Near-miss, Boeing B757-204, G-BYAN and McDonnell Douglas F15E

Micro-summary: **Near-miss at 10,000' involving an F-15E and Boeing 757.**

Event Date: **2000-11-22 at 1020 UTC**

Investigative Body: **Aircraft Accident Investigation Board (AAIB), United Kingdom**

Investigative Body's Web Site: **http://www.aaib.dft.gov/uk/**

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Boeing B757-204, G-BYAN and McDonnell Douglas F15E

AAIB Bulletin No: Ref: EW/C2000/11/05 Category: 1.1

INCIDENT

Aircraft Type and Registration:	(i) Boeing B757-204, G-BYAN
	(ii) McDonnell Douglas F15E
Date & Time (UTC):	22 November 2000 at 1020 hrs
Location:	5 miles west of Daventry VOR
Type of Flight:	(i) Public Transport
	(ii) Military
Persons on Board:	B757 Crew -8 - Passengers -234
	F15E Crew -2 - Passengers - None
Injuries:	None
Nature of Damage:	None
Information Source:	AAIB Field Investigation

Synopsis

This incident occurred when an F15E military fast jet came into close proximity to a Boeing B757 at the same level in the Daventry Radar Corridor.

History of the flights

The Boeing 757

The Boeing 757 (B757) was scheduled for a turnaround flight from Birmingham Airport to Paphos, Cyprus. The aircraft departed Birmingham in a southerly direction on a Cowley 1E departure and entered cloud in the climb between 3,000 and 4,000 feet. Not long after becoming airborne the departure controller cancelled the Standard Instrument Departure procedure and placed the aircraft under radar control. At FL60 control was handed from Birmingham Departures to Midland Terminal Control (MTC).

Immediately upon contact with MTC the B757 was cleared to climb to FL 90 and shortly thereafter given a radar heading of 140°. About one minute after initial contact with MTC the B757 was re-cleared to FL100. The controller acknowledged the B757 crew report on reaching FL100 and advised "MILITARY TRAFFIC IN YOUR ELEVEN O'CLOCK POSITION CROSSING LEFT TO RIGHT, ONE THOUSAND FEET ABOVE". The B757 crew acknowledged the advice and

although the aircraft remained in cloud, they immediately began a visual search for the traffic, which their Traffic Alert and Collision Avoidance System (TCAS) was indicating one thousand feet above. The cloud proved to be too thick for visual contact with the military traffic, but the crew remained looking out as the TCAS contact passed clear down their right side.

Shortly after the traffic passed clear and, whilst still in cloud, the commander and the first officer suddenly became aware of an aircraft in their left 'half-past ten' position at very close range and at about the same level. The aircraft, which they were immediately able to identify as a twin-tailed fighter and later as an F15, passed rapidly across the B757's nose and disappeared down their right side. The B757 crew heard the noise of the F15's engines and their aircraft encountered its wake turbulence. There was no time for the B757 crew to take avoiding action. Subsequent analysis of radar data indicated that at the closest point of approach the two aircraft were separated by less than the minimum range detectable by the radar which is 0.0625 of a nautical mile. As far as is known, none of the cabin crew or passengers saw the F15, but the cabin crew felt the disturbance as the B757 flew through the F15's wake. The flight deck crew filed an AIRPROX report with ATC and continued to Cyprus.

The F15s

The two F15s were two-seat E models, and the flight was planned as training for the front seat occupant of the No 2 aircraft. The pilot under training was in current flying practice on the single-seat F15C, but there are several significant differences between the F15C and the F15E, and an F15E instructor pilot was therefore in the rear seat. The plan was to carry out tactical low flying training in Wales followed by weapons delivery practice on one of the air-ground ranges in the Wash before returning to base at Lakenheath for circuit training. The route to Wales was to be flown at medium altitude crossing controlled airspace through the Daventry Radar Corridor and descending to low level once clear of controlled airspace to the west.

The two aircraft took off from Lakenheath approximately 20 seconds apart and took up a 'trail' formation with the No 2 aircraft about two miles behind the leader. In accordance with standard procedures for this type of formation only the lead aircraft was transmitting a Secondary Surveillance Radar (SSR) code (Squawk). The aircraft climbed through cloud, with the No 2 aircraft maintaining position by use of radar, and levelled at FL100 in VMC. Part of the briefed flight profile included an aircraft systems check for both aircraft to be carried out in VMC. The procedure for the checks involved a change of lead aircraft. The formation No 2 completed his checks and began to close on the lead aircraft to take the lead position, but the formation entered IMC, and the No 2 aircraft aborted the change of lead and dropped back to about a 1.5 mile trail. In an attempt to regain VMC the lead aircraft requested from ATC a climb to FL110.

Not long after the F15s became airborne, ATC control was handed to London Military Radar (in particular the London Joint Area Organisation Central (LJAO) of London Military Radar) by Lakenheath Departure Control. LJAO cleared the F15s to cross the Daventry Radar Corridor at FL100, and the F15's request to climb to FL110 was made to LJAO shortly after the aircraft entered the Daventry Radar Corridor. The controller's initial response was for the flight to maintain FL100, but she contacted the MTC controller by landline to co-ordinate a climb. The MTC controller agreed the higher level and LJAO later cleared the F15 flight to climb to FL110.

The leader immediately began a climb to FL110, but the No 2 aircraft did not hear the ATC clearance and maintained FL100. The two pilots of the No 2 aircraft later noticed that their radar showed the leader to be above their level, and they began a discussion of the indication. At about

this time the front seat occupant was vaguely aware of a 'shadow' flashing rapidly down his right side. Shortly thereafter the LJAO controller asked the flight to confirm that both aircraft were level at FL110, and at this point the No 2 climbed rapidly to FL110. Some time later the F15s were advised that the B757 had filed an airborne AIRPROX report, and only then did the front seat occupant of the No 2 aircraft associate the 'shadow' with the possible presence of another aircraft. The rear seat occupant saw nothing of the B757.

Daventry Corridor Procedures

The Daventry Radar Corridor is established to facilitate airways crossing by military aircraft. The corridor is 8 nm wide at FL100 and is centred on the Daventry VOR/DME orientated on the O66°/246° radials. FL110 is available as an alternative level when required. The corridor is in Class A airspace controlled by MTC based at the London Area Terminal Control Centre (LATCC), West Drayton. Military aircraft flying through the corridor are controlled by military controllers based at the LJAO which is also located at LATCC. The LJAO controller co-ordinates the use of the corridor by telephone with MTC.

Once use of the corridor has been co-ordinated and approved, the civil controllers at MTC should regard the corridor level as sterile airspace and must provide traffic under their control with at least 1,000 feet vertical separation from the corridor unless co-ordination has been effected with the LJAO controller.

Military aircraft wishing to use the corridor must provide London Military Radar with a minimum of five minutes notice of their intention to use the corridor. Pre-notification can be given either prior to departure or by radio once airborne. There are special corridor procedures laid down for aircraft departing from Lakenheath because of the close proximity of Lakenheath to the eastern entrance of the corridor. Pre-notification action by Lakenheath Operations is carried out directly with LJAO rather than through London Military Radar and aircraft en-route to the corridor contact LJAO direct rather than first contacting London Military Radar.

Pre-notification can either take the form of a telephone call between Lakenheath operations staff and the LJAO controller or, if a flight plan has been filed, the information is provided to the controller on a printed strip. If a printed strip is available the planned number of aircraft making the crossing is provided on the strip, but aircraft unserviceabilities prior to departure can effect the actual number of aircraft that become airborne. When pre-notification is given verbally over the telephone the number of aircraft may or may not be mentioned by the operations staff and the system relies on the LJAO controller asking for the number of aircraft from the operations staff.

There was some confusion with the pre-notification of the incident F15 flight. A flight plan had been filed for a pair of F15s, callsign EAGLE 31, and a printed flight progress strip showing a flight of two aircraft planning to use the Daventry Radar corridor had been prepared and was at the LJAO controller's position. At 1003 hrs Lakenheath Departures called LJAO to pre-notify F15 traffic for the Daventry Corridor, callsign BOLAR 31. The LJAO controller confirmed that this traffic was in fact the same flight pre-notified as EAGLE 31, and prepared a hand written flight progress strip reflecting the new callsign, but he assumed that the flight was now a single aircraft and he annotated the hand written strip accordingly. The printed strip for EAGLE 31 showing a flight of two aircraft was discarded.

Midland Terminal Control

At the time of the AIRPROX the MTC position in LATCC was manned by a controller and a co-ordinator. The controller provided ATC control to aircraft directly by radio while the co-ordinator helped plan and co-ordinate aircraft movements and communicated with other agencies by telephone. About ten minutes before the incident the MTC co-ordinator agreed with LJAO a Daventry Radar Corridor crossing for a 'SINGLE F15' from Lakenheath at FL100 and provided the MTC controller with the normal flight progress strips giving details of the flight.

The MTC controller was controlling the departure of the B757 from Runway 15 at Birmingham Airport en-route to Paphos, Cyprus. The B757's departure required a climb through the Daventry Radar Corridor and initially the aircraft was cleared to climb to FL90 to provide 1,000 feet of separation on the Daventry Corridor traffic at FL100. About 2 minutes before the incident the co-ordinator received a telephone call from LJAO requesting a climb for the corridor traffic to FL110. After checking with the controller, the co-ordinator agreed to the climb and in accordance with normal procedures the MTC controller cleared the B757 to climb to FL100 after he had observed the F15 level at FL110 on SSR Mode C. The MTC controller advised the B757 of the crossing military traffic 1,000 feet above, and this was acknowledged by the crew who stated that the traffic was indicating on their TCAS. At this stage MTC had not been advised of the second F15 and neither the controller nor the co-ordinator had noticed the primary radar return of the rear F15 which was partly obscured on the radar display by the lead aircraft SSR label.

London Joint Area Organisation Central

The LJAO Central position was manned by a controller and, for part of the time, a member of the ATC Examining Board who acted only as an observer. In the fifteen minutes prior to the incident three different controllers occupied the LJAO Central control position at LATCC. The first controller received the pre-notification of the F15 corridor crossing from Lakenheath Operations. The second controller telephoned MTC to co-ordinate the crossing of the Daventry Radar Corridor by a "single F15" and subsequently took control of the aircraft from Lakenheath Departures and cleared it to fly through the corridor under its own navigation. At this time the LJAO controller was also arranging an airways crossing for a military aircraft departing from Yeovilton. The transcript of RTF and telephone conversations for the period shows that when the F15s first called on the LJAO frequency the No 2 aircraft transmitted to indicate to the lead aircraft that he was on frequency. In normal circumstances this would have been an indicator to the controller that there was a second aircraft in the flight, but the transcripts indicate that the second aircraft's transmission was partially obscured by an engaged (busy) tone on an open telephone line to Yeovilton. The third controller, who was controlling the F15s at the time of the incident, took over the control position shortly before the F15s entered the corridor.

One of the third controller's first acts on taking control was to check the flight progress strip of the F15 and to re-confirm with the F15 that it was cleared through the corridor at FL100. When the F15s requested a climb to FL110 the controller noted that descending civilian traffic would prevent an immediate climb, and she told the aircraft to "....STANDBY MAINTAIN FL100". The lead F15 acknowledged the requirement to maintain FL100 and advised that there was a second aircraft in 1.5 mile trail.

This was the first point at which any of the LJAO controllers on duty that day were aware of the second aircraft. However, the controller assumed that her predecessors in the control position had known of the second aircraft, and that there had simply been a mistake in completing the flight progress strip; she amended the strip accordingly. The LJAO controller then contacted MTC to co-

ordinate a climb to FL110, but because she assumed MTC was already aware of the second aircraft, she did not mention the presence of the second aircraft in 1.5 miles trail.

About two minutes before the incident the LJAO controller cleared the F15s to climb to FL110, and about one minute before the incident she advised the F15s of civilian traffic climbing "NOT ABOVE FL100". The lead F15 responded that he had the civilian traffic in radar contact.

Formation procedures

ATC procedures to be followed by aircraft flying in formation are outlined in CAA Manual of Air Traffic Services Part 1 (MATS Part 1) and MOD Joint Service Publication 318, Part 2 Air Traffic Control General (JSP 318A).

MATS Part 1 states that clearance for formation flights to enter controlled airspace may be granted provided the aircraft of the formation can maintain separation from each other visually and all aircraft are able to communicate with the formation leader. MATS Part 1 goes on to state that all ATC instructions and clearances will be addressed to the leader.

JSP 318A states that the formation leader is responsible for separation between the individual units comprising the formation. For separation from other aircraft, formations may be considered as a single unit provided that the formation elements are within one nautical mile both horizontally and longitudinally and are at the same level or altitude. At the controller's discretion, these distances may be increased to 3nm and/or 1,000 feet vertically.

While MATS Part 1 covers only formations that can maintain separation from each other visually, JSP 318A outlines procedures to be followed for 'stream' formations in which formation elements may maintain separation from each other either visually or by radar or by the use of station keeping equipment. For stream formations of more than one mile but less than three miles in length only the lead aircraft is required to squawk Mode 3/A and Mode C. Controllers are to identify the full extent of the stream formation during radar handovers, when effecting co-ordination and when passing traffic information. There is no requirement for formation elements not in visual contact with the leader to confirm that they have received or acted upon ATC instructions or clearances.

Formation callsigns

The USAF commonly uses a system of formation callsign allocation that uses a single aircraft callsign (e.g. BOLAR 31) and for additional elements simply adds consecutive numbers to the prefix. Thus, numbers two three and four in a formation could be BOLAR 32, 33 and 34; however, when dealing with ATC as a single speaking unit the formation would be known only as BOLAR 31. From an ATC perspective, BOLAR 31 could be a single aircraft or a formation of many aircraft.

Collision Alert and Avoidance Systems

Alerting and collision avoidance systems have been introduced in recent years to assists pilots and air traffic controllers in maintaining safe separation.

Airborne Collision Avoidance System (ACAS)

The requirement for certain categories of civil aircraft either registered in UK or flying within UK airspace to be equipped with ACAS took effect on 1 January 2000. ACAS equipment currently available is TCAS II which uses SSR transponder returns to calculate potential airborne conflicts and automatically provides the flight deck crew with alerting and collision avoidance information. TCAS can provide alerting information on any aircraft transmitting an SSR code but collision avoidance guidance can only be provided for conflicting aircraft transmitting Mode C or Mode S.

Short Term Conflict Alert (STCA)

STCA is an automated system that alerts controllers to potential conflicts between aircraft returns on the radar display. STCA recognises an aircraft under ATC control by reference to its Mode A code. Conflict alert warnings will only be given for two aircraft where at least one is being controlled from an ATC unit equipped with STCA.

Required separation standards differ depending on the type and use of controlled airspace. STCA trigger parameters can be changed to reflect the separation standards in use. When the system detects a potential conflict, flashing SSR labels, suitably coloured to denote the severity of the conflict, alert the controller. It is difficult to programme the STCA to ignore alerts between aircraft in formation whilst continuing to alert against non-formation traffic.

Radar

Current ground radar systems and radar displays have limitations when dealing with aircraft squawking whilst in close formation. SSR labels from aircraft in close formation tend to overlap on radar screens, which makes it difficult for controllers to read and validate data. Modern radar displays have the capability to orientate SSR labels to minimise overlap, but whilst the re-orientation capability exists on older systems the procedures are cumbersome and difficult to use. A further limitation of current radar systems is a phenomenon known as 'garbling'. Garbling can occur when data arriving at the SSR sensor from one aircraft overlaps with data from another. This may not be a problem if the overlapping transponder replies can be deconflicted but when simultaneously arriving data cannot be separated the SSR data from either or all of the aircraft can be corrupted. Modern monopulse SSR sensors include techniques to minimise the effects of garbling, but there is currently no completely effective degarbling mechanism.

Carriage and use of SSR transponders

The UK Aeronautical Information Publication (AIP) outlines the requirements for carriage and operation of SSR transponder equipment in accordance with Article 15 and Schedule 5 to the Air Navigation Order. The requirements relevant to this incident are that all aircraft in UK airspace above FL 100 and all aircraft below FL 100 operating under IFR in controlled airspace are required to carry and operate an SSR transponder. There is an exception for aircraft below FL 100 in controlled airspace if they are receiving an approved crossing service. Short notice exemptions from the carriage and operation of SSR transponder equipment may be permitted provided that prior approval of the ATC unit responsible for the airspace has been gained. Entry into controlled airspace is not guaranteed and short notice exemptions are not permitted in the London TMA. It is understood that the CAA is currently reviewing the requirements for flights in controlled airspace without a serviceable transponder.

Analysis

This incident was the result of the crew of the second F15 not hearing and taking action on a radio call from LJAO clearing the formation to climb to FL 110. Because of inter-cockpit discussion between the two pilots the second F15 missed the clearance to climb, and at least two other transmissions that might have triggered an appreciation that the climb clearance had been missed. Since there will always be potential for radio calls to be missed, especially in a training environment, this analysis concentrates on means by which procedures and systems might be changed to mitigate the effects of a missed clearance by a formation element.

Daventry Radar Corridor procedures

The general consensus amongst civil and military controllers interviewed during the course of this investigation was that the radar corridors for military aircraft crossing controlled airspace normally work well. The use of three controllers in the space of a few minutes by the LJAO was not ideal but is not considered to have had a material effect on the incident. Indeed with the exception of the confusion over the number of aircraft in the formation, the procedures worked well during this incident.

There is, however, no evidence that the confusion over aircraft numbers was causal in this incident. Separation between civil traffic under the control of MTC and military traffic in the corridor is based purely on the requirement for the MTC controller to provide traffic with 1,000 feet of vertical separation on the corridor traffic's cleared level. Even if the MTC controller had been aware of the second aircraft, he would have been entitled to assume that both aircraft were at their cleared level and by providing the B757 with 1,000 feet of vertical separation he complied with the required separation standards.

ATC formation procedures

MATS Part 1 makes it clear that ATC instructions should be issued only to the leader of a formation and the unwritten assumption is that the other members of the formation will either hear the same radio clearance and respond accordingly or receive instructions separately from the formation leader. If communication with ATC or between formation elements is lost or missed, the MATS Part 1 requirement that all formation elements be in visual contact provides a safety backup since formation elements seeing the leader manoeuvre in accordance with ATC instructions would be expected to follow the leader.

In this incident the F15s were operating in a stream formation in accordance with JSP 318A, with the second aircraft out of visual contact with the leader and only the leader squawking an SSR code. Since the No 2 aircraft was not in visual contact with the leader, the safety backup described above was not available. The lack of any requirement for the second aircraft to acknowledge the climb clearance or to call established at the new level, and the lack of SSR data available to the controllers meant that nobody was aware that the No 2 had missed the clearance and had not climbed.

Recent emphasis on preventing mid-air collisions has been the provision of automatic safety systems such as ACAS and STCA, and generally these systems have proved successful. Had ACAS or STCA been able to act as a safety net in this incident what was a near disaster would more likely have been a disconcerting, but relatively low risk, loss of separation. However, in order for STCA and ACAS to operate it is essential that conflicting aircraft are transmitting SSR information. Further, the lack of a squawk from the second F15 also rendered the ATC controllers blind to the developing situation and thus both automatic and 'manual' safety nets were inoperative.

The requirement to carry and operate SSR equipment was introduced to cope with the increasing volume of air traffic and the complexity of ATC procedures, and on current trends the importance of SSR is likely to increase rather than decrease. Given the dependence on SSR of both automatic and 'manual' ATC safety systems it seems imprudent to operate routine flights in controlled airspace without all aircraft squawking.

Recommendations and responses

As a result of this analysis, AAIB Safety Recommendation 2000-71, was made twelve days after the incident, and recommended that 'the CAA and NATS should, without delay, implement procedures by which the safety assurance based on the use of SSR is established for aircraft operating in formation'. [Note: this bulletin amends the words 'without delay' to read 'as soon as possible'.]

The CAA has accepted this Recommendation and the UK Ministry of Defence (MOD) has promulgated a temporary amendment to JSP 318A which introduces wide ranging changes to formation procedures. The effectiveness of these temporary procedures is to be assessed before permanent changes are implemented. In particular the MOD has reduced the maximum permitted separation between aircraft within formations receiving an ATS service and introduced further restrictions for formations flying in category A to E airspace. In addition revised RT procedures aimed at preventing confusion over the number of aircraft in formation and ensuring that all aircraft are at the formation's assigned level or altitude have been introduced. NATS and MOD have independently but co-operatively commissioned research into SSR garbling and the problems associated with formations and STCA with the aim of allowing all elements of a formation to be allocated individual SSR codes.

Whilst the revised procedures should reduce the chances of a recurrence of this type of incident, in the main they apply only to controlled airspace. However, a similar incident could occur to aircraft in receipt of a radar advisory service in Class F or Class G airspace. As a result of a previous AIRPROX in Class G airspace, AAIB Safety Recommendations 2000-57 calls for an assessment of the risk of mid-air collision between public transport aircraft and other airspace users. Pending the results of that assessment it is recommended that the revised MOD formation RT procedures be extended to apply to Class F and G airspace (Recommendation No. 2001-31).

Published procedures

It was evident during the investigation that there are differences between the ATC formation procedures laid down in MATS Part 1 and those in JSP 318A. It was also noted that some civil controllers were unaware that some formation elements operating in accordance with JSP 318A would not be in visual contact with the leader. Whilst there is no evidence to suggest that these differences in procedure were causal in this incident, they are not conducive to a good understanding between civil and military controllers and they make it difficult for civil controllers to achieve full situational awareness. The CAA has recognised this issue and has requested more information on formation procedures from the MOD with a view to their publication for the benefit of civil air traffic controllers.

Formation callsign allocation

The system of formation callsign allocation by the USAF has the potential to cause uncertainty regarding the actual number of aircraft in a formation. One of the interim amendments to JSP 318A

introduced by the UK MOD requires ATC controllers to ensure that information on the number of aircraft in the formation is obtained before providing a service.

Safety Recommendations

It is recommended that

Recommendation 2000-71

The CAA and NATS should implement as soon as possible procedures by which the safety assurance based on the use of SSR is established for aircraft operating in formation.

Recommendation 2001-31

The Ministry of Defence should extend the applicability of its recently revised RT procedures for formation operations to include Class F and G airspace.