RAF Form 412A
(Revised 2/97)

Copy No 1 of 7

ORIGINAL

ROYAL AIR FORCE
BOARD OF INQUIRY/UNIT INQUIRY
INTO AN
AIRCRAFT ACCIDENT
OR INCIDENT

PART 1 - GENERAL DETAILS OF THE ACCIDENT OR INCIDENT

DATE	23 APR 08	**LOCATION AND GRID REFERENCE**			
AIRCRAFT TYPE(S)		MARK(S)	SERIAL NUMBER(S)		PARENT UNIT(S)
TYPHOON		FGR4	ZJ943		RAF CONINGSBY
NAME(S) OF PILOT(S)		FLT LT [redacted]	PARENT UNIT(S)		RAF CONINGSBY

NUMBER OF CASUALTIES					
KILLED			INJURED		
CREW	PASSENGERS	OTHERS	CREW	PASSENGERS	OTHERS
0	0	0	0	0	0

BOI FOR TYPHOON ZJ943 ACCIDENT – 23 APR 08

PART 1.1
DETAILS OF THE BOARD

601010

RAF FORM 412 (ADP)
(Revised 2/97)

ROYAL AIR FORCE
PROCEEDINGS OF A BOARD OF INQUIRY
INTO AN AIRCRAFT ACCIDENT

PART 1.1

DETAILS OF THE BOARD

Assembled on 24 Apr 08 at 1600L at HQ AIR.

By order of the Chief of Staff (Operations).

To inquire into an accident involving Typhoon FGR4 ZJ943 at 1456Z on 23 Apr 08 at NAWS China Lake.

1. Composition of the Board.

Duty	Rank, Name, Service No & Decoration	Branch	Unit
President	Wg Cdr [redacted]	GD(P)	HQ 1 Gp
Members	Sqn Ldr [redacted]	GD(P)	29 Sqn
	Sqn Ldr [redacted]	ENG	13 Sqn
	Flt Lt [redacted]	GD(P)	IX(B) Sqn
In Attendance (QR 1261)	Wg Cdr [redacted]	RAFCAM	
	Sqn Ldr [redacted]	GD(P)	DAS
	Sqn Ldr [redacted]	ENG	DAS
	WO [redacted]	ARO	JART
	Ms [redacted]	RAFCAM	
	Mr [redacted]	AAIB	
	Mr [redacted]	BAe	

2. Full Terms of Reference.

a. Investigate the circumstances of the accident to Typhoon FGR4 ZJ943 at 1456Z on 23 Apr 08.

b. Determine the cause or causes of the accident and examine related factors.

c. Collate and secure all available information relating to the accident.

d. Ascertain degree, cause and time of injury suffered by persons both Service and civilian.

e. Detail the circumstances, and determine as far as possible, the likely sequence of events that caused the incident.

f. Report any tactical, operational or flight safety matters of an urgent nature to COS (Ops) without delay.

g. Investigate any operational support issues that might pertain to the accident and, in particular, whether the basic reporting system for the initial report outlined in JSP 551 Vol 1 Section 200 and Annex F was utilised.

h. Ascertain if Service personnel involved were on duty.

i. Ascertain if all relevant orders and instructions were complied with.

j. Ascertain if aircrew escape, survival and rescue facilities were utilised and functioned correctly.

k. Ascertain extent of damage to the aircraft, public and civilian property.

l. Assess any human factors involved in the accident.

m. Make appropriate recommendations and observations.

n. Ensure COS (Ops) is regularly updated on progress and finding s of the Board.

PART 1.2
NARRATIVE OF EVENTS

GLOSSARY OF TERMS AND ABBREVIATIONS

AAIB	Air Accident Investigation Branch
ACT	Air Combat Training
AIS	Air Information Sub-System
A/L	Approach and Landing
AOA	Angle of Attack
ASRAAM	Advanced Short Range Air to Air Missile
ARDS	Advanced Range Data System
ATEC	Aircraft Test and Evaluation Centre
BAES	BAE Systems
BDS	British Defence Staff
BoI	Board of Inquiry
CSG	Computer Symbol Generator
CSMU	Crash Survivable Memory Unit
DOD	Department of Defense
DVM	Digital Volt Meter
EADS	European Aeronautics Defence Systems
ECS	Environment Control System
ELC	Enhanced Lighting Controller
EPC	Eurofighter Partner Company
FCS	Flight Control System
GPS	Global Positioning System
HD	Head Down
HN	Host Nation
HP	High Pressure
HUD	Head-Up Display
ITSPLs	Integrated Tip Stub Pylon Launchers
kts	Knots
LDP	Laser Designation Pod
LGC	Landing Gear Computer
LGS	Landing Gear Selector
LP	Low Pressure
LRI	Line Replaceable Item
MELs	Missile Ejection Launchers
MHDD	Multi-Function Head-Down Display
MLG	Main Landing Gear
MMR	Multi-Mode Receiver
NAWS	Naval Air Weapons Station
NLG	Nose Landing Gear
NVM	Non-Volatile Memory
OEU	Operational Evaluation Unit
OT&E	Operational Test and Evaluation
PAT	Production Acceptance Test
PoF	Phase of Flight
PMDS	Portable Maintenance Data Store
RAF	Royal Air Force
QWI	Qualified Weapons Instructor
RTS	Release To Service
SDR	System Design Responsibility
S/N	Serial Number
SEM	Scanning Electron Microscope
SME	Subject Matter Expert
STTTE	Special to Type Tests Equipment
TC	Temporary Clearance
UCS	Utilities Control System
VFR	Visual Flight Rules
VVR	Video Voice Recorder

PART 1.2

NARRATIVE OF EVENTS

(All Times LOCAL)

1. **Introduction**. Typhoon FGR4 ZJ943 of XI Sqn, but operated by 17(R) Sqn, the Typhoon Operational Evaluation Unit (OEU), deployed to N America on 31 Mar 08 in support of HIGHRIDER 08-1. At 0700L on 23 Apr 08, the aircraft launched from Naval Air Weapons Station (NAWS) China Lake, California, for a Trial DAYSTAR air-to-surface Operational Test and Evaluation (OT&E) sortie in the adjacent weapons range. After successfully completing a range detail, the pilot flew a standard Visual Flight Rules (VFR) recovery to NAWS China Lake and broke into the circuit. Having selected the undercarriage handle to the DOWN position at the appropriate point in the pattern, he commenced a finals turn and touched down on the runway with the undercarriage fully retracted and the doors closed. Significant damage to the underside of the aircraft, underwing and under-fuselage stores, and the runway ensued and the airframe ignited approximately 2500 ft from the touchdown point. The aircraft remained on the runway throughout and was vacated by the pilot when it eventually came to a halt. Airfield crash vehicles responded and, with the fire extinguished, standard post-crash management procedures were initiated.

2. **Pilot Background**. [redacted] Witness 1, 2

[redacted] Annex C

3. **Aircraft Background**. ZJ943 was a Typhoon FGR4 (Block 5) at SM/Typh/0052A software standard and fitted with 2 EJ200 engines. The aircraft was fitted with 6 underwing pylons, one underfuselage pylon, 2 Integrated Tip Stub Pylon Launchers (ITSPLs), 4 Missile Ejection Launchers (MELs). In preparation for the sortie, the aircraft had been configured with a Litening III Laser Designator Pod (LDP) on Stn 13 (centreline), an Advanced Range Data System (ARDS) GPS pod on Stn 1 (R/H outer underwing), an ASRAAM Acquisition Training Missile (ATM) on Stn 2 (L/H outer underwing) and six inert 1000lb free fall bombs on the remaining underwing pylons. Annex B

4. At the time of the accident, ZJ943 had flown 85.46 hrs, having been delivered to the RAF on 10 Jan 08 with 3.25 hrs recorded. This was the last Tranche 1 Block 5 production aircraft delivered to the RAF and was to be allocated to XI Sqn as 'DK'. However, due to delays in delivering other aircraft, ZJ943 was accepted by 17(R) Sqn to support the OEU's trials programme and deployment on Ex HIGHRIDER 08-1, and had therefore been fitted with Flight Test Instrumentation (FTI) wiring and recording devices during acceptance.

5. The Ex HIGHRIDER trail departed RAF Coningsby on 31 Mar 08 and arrived at NAWS China Lake on 2 Apr 08. ZJ943 was then flown on trials sorties until 11 Apr 08 at which point SM/Typh/0052A[1] was embodied. This was completed on 15 Apr 08 but the aircraft did not subsequently fly until 21 Apr 08 due to recurring Environmental Control System (ECS) problems. It then flew a further 3.04 hrs before the accident, remaining fully serviceable throughout. At the time of the accident, 7 engineering instructions were outstanding. Annex B

6. **Previous 48 Hours**. Two days prior to the accident the pilot had worked a 12-hour day, albeit on the ground preparing air-to-surface briefs for frontline pilots on Ex TORPEDO FOCUS at Davis-Monthan AFB, Arizona, in May 08. The following day, he worked just short of a 9-hr shift, planning and leading a 4-ship range sortie, which was subsequently curtailed after one hour airborne due to a number of equipment failures. After debriefing, he left work at 1800 to ensure that he was appropriately rested in anticipation of an early start the following morning. After having dinner with colleagues, he retired to bed at 2120 and slept well thereafter. Reporting for duty at 0500 on 23 Apr 08, he was fit, well rested and suitably prepared to fly. Witness 1 Witness 4

7. **Pre-flight Briefing**. After eating a light breakfast, he began briefing at 0530 as callsign Gauntlet 13, the third aircraft in a flight of 4. The sortie was thoroughly briefed by the lead pilot, Gauntlet 11, and authorised appropriately. The briefed weapons profiles included 10°, 30° and 40° dive attacks, with Gauntlet 12 and 14 briefing an altex of 1v1 Air Combat Training (ACT) for the benefit of a supernumerary pilot flying in the rear cockpit of Gauntlet 14. Witness 1, 3 and 4 Exhibit 1

8. **Pre-Accident Airborne Events**. The pilot of Gauntlet 13 walked first, as briefed, and had an uneventful start up, taxy and take off, getting airborne on time at 0700. On handover to China Lake Control he was cleared to enter R2505 Air Weapons Range and after checking in with his range controller, he undertook a range recce before completing a dry pass and 8 hot passes. After releasing his final weapon, he confirmed that all his switches were safe and contacted China Control for recovery to the airfield. Witness 1

9. **Accident Events**. A standard VFR recovery to Runway 21 was Witness 1

[1] A pre-Release to Service version of the multi-role Software Release Package 4.2.

flown and, once in contact with China Tower, Gauntlet 13 positioned for a left-hand break into the visual pattern. The break was initiated at the upwind end of the runway from 300 kts, 3800 ft AMSL/1560 ft AGL descending to be established at 3300 ft downwind. When at around 235 kts on his downwind heading, the pilot selected the undercarriage by moving the Landing Gear Selector (LGS) to the DOWN position. The aircraft entered Approach & Landing Phase of Flight (A/L PoF), at which point the pilot's attention was immediately drawn to a RED MMR (multi-mode receiver) caption on the Dedicated Warning Panel (DWP) and the associated audio, both of which he cancelled. After calling "Gauntlet 13 base, gear, full stop"[2] on the China Tower frequency, the pilot commenced the finals turn from 3300 ft and approximately 210 kts. His radio call was acknowledged by the Tower Controller, who cleared Gauntlet 13 to land. The final turn was uneventful and the speed and Angle of Attack (AOA) within limits throughout. At about 70 ft RADALT, the pilot prepared to flare but, thinking that this may have been a little premature, he applied a small amount of power to check the rate of descent and consequently landed just beyond the usual touchdown point.

10. Because he had landed slightly long, the pilot elected to lower the nosewheel on to the runway earlier than normal in order to commence braking. However, as he did so, he felt a loud thump and heard a bang from under the nose of the aircraft. Almost immediately, he heard another loud bang from the right side of the aircraft. Perceiving that he was travelling down the runway in a nose-down condition, he diagnosed a burst tyre. At that moment, the aircraft began to slew to the right and the pilot considered ejecting; however, he discounted this option when it became clearer that the aircraft was unlikely to leave the runway. In an attempt to slow down more quickly, he successfully deployed the brake chute and endeavoured to maintain directional control with rudder inputs. Once the aircraft had stopped, and aware of the flames towards the rear of the aircraft, the pilot egressed and moved quickly to safety.

11. **Escape, Survival and Aircraft Impact**. The aircraft escape system was not used. When the pilot began to lose directional control of the aircraft, he briefly considered ejection. However, the aircraft quickly stabilised and he elected to remain in the cockpit. Annex I

a. **Egress**. Once the aircraft had come to a complete standstill, the pilot carried out an emergency ground egress. When the canopy was fully open, he stepped on to the left hand fuselage strake and jumped to the ground. He saw that flames were quickly spreading forward from the rear of the aircraft and therefore ran to the edge of the runway and, subsequently, into the scrub where he awaited the emergency services. Although shaken, the pilot was uninjured.

b. **Accident Site**. The aircraft was resting on the remains of the centre pylon, on its engine intake, and on the outboard stores,

[2] The USAF/USN SOP, equivalent to the UK call of "Finals, gear down".

approximately 4000 ft from the Runway 21 threshold, left of the runway centreline and cocked slightly to the right. The remains of the laser targeting pod, which had been mounted on the centre pylon, were scattered along the runway. The impact marks on the runway were consistent with the aircraft having touched down gently on its laser targeting pod, close to the Runway 21 threshold. The pod had then abraded away, eventually shedding its contents and digging grooves into the runway surface. As the pod abraded away, the aircraft sank resulting in the outboard stores touching and scraping along the runway. The aircraft remained close to the runway centreline for most of its deceleration and then deviated to the left before coming to a rest. The drag chute had been deployed and had operated as designed. The LGS was found in the DOWN position, all 3 landing gear doors were closed and locked, and the battery switch and both throttle levers were all in the OFF position.

12. **Conclusions**. The Board concludes that:

a.	The flight was properly authorised.	Exhibit 1
b.	The flight was adequately briefed.	Witness 3
c.	The pilot was competent to undertake the flight.	Witness 2
d.	The aircraft was serviceable to undertake the flight.	Witness 1, 9
e.	The weather was suitable for the flight.	Exhibits 2

DEGREE OF INJURY

13. The Board finds that:

a. **Service Personnel**. There were no injuries to any Service personnel.

b. **Civilian Personnel**. There were no injuries to any civilian personnel.

WHETHER SERVICE PERSONNEL WERE ON DUTY

14. The pilot was on duty at the time of the accident. Witness 4

AIRCRAFT ESCAPE FACILITIES

15. The aircraft escape system was not used.

DAMAGE TO AIRCRAFT, PUBLIC AND CIVILIAN PROPERTY

16. **Aircraft and Role Equipment**. The damage to ZJ943 is categorised as Provisional Category 4, requiring repair or replacement of all Annex E

damaged items. A further assessment will be required once the aircraft has been recovered to the UK and the full extent of the damage has been determined. The aircraft had suffered significant fire damage to its underside, to the wing inboard leading edges and to the inboard elevons. The fire evidence is consistent with the fire having ignited after the aircraft came to rest, or was almost at rest. On examination, there was evidence of a substantial fuel leak from the underside centre fuselage, in all probability from the main fuel feed pipe upstream of the LP cocks. The Litening III LDP was destroyed on impact with the runway. Annex H

17. **Public (MOD) Property**. There was no damage to MOD property.

18. **Public (DoD) Property**. There was significant damage to the runway and runway intersection which required immediate temporary repair in order to re-open the airfield for normal operations. Longer-term repairs will be required in due course. The costs of both temporary and long-term repairs is currently estimated to be in excess of $124 000[3]. After seeking guidance from BDS Washington, it was agreed that the RAF would make good all damage to DOD property and the Board advised NAWS China Lake to invoice the RAF through the existing Foreign Military Sales process. Exhibit 3

19. **Civilian Property**. There was no damage to civilian property.

LOSS OF, OR DAMAGE TO, CLASSIFIED MATERIAL

20. There was no loss of classified material due to the accident and the crash sight was secured by the HN in accordance with routine Post-Crash Management procedures. Four days after the accident, the wreckage was removed under the Board's direction and re-located to a secure on-base compound for close examination. The Board subsequently authorised removal of classified material from the aircraft and initiated recovery of the aircraft back to the UK. The IPT will manage the recovery project assisted by Air Command and the Joint Aircraft Recovery and Transportation Squadron (JARTS). The aircraft and any components removed from it during the recovery will remain quarantined until released by the Board upon completion of the investigation.

DIAGNOSIS OF CAUSES

AVAILABLE EVIDENCE

21. **Evidence**. To assist the Board in their deliberations, a considerable amount of evidence was available from an early stage including:

a. The aircraft crash site and wreckage.

[3] Excluding the costs of airfield emergency response.
[4] Quarantined within Engineering Support System (ESS) database.

b. Crash survivable Memory Unit (CSMU), Portable Maintenance Data Store (PMDS) and Video Voice Recorder (VVR) data. Exhibit 4 Annex H Exhibit 6, 11

c. The pilot, formation leader and authoriser, key Sqn aircrew and engineering personnel.

d. Key HN personnel including the NAWS China Lake duty air traffic controller, Assistant Fire Chief, and a civilian witness.

e. Maintenance documentation for ZJ943[4].

22. **Services**. To assist the Board in its investigation, the following services were available:

a. An Aviation Psychologist and Accident Investigator from RAFCAM. Annex G

b. An AAIB Inspector. Annex D

c. A BAES Air Accident Investigation Specialist, who had access to a variety of external technical experts including representatives from BAES and EADS-D[5]. Annex F

FACTORS CONSIDERED BY THE BOARD

23. At an early stage, the Board was able to discount airframe structural failure, birdstrike, pilot incapacitation and weather as factors in the accident.

24. While not discounting other possible failures and factors, the Board concentrated its investigation on the following factors in determining the cause of the accident:

a. Serviceability of the aircraft, focusing on the landing gear and associated systems including:

(1) Hydraulics and utilities.

(2) Landing Gear Computer (LGC).

(3) Landing Gear Selector (LGS).

(4) Associated cockpit indications.

b. Aircraft software standard.

c. Human factors:

[5] EADS-D has System Design Responsibility (SDR) for the landing gear.

(1) Fatigue.

(2) Arousal level.

(3) Distraction.

(4) Mental model.

(5) Cockpit workload.

d. Organisational factors:

(1) Gear lowering procedures.

(2) OEU workload and influences.

(3) OEU working practices.

(4) HF training.

DISCUSSION OF FACTORS

25. **Serviceability of the Aircraft**. The Board concludes that the aircraft was serviceable and had responded normally throughout the flight up to the point at which the pilot attempted to lower the gear. Preliminary examination identified that, at touchdown, the landing gear appeared fully retracted, the doors closed and locked, with the LGS in the DOWN position. Analysis of the CSMU data confirmed that the LGS had been selected to DOWN but the doors and gear did not travel, and that an emergency gear selection was not made. Analysis of the PMDS data showed the failure messages 'LDG_COMPUTER_FAIL' and 'LDG_NML_UC_SELC_FAIL'. Both messages were instantaneous and arose 1.5 secs after the DOWN selection. These two failure messages would indicate a disparity between the actual position of the LGS and the position of the LGS as detected by the LGC. Witness 1 Exhibit 6

a. **Hydraulics and Utilities**. The hydraulics and utilities systems remained fully serviceable throughout the sortie until engine shutdown. The Board concluded, therefore, that a failure in the hydraulic or utilities systems was not a factor in the accident. Exhibit 6

b. **Landing Gear Computer (LGC)**. The LGC provides control, interfacing, monitoring and test functions for the landing gear, brakes and anti-skid systems. Three sorties prior to the accident, the LGC was changed as part of a diagnostic rob for another aircraft but this maintenance activity is thought to be unrelated. No other significant landing gear related maintenance activity had taken place on this aircraft since delivery from the production line. The LGC was removed from the aircraft and shipped back to the UK for further examination. Bench testing has subsequently confirmed that the Witness 5

LGC was fully serviceable at the time of the accident and has therefore been eliminated by the Board as a factor.

c. **Landing Gear Selector (LGS).** The LGS contains 8 microswitches. Two of these microswitches, S7 and S8, are wired directly to the LGC and are used to determine the gear position demanded by the pilot. The LGC requires signals from both of these microswitches to agree before commanding the gear to move. The Landing Gear Extension and Retraction Equipment Fault Isolation Procedure calls for the disconnection of the LGC connectors J1-J2 to allow continuity checks to be carried out. However, in order to preserve the integrity of the connector, it was agreed that the requirements of the above procedure would be carried by identifying each wire in turn and cutting the wire outside of the connectors, first at the LGC and then at the LGS. Annex D, F

(1) As each wire was identified and cut, a continuity check was carried out that confirmed an open circuit in wiring loom 6TUC, indicating an open circuit in either the aircraft wiring or the LGS itself. This procedure was repeated with the wires cut at the LGS, which confirmed an open circuit within the LGS that would normally be closed with the LGS in the DOWN position.

(2) The LGS was removed from the aircraft by cutting the wires to the connectors and the continuity check was repeated using the wires directly into the selector and this again revealed the same anomalous open circuit. This result indicated a problem either with the wiring into the LGS or the microswitch inside and proved that the open circuit was not present in the aircraft wiring. The LGS was then X-rayed and returned to the UK for further detailed examination by the manufacture with aircraft connectors, J1 and J2, still connected. The anomalous open circuit across connector J2 (from pin 27 to pin 13), was confirmed and the connector was carefully removed. There was no evidence of damage to the connector, or any contamination, and further continuity checks revealed that the open circuit was internal to the LGS.

(3) Internal examination revealed the LGS to be in good condition and, on ruling out any loose connections, a further continuity check confirmed that the open circuit was present in the microswitch itself, one of the 2 microswitches wired directly to the LGC and used to determine if the gear should be commanded up or down. The short circuit was subsequently shown to be attributable to a failure of a moving contact. Such an open circuit condition would send conflicting signals to the LGC from microswitches S7 and S8, thus preventing the landing gear from travelling and generating the fault messages observed.

The Board concluded, therefore, that a failure in the LGS was a cause of the accident.

d. **Cockpit Indications of Normal Gear Operation**. Under normal operation, the status of the landing gear is displayed in-cockpit in 2 places:

(1) **Head-down Landing Gear Status Display**. Three green indicators are displayed on the Landing Gear Status Display on the left quarter panel above the LGS and illuminated when the respective gear leg attains the down and locked position. Upon extension, the 6 proximity sensors on the gear actuators[6] feed into the LGC, which drives the relay outputs for the green indications. The signals then run from the LGC into the cockpit via the lighting controller. At all other times, including the transition phase, the gear lights are occulted. In addition, while the gear is in transit, 2 red LEDs in the LGS will flash to reflect that the actual landing gear position does not correspond with the position as defined by selector position, regardless of the status or movement of the undercarriage.

(2) **HUD**. When the landing gear is commanded to move by selection of the LGS to DOWN, and any one of the door unlocking microswitches changes state, the LGC instructs the Computer Symbol Generator (CSG) to display the gear status indications in the HUD[7]. If the CSG back-path monitoring function identifies that incorrect data is present, the HUD will be blanked. However, this only applies to parameters for which the HUD is the primary source of flight reference information. For other HUD displays such as the landing gear position, the RTS[8] dictates that HUD symbology must be cross-monitored with alternative sources of information.

Of note, however, a second order effect of the LGS being selected to the DOWN position is the change in PoF from Nav to Approach & Landing (A/L), which is driven wholly by the position of the LGS. Four microswitches in the LGS, independent of the LGC, change state and signal the Flight Control System (FCS) to enter A/L PoF, with a distinctive change in both HUD and Right-hand Multi-Function Head-Down Display (R MHDD) symbology. Therefore, under normal operation, selecting the LGS to DOWN will command a change in PoF to A/L and, as soon as the gear starts to travel, will display gear status in the HUD.

[6] Left main gear, nose gear and right main gear.
[7] Either **-X-X-X-** for gear travelling or **D D D** for gear down and locked.
[8] Typhoon FGR Mk 4 and T Mk 3 RTS (C 20.2.2).

e. **Cockpit Indications of Gear Malfunctions**. The LGC Risk Class 1 software in the Monitor Processor of LGC System 1 continuously checks to see if the GEAR NOT LOWERED condition has been met and transmits this on the UCS Bus to the CSG. If the condition has been met, the HUD subsequently displays 'GEAR', flashing at 4hz, with a simultaneous voice audio warning. The warning is only generated if all of the following conditions are satisfied:

(1) Aircraft below 500 ft RADALT.

(2) Aircraft speed below 180 kts KDAS.

(3) LGS in the UP position.

(4) Both left and right throttles set below 85% N_H.

If the LGS is moved away from the UP position, the GEAR warning will not be generated, regardless of aircraft height, speed or throttle settings. The actual position of the gear is not used, in any circumstances, either to generate or suppress the warning. The Board therefore considered that the way in which Typhoon gear malfunctions are detected and displayed to the pilot was a contributory factor in the accident.

The Board concluded that, due to the failure in the LGS, the LGC did not receive the necessary down signals and therefore left the landing gear in the UP position. As a consequence, there was no signal to the CSG demanding that gear status indications be generated in the HUD, which was confirmed by examination of the Video Voice Recorder (VVR). In addition, there was no indication of gear travel, or subsequent status, on the head-down Landing Gear Status Display. However, the aircraft did enter A/L PoF with all the corresponding changes in the HUD and R MHDD symbology, and testing has confirmed that even with the short circuit condition as found in the LGS, the flashing red LEDs would have been present. Exhibit 11 Annex F

26. **Aircraft Software Standard**. ZJ943 is a Block 5 (FGR4) Typhoon configured to SM0052a software standard, an early release of the multi-role Software Release Package 4.2, and operated by the Typhoon OEU under a Temporary Clearance (Clearance with Limited Evidence). SM0052 was originally embodied by 17(R) Sqn on ZJ815 and flown as a trials fit, under QinetiQ Airworthiness Release (QARel), by ATEC pilots before wider embodiment across the OEU fleet.

a. **Restrictions**. The original design intent for SM0052A required the MMR and DME-P circuit breakers to be set to power the related equipment. However, without the appropriate clearance evidence, use of the equipment was not permitted and therefore the circuit breakers could not be reset. Accordingly, Para C17.7 of Witness 12

Annex A to Temporary Clearance 1032 states that 'MMR is cleared for installation and has been electrically isolated'. The effect of this electrical isolation is a permanent AMBER MMR caption on the DWP from aircraft power up, transitioning to a RED MMR caption, attention getters and audio, when the aircraft enters A/L PoF. Early flights with SM0052A had exposed both ATEC and 17(R) Sqn pilots to these warnings, which had been noted as a nuisance to the pilot. This was covered by 17(R) Sqn in their 'SM 52 Issues Observed' log and presented at the Review Meeting on 5 Mar 08, post-QARel flying.

b. **Technical Advice**. The ATEC Customer Report on SM0052A recognised the distraction hazard associated with the RED MMR caption on a landing gear DOWN selection. Initial clearance advice from BAES Avionics acknowledged the issue and advised users to inhibit the warning by manipulation of the aircraft's data-set. This was also reflected in the QinetiQ Independent Safety Advice. However, specialists highlighted a functional limitation of the Engineering Support System software that ruled out this option and the matter therefore remained unresolved. Witness 12 Exhibit 12

Given that the ATEC Customer Report on SM0052A recognised the distraction hazard associated with the RED MMR caption on a landing gear DOWN selection, the Board concluded that the aircraft software standard was a contributory factor in the accident.

27. **Human Factors (HF)**. Given the nature of the accident, the Board considered that there was a clear HF element. A more detailed analysis of the relevant HF is therefore summarised in paras 32-33.

28. **Organisational Factors.**

a. **Gear Lowering Procedures**. In principle, the gear lowering procedures in Typhoon are no different to any other FJ aircraft. However, there has been a proliferation of gear malfunctions of late and the Board therefore elected to examine Typhoon procedures and mitigation strategies in more detail.

(1) **Typhoon SOPs**. Under current Typhoon SOPs, there is only one mandated gear check: the one that takes place coincident with gear lowering in the pattern as defined in the Typhoon Flight Crew Checklist (FCC)[9]. The radio call made on finals in which the status of the gear is confirmed does not specifically require a further visual check of cockpit gear indication, but merely confirms to Air Traffic Control the findings of the previous check undertaken downwind. Moreover, for multiple circuits, it is the SOP to leave the gear down once selected in order to reduce the number of gear

[9] AP101B-5400-14 Card **N-18 PRE LANDING**: Landing gear.....Below 290 KDAS, DOWN, 3 greens/DDD.

cycles[10]. It was the Board's opinion that such a procedure could lead to negative training, false behaviour patterns and, ultimately, a degree of complacency with respect to the position of the gear at any given point on the downwind leg or thereafter.

(2) **AP3456 Guidance**. The RAF Manual of Flying advises[11] that, after carrying out pre-landing checks on the downwind leg, pilots should complete final checks before commencing final approach, in particular ensuring that the undercarriage is locked down. Furthermore, the Manual goes on to state that the 'Finals' call should be made during the finals turn, confirming, if applicable, that the undercarriage has been checked.

(3) **Last Chance Checks**. Although not mandated, many pilots have a personal preference for a self-initiated last chance gear check on short finals. While airmanship may well dictate a second visual check by the pilot at some point prior to touchdown, the Board were unable to confirm any absolute requirement to do so. Witness 2, 3 and 8

(4) **Local Orders**. A spate of nose leg gear (NLG) uplock failures during 2007 led to a number of operating restrictions on the Typhoon Force. As a consequence, Wg PIF 08_2 was raised in order to minimise the risk of damage to property and/or injury to personnel on the ground in the event of aircraft components detaching in flight upon gear lowering. In addition to those measures designed to minimise the aircraft's ground track over any populated areas during gear travel, the Order requires pilots to monitor landing gear travel in order that an early diagnosis of a NLG uplock problem can be made. Exhibit 7

(5) **Risk Management**. The residual risks attendant with the mandated generic gear lowering SOPs are well mitigated in the UK, not least by the widespread use of runway caravans. The Board noted that there was no runway caravan at NAWS China Lake and that no alternative risk mitigation had been employed. Although ATC personnel were encouraged to undertake a visual check of aircraft gear configuration on finals, subject to controller workload, there was no mandated requirement to do so.

In light of the concerns regarding the integrity of the NLG door uplocks, it was clear that there was increased focus on the behaviour and status of the gear after DOWN selection. Nevertheless, it was Witness 2, 3 and 4

[10] The gear is lifed to an average of 1.3 cycles per flying hour.
[11] AP3456 Vol 5 – Part 2, Chapter 2, para 28.

the opinion of the Board that the extant policy for reducing the number of gear cycles in the visual pattern increased the risk of gear complacency and was therefore a contributory factor in the accident. Furthermore, given that the principal method of risk mitigation was absent on the occasion of the accident, the Board regarded the lack of runway caravan to be a contributory factor.

b. **OEU Workload and Influences.** In mid-07, it became apparent that the Typhoon 4-nation core programme would not deliver the UK's desired level of air-to-surface capability[12] before Oct 08. The Typhoon Force has nonetheless made great progress in shifting its capability growth focus from air defence to a timely and meaningful MR capability in order to meet Multi-Role OED (MR OED) on 1 Jul 08 by way of a 2-part plan:

(1) **Project GORDIAN.** Recognising the enormous effort required across all Typhoon DLODs to prepare the Force for MR OED, Project GORDIAN was developed as a manageable route to declaring a credible and deployable MR capability on 1 Jul 08. Given that any residual programme risks would ultimately transfer to, and be borne by, the Training DLOD, the principal objective of the Project was to provide the required number of Combat Ready (MR) Typhoon pilots by MR OED.

(2) **Trial DAYSTAR.** A UK-only Typhoon Combined Test Team (CTT) strategy was developed to deliver the required air to surface capability in sufficient time to allow the frontline to train to the standard required by MR OED. A fundamental element of this strategy was the utilisation of SM0052A software, the early release of the MR Software Release Package 4.2, by the Typhoon OEU. Trial DAYSTAR was created in order to expose a limited number of frontline pilots to the LDP and EPWII capability in advance of a full Release to Service, using SM0052A software under the supervision of the OEU during OT&E.

Critical to the successful conclusion of Project GORDIAN was a productive N America exercise plan incorporating Exercises TORPEDO FOCUS[13] and GREEN FLAG (WEST)[14]. Trial DAYSTAR was therefore the critical path to allowing the frontline to train and the pressure on 17(R) Sqn to complete the Trial on time was widely recognised across the national Typhoon programme. Indeed, the very concept of DAYSTAR was aimed at expediting pilot training and was underpinned by an innovative, accelerated software clearance strategy. In acknowledgement of the aggressive MR OED

[12] Litening III LDP and EPWII.
[13] Davis-Monthan AFB, 28 Apr to 16 May 08.
[14] Nellis AFB, 23 May to 6 Jun 08.

timeline, it was agreed that the QARel route was a pragmatic strategy that would serve to bound the risks and therefore offer a more expeditious route forward than flight trials under an AWC Temporary Clearance that would otherwise have required independent advice from QinetiQ. Evidence suggested that opinion was divided as to whether the pressure on OEU personnel to achieve the task was acceptable. Moreover, it was suggested that the Trial DAYSTAR approach lacked rigour and did not offer the optimal regulatory or airworthiness mechanisms more traditionally associated with the full spectrum of MOD T&E resources. On balance, it was the opinion of the Board that considerable tension in the UK's Typhoon programme exerted significant pressure on the OEU, which may have contributed indirectly to the accident. The Board therefore concluded that OEU workload and external influences may have been contributory factors in the accident. Witness 13

c. **OEU Working Practices**. The lack of understanding amongst 17(R) Sqn aircrew of an SOP Typhoon circuit prompted the Board to examine Sqn flying standards and the broader aspects of Ops Desk administration. A review of ops and training related documentation on 17(R) Sqn at RAF Coningsby was undertaken. Recurring anomalies included: Witness 1, 2 and 3

(1) **Documentation**. There was no apparent consolidated method of tracking all pilot currencies. Whilst there was evidently a spreadsheet tracking some relevant statistics, it was notable that dual checks and IRTs were not included. In addition, there were a number of irregularities in the Pilot Signature (and training) Folders and most were generally incomplete. Exhibit 8

(2) **Currencies**. Typhoon flying currency requirements are laid down in HQ 1 Gp Air Staff Orders (GASOs). While all 17(R) Sqn aircrew appeared to be well aware of the need to adhere to GASOs, albeit that the Sqn sits outside the HQ 1 Gp chain of command, the requirement is not clearly articulated in any readily available reference document. That said, 17(R) Sqn pilots are required to sign as having read and understood GASOs prior to flying. With that in mind, therefore, the Board considered the following currencies to be relevant to the investigation:

(a) **Periodic Pilot Handling Checks**. The policy for periodic checks is defined by HQ 1 Gp Air Staff Orders (GASOs)[15]. Pilot handling checks are valid for a maximum of 12 months[16] and are designed by the

[15] 1G360.110.5 and 1G(3)360.110.2
[16] This is reduced to 6 months for dilutee pilots.
[17] 1G360.200.

checking officer to allow the pilot to practice and demonstrate pure flying skills. The sortie is to include, as a minimum, low speed/high AOA, maximum performance manoeuvring, circuit flying and, where appropriate, asymmetric flying. On checking Ops Desk documentation and available log books, only 4 of the 7 pilots on the Sqn were recorded as having had dedicated pilot handling checks in the previous 12 months. Indeed, all of these were Sqn arrival checks and generally did not follow the prescribed GH sortie profile.

(b) **Standardisation and Evaluation (STANEVAL) of Aircrew**. In order to ensure, *inter alia*, the maintenance of the highest standards of pure flying, GASOs[17] requires formal STANEVAL visits to sqns to take place at an interval not exceeding 2 years. The Board was unable to find evidence of any of the Sqn pilots having flown formally with the Typhoon CFS agent in the previous 2-year period.

The Board concluded that the fact that non-adherence to the policy for periodic pilot handling checks is likely to have precipitated an erosion of flying standards, which remained unchecked in the absence of any STANEVAL visit, and may have contributed to the accident. Furthermore, whilst not a causal factor, the Board considered that the standard of documentation and, in particular, currency tracking, was an other factor.

d. **HF Training**. Tri-Service HF policy[18] outlines a formal through-life training programme delivered in 3 phases, the final one of which is continuation and refresher training at unit level. This policy is supported by a more specific guidance from HQ AIR in which Stn Flight Safety Officers (SFSOs) are directed to work towards providing training at their units using qualified HF Facilitators, or by seeking training from RAF Air Safety Group (ASG). Although the 17(R) Sqn groundcrew had gone some way toward establishing a coherent HF training strategy, this had not been replicated on the aircrew side of the Sqn. Exhibit 9 Witness 5 Witness 3, 4 and 8

RECONSTRUCTION OF EVENTS IMMEDIATELY PRIOR TO THE CRASH

29. The Board considers the following to be the most likely sequence of events in the period immediately prior to the accident:

a. The pilot returned to the circuit without incident and positioned the aircraft downwind. Upon moving the LGS to the DOWN position,

[18] JSP 551 Vol 1 Section 400 – Human Factors Defence Policy.

and verbalising the relevant check, the MMR warning caused an initial startle response, masking any physical sensation of gear lowering and interrupting the pilot's scan pattern by: Witness 1 Annex G

(1) Drawing his attention to the red MMR caption on DWP.

(2) Prompting left-hand movement to cancel the attention getters.

(3) Distracting him from monitoring the gear unlock and travel.

b. Due to an open circuit failure condition in a microswitch within the Landing Gear Selector, the Landing Gear Computer did not receive the 2 'down' signals necessary to initiate gear travel and therefore left the landing gear in the UP position. Although A/L PoF was initiated, as designed, by selection of the LGS to DOWN, there was no indication of gear travel, or subsequent status, on either the head-down Landing Gear Status Display or in the HUD.

c. Based on the pilot's usual habit pattern, he did not re-check the gear on calling "Base, gear, full stop" as he tipped in on finals. With no further check of landing gear status since selection of the LGS to DOWN, the pilot landed wheels up. Annex G

CONSIDERATION OF HUMAN FACTORS

30. When interviewed, the pilot stated that, when operating at home plate, he normally checked the landing gear indications on selection of the LGS to DOWN (Scan 1), verbalising the check accordingly. He went on to say that he did not usually re-scan prior to his normal "Finals, gear down" radio call to ATC (Scan 2) and, more significantly, admitted that, given the QNH-based approach at China Lake, he had prioritised altitude control and had got out of the habit undertaking a final check on short finals (Scan 3). He was also aware of the requirement[19] to monitor gear travel. It is therefore highly likely that he neither scanned the landing gear status indicators, either head-up or head-down, when he made his finals turn radio call, nor did he undertake Scan 3 on short finals. Alternatively, he may have scanned the indications but seen the 3 greens that he was expecting – an effect known as anticipation. Of note, such auto-skill actions are governed at the lower levels of the brain and the pilot would therefore almost certainly not be able to recall the activity. It was therefore a risk on any flight at NAWS China Lake that a systems failure during the pilot's Scan 1 would have remained unnoticed until landing. A closer analysis of the likely influencing factors can be summarised as follows: Witness 1 Annex G

a. **Fatigue.** Although the pilot reported being well rested, he had, like all the 17(R) Sqn pilots, been operating close to the edge of

[19] RAF Coningsby Wing Pilot Information Folder (PIF) 08_02.

the crew duty limitations mandated by GASOs[20] for an extended period during the detachment. Moreover, the range slot allocation had often required the pilots to report for duty exceptionally early in the morning. Indeed, 3 days prior to the accident, the pilot had reported for duty at 0430. Similarly, on the morning of the accident, he left the hotel at 0445 for a mission brief at 0530. The Board noted that all the pilots had acknowledged the demanding flying programme and long working days but, equally, it was evident that crew duty and rest times were strictly enforced, the off-duty routines were appropriate, aircrew fatigue was closely monitored and each pilot was clearly confident that his reporting chain would be fully supportive in the event of any pilot being unfit to fly. That said, it was equally evident that the Sqn was extremely task focused and dedicated to completing the Trial in the necessary timescales. On balance, however, the Board considered that cumulative fatigue may well have been a contributory factor in the accident in that it made the pilot more susceptible to distraction, and therefore interference, during Scan 1.

b. **Arousal Level**. The pilot believed that the mission phase of the sortie was significantly more complex and demanding than the recovery and approach phases, with a marked increase in workload. Consequently, the likelihood of reduced arousal on returning to the circuit cannot be discounted and the Board therefore concluded that this may have been a contributory factor.

c. **Distraction**. The pilot had a widely acknowledged reputation as a highly professional operator with high personal standards. At interview, he stated that he had diverged from the planned order of weapon releases owing to sighting problems during the 40º dive profile. Furthermore, he had also incurred an LDP failure after the first 10º dive hot pass. Given the profile of the sortie in the context of the Trial output, mission evaluation may have been an initial distraction during the recovery phase. Furthermore, during Scan 1 following gear down selection, it is likely the RED MMR warning caused an initial startle response and interrupted the pilot's scan pattern, which should otherwise have included monitoring landing gear travel. Thereafter, the pilot's attention was not drawn back to either the head up or head down gear indications. Furthermore, the presence of other text on the left side of the HUD may have affected the pilot's peripheral pattern recognition thus rendering the absence of HUD gear indications less likely to be detected. The Board therefore concluded that distraction was a contributory factor.

d. **Mental Model**. It is evident that 17(R) Sqn pilots associate the MMR warning with A/L PoF, which is in turn corroborated by the distinctive change in both HUD and R MHDD symbology upon

[20] 1G345.100.2.

selection of the LGS to DOWN. It is therefore possible that the clearly displayed change to A/L PoF, coupled with the RED MMR warning, reinforced the pilot's belief that the gear was down and locked – his gear-down mental model. Moreover, the verbalisation of his gear check downwind, albeit incorrect, further reinforced this. The pilot stated that he had a strong belief that ATC would report a gear-up situation thus reinforcing his mental model when he made his radio call of "Base, gear, full-stop". Given that he believed he had burst his tyres on landing, his gear-down mental model remained until egress. Witness 1

e. **Cockpit Workload**. Due in part to the lack of PAPIs at NAWS China Lake and the QNH based approach to a runway with an elevation of 2240 ft, the pilot reported working slightly harder on short finals compared to an approach at RAF Coningsby and, as a result, had previously taken to omitting Scan 3. The workload was further increased by the efforts to capture 14 alpha in an unfamiliar configuration and with a power setting close to flight idle[21]. It may be reasonable to expect a pilot of his experience to have questioned the reason for such an increased handling burden; however, it is likely that his gear-down mental model was so compelling that the increasing workload remained insignificant. The Board concluded, therefore, that increased cockpit workload associated with an approach to the runway at NAWS China Lake may have been a contributory factor.

31. Given the evidence from previous occurrences of this type, it is likely that a recycle of the LGS would have been successful in achieving gear lowering. Furthermore, rig testing of both the LGC and the LGS has shown that emergency selection of the gear would have functioned as designed and also have allowed the pilot to achieve a safe landing configuration. Therefore, notwithstanding the mitigating factors discussed above, the Board concluded that the omission of a positive check of gear status on the Landing Gear Status Display, the associated primary information source, was a cause of the accident. Annex F

SUMMARY OF CAUSES AND FACTORS

32. **Cause**. The accident was caused by a microswitch failure in the Landing Gear Selector that prevented the gear from operating normally on the DOWN selection, which remained undetected by the pilot. Para 25c Para 32

33. **Contributory Factors**. The Board identified the following contributory factors that did not directly cause the accident but made it more likely to happen:

a. The detection and display of Typhoon gear malfunctions. Para 25e

[21] More normally in the band 60-65%N_H.

b. The aircraft software standard (SM0052A). Para 26, 32c

c. Typhoon gear operating procedures and policy. Para 28a

d. The absence of a runway caravan. Para 28a

34. Furthermore, the Board considered that the following factors may have contributed to the accident:

a. 17(R) Sqn workload and external influences. Para 30a

b. The absence of regular dedicated Pilot Handling Checks and STANEVAL assessments on 17(R) Sqn. Para 30b

c. Pilot fatigue. Para 30f

d. Pilot arousal level. Para 28b

e. Cockpit workload. Para 28c

35. **Aggravating Factors**. Examination of the aircraft wreckage had revealed extensive heat damage to the airframe, consistent with evidence of a fuel leak from the fuselage centreline. The Board considered this leak, the origin of which is still under investigation, to be an aggravating factor. Para 16

36. **Other Factors**. The Board considered that the standard of 17(R) Sqn documentation and ops administration was an other factor in the accident which, if addressed, may prevent future accidents. Para 28c

RELEVANT ORDERS AND INSTRUCTIONS

37. The Board noted that that relevant orders and instructions were complied with except for the following:

a. **Orders**.

(1) The pilot did not comply with the requirements of Wg PIF 08_2 in that he did not monitor the landing gear after the DOWN selection. Para 28a

(2) 17(R) Sqn did not comply with the requirements of:

(a) HQ 1 Gp GASOs 1G360.110.5. and 1G(3)360.110.2 (Periodic Pilot Handling Checks). Para 28c

(b) HQ 1 Gp GASO 1G360.200 (Standardisation and Evaluation of Aircrew). Para 28c

b. **Instructions**. The pilot did not comply with the requirements of:

(1) AP3456 (RAF Manual of Flying) in that he did not ensure that his landing gear was down and locked before commencing his final approach, thereby invalidating his confirmatory gear status radio call during the finals turn. Para 28a

(2) The Typhoon Aircrew Manual (DAP101-5400-1A) and Typhoon FCCs (AP101B-5400-14) in that he did not check the gear status indicators, either head-down or head-up, after his gear down selection. Para 28a

c. **Reporting**. The basic reporting system for the initial report outlined in JSP 551 Vol 1 Section 200, as referenced in OpO 01/08 (HIGH RIDER 08-1 Phase 2), was not utilised. Exhibit 10

OBSERVATIONS

38. The Board observes that:

a. There were no inserts in the pilot's F5250 covering the period of his exchange tour with the RAAF. Para 2

b. While all 17(R) Sqn aircrew appeared to be well aware of the requirement to adhere to HQ 1 Gp Air Staff Orders, albeit that the Sqn sits outside the HQ 1 Gp chain of command, the requirement is not clearly articulated in any readily available reference document. Para 28c, 37a

c. Although a coherent Human Factors (HF) training strategy was evident on the groundcrew side of 17(R) Sqn, there is scope for developing a similar strategy for the aircrew. Para 28d

d. In light of the fact that there was no runway caravan at NAWS China Lake and that no alternative risk mitigation had been employed, HN ATC personnel may well have benefited from a dedicated Typhoon operations brief from a 17(R) Sqn pilot early in the detachment. This would have been all the more relevant given the current focus of the Typhoon Force on nose leg gear malfunctions. Para 28a

e. There is evidence of shortfalls in the routine management of flight safety on 17(R) Sqn that may go some way to explain the significant deviation from the requirements of JSP 551 Vol 1 Section 200 as referenced in OpO 01/08 (HIGH RIDER 08-1 Phase 2). Witness 8, 11 Exhibit 10

f. The BAES Accident Investigation Report includes the findings of a review of all incidents in which the gear failed to travel on selection. In all cases the failures were overcome simply by recycling the LGS through the UP position, thereby clearing any mechanical faults in the microswitches. Annex F

g. HN personnel at NAWS China Lake provided outstanding support to the RAF both at the scene of the accident and throughout the duration of the Board's in-country activities.

i. The post-crash management (PCM) procedures executed by the Sqn were first class and not only set a firm foundation for the Board's investigation but also went some considerable way to preserving the goodwill of the HN.

j. There was a breach of security on the night of 28 Apr overnight at NAWS China Lake in that the compound in which the wreckage of ZJ943 was stored was left unlocked by duty RAF personnel at cease-work. However, the Board was satisfied that there had been no unauthorised access to the compound during the silent hours and that no evidence had been disturbed.

k. Computer modelling by QinetiQ prompted advice in the Temporary Clearance for SM/Typh/0052A to the effect that "when flying with the LDP and in the event that all landing gears fail to travel or only the nose landing gear extends, the LDP must be jettisoned". Consequently, there may be considerable value in allowing QinetiQ access to elements of this Board of Inquiry in order that their computer model may be validated. Exhibit 12

l. The Aircrew Fatigue Management section of HQ 1 Gp Air Staff Orders gives no consideration to, or guidance on, the additional risk of fatigue associated with aircrew transiting multiple time zones.

RECOMMENDATIONS

39. The Board recommends that:

a. The landing gear system element of the Typhoon Safety Case is reviewed to determine whether the current LGS failure rate falls within acceptable limits of risk.

b. All Typhoon operators are reminded of the requirement to adhere strictly to:

(1) Extant landing gear lowering procedures as articulated in the Typhoon Flight Crew Checklist (FCC)[22].

(2) All relevant local Typhoon orders, in particular those pertaining to gear lowering procedures[23].

c. Typhoon gear malfunction and status warnings and

[22] AP101B-5400-14.
[23] Typhoon Undercarriage Operating Restrictions Wing PIF 08-04 (revised and issued 8 Jul 08).
[24] A Eurofighter System Enquiry has since been raised by the Typhoon Support Centre in anticipation of this recommendation.

indications are redesigned such that the GEAR NOT LOWERED condition is predicated on, *inter alia*, actual gear position rather than LGS position. Such a modification may also be sufficient to reinforce the Typhoon Safety Case to such a degree that any requirement to modify the design of the LGS microswitches is negated.

d. The MMR warnings (DWP and audio), coincident with gear lowering, are inhibited on all aircraft with SM/Typh/0052A embodied[24].

e. Typhoon gear operating procedures and policy are reviewed to eliminate negative training, develop and reinforce sound habit patterns and ensure best practice is achieved and maintained.

f. Flying units develop robust mitigation strategies for prolonged periods of operation at airfields without a runway caravan.

g. Consideration is given to amending the Aircrew Fatigue Management limitations, as defined in HQ 1 Gp Air Staff Orders, to reflect the additional risk of fatigue associated with:

(1) Operating at short notice outside regular working hours.

(2) Transiting multiple time zones.

h. A Formal Staff Visit, or equivalent assurance process, is conducted on 17(R) Sqn as soon as reasonably practical.

i. The performance of all aircrew officers in overseas exchange and loan posts is routinely assessed and recorded in their respective F5250s.

j. The applicability of GASOs is captured within the relevant Air Warfare Centre governance and regulatory framework.

k. 17(R) Sqn reviews its training policy to ensure that all Sqn personnel are exposed to an appropriate level of HF training.

l. All flying units provide operations/capabilities briefings to key local personnel when operating for prolonged periods at deployed locations.

m. In the event of future gear failing to lower incidents, full and thorough debriefs of the aircraft recording system are undertaken prior to any rectification, focusing on LDG_COMPUTER_FAIL and LDG_NML_UC_SELC_FAIL failure messages indicative of LGS microswitch failures.

President: [redacted] [redacted] Wg Cdr

Members: [redacted] [redacted] Sqn Ldr

[redacted] Sqn Ldr

[redacted] Flt Lt

Date: 31 July 2008

[redacted]

[redacted]

PART 1.3
REMARKS BY UNIT OR FORCE COMMANDER

20081125-ComdtAWC BOI Comments

HQ Air Cmd – Cmd Avn Safety Officer

25 Nov 08

BOARD OF INQUIRY – TYPHOON ZJ 943 COMMENTS – COMMANDANT AWC

"There are those who have, and there are those who will". Wheels-up approaches to runways are as old as the hills and for that reason were, and still are, deliberately practiced to check the 'belt and braces' system of pilots' and Air Traffic's professionalism and Flight Safety awareness. The reason for wheels-up approaches and landings are many and varied, but tend to revolve around either technical problems or Human Factors - either of which can have a compounding effect on the other.

This avoidable accident is a catalogue of such woe and resulted in the serous damage and probable long-term loss of an aircraft from the front line. The Board are to be congratulated on completing a thorough inquiry and for recognising the cause of the accident with all its contributing, aggravating and other factors, which I fully support. I also agree with their observations and recommendations, most of which have already been implemented.

The Board of Inquiry paints a picture of an accident against a background of contributory factors and a chain of 'events' (or an alignment of the "holes in the Swiss cheese"), where the outcome was dependent on Human Factors and the roll of the dice. The operational requirement; the accelerated tempo of test and evaluation of Typhoon air/ground capability, coupled with the subliminal pressure and desire to succeed; the lack of thorough Squadron housekeeping, detailed background supervision and standardization of Squadron crews, in contrast to the obvious positive hands-on working-level practical supervision of personnel on deployment; flight operations and procedures in a less than familiar local environment; the absence of the familiar RAF runway caravan and its alert Air Traffic personnel; a running history of Typhoon undercarriage malfunctions; an aircraft with a design flaw that predicates the Landing Gear warning system on the position of the landing gear selector (LGS), rather then the actual position of the undercarriage and that reinforces this with highly compelling approach and landing displays; the glitches in SM0052 software that led to startling and distracting MMR warnings upon gear selection; the possible cumulative fatigue of the pilot caused by the tempo and nature of the work, his personal drive, long hours and early starts; and of course, finally – a faulty micro switch in the LGS that prevented the gear from operating normally on the DOWN selection; and the pilots adherence to a faulty mental model, [redacted] – a classic case of "Don't Assume - Check" - which all meant that the lack of undercarriage DOWN indications remained undetected and the pilot landed wheels-up.

So far, so obvious, but I suspect the collusion of a number of other background factors.

Firstly, the RAF is at war, so the operational focus and the psychological connection to operations (especially on an OEU), combined with the desire to forge ahead and make a difference or increase the operational margin, become powerful subliminal drivers to our modus operandi. Everybody knows that the Harrier Force needs to reconstitute and recuperate and that other platforms and capabilities, especially new ones such as Typhoon that have not yet won their spurs, need to be tested in battle and play their part in "The War". The wholly laudable drive to aggressively expand

capability by set dates through coherent Test and Evaluation benefits the Front Line – but it puts pressure on those charged with advancing the programme and those intimately involved with delivering results. If this is kept in proportion, all is well, but it is the subliminal nature of external or individually-interpreted pressure that affects, that becomes a Human Factor and therefore has a bearing on Flight Safety. (I do not wish to rehearse the semantic discussion between Flight Safety and Operational Flight Safety – to me they are the same thing, but war has a habit of making its own rules.)

Secondly, the RAF's focus on Flight Safety as central to everything we did, the way we operated and how we thought as operators has altered from where we were before the Mull of Kintyre Chinook accident. Our people are just as professional, if not better informed than their forbears, but societal and organisational change; a more legislative, yet less rules-based approach to life; the transformation of IFS; and the perception of relegation of Flight Safety to the same bucket as Health and Safety Legislation, have all detracted from the obvious priority previously accorded an approach that certainly kept me from killing or damaging myself and others accidentally. Compound that perceived (though unsubstantiated) change in attitude with not only a "Can-Do", but an operational "Must-Do" (for the troops) attitude – then the assumed context and the background against which decisions are made differs. This is not the Dinosaur's roar for a return to the old days of Air Clues and "How many hours have you got at the top of a loop, son" - but it merits consideration.

This accident was avoidable, we can learn and have learned from the examination of factors and circumstances, practices have been changed and housekeeping done - but at the end of the day the pilot landed wheels up, because the kit let him down and he didn't check - he assumed. There is nothing new under the sun.

[redacted]

J STINTON
Air Cdre
Commandant AWC

PART 1.4
REMARKS BY
CONVENING AUTHORITY

PART 1.4: COMMENTS BY COS OPS

1. The Board has produced a clear view of the events that caused ZJ943 to land without its undercarriage extended. However, I do not agree with the finding that the cause of the accident was the microswitch failure in the LGS. If the normal method of undercarriage selection was the only method of lowering the undercarriage then it would have been the cause, but the Board has shown that use of the emergency lowering system, or even recycling the LGS, should have resulted in the undercarriage extending. Therefore, I believe that the cause should be that the ac was landed with its undercarriage retracted. It is, however, disappointing to note that such a modern and technologically advanced aircraft effectively conspired against the pilot to leave him convinced that the undercarriage was down.

2. Despite his having successfully completed the trials part of the sortie, I am content that the pilot was not under aroused as he arrived back in the circuit, but was concentrating on flying a circuit at an unfamiliar airfield and at QNH altitudes. The fact that the MMR caption took his attention, as it was always going to do, as he selected undercarriage down shows that little has changed since the days of the Phantom; on that aircraft, each time the flap was lowered on entering the finals turn a failure of the boundary layer bleed air was indicated and the 'attention getters' had to be cancelled. That the symbology in the HUD changes to the A/L PoF as the undercarriage handle is moved to the DOWN position, irrespective of the position of the undercarriage, and that HUD and aural indications that the undercarriage is not locked down are only generated if that handle is in the UP position, perhaps shows a lack of Human Factors input at the design stage of the system.

3. It was not, however, only distractions and system factors which led to this accident. I believe that the timescales which have been required to bring the Typhoon into service have resulted, especially within the SAOEU, in the focus being almost solely on operational output, to the detriment of handling skills, necessary administrative support requirements and ac systems knowledge. Perhaps the clear understanding of which orders and instructions the Unit were operating to would have been better understood had more formal periodic inspection regimes still been extant. Notwithstanding the lack of formal inspection of the unit, I am disappointed that crews were not tracking their own currencies. Similarly, the lack of a cohesive flight safety system within the unit could also have been identified, however, on a more positive note, formal flight safety visits to stations have already recommenced.

4. This accident, like many previously, resulted from several events coming together at the same time, under a perception, real or otherwise, of pressure to achieve the task. It is especially disappointing that the design of the aircraft did little to alert the pilot to the fact that the undercarriage had not lowered. That said, the necessary indications were available.

[redacted]

NDA MADDOX
Air Vice-Marshal
COS Ops

PART 1.5
REMARKS BY REVIEWING AUTHORITY

PART 5

COMMENTS BY COMMANDER-IN-CHIEF AIR COMMAND

No matter how technologically advanced an aircraft may be, the basic tenets of flying remain a constant. In this case, and indeed for every flight made, a successful landing is a *sine qua non,* no matter what the complexity or ease of the preceding sortie. In this case there were indications to suggest to the pilot that the landing gear may have been locked down (such as the mode change in the HUD); the fact remains however that the landing gear indicator (the primary source of indication) clearly and correctly showed that it was not. The failure of the LGS initially to lower the landing gear was therefore a major contributory factor, but at that stage of the approach the accident was far from inevitable. There are often distractions during an approach to land: weather; proximity of other aircraft; radio calls; etc. The landing checks for the Typhoon are probably the least complex of all the Service's fast jet types. Adherence to these basic checks, and supported by sound airmanship to cross check during the final turn or short final approach could have prevented a touch down in an unsafe configuration. I therefore agree with the Convening Authority that the cause of the accident was that the aircraft was landed with the landing gear retracted.

The Board, having conducted a comprehensive investigation, highlighted a number of contributory factors, all of which I accept, along with the Board's recommendations. Whilst elements of aircraft warning systems design need to be addressed, it must be stressed that human factors will most probably be part of any "gear up" incident or accident. Therefore sound TTPs (ie airmanship) need to be enforced through good supervision and, most importantly, practised by aircrews. In this regard the most pressing recommendation from this inquiry is the need to instigate regular STANEVAL visits to 17(R) Sqn, and all AWC units, together with the requirement to ensure that up to date regulatory and governance processes are in place for AWC flying units.

[redacted]

Sir Chris Moran
Air Chief Marshal
Commander-in-Chief Air Command

8 May 2009