



**MINISTRY OF DEFENCE**  
MILITARY AIRCRAFT ACCIDENT SUMMARY

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**AIRCRAFT ACCIDENT TO ROYAL AIR FORCE TORNADO  
GR MK4A ZG710**

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AIRCRAFT:	RAF Tornado GR Mk4A ZG710
DATE:	22 March 2003
LOCATION:	Kuwait
PARENT UNIT:	RAF Marham
CREW:	Two – pilot and navigator
INJURIES:	Two fatalities

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Issued by: Directorate of Air Staff, Metropole Building, Northumberland Avenue, London WC2N 5BP



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**INTRODUCTION**

1. Royal Air Force Tornado GR4A ZG710 was returning to Ali Al Salem Air Base in Kuwait at 2348 hrs on 22 Mar 03 (0248 hrs on 23 Mar 03 local time) when it was destroyed by a US Army Patriot Surface-to-Air-Missile after being wrongly identified as an Iraqi Anti-Radiation Missile. The aircraft was the second of a pair of Tornados, flying as part of a package of Coalition aircraft, operating during the early part of the war in Iraq. Both members of the crew were killed instantly when the missile hit their aircraft.

2. The command and control arrangements were based on standard Allied and UK Joint Doctrine. The Combined Operational Headquarters in Qatar, with a 4-star US officer and a 3-star UK National Contingent Commander, had overall command of the war in Iraq. Responsibility for the air campaign lay with the US-led Combined Air Operations Centre based at Prince Sultan Air Base in Saudi Arabia; it was commanded by a USAF 3-star General with an RAF 2-star as part of his team. The Centre had responsibility for air operations including airspace co-ordination and tactical control of all air defence. The Land Component Commander, based at Camp Doha in

Kuwait, held operational command of US Army ground based air defence. There were liaison elements in both Land and Air Component HQs and at the local USAF Control and Reporting Centre.

### **EVENTS LEADING TO THE ACCIDENT**

3. ZG710 had been operating as part of the RAF Combat Air Wing based at Ali Al Salem in Kuwait. ZG710's mission had been tasked and planned in accordance with appropriate orders. Flight preparation, start up, take off and the operational phase of the sortie were all completed as planned. Prior to engine start, ZG710's Identification Friend or Foe (IFF) system was checked by the groundcrew and confirmed to be working correctly. Returning to Kuwait airspace after their mission over Iraq the crew of ZG710 completed appropriate checks, including noting that the IFF switches were set correctly. The pilot had just begun a descent towards Ali Al Salem and the aircraft was at an altitude of 17938 ft when it was struck by the Patriot missile.

4. The Patriot Battery crew were monitoring for Iraqi Tactical Ballistic Missiles when ZG710 was tracked by their system. The symbol which appeared on their radar indicated that an Anti-Radiation Missile was coming directly towards them. The track was interrogated for IFF but there was no response. Having met all classification criteria, the Patriot crew launched the missile, and the Tornado, mistaken for an "Anti-Radiation Missile", was engaged in self-defence. The Patriot crew had complied with extant self-defence Rules of Engagement for dealing with Anti-Radiation Missiles.

### **SURVIVAL ASPECTS**

5. Detailed examination of ejection seat and other equipment proved conclusively that neither crewman had initiated ejection, and that they had been killed instantly.

### **THE BOARD OF INQUIRY**

6. The RAF Board of Inquiry was conducted in parallel with US Army investigations into the incident. The investigations shared information in an open manner, and the RAF Board had access to the Accident Data Recorder and wreckage from ZG710, as well as witness statements from both British and US personnel.

7. The Board noted that without the excellent co-operation and help of the US Army, it would not have been possible to gain such an accurate picture of the events that led to the loss of ZG710. However, this Military Aircraft Accident Summary relates to the UK Board only.

### **DETERMINATION OF THE CAUSE**

8. It became clear early on in the investigation that the immediate cause of the accident was that a Patriot missile destroyed ZG710. The Board concluded that the following were contributory factors: Patriot Anti-Radiation Missile

classification criteria; Patriot Anti-Radiation Missile Rules Of Engagement; Patriot firing doctrine and crew training; Autonomous Patriot battery operation; Patriot IFF procedures; ZG710's IFF serviceability; aircraft routing and airspace control measures, and Orders and Instructions. A variety of other factors were considered and discounted once the evidence had been analysed.

#### Patriot System Anti-Radiation Missile Classification.

9. The Patriot system identifies hostile missiles through their flight profile and other characteristics, including the lack of an IFF response. The criteria programmed into the Patriot computer were based on the many different Anti-Radiation Missiles available worldwide, and were therefore very broad. ZG710's flight profile met these criteria as it commenced its descent into Ali Al Salem. The Board considered that the criteria should have been much tauter, based on the known threat from Iraq, and concluded that the generic Anti-Radiation Missile classification criteria programmed into the Patriot computer were a contributory factor in the accident.

#### Patriot Anti-Radiation Missile Rules Of Engagement.

10. The Board concluded that the Patriot Anti-Radiation Missile Rules Of Engagement were not robust enough to prevent a friendly aircraft being classified as an Anti-Radiation Missile and then engaged in self-defence, and were thus contributory factors in the accident.

#### Patriot Firing Doctrine and Training.

11. Patriot crews are trained to react quickly, engage early and to trust the Patriot system. If the crew had delayed firing, ZG710 would probably have been reclassified as its flight path changed. The crew had about one minute to decide whether to engage. The crew were fully trained, but their training had focused on recognising generic threats rather than on those that were specific to Iraq or on identifying false alarms. The Board concluded that both Patriot firing doctrine and training were contributory factors in the accident.

#### Autonomous Patriot Battery Operation.

12. The Patriot crew were operating autonomously, with a primary role of protecting ground troops from missile attack, but the Rules of Engagement allowed the Battery to fire in self-defence. Because its communications suite was still in transit from the US, contact with the Battalion HQ and other units was through a radio relay with a nearby Battery, which was equipped with voice and data links to and from the Battalion HQ. The lack of communications equipment meant that the Patriot crew did not have access to the widest possible "picture" of the airspace around them to build situational awareness. The Board considered it likely that a better understanding of the wider operational picture would have helped the Patriot crew, who would then have been more likely to identify ZG710 as a friendly track, albeit one without a working IFF. The Board concluded that the autonomous operation of the Patriot battery was a contributory factor.

### Patriot IFF Procedures.

13. IFF is a system designed to identify automatically whether or not a particular asset, such as an aircraft, is a “friend or foe”; civilian Air Traffic Control also use it to identify and track aircraft. A signal is sent from the ground or air to the aircraft, which then replies. There are five different modes of IFF, which can work in parallel or alone. These include Mode 1 (an unencrypted code, which was used in Iraq by all the Coalition aircraft) and Mode 4 (an encrypted form of IFF).

14. Investigation showed that the Patriot Battery’s IFF interrogator for Mode 4 was working throughout the engagement period, but that Mode 1 codes were not loaded. The Board believed that autonomous operations without voice and data connections to and from Battalion HQ might have contributed to the difficulty the Battery had in receiving the Mode 1 IFF codes. The Board concluded that the lack of IFF Mode 1 codes increased the probability of the accident, and was therefore a contributory factor.

### ZG710’s IFF system.

15. The Board considered IFF serviceability, potential IFF failures, and aircrew actions relating to the IFF. The Board was able to discount external damage to the IFF.

a. Serviceability. The ground engineering check on ZG710’s encrypted Mode 4 IFF was completed satisfactorily pre-engine start, and an RAF Regiment Rapier Missile unit that regularly checked the IFF of departing aircraft did not report the aircraft or log a fault. In line with extant procedures, only Mode 4 was checked on the ground. However, there is no firm evidence that ZG710 responded to any IFF interrogations throughout the entire mission, although there is evidence that the navigator checked the IFF switches at the appropriate times. The Board concluded that ZG710’s IFF had a fault and, as an IFF Mode 4 response would have prevented the Patriot Anti-Radiation Missile classification and engagement, concluded that the lack of IFF at the time of the accident was a contributory factor.

b. Failure Modes. Following initial investigation, it became apparent that certain power failures associated with the IFF may not be displayed to the crew. The most likely explanation for the absence of an IFF response was that there had been a power supply failure. The Board recommended that further work be conducted to research the failure modes, reliability and serviceability of the Tornado IFF system.

c. Aircrew Actions. The Board considered whether the navigator could have accidentally or consciously switched off the IFF. The Board concluded that the navigator did not disable the IFF either accidentally or consciously.

The Board concluded that ZG710's IFF had a fault, which was unknown to the aircrew, and that the lack of IFF at the time of the accident was a contributory factor.

#### Aircraft Routing and Airspace Control Measures.

16. ZG710 followed the published speed and height procedures for a return to Ali Al Salem. If the position of the Patriot batteries and the likely "arcs" of their missiles had been taken into account in writing the procedures, ZG710 might have taken a different route. In addition, procedures were in place to deal with a situation where an aircraft's IFF had failed, but the crew would have needed to know that the IFF was inoperative to employ them. The Board concluded that airspace routing, airspace control measures and a breakdown in planning and communication were contributory factors in the accident.

#### Instructions.

17. The Board considered that the instructions available to aircrew regarding aircraft operating without IFF were misleading and that this was a contributory factor.

### **RECOMMENDATIONS**

18. The Board made 12 recommendations including the following:

- a. Further work is conducted to research the failure modes, reliability and serviceability of the Tornado IFF system.
- b. Closer co-ordination is implemented between planning and operations organisations regarding airspace usage.
- c. The US Board of Officers and US Safety Board receive a full copy of the RAF Board of Inquiry.
- d. UK liaison officers at US Central Command (CENTCOM) should follow up on US actions following issue of their Report.
- e. The RAF Board of Inquiry report is used to inform the process of Lessons Identified from the War in Iraq.

19. The Commander-In-Chief RAF Strike Command, who reviewed the Board, agreed with the Board's recommendations, and made the following additional recommendations:

- a. A positive challenge and response IFF check be completed after take-off between every aircraft and an appropriate control authority.
- b. The Tornado IFF installation be modified to ensure that the cockpit warning is triggered in all failure modes.

- c. Operational doctrine is examined to enhance inter-component Combined Air Operations Centre liaison and air space co-ordination.

The recommendations are currently being implemented.

## **CONCLUSION**

20. The war in Iraq was completed in a highly efficient and effective manner, for which all those involved must take great credit. As part of that campaign, the crew of ZG710 conducted a dangerous and demanding combat mission in an exemplary manner yet did not return safely. Overall, the losses suffered by the Coalition were remarkably low, particularly in the air, and ZG710 was the only Royal Air Force aircraft lost during the war. The Board of Inquiry has established the causes of this tragic accident and has highlighted the various factors that contributed to it. As is often the case, these factors were complex, many and various; the Board's recommendations are now being implemented.