order (ANO) 1989. The following extracts are pertinent to this investigation:

'Low Flying

5 (1) Subject to the provisions of paragraphs (2) and (3):

(b) A helicopter shall not fly below such height as would enable it to alight without danger to persons or property on the surface, in the event of failure of a power unit.

(e) An aircraft shall not fly closer than 500 feet to any person, vessel, vehicle or structure.

Rules for avoiding aerial collisions

17 (1) General

(a) Notwithstanding that the flight is being made with air traffic control clearance it shall remain the duty of the commander of an aircraft to take all possible measures to ensure that his aircraft does not collide with another aircraft.

(b) An aircraft shall not be flown in such proximity to other aircraft as to create a danger of collision

(2) Converging

(b) .....when two aircraft are converging in the air at approximately the same altitude, the aircraft which has the other on its right shall give way:

(3) Approaching head-on

When two aircraft are approaching head-on or approximately so in the air and there is a danger of collision, each shall alter its course to the right.

Speed Limitation

23 (1) Subject to paragraph (3), an aircraft shall not fly below flight level 100 at a speed which according to its airspeed indicator is more than 250 knots unless it is flying in accordance with the terms of a written permission of the Authority.'

1.17.8.2 Military Flying Regulations

Military Flying Regulations (Second Edition April 1992) are published for official use in a Joint Service Publication (JSP) No 318. The following entry appears in the joint regulations section Chapter 053 paragraph 05304:

'2. Military aircraft are to conform to the civil national ATC system of all foreign countries over which they fly. In the UK, the system of air traffic control is based on a joint civil/military scheme in which the military aviation authorities observe such ICAO regulations as have been accepted by the Civil Aviation Authority, provided they do not impair the operational freedom of military aircraft.'

Furthermore the Air Navigation Order Part VIII, Control of Air traffic, Article 69 paragraph 3 states:

'(3) It shall be lawful for the Rules of the Air to be departed from to the extent necessary:

(a) for avoiding immediate danger

(b) for complying with the law of any country other than the United Kingdom within which the aircraft then is; or

(c) for complying with Military Flying Regulations (Joint Service Publication 318) or Flying Orders to Contractors (Aviation Publication 67) issued by the Secretary of State in relation to an aircraft of which the commander is acting as such in the course of his duty as a member of any of Her Majesty's naval, military or air forces.'

In addition to JSP 318 regulations, Service pilots fly to detailed rules promulgated in the UK Military Low Flying Handbook (LFHB).

1.18 New investigation techniques

None.

2 Analysis

2.1 The collision

The collision between the high speed low flying military jet and the slow speed low flying civil helicopter occurred at a height of about 380 feet agl in uncontrolled airspace where both aircraft were being operated in accordance with their relevant regulations. It is clear from the Tornado crew's recollection that they had not sighted the JetRanger; indeed they were unaware of the collision until after they had landed and examined the damage sustained by their aircraft. It is highly unlikely that the JetRanger pilot saw the Tornado since he had just completed a left-hand orbit before rolling onto a northerly heading. The pilot therefore would have been looking initially to his left and then concentrating on the next part of his route which was almost at right angles to the Tornado's track. Strict interpretation of the Rules of the Air required the JetRanger to give way to the Tornado because the latter aircraft was on the JetRanger's right. Moments before, however, the aircraft had been head on to each other requiring both to give way. In either case a sighting was an essential pre-requisite for avoidance. Even if the JetRanger pilot had seen the Tornado at a late stage his speed of horizontal manoeuvre may have been too slow to move out of the way, although a rapid descent may have been possible. Furthermore, with such a rapidly changing spatial relationship, consideration of the 'right of way' rules is quite inappropriate.

The tragedy was compounded by the loss of control of the helicopter after it had been struck by the Tornado. Whilst the collision was probably catastrophic, there may have been a slight chance for the JetRanger pilot to cope with the loss of his tail rotor. Routine training and proficiency checks include the simulation of loss of tail rotor thrust and handling techniques are available to permit a safe landing under such conditions. In this case, however, the complete tail rotor assembly and vertical stabiliser had been severed in the collision and this would have significantly affected the helicopter's centre of gravity. This factor, combined with the pilot's shock and disorientation due to the initial rotations in yaw, most likely contributed to the ultimate loss of control.

2.2 See-and-avoid

Primary reliance on the principle of 'see-and-avoid' for separation, with its acknowledged limitations, is a major contribution to the risk of collision. Military low flying training is an essential feature of UK national defence policy and requires constant practise by military pilots. Under existing arrangements this requires the use of major portions of the UK low level airspace. Civil aviation has an equal right and need to use the same airspace and, because of a gross

incompatibility in operational modes, civil and military airspace users constitute a risk to each other. However, such a risk can be set in the context of many natural hazards which may be encountered by both military and civil aircraft. For example turbulence, thunderstorms, freezing rain, high tension cables, tall aerial masts and cloud covered high ground are frequently encountered. Most of these are either predictable or documented and publicised so that a pilot may, by careful briefing, meticulous planning and prudent flying, avoid or reduce the hazards. However, the risk posed by a FJ / light aircraft confliction is less easily foreseen and therefore it cannot be countered simply by using the same methods as those employed against natural hazards. Additional help is required by using technology such as a Collision Warning System (CWS) and, where available, ATC information in order to increase traffic awareness and hence reduce further the risks involved.

The only separation criteria in force at the time of the Tornado/JetRanger collision were that both pilots were responsible for their own collision avoidance using the 'see-and-avoid' principle. There was no other air traffic control or information service being provided. There was no technical system available to alert either crew to the proximity of other aircraft, even the Tornado's electronic sensors are not designed to do this. The collision was clear evidence that, in this situation, the 'see and avoid' principle had failed. It is therefore questionable as to whether it is an appropriate method for the deconfliction of such incompatible users of the low level airspace.

Failure in the 'see-and-avoid' principle was a feature of the three other collisions between FJs and civil light aircraft which have occurred since 1976, the previous one having occurred in August 1991. They all occurred because one or both pilot's failed to 'see-and-avoid' the collision. Furthermore, in all cases the type of operation did not allow total concentration on collision avoidance which is an essential prerequisite of 'see-and-avoid'. In the case of this accident the JetRanger pilot was performing an observation task on a pipeline and the Tornado pilot was looking for his leader. In the case of the Carno collision in August 1991, the Cessna pilot was engaged in aerial photography while the Jaguar crew were identifying a particular object on the ground. In the case of the 1984 collision between an A10 and a Cessna 152, the Cessna pilot was engaged on a student qualifying navigation exercise and the A10 pilot was selecting an RT frequency which required him to look inside the cockpit. In every case there were valid reasons for less than complete attention to the 'see-and-avoid' task.

Also, during the year of this accident, there were six reported airmisses involving military FJs and civil light aircraft. They were all assessed by JAWG as Category 'B' *i.e.* a possible risk of collision. In some cases a very late sighting had enabled an avoiding manoeuvre to be executed but the airmisses nevertheless

highlight the limitations of 'see-and-avoid'. Although the collisions and airmisses just mentioned represent a small statistical sample, it is clear that the chance of another collision under the existing system of low flying in the UK, relying as it does so heavily on the principle of 'see and avoid', remains finite.

It is therefore recommended that the Ministry of Defence should commission an operational analysis of 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. [Recommendation 94-1]

2.3 Conflicting interests of low level airspace users

Whereas military aircraft are deemed to be low flying when below 2,000 feet agl, civil aircraft are bound by the 'Low Flying' rules of The Rules of the Air Regulations 1991 which for all practical purposes mean that low flying is deemed to occur below 500 feet agl. This analysis will concentrate on the lower height band (below 500 feet) because that is where most of the FJ activity takes place. Nevertheless the definition of 'low level airspace' includes the height band from ground level to 2,000 feet and the problems of deconflicting civil and military traffic should be considered in this broader height band. There is no doubt that the mix of FJ and civil aircraft in the low level airspace constitutes a risk to all who use it.

National policy governing civil and military aviation permits joint use of the low level airspace and has been in existence for many years. Any exclusivity of use would require legislation and this investigation has noted the views of the House of Commons Select Committee on Defence on the subject of military low flying [9] which considered, amongst other matters, the conflicting interests of FJ and civil aircraft. The safety problem stems from the incompatibility of the joint airspace users, both of whom are entitled under UK law to exercise their respective privileges equally. The increase in FJ capability in terms of speed and navigational accuracy combined with their requirement for large training areas has, in recent years, widened the gulf of incompatibility with slower flying aerial work and GA aircraft. There is serious concern by those responsible for the safety regulation of civil aviation that the continuing risk of collision merits more positive steps towards deconfliction.

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9 House of Commons Defence Committee report printed on 28 March 1990.

There are four main areas in which improvements may be considered. They are:

a. physical separation of incompatible airspace users by time and space and;

b. procedural deconfliction and;

c. technological assistance for visual acquisition and recognition times and;

d. common radio communication in the low level airspace.

2.4 Separation of civil and military traffic in the low level airspace

Military aircraft are by far the major users of the low level airspace. There are some 600 sorties each weekday. The current annual figure of some 120,000 military low flying sorties far outweighs the annual total of aerial survey flights (6,000 hours pipeline and 4,000 hours power line). Within the low level airspace up to 2,000 feet, civil aircraft activity increases considerably taking account of a large amount of GA flying. Total GA activity in the UK has been estimated as 2 million hours per year. Unrefined statistics such as these may give a misleading impression but what is clear is that military aircraft are the majority users of the low level airspace below 500 feet and it is that height band that is most relevant to this accident.

Military aircraft operating in the low level airspace are not required to conform to the same regulations applying to civil aircraft (see paragraphs 1.17.1 and 1.17.2). Military regulations are contained in JSP 318 and in the UK LFHB. Civil regulations are found in the Air Navigation Order. Whereas military aircraft will observe ICAO and national regulations, except where operational requirements dictate otherwise, a lack of common regulations for users of the low level airspace must contribute to the risk of collision. This is most manifest in the different airspeeds which are permitted. Although civil aircraft are limited to speeds less than 250 kt when operating below FL100 (10,000 feet on the standard altimeter setting) in practise very few of the civil aircraft operating in the open FIR and even fewer operating below 1,000 feet can be described as high speed. The majority of high performance civil aircraft operate in controlled airspace where traffic is under positive control and collision avoidance is more assured. This means that there is an even greater speed discrepancy between FJ and civil aircraft at low level particularly since the probability of detection is inversely proportional to closing speeds.

Exclusivity of use of the low level airspace, however desirable, is unlikely to be approved for either military or civil users. It would be politically unacceptable to deny the open FIR to one or other of the legitimate users although mutual

programming of activity might be considered. For example there is increased GA traffic at weekends and a corresponding decrease in military flying. To formalise a programme of exclusive use of the low flying areas would need to account for bad weather and might prejudice the flexibility of all the current low level airspace users. Thus incompatibility of FJ and GA remains as the major air safety problem but there are certain palliative measures, which taken together, could reduce the risks of collision.

2.4.1. Lateral separation - Low Flying System

In the past, military low flying in the UK has been confined to recognised low flying areas with a system of low level link routes permitting transit from one to the other. This system was discontinued in 1979 since the RAF had concluded that the link route and area system then in force could only safely accommodate some 80,000 low flying sorties per year. Calculations showed that, when the full complement of Tornado aircraft entered service, there would be a need for some 150,000 sorties a year. The old system could not cope with these numbers and thus, primarily for reasons of safety, the modern UK Low Flying System (UKLFS) was introduced. The actual area available for low flying is much restricted by large urban areas, controlled airspace and other areas which must be avoided. Although the previous low flying system was superseded, the actual gain in available area would appear to have been minimal. One undesirable feature of the low level link routes was that it tended to concentrate low flying over specific areas which gave rise to understandable complaints from residents living beneath the affected areas. By adopting a somewhat more free traffic pattern and by using, in theory, the whole country these complaints were diluted. One highly desirable feature of the link routes was that other airspace users could be much more certain about the chances of encountering low flying military aircraft in the vicinity of the routes than they could be in the open airspace. This required them to know the location of the low level routes and, although only published on military low flying charts, there was widespread civilian knowledge of the routes.

Following the collision between an RAF Jaguar and Cessna 152 near Carno, Powys in August 1991, it was recommended in AAR 2/92 that military flow directional arrows should be published on civil aeronautical charts.[10] These flow direction arrows were practically the successors to the low level link routes and came about partly as a result of the natural constrictions placed on low flying by numerous obstructions such as urban areas, other airspace, avoidance and sensitive areas and partly as a safety measure introduced to the military low flying system so that all its users could be aware of 'choke points' and to flow through

10 AAR 2/92 Recommendation 92-8.

them in a single specified direction. Unfortunately, the implementation of the AAIB recommendation resulted in this information being published in the UK AIP as an addition to an existing small scale chart showing the military low flying system in the UK. It has not appeared, as the recommendation intended, on the topographical charts most commonly used by civil pilots and which are instantly available in the cockpit. Reluctance to further clutter a chart which already contains a mass of useful information was given as a reason for using the AIP as the method of promulgation.

A more recent review of the UKLFS by MOD in 1991/2 re-examined the question of link routes and training areas. Its re-introduction was rejected primarily on safety grounds. The majority of military low flying involves independent flows which are highly localised and are designed to prevent military only conflictions. They do not lend themselves to being part of a link route and low flying area system. Nevertheless knowledge of the flow directions and choke points is valuable safety information for civil pilots and should be readily available. It is recommended that the Ministry of Defence and CAA should arrange for flow directions and choke points of the UK Low Flying System to be published on those topographical charts which are most commonly used by civil pilots. [Recommendation 94-2]

2.4.2 Vertical separation

FJ crews have a continuing requirement to train at high speed and low level. FJ aircrew may be authorised to fly in day VMC down to 250 feet MSD and at night, or in IMC, down to 500 feet MSD. Selected and appropriately qualified aircrew occasionally train down to 100 feet MSD, when specifically authorised to do so and only in certain tactical training areas and under strict control.

Civil aircraft involved in aerial work, which includes aircraft carrying out pipeline and power line surveys, aerial lifting, aerial photography, agricultural aviation (crop spraying) as well as air ambulance and police helicopters, also operate in the lower height bands. They do so in accordance with Rules of the Air, Rule 5 (1) (e) in most areas (see paragraph 1.17.7.1) but with a CAA authorised exemption they may fly as low as 300 feet agl. Aircraft involved in power line inspections fly even lower and can operate as low as the power lines themselves on certain occasions. The exemption from Rule 5 (1) (e) carries with it the condition that, when operating below 500 feet agl, aircraft must carry and operate a HISL. There is no requirement to operate the HISL when above 500 feet but to have such equipment fitted, which is designed to increase conspicuity, and not be required to use it when above 500 feet agl does not make the best use of such an aid. It is therefore recommended that the CAA should amend Rule 1 (1) of Rules of the Air Regulations 1991 so that the interpretation of 'anti-collision light'

means, in relation to any aircraft, a flashing red or a flashing white light. [Recommendation 93-51 made on 28 September 1993]

Most of the FJ training (about 80%) is conducted between 250 feet and 500 feet agl and military aircraft are, by a considerable margin, the major users of this lower airspace. A modicum of vertical separation can be achieved by the recently introduced upper limit of 500 feet for normal FJ operations and the recent advice to aerial survey aircraft to minimise their operations below 600 feet agl. The MOD have proposed that the CAA should consider certain aerial work tasks taking place below 250 feet. The operating and safety aspects of such a proposal will need to be carefully considered. With the exception of aircraft involved in power line surveys, which are afforded a degree of protection by the pylons and wires themselves acting as known obstructions and whose positions are published on aeronautical charts, aircraft involved in low level survey operations and which are not subject to CANP notification (see paragraph 1.17.4) should be encouraged, where possible, to operate above 500 feet and preferably at 700 feet agl for the majority of their operations. For these reasons it has been recommended that the Civil Aviation Authority should circulate a notice to those AOC holders involved in aerial surveys recommending that where practical they operate in the height band of 500 feet to 700 feet thus providing a degree of vertical separation from high speed low flying military aircraft which will generally operate below 500 feet. [Recommendation 93-47 made on 28 September 1993]

2.5 Procedural separation

2.5.1 Civil aircraft notification procedure (CANP)

Besides physical separation it is also possible to arrange procedural separation. CANP has been available to civil operators since 1974. The opportunity to use CANP in the circumstances of this accident did not arise because pipeline and power line inspection flights had been specifically excluded from the procedure (see paragraph 1.17.3). In 1984 it was at the instigation of the principal operator at the time, and with the full agreement of the British Helicopter Advisory Board (BHAB), that such inspection flights were excluded from the system. Experience by the main operators had shown that there was considerable difficulty in providing, at the necessary notice, sufficiently accurate times and positions for aerial survey activities. This was in large measure due to the extensive areas covered which did not lend themselves to the 'point target' nature of CANP. Whether or not a notification procedure would have prevented this accident cannot be determined. Shortly after the accident NATS initiated a review of CANP from which a notification system more applicable to pipeline inspection flights was devised (PINS see paragraph 2.5.2.2 below). This suggests that there has

always been a need to notify military users of the low level airspace about aerial survey flights and voluntary withdrawal from CANP may, with hindsight, be seen to have been unwise. Despite its limitations it must have had some benefit.

The relatively low number of daily CANP notifications (seldom more than five per day) tends to confirm a number of assumptions about the procedure. Firstly, it may be that typical users of this airspace such as microlight aircraft, hot air balloons, aerial application aircraft and minor air displays are adequately covered by other procedures such as the NOTAM system and by the creation of protected airspace. Secondly, the civilian pilots who would be well advised to use the procedure may be unwilling to compromise their flexibility of operation by the somewhat exacting terms of the notification for time, area and forewarning. Thirdly, the low usage rate of the procedure may imply a lack of confidence in it by those to whom it is made available based on their past experience of close encounters with FJs who may inadvertently miss the sighted civil traffic by quite narrow margins. The procedure itself only specifies a vertical avoidance by 300 feet. For this reason it has been recommended that the current review of Civil Aircraft Notification Procedures by the CAA should examine the existing separation criteria concerning over flights of sites notified under the procedure. [Recommendation 93-52 made on 28 September 1993]

2.5.2 Pipeline Inspection Notification System (PINS)

Experience of operating within the provisions of PINS, which became operational on 25 October 1993, will decide its own effectiveness. It has to be recognised that this procedure applies to a quite specific type of activity within the low level airspace and other users remain without its protection. There is a growing level of aerial activity associated with the Police and Helicopter Emergency Medical Services aircraft. By definition these flights are entirely random and unforeseen and therefore cannot fall within any system of prior notification. These airspace users must rely on some of the other collision preventative measures which are recommended in this report.

2.5.3 System effectiveness

Both notification systems (CANP and PINS) are essentially a one-way flow of information in that participating pilots are able to inform the military low flying system of their intentions but, apart from an acknowledgement, civil pilots must take on trust the guarantee that they will be avoided. There is no 'confidence check' built into the system. It is both impractical and operationally unsuitable for the military low flying programme to be published on a daily basis. There is a requirement for some feedback to civil operators that the procedural separation systems are effective. The current avoid criteria for CANP permits FJs to avoid a

notified area by as little as 300 feet vertically. Whilst the FJ pilot's perception of such separation is probably adequate it almost certainly is not for the civil light aircraft pilot. In recent airmiss reports it has been impossible to decide whether the FJ pilot was deliberately avoiding by the minimum or whether the avoidance was the best that could be managed following a late sighting. A dialogue between the users of low level airspace must be established so that all users can have confidence in the procedural separation systems.

It is therefore recommended that the Ministry of Defence publish annually statistics relating to the monthly number of CANP and PINS flights which are filed together with any significant reports of failures in the system whether arising from breaches of the notified areas by military aircraft or non-compliance with the notification by civil aircraft. [Recommendation 94-3]

2.6 Improving visual acquisition and recognition times with technology

The problems of visual target acquisition, which is the fundamental requirement for 'see-and-avoid', have been re-stated and examined in this report. The margins available at the present speed of FJs at low level are such that technological aids are essential in order to further reduce the risk of collision.

The report at Appendix B examined the reflectance of the two colours of the helicopter's fuselage and the effects that a 2,000 cd HISL had on the probability of visual detection. Work was also carried out on the reflectance of the grey / green camouflage of the Tornado. Estimates were made of the likely detection time for the HISL on the JetRanger and a hypothetical 80,000 cd beacon. The cumulative probability of detection for the HISL would pass the 50% point less than 3 seconds before impact. For the brighter light the estimate was more than 16 seconds. A graphical presentation (Appendix B, Annex A, figure 4) also highlighted the increase in detection times achieved by painting a helicopter black.

Following a recommendation by JAWG the CAA specified the fitting of HISLs to all aerial work aircraft whilst exercising the privilege of their exemption from Rules of the Air 5(1)(e). It is unfortunate that the advice then was that a light of at least 2,000 cd intensity was required. This is now superseded by advice that at least 40,000 cd and ideally 80,000 cd is recommended if such lighting is to be effective in all conditions. Suitable light sources are now available and suitable applications for light aircraft can, in principle, be developed.

Research is being carried out by MOD into conspicuity enhancing aircraft lights and the adoption of high conspicuity colour schemes for certain classes of aircraft (notably training ones). This research is being conducted in association with the testing of an electronic CWS. A combination of increased conspicuity measures

(paint schemes and enhanced lights), an effective CWS and a successful electronic strobe detector would do much to reduce the risks involved.

It is therefore recommended that the Ministry of Defence should give a high priority to the development and introduction of technology which provides low flying military FJs with an aircraft collision warning system, and the CAA should give similar priority to the research project for an electronic strobe detector. [Recommendation 94-4]

2.7 Air-to-air communications

It is significant that, under existing arrangements, joint users of low level airspace have no compatible method of communicating with each other. Civil aircraft communicate using the VHF frequency band while military aircraft generally use UHF frequencies. In civil VFR operations, taking place in the open FIR and without a Radar Information or Advisory Service being available [11], pilots rely to a considerable extent on intelligent monitoring of local VHF frequencies, perhaps a major aerodrome approach control or a Lower Airspace Radar Service (LARS) or a Flight Information Service (FIS). Much useful traffic information can be gleaned by listening to ATC instructions, position reports and service requests by other aircraft flying in the vicinity. This is a subtle and informal method of building up a mental picture of the traffic situation and one which applies equally in the crowded controlled airspace of a Terminal Manoeuvre Area.

Similarly, military aircraft can benefit from monitoring their own traffic pattern and flow on their UHF frequencies but they have several other important tasks, such as formation control, range work and tactical information, which also require the use of their radios. There is a practical limit to the number of frequencies that a crew can operate simultaneously and monitoring VHF frequencies may not be routinely feasible. Military ATC controllers often transmit simultaneously on VHF and UHF when communicating with either civil or military aircraft but pilots monitoring either frequency band can only hear one half of the conversation i.e. they cannot hear the other aircraft. This denies them much useful information.

By the use in the open FIR of these different and incompatible frequency bands there is, quite clearly, a communications gap. The ability of both military and civil aircraft to monitor each other's air traffic information could contribute towards deconfliction although it is acknowledged that, because of the large areas traversed by FJs in a short time, the validity of traffic information will be of short duration. Also an 'open' frequency lacks the discipline imposed by positive

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11 Radar Advisory Service is seldom available below 2,000 feet because of limitations in radar coverage.

control and unnecessary 'chatter' can degrade its effectiveness. As a contribution towards greater deconfliction and despite these obvious limitations as well as those caused by the lack of radios in many gliders, microlights and hang gliders, terrain screening of the radio signal and limited range at low level, it is desirable that all aircraft operating in the open FIR should have the facility to listen in to and to make 'blind' [12] transmissions for the benefit of all other users in the vicinity. It is therefore recommended that the MOD and the CAA should examine the existing ATC communications available to civil /military aircraft operating in the open FIR to see whether the incompatibility of frequency bands adversely affects flight safety. [Recommendation 94-5]

2.8 Summary

The Tornado and JetRanger collided because of a failure in the 'see and avoid' principle whereby neither pilot saw the other aircraft in time to take avoiding action. The Tornado was fortunate in being able to land at a nearby airfield despite having sustained considerable damage. The JetRanger was most unlikely to have been able to survive the catastrophic loss of its tail rotor assembly and stabiliser.

UK aviation policy permits use of the low level airspace in the open FIR by both civil and military aircraft but there is an incompatibility, based largely upon performance and operational differences, between the joint users of the low level airspace. The degree of reliance on the 'see-and-avoid' principle in the open FIR for the deconfliction of aircraft of widely differing performance is inappropriate. Physiological limitations which contribute to the inadequacy of 'see and avoid' may be reduced by improvements in visual acquisition through the optimum use of paint schemes and the installation on aircraft of brighter lights.

Several other measures need to be implemented to reduce the risks of collision and near misses. The surest way to avoid collision is through physical separation but this ideal is unlikely to be realised because of political realities. Some deconfliction can be achieved by means of notification procedures (CANP and PINS) and with the assistance of ATC units, when available, and a common communications frequency. The recent system providing for the notification, co-ordination and vertical separation of pipeline inspection flights (PINS) was introduced on a trial basis and experience of its use will determine its effectiveness. Research into the development of a collision warning system and electronic strobe detectors is in progress but neither system is likely to be in widespread service for a number of years. Different frequency bands (UHF and

12 A 'blind' transmission occurs when a pilot has not established a communication link with either an ATC unit or another aircraft but where the pilot deems it prudent to make a broadcast of his position and intentions.

VHF) used for air traffic communications by military and civil aircraft do not permit the exchange of position/intention information or routine traffic monitoring by the respective airspace users.

3 Conclusions

(a) Findings

(i) Both aircraft were operating in accordance with their respective regulations and their crews were adequately rested, properly briefed and suitably qualified.

(ii) Both aircraft involved were airworthy immediately prior to the collision.

(iii) The collision occurred in good weather with excellent visibility.

(iv) The Tornado pilot was unlikely to have sighted the JetRanger until about 5 seconds before the collision. Research shows that at least 10 seconds are required for effective avoiding action to be taken.

(v) The pilot of the JetRanger had just completed an orbit of a ground based target and his attention was probably still directed at this. If he had seen the Tornado his ability to avoid it in the horizontal plane was extremely limited due to its relatively slow speed. However, a descending manoeuvre may have been possible, given sufficient recognition and reaction time for the helicopter pilot.

(vi) After the collision damage to the JetRanger, which resulted in a combination of lost yaw control and an out of limit centre of gravity, was such that, despite the evident best efforts of its pilot, who was most likely disorientated, control was lost and it crashed to the ground with considerable velocity.

(vii) Impact forces sustained by the helicopter and its crew rendered the crash non-survivable.

(viii) Just before the impact the Tornado was on the JetRanger's right and, under the Rules of the Air, it had right of way. However, moments before, both aircraft had been head on to each requiring each to alter course. In these circumstances, involving a closing speed of 440 kt and a rapidly changing spatial relationship this aspect of the 'right of way' rules was quite inappropriate.

(ix) There was no routine system of flight notification in force by which either aircraft could have been made aware of the likely presence of the other. CANP was not applicable to a pipeline survey flight and whether or not

prior notification of the accident flight would have prevented it cannot be determined.

(x) The decision to introduce PINS after the accident suggests that there has always been a need to notify military users of the low level airspace about aerial survey flights and the operators' voluntary withdrawal from CANP in 1984 may, with hindsight, be seen to have been unwise.

(xi) 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. Airspace control is vested in the joint civil/military organisation of NATS.

(xii) There are limits to the effectiveness of 'see-and-avoid' using purely visual acquisition methods. Deconfliction may be enhanced using other methods such as physical and procedural separation.

(xiii) Recognition and traffic acquisition may be augmented by technological means including electronic alerting devices and optimum paint and lighting schemes. Most of these are at an early stage of development.

(xiv) Both aircraft were being operated in a professional manner and the collision was the tragic consequence of what must be considered a risky operational environment.

(xv) There is limited intercommunication between military and civil aircraft because they normally operate on different frequency bands (UHF & VHF).

(b) Causes

The investigation identified the following causal factors:

(i) Neither pilot saw the other aircraft in time to avoid the collision.

(ii) Incompatibility of operational modes and the unsuitability of the 'see-and-avoid' principle in these circumstances failed to ensure the necessary separation.

(iii) There were no routine procedures, such as CANP, or facilities, such as CWS, to inform either pilot about the presence of the other aircraft prior to the impact.

4 Safety Recommendations

The following safety recommendations were made on 28 September 1993 and are repeated here for completeness:

93-47 The Civil Aviation Authority should circulate a notice to those AOC holders involved in aerial surveys recommending that where practical they operate in the height band of 500 feet to 700 feet thus providing a degree of vertical separation from high speed low flying military aircraft which will generally operate below 500 feet.

93-48 The Civil Aviation Authority should introduce a system of area notification of information to military crews involved in low flying training that provides the timely distribution on civil aerial activity relating to the surveying of pipelines in the UK.

93-49 The Ministry of Defence, in consultation with the Health and Safety Executive and the known energy providers, should obtain for crews involved in low level flying training suitable briefing material on the location and routes of the major pipelines within the UK. The briefing material should include any known frequency of routine inspections with provision for any variations to be notified by the operators.

93-50 Not used.

93-51 The Civil Aviation Authority should amend Rule 1 (1) of Rules of the Air Regulations 1991 so that the interpretation of 'anti-collision light' means in relation to any aircraft a flashing red or a flashing white light.

93-52 The current review of Civil Aircraft Notification Procedures by the Civil Aviation Authority should examine the existing separation criteria concerning over flights of sites notified under the procedure.

Other recommendations made as a result of this investigation are:

94-1 The Ministry of Defence should commission an operational analysis of 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.

94-2 The Ministry of Defence and CAA should arrange for flow directions and choke points of the UK Low Flying System to be published on those topographical charts which are most commonly used by civil pilots.

94-3 The Ministry of Defence should publish annually statistics relating to the monthly number of CANP and PINS flights which are filed together with any significant reports of failures in the system whether arising from breaches of the notified areas by military aircraft or non-compliance with the notification by civil aircraft.

94-4 The Ministry of Defence should give a high priority to the development and introduction of technology which provides low flying military FJs with an aircraft collision warning system and the CAA should give similar priority to the research project for an electronic strobe detector.

94-5 The Ministry of Defence and the CAA should examine the existing ATC communications available to civil /military aircraft operating in the open FIR to see whether the incompatibility of frequency bands adversely affects flight safety.

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