PART 1.1
DETAILS OF THE BOARD

[redacted]

RAF FORM 412 (ADP)
(Revised 3/08)

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

PART 1.1

Details of the Board

Assembled on 15 Nov 07, 1500Z at RAF Marham.

By order of the Assistant Director Air Systems - Test and Evaluation Support Division (AD AS - TESD).

To inquire into an accident involving Tornado GR Mk4, ZA554 on 14 Nov 07 at 1510Z.

1. Composition of the Board.

Duty	Rank, Name, Service No & Decoration	Branch	Unit
President	Wg Cdr [redacted] S 40	GD	RAF High Wycombe
Members	Sqn Ldr [redacted] S 40	Eng	MOD Whitehall
	Sqn Ldr [redacted] S 40	Fg(P)	MOD Boscombe Down
Observing	Mr [redacted] S 40	BAE Systems	BAES Warton
In Attendance	Wg Cdr [redacted] S 40	Med	RAF Henlow
(OR 1261)	Sqn Ldr [redacted] S 40	Legal	RAF Coningsby
	Sqn Ldr [redacted] S 40	Legal	RAF High Wycombe
	Sqn Ldr [redacted] S 40	Fg(P)	BOIA, RAF Northolt
	Sqn Ldr [redacted] S 40	Fg(N)	BOIA, RAF Bentley Priory
	Sgt [redacted] S 40	Wpn Tech	RAF Marham

[redacted]

[redacted]

Duty	Rank, Name, Service No & Decoration	Branch	Unit
	Sgt [redacted] S 40	Wpn Tech	RAF Marham
	Mr [redacted] S 40	AAIB	Farnborough
	Mr [redacted] S 40	BAE Systems	BAES Warton
	Mr [redacted] S 40	MBA	Higher Denham
	Mr [redacted] S 40	BAE Systems	BAES Warton

Full Terms of Reference.

a. Investigate the circumstances of the accident involving Tornado GR Mk4, ZA554 on 14 Nov 07 at 151OZ.

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

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

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

e. Ascertain if the personnel involved were on duty.

f. Ascertain if aircrew escape, survival and rescue facilities were utilized and functioned correctly.

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

h. Assess any human factors involved in the accident.

i. Make appropriate recommendations and observations.

[redacted]

[redacted]

ACTION copy 1 for [redacted]
MARHAM STAFF
S 40 MARHAM SEC

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at 151400Z NOV 07

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HQAIR FOR DDLS, CASO AND CFMO. MODUK FOR DC AND L (F AND S) AND MOD EC-TA APS AND DAS. MODUK DES FOR CHIEF OF MATERIAL (AIR), DG COMBAT AIR, DGS AND E AND D AIR SYSTEMS. DES WYTON FOR TOR IPTL, HARRIER JAGUAR AND SURVIVAL IPTL, CASD. MARHAM FOR STN CDR. HENLOW FOR RAF CAM. DASC FOR BOIA AND SOI OCCURENCES. QINETIQ FOR CTP.

ALSO SENT TO BAE SYSTEMS WARTON AND BAE SYSTEMS MARHAM BY EMAIL

SUBJECT IS CONVENING ORDER FOR BOARD OF INQUIRY.

1. BY ORDER OF THE ASSISTANT DIRECTOR AIR SYSTEMS - TEST AND EVALUATION SUPPORT DIVISION (AD AIR SYS - TESD) , A BOARD OF INQUIRY IS TO ASSEMBLE AT OPERATIONS RAF MARHAM AT 1500 LOCAL ON 15 NOV 07.

COMPOSITION OF THE BOARD IS:

PRESIDENT	WG CDR	[redacted]
MEMBERS	SQN LDR	[redacted]
	SQN LDR	[redacted]
	BOI ADVISOR (DAS)	SQN LDR [redacted]
	AAIB INVESTIGATOR	MR [redacted]

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2. TERMS OF REFERENCE ARE TO:

A. INVESTIGATE THE CIRCUMSTANCES OF THE ACCIDENT INVOLVING TORNADO GR MK4, ZA554 ON 14 NOV 07 AT 1510Z.

B. DETERMINE THE CAUSE OR CAUSES OF THE ACCIDENT AND EXAMINE RELATED FACTORS.

C. ASCERTAIN THE DEGREE, CAUSE AND TIME OF INJURY SUFFERED BY PERSONS BOTH SERVICE AND CIVILIAN.

D. ASCERTAIN IF ALL RELEVANT ORDERS AND INSTRUCTIONS WERE COMPLIED

RAF MARHAM MRM P03.7017/1

[redacted]

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E MODUK DES BOSCOMBE DOWN — MARHAM STAFF
at 151400Z NOV 07 — S40 MARHAM SEC

WITH.

E. ASCERTAIN IF THE PERSONNEL INVOLVED WERE ON DUTY.

F. ASCERTAIN IF AIRCREW ESCAPE, SURVIVAL AND RESCUE FACILITIES WERE UTILIZED AND FUNCTIONED CORRECTLY.

G. ASCERTAIN THE EXTENT OF DAMAGE TO THE AIRCRAFT, PUBLIC AND CIVILIAN PROPERTY.

H. ASSESS ANY HUMAN FACTORS INVOLVED IN THE ACCIDENT.

I. MAKE APPROPRIATE RECOMMENDATIONS AND OBSERVATIONS.

J. REPORT ANY TACTICAL, OPERATIONAL, OR AVIATION SAFETY MATTERS OF AN URGENT NATURE TO AD AIR SYS - TESD WITHOUT DELAY.

4 . WHILE THE BOI IS TO CONSIDER WHETHER HUMAN FACTORS CONTRIBUTED TO THE ACCIDENT IT SHOULD NOT CONSIDER, NOR MAKE ANY STATEMENT ABOUT, BLAMEWORTHINESS . NOTWITHSTANDING THAT HUMAN FAILINGS ARE NOT TO BE ASSESSED, INDIVIDUALS WHOSE PROFESSIONAL REPUTAION MAY BE AFFECTED BY THE BOARD OF INQUIRY FINDINGS ARE STILL TO BE AFFORDED THE PROTECTION OF QR1269. SHOULD ANY PERSONNEL BE AFFORDED THE RIGHTS OF QR1369, THE PRESIDENT IS TO INFORM AD AIR SYS - TESD.

5 . THE BOARD IS TO BE CONDUCTED AND PROGRESSED IN ACCORDANCE WITH AVP67, AS AMPLIFIED BY JSP551, VOLUME 1, SECTION 205 AND IS TO BE COMPLETED ON RAF F412. IN ACCORDANCE WITH SECTION 113 OF THE STATUATORY DECLARATIONS ACT 1835, EVIDENCE IS NOT TO BE TAKEN ON OATH. QR1272 (DISCLOSURE OF PROCEEDINGS) AND, IN THE CASE OF FATAL ACCIDENTS, QRS J968 (INQUESTS IN ENGLAND, WALES AND NORTHERN IRELAND) AND J969 (INQUESTS ABROAD) SHOULD BE CONSULTED. THE PRESIDENT IS TO ENSURE THAT ONLY THOSE PAGES OF THE COMPLETED INQUIRY PROCEEDINGS WHICH REQUIRE SAFETY PROTECTION ARE SO MARKED. AD AIR SYS - TESD IS TO BE CONSULTED PRIOR TO DISTRIBUTION OF BOTH THE INTERIM REPORT AND THE FINDINGS OF THE BOARD.

6. THE ATTENTION OF THE BOARD IS DRAWN TO THE FOLLOWING PARAS OF JSP 551 VOL 1 SECTION 200 ANNEX C AND ANNEX J, SECTION 205 AND SECTION 205 ANNEX C:

A. SUBMISSION OF INITIAL SIGNAL
B. SUBMISSION OF INTERIM FINDING
C. PROGRESSION OF THE BOARD
D. IMMEDIATE REPORTING OF HAZARDS

7. THE ATTENTION OF THE BOARD IS ALSO DRAWN TO THE CONTENTS OF DINOS- 151 - DISCLOSURE OF BOARD OF INQUIRY REPORTS. THIS DIN CONTAINS ESSENTIAL INFORMATION PERTINENT TO THE PRODUCTION AND DISCLOSURE OF BOI REPORTS.

[redacted]

[redacted]

ACTION copy 1 for [redacted]
MARHAM STAFF
S 40 MARHAM SEC

MODUK DES BOSCOMBE DOWN
at 151400Z NOV 07

8. GUIDANCE MAY BE SOUGHT AT ANY STAGE FROM AD AIR SYS - TESD([redacted]) AND THE RAF BOI ADVISOR ([redacted] OR [redacted]) AND DLS ([redacted]).

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tion Distribution

ddressee	Code	Action-Officer	Retrieval
AF MARHAM	KQL	MARHAM STAFF	
	WAL	MARHAM STAFF	
	Z5A	MARHAM STAFF	

formation Distribution

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PART 1.2
NARRATIVE OF EVENTS

Abbreviations

AAES	Aircraft Assisted Escape System
AAIB	Aircraft Accident Investigation Branch
AAMSS	Aircraft Armament Maintenance Support Section
ADF	Acceptable Deferred Fault
ADR	Accident Data Recorder
AEA	Aircrew Equipment Assemblies
AGL	Above Ground Level
AM	Aircrew Manual
AMSL	Above Mean Sea Level
AoB	Angle of Bank
AP	Air Publication
APU	Auxiliary Power Unit
ARCC	Aeronautical Rescue Coordination Centre
ARO	Aircraft Recovery Officer
ASG	Aviation Safety Group
ASO	Aircraft Stage Orders
ATC	Air Traffic Control
ATTAC	Aircraft Tornado Transformation Availability Contract
AvP	Aviation Publication
BOI	Board of Inquiry
BTRU	Barostatic Time Release Unit
BTTDFU	Breech Type Time Delay Firing Unit
CA	Convening Authority
CJRM	Canopy Jettison Rocket Motors
CMU	Combined Maintenance and Upgrade Facility
COM (Air)	Chief of Materiel (Air)
ComCen	Communications Centre
CPS	Crown Prosecution Service
CSI	Crime Scene Investigator
CTP	Chief Test Pilot
CWP	Central Warning Panel
D&D	Distress and Diversion Cell
DAP	Digital Air Publication
DDLS	Deputy Director of Legal Services
DMS	Dedicated Maintenance System
DMSD	Design and Modification Support Division
DQAFF	Defence Quality Assurance Field Force
DSMO	Deputy Senior Medical Officer
EA	Engineering Authority
ECS	Environmental Control System
EMC	Engineering Management Cell
FAC	Flight Authorisation Certificate
FCC	Flight Crew Checklist
FL	Flight Level

[redacted]

FOB	Flying Order Book
FP	Force Protection
FSW	Forward Support Wing
FTS	Tornado GR4/4A Flight Test Schedule
GDAS	Graphical Data Analysis System
GFx	Government Furnished Services, Property, Equipment
HAS	Hardened Aircraft Shelter
HDPF	Home Department Police Force
HF	Human Factors
HJS	Harrier, Jaguar and Survival
HSE	Health and Safety Executive
HUD	Head-up Display
IDG	Integrated Drive Generator
IDS	Interdictor Strike
ILS	Instrument Landing System
IO	Incident Officer
IPT	Integrated Project Team
IPTL	Integrated Project Team Leader
JARTS	Joint Aircraft Recovery and Transportation Sqn
JPA	Joint Personnel Administration
JSP	Joint Service Publication
LATCC (Mil)	London Air Traffic Control Centre (Military)
LITS	Logistics Information Technology System
LFA	Low Flying Area
MAFTR	MOD Airworthiness and Flight Test Regulator
MAOS	Maintenance Approved Organisation Scheme
MBA	Martin Baker Aircraft Limited
MDC	Miniature Detonating Cord
mod	modification
MOMIDS	Meteorological Office Military Information Distribution System
MMP	Mandatory Maintenance Procedure
MP	Maintenance Procedure
MT	Military Transport
NCO	Non-Commissioned Officer
NDT	Non-Destructive Testing
NETMA	NATO EF2000 and Tornado development, production and logistics Management Agency
NOK	Next of Kin
OOA	Out of Area
OOH	Out of Hours
PACE	Police and Criminal Evidence Act
PEC	Personal Equipment Connector

[redacted]

[redacted]

PFAT	Post maintenance Flight Air Test
POC	Point of Contact
QA	Quality Assurance
QR	Queen's Regulation
RAFCAM	RAF Centre of Aviation Medicine
RAFP	RAF Police
RLA	Regional Legal Advisor
RRI	Rocket Remote Initiator
RTS	Release to Service
SA	Situational Awareness
SAR	Search and Rescue
SEM	Service Engineering Modification
SIB	Special Investigations Branch
SIO	Senior Investigating Officer
SME	Subject Matter Expert
SNCO	Senior Non-Commissioned Officer
SOC	Scene of Crime
SPFH	Seat Pan Firing Handle
TAMPA	Tornado Advanced Mission Planning Aid
TESD	Test and Evaluation Support Division
TLP	Top Latch Plunger
TOR	Terms of Reference
UTI	Urgent Technical Instruction
WSO	Weapons Systems Officer
WTS	Weapon Training Section
XO	Executive Officer

[redacted]

[redacted]

PART 1.2 - CONCLUSIONS OF THE BOARD

Narrative of Events

(All times LOCAL)

Introduction

1. On 14 Nov 2007, Tornado GR4, ZA554, allotted to BAE Systems under the BAE Systems Combined Maintenance and Upgrade Facility (CMU) contract, and crewed by a BAE Systems civilian flight test crew, was conducting its post maintenance flight test following CMU Major maintenance and upgrade activities. The flight test required a negative-g loose article check, which was accomplished by means of an inverted flight check. During this manoeuvre, at 5900 feet and 400 knots, there was a loud bang accompanied by rapid cockpit depressurisation. The aircraft was recovered to erect, straight and level flight. Thereafter, the pilot realised that the rear cockpit transparency had shattered and that the rear cockpit was unoccupied, with both the Weapons Systems Officer (WSO) and the rear ejection seat missing. A MAYDAY was declared and an in-flight inspection by a USAF F-15E ascertained that the rear cockpit transparency, rear ejection seat and WSO were absent. There was evidence of impact damage at the base of the aircraft fin in the pre-cooler area. ZA554 was recovered to RAF Marham without further incident. The WSO was found on the ground in his ejection seat shortly afterwards, having sustained fatal injuries.

Introduction to CMU

2. The MOD contracted BAE Systems, through the Aircraft Tornado Transformation Availability Contract (ATTAC), to undertake all maintenance and upgrade work on its Tornado GR4s that was beyond squadron capability for reasons such as tools, skills, facilities and time. This work was conducted in CMU at RAF Marham. CMU consisted of both BAE Systems and RAF technicians, supervisors and managers working side-by-side on aircraft maintenance activities. In addition, some specialist services were provided to CMU by the RAF through the Government Furnished Services, Property, Equipment (GFx)[1] element of the contract. Civilian and RAF personnel that worked within the CMU contract had to do so in accordance with Aviation Publication (AvP) 67[2], Defence Standard 05-130 Mil-Part-145[3] and ISO-9001:2000[4]. RAF GFx personnel worked in accordance with JAP100A-01[5] and Queen's Regulations (QRs). The respective quality

[1] GFx personnel include armourers, Non-Destructive Testing (NDT) specialists, aircraft weighing specialists, and aircraft and component painters.
[2] Flying Orders to Contractors.
[3] Maintenance Approved Organisation Scheme, Part 1: MAOS Military Regulations Part 145: Maintenance Organisations.
[4] Quality Management Systems-Requirements.
[5] Military Aviation Engineering Policy and Regulation.

[redacted]

[redacted]

organisations undertook audits to ensure that their organisations were complying with the appropriate regulations and that personnel were correctly trained and authorised to carry out the work.

3. Aircraft requiring maintenance and/or upgrade in CMU were allotted to CMU by an allotment signal. This signal passed temporary responsibility for the aircraft to CMU until such time as the aircraft was ready to be returned to RAF service. The CMU contract included any flight testing that may have been required as a result of the maintenance that had been undertaken. Flight testing was conducted by BAE Systems flight test crews subject to completion of a Flight Authorisation Certificate (FAC) which had to be signed by: a BAE Systems Cat C engineer, declaring the aircraft airworthy; and by the MOD Defence Quality Assurance Field Force (DQAFF) agent, who permitted the flight to proceed, thus invoking DEFCON638 via Defence Standard 05-100.

4. All scheduled maintenance was pre-planned on the BAE Systems' Dedicated Maintenance System (DMS) and the work was broken down into work packages known as Aircraft Stage Orders (ASO) that aligned to pulse maintenance methodology. Each maintenance activity within an ASO was raised on a DMS chit[6]. Clearance of a DMS chit certified that the work had been completed by an authorised person in accordance with the appropriate regulations. Any unscheduled work was also raised and subsequently cleared on DMS. Although GFx personnel recorded their work on the MOD Form 707 series paperwork, they also certified on DMS that their work had been completed. Consequently, once all relevant DMS entries had been cleared, all relevant maintenance activities should have been completed and the aircraft should have been airworthy in a similar manner to the way the RAF used the MOD Form 707 series paperwork.

Crew Background

5. The crew of ZA554, operating under AvP67, were approved for their respective flying duties by: the Directorate of Flying[7] (now the Test and Evaluation Support Division (TESD)); NATO EF2000 and Tornado development, production and logistics Management Agency (NETMA); and BAE Systems. The crew background was as follows: Annex S, AQ

a. **Pilot.** The pilot (Witness 1) was the BAE Systems Tornado GR4 CMU Unit Test Pilot, RAF Marham, having fulfilled that role since 20 Apr 06. He had 2975 hours Tornado Interdictor Strike (IDS)/GR1/GR4 experience and was trained by BAE Systems as a Post Maintenance Test Pilot. The pilot's last flying assessment was Exceptional. Exhibit 7 Annex C Witness 1

[6] The CMU equivalent to a pre-printed MOD Form 707B.
[7] Directorate of Flying is used here because the approval was issued under this title.

[redacted]

[redacted]

b. WSO. The WSO, Mr Michael Charles HARLAND (BAE Systems Clock No 0912172), was the BAE Systems Tornado GR4 CMU Head of Flight Operations, RAF Marham, having fulfilled that role since 1 Jan 06. He had approximately 1450 hours experience as a Tornado GR1/GR4 WSO. There was no annual write-up on the WSO's flying proficiency by the BAE Systems Head of Flying (Director Flight Operations) either in the WSO's training folder or elsewhere.

Annex C

Exhibit 7

Annex C

Aircraft Background

6. ZA554 was the first aircraft to enter CMU for Major[8] maintenance [redacted] S 26 . It was allotted to CMU on 22 Jan 07 with an expected return to RAF service date of 15 Jun 07. However, because a significant amount of unscheduled work[9] had occurred during this maintenance, the aircraft still had scheduled work outstanding on 2 Nov 07. Although CMU work on the aircraft was nearing completion (it was starting the functional test stage), at the weekly Depth Performance Review on 2 Nov 07, OC Depth Support Wing and the General Manager, BAE Systems, RAF Marham were concerned that the amount of work remaining on the aircraft exposed a significant risk that the aircraft would not meet its scheduled [redacted] date. S 26 Thus, CMU was tasked to create and implement a recovery plan. The resultant recovery plan consisted of working the aircraft over 24 hours in three 8-hour shifts, 7 days a week, and came into force the following day, 3 Nov 07. Under this plan, the flight test was scheduled for 12 Nov 07, which allowed time for CMU to complete post flight test activities, and time for the RAF to undertake some [redacted] S 26 'shake-down' flights and preparation. Due to faults found during this final maintenance stage, including with the rear ejection seat and cabin pressurisation, the flight test was conducted on 14 Nov 07.

Annex AJ, AK, AL

Witness 10, 12

Pre-Accident Events - Engineering

7. Although a myriad of aircraft recovery and functional testing was ongoing in the 3 weeks leading up to the accident,-the nature of the accident led the Board to concentrate on the Aircraft Assisted Escape System (AAES) activities being undertaken on the aircraft. However, because of anomalies within the Aircraft Armament Maintenance Support Section (AAMSS) maintenance documentation, and a lack of coherence between AAMSS maintenance documentation, LITS, DMS and diary entries, the Board was unable to positively determine the sequence of AAES engineering events leading up to the accident.

Witness 3, 4, 5,6,8, 12 Annex AH, AM Exhibit 20, 21,

[8] From DAP101 B-4100-2R1 Part 1 Leaflet 001 A. Major maintenance occured every 3300 flying hours. The maintenance was carried out in accordance with the DMS Integrated Work Package as derived from DAP101 B-4104-5A1 and DAP101B-4100-2R1 Parti Leaflet 17A by CMU.

[9] It was expected that much unscheduled work, the details of which could not be predefined and thus could not be pre-programmed, would be raised during the undertaking of this type of maintenance.

[redacted]

[redacted]

However, the Board considered that the most probable sequence of events was as follows: — 22, 23, 24, 25, 26

a. **23 Oct – 1 Nov 07.** Ejection seats[10] were originally prepared for installation in ZA554 between 23 and 28 Oct 07. However, possibly because of problems with canopy pressurisation tests, the seats were not fitted. At the same time, ejection seats[11] were also being fitted to Tornado ZA613[12]. The AAMSS personnel fitting ZA613's seats found that the Breech Type Time Delay Firing Unit (BTTDFU) would not fit into the rear ejection seat (believed R998) due to fouling with the ejection seat top block[13] and this seat was removed along with its ejection gun (believed R37814) on 1 Nov 07 and returned to the seat bay, where the top block was replaced[14]. Later that day the rear ejection seat (R2135) and ejection gun (DC1423), believed to have been originally allocated to ZA554, were fitted to ZA613[15]. — Exhibit 20, 21; Exhibit 22, 23, 24, 25; Annex AM; Witness 6, 11

b. **2 – 5 Nov 07.** On 2 Nov 07, the rear ejection seat that could not be installed in ZA613 (R998), along with its gun (R37814), was prepared for installation in ZA554; this appears to have involved taking equipment allocated to other aircraft (front and rear rocket packs, night vision goggles built-in test box, EO_2 cylinder and EO_2 regulators, along with canopy jettison rocket motors). Following further aircraft canopy work, the front and rear ejection seats (R2134 and R998 respectively) were installed into ZA554 by the AAMSS night shift on 5 Nov 07. However, on attempting to fit the BTTDFU to the rear ejection seat, the tradesman found that the BTTDFU would not fit due to fouling with the ejection seat top block. Due to the recent problems with this seat, and to allow cabin pressurisation checks to be undertaken, the seat was left in the aircraft for the day shift to rectify in consultation with the seat bay. — Witness 9; Exhibit 20, 21

c. **6 – 8 Nov 07.** On 6 Nov 07, seat bay personnel joined AAMSS personnel to investigate the rear seat BTTDFU fault on ZA554. The team believed that, possibly due to tolerances, the inner piston and ejection seat were out of alignment and that this was preventing the BTTDFU from fitting. As the top block had already been changed, the team decided to try another ejection gun. A spare gun (allocated to another aircraft) was slaved into ZA554, the seat lowered and the BTTDFU found to fit. The team decided that the ejection gun (R37814) was therefore the problem and a third gun (DF3108) was prepared and delivered to CMU by — Witness 4, 6, 11

[10] Believed to be R2134 and R2135 from LITS data. However, this could not be positively determined.
[11] Believed to be R992 and R998 from LITS data. However, this could not be positively determined.
[12] SNOW3410ZA613080507.
[13] The top block (top cross beam) sits at the top of the main beam assembly and bolts to the sides of the main beams. The top block sits on the ejection gun; the BTTDFU fits though the top block to screw into the ejection gun inner piston. The top block also houses the Top Latch Plunger (TLP) and spring.
[14] Subsequent investigation found the removed top block serviceable.
[15] SNOW3410ZA613080507.

[redacted]

the seat bay. AAMSS fitted this gun to the aircraft at lunchtime on 6 Nov 07. The seat (R998) was then lowered onto the ejection gun (DF3108) and a trial fit of the BTTDFU was undertaken, following which the seat installation was completed. The Board has been unable to establish whether the trial fit was undertaken before or after the handwheel holding the Top Latch Plunger (TLP) was removed. The canopy was then installed and armed by the night shift. Because of other work on the aircraft, possibly including canopy removal and refit, the independent checks on the seat and the canopy did not occur until 1530 on 7 Nov 07. The independent checks failed on 3 faults – manual separation lockwire, Canopy Jettison Rocket Motor (CJRM) lockwire and Miniature Detonating Cord (MDC) Go/NoGo test. Rectification of these faults required removal of the front ejection seat safety equipment. The faults were rectified by the night shift, and the front ejection seat safety equipment was refitted the next morning. A second independent check was carried out, which found the front seat aircraft portion Personal Equipment Connector (PEC) damaged. A spare PEC was slaved into the aircraft to allow TEMPEST[16] testing to take place. At lunchtime the final aircraft portion PEC was fitted to the aircraft, which was then singularly checked by the independent checker before the independent checks were finally signed off.

Annex AP (i)

Witness 5
Annex P, AM

Witness 5, 6

d. **9 – 14 Nov 07.** According to DMS further non seat-related work was carried out on ZA554 in order to finish the maintenance schedule and prepare the aircraft for flight test. A final check of elements of the ejection seats, which did not call for a check to ensure correct locking of the seat, was undertaken in the hours prior to the flight test as part of the trade-specific after flight/before flight checks[17].

Witness 3

Pre-Accident Events – Aircrew

8. **Previous 24 Hours.** On 13 Nov 07, the day prior to the accident, the BAE Systems test crew, who were waiting to conduct the post maintenance flight test on ZA554, were informed that the aircraft would not be ready until the following day, 14 Nov 07. On the afternoon of 13 Nov 07 both the pilot and WSO flew from RAF Marham to RAF Barkston Heath in a privately owned light aircraft. They then spent the evening and night in their respective family homes. Both crew members had breakfasted and were well rested when they returned by car to RAF Barkston Heath at approximately 0815 the following morning, 14 Nov 07. They departed RAF Barkston Heath at approximately 0830 in the same light aircraft, landing at RAF Marham at approximately 0900 when their duty day was deemed to have begun.

Witness 1

Witness 1, 7

Witness 1

Witness 1, 7

[16] Part of the aircraft scheduled maintenance.
[17] AP101B-4104-5B1.

[redacted]

9. **Aircrew Briefing and Preparation.** At 0915 the crew contacted the CMU engineers to ascertain the latest situation in relation to ZA554 and were informed that there was a problem with an undercarriage selector valve that would delay the flight test. An unusual aspect of 14 Nov 07 was that there was an Intersoft[18] film-crew present at CMU Flight Operations filming for a presentation that would accompany a BAE Systems Chairman's Award, which was to be awarded to CMU at a later date. Witness 1 / Witness 1, 7

a. **Flight Planning.** After a short period of administration at CMU Flight Operations the crew proceeded to 13 Sqn and completed the flight planning for the flight test, including a low level route planned on the Tornado Advanced Mission Planning Aid (TAMPA). The crew routinely planned at 13 Sqn as CMU Flight Operations did not have a TAMPA terminal, and their flying clothing was routinely stored and serviced on 13 Sqn. After flight planning the crew returned to CMU Flight Operations at approximately 1130. During the morning the crew self-briefed the meteorological conditions for the day utilising a Meteorological Office Military Information Distribution System (MOMIDS) terminal situated in CMU Flight Operations and weather information produced by the RAF Marham Met Office displayed on the wall of CMU Flight Operations. The crew ate lunch in the CMU Flight Operations crew room as normal, after which they proceeded to CMU 4 Hangar to ascertain how the undercarriage problem was progressing. The crew made a non-pressured approach to the engineers and the rectification work was explained. ZA554 was ready for the crew to walk at 1400. Witness 1, 7 / Witness 1, Exhibit 2 / Witness 1, 7 / Witness 1 / Witness 1, 7

b. **Engineering Brief.** After flight-planning and prior to the sortie outbrief the CMU Production Manager gave a detailed engineering brief to the crew, which was filmed by the Intersoft film-crew. This brief covered the engineering aspects of the flight test including engineering Limitations, Acceptable Deferred Faults, Service Engineering Modifications and any problems encountered during the aircraft's preparation. There were 2 recently identified and rectified faults discussed at this brief; one concerning aircraft pressurisation, and one concerning the fuel vent pack at the top of the aircraft fin. Therefore, canopy and pressurisation problems were fresh in the crew's mind. Witness 1, 7, 10 / Annex V / Witness 1

c. **Sortie Brief.** The crew did not complete a formal sortie brief. However, the flight test was a standard format with which the crew were familiar. Additionally, the crew completed the sortie flight planning together, during which all airmanship aspects of the sortie were covered. The Air Traffic Control (ATC) aspects and co-ordination with London Air Traffic Control Centre (Military) Witness 1 / Annex AQ

[18] A privately owned company in Lancashire contracted by BAE Systems to provide presentation services and audio-visual production.

[redacted]

(LATCC (Mil)) for the supersonic run in the flight test was covered by a standing agreement between CMU, RAF Marham ATC and LATCC (Mil).

d. **Outbrief and Authorisation.** The standard CMU Flight Operations outbrief was used as the crew's final preparation for the sortie, and was briefed by the pilot. The Authorisation Sheet was signed by the WSO as the authoriser, and the pilot, as the aircraft captain. The duty column did not include reference to the flight test schedule to be carried out, or the Low Flying Areas (LFA) for the low-level booking. The Board noted that the WSO was not empowered to authorise sorties; however, the Board considered that the WSO believed that powers of authorisation had been conferred to him by his line management. Exhibit 11 Witness 1 Exhibit 7 Para 55 Annex AQ

10. **Events Post Outbrief.** The crew walked from CMU Flight Operations at 1350 with the WSO going directly to the aircraft to help the Intersoft cameraman position himself at a good filming point. In order to sign the aircraft paperwork, the pilot proceeded to the CMU Production Co-ordination Cell, which managed CMU 4 Hangar engineering and liaised with CMU Flight Operations regarding engineering aspects of post maintenance flight tests. However, the paperwork was still at the Documentation Cell at that time so the pilot proceeded there to sign for the aircraft, where the WSO rejoined him. Both crewmembers left the Documentation Cell at the same time and arrived at the aircraft cockpit area together. Following pre-start checks, and because external power disengaged during Auxiliary Power Unit (APU) start, and would not re-engage with the APU running, the pilot opted for an internal start. There were no further problems during the start-up and taxi so the flight test was ahead of schedule. The aircraft took off 40 minutes earlier than planned and the CMU Flight Operations Manager brought the low level booking forward accordingly. Witness 1, 7 Witness 1 Annex V Witness 1 Witness 1, 7

11. **Airborne Events Prior to Accident.** ZA554 got airborne at 1430. The test schedule flown was the BAE Systems ZA554 CMU Test Schedule No1, Issue A, which included all of the items found in the equivalent MOD Flight Test Schedule (FTS)[19]. No anomalies were apparent until 36 minutes and 39 seconds after take-off when Item 22e of the CMU test schedule, Item E17e of the MOD FTS, 'Loose Article Check', was carried out. Witness 1, 7, Exhibit 7 Exhibit 1 Annex I, R, W

Accident Events

12. **Loose Article Check.** In order to track the events surrounding the accident, the illumination of the Central Warning Panel (CWP) ICE caption[20], which was an Accident Data Recorder (ADR) parameter and

[19] MOD Tornado GR4/4A Flight Test Schedule AP101B-4104-5M 2nd Edition, Aug 00 Serial No 37/07.
[20] ICE caption indicated that icing had been detected or there had been ice detection equipment failure. The ice detection probe was situated at the base of the fin.

[redacted]

was most likely a result of damage sustained during the accident, has been used as a timing reference – the ICE caption occurred 1.4 seconds after a bang, taken to be the rear cockpit MDC firing, occurred on the ADR audio recording. The crew elected to undertake the loose article check by means of a level inversion and push to minus 1.0g. Prior to this event ZA554 had only been subjected to normal accelerations of greater than zero g. To undertake the loose article check, 6 seconds prior to the ICE caption, the pilot applied approximately half left lateral stick to roll the aircraft inverted, CMU test schedule item 22e. As the aircraft approached 170 degrees Angle of Bank (AoB), and while pushing to achieve minus 1.0g, at minus 0.7g[21] an explosion was apparent to the pilot, followed shortly by ICE and Environmental Control System (ECS) captions illuminating on the CWP. On hearing the explosion the pilot immediately reversed the roll direction and rolled back to nominally wings-level, erect flight. The pilot felt some buffeting and yawing while inverted. At the time the ICE caption illuminated flight conditions were 45° wing sweep, 406 knots calibrated airspeed and 5900 feet pressure altitude, i.e. referenced to 1013.25mb.

Annex R

Witness 1, Annex I, W

Exhibit 1 Witness 1, Annex R, W

Witness 1

Annex W

13. **Pilot's Account and Immediate Actions.** The pilot recalled there being chaos in the front cockpit with a rush of cold air and the appearance of lots of yellow matter, which he initially thought were feathers but subsequently realised was wadding from the aircraft bulkhead insulation. The pilot initially diagnosed a substantial failure of the canopy seal, this being one of the recently rectified engineering faults briefed to them in the flight test engineering brief. The pilot attempted to speak to the WSO; however, assessing this as ineffective due to the external noise level, he looked in his canopy arch mirrors to visually confirm with the WSO that the aircraft remained under control. As the dust in the cockpit cleared the pilot was shocked to be able to see all the way to the rear cockpit bulkhead. Furthermore, he could not see an ejection seat or any canopy over the rear cockpit. It was at this point he realised that the WSO was no longer in the aircraft. The pilot initiated a visual search of the area for signs of a parachute, but could not see one. On re-examination of the rear cockpit it became evident to the pilot that there was no ejection seat gun extension and in his mirrors he could see damage to the base of the aircraft fin. Also, the pilot had not been ejected despite command eject being set to BOTH. Therefore, the pilot concluded that the WSO had not ejected but that the WSO and ejection seat had fallen from the aircraft and had probably impacted the aircraft fin. The pilot declared a MAYDAY at 1509, 59 seconds after the ICE caption. Prior to the accident there were no aircraft anomalies; post accident the pilot observed no indications of aircraft malfunctions other than the ICE and ECS captions.

Witness 1

Witness 1, 10, Annex V

Annex R, W, X, Witness 1

[21] Head-up Display (HUD) indications were used for normal acceleration values as the normal acceleration channel of the ADR was unserviceable when interrogated post flight.

[redacted]

[redacted]

14. Rear Ejection Seat and Occupant. On exiting the aircraft the rear ejection seat canted backwards by approximately 90° in the airflow and impacted the spine of the aircraft followed by the base and right hand side of the fin. The impact with the fin caused considerable damage to the ejection seat, shearing the main beam assembly immediately above the Harness Power Retraction Unit (HPRU) thereby separating the main beam assembly and headbox from the remainder of the seat. The fatal injuries suffered by the WSO were probably sustained during the impact with the fin. The WSO remained strapped into the main portion of the ejection seat and fell to the ground. The main beam assembly and headbox descended with the 22-inch drogue deployed. The main parachute canopy was ripped unsystematically from the headbox during, or immediately following the impact with the fin, and descended separately from the other sections of the seat. Annex E, H, J, Exhibit 16 Annex E Annex E Annex E, Exhibit 16

Post-Accident Events

15. Pilot's Actions. The pilot's MAYDAY call was worded to indicate to LATCC (Mil) that the WSO had not ejected from the aircraft, but appeared to have fallen out. After transmitting the MAYDAY the pilot set up an orbit at 1500 feet, in the approximate location where he thought the rear ejection seat had fallen out, in order to search for signs of a parachute. He requested airborne assistance for a visual inspection and LATCC (Mil) vectored a nearby USAF F-15E aircraft ([redacted]) to assist. Three minutes after the MAYDAY call the pilot S 27 was informed that Search and Rescue (SAR) assets had been scrambled and were proceeding to the accident site. The pilot stated that he may shortly start suffering from shock and wished another aircraft to take over search duties. [redacted] arrived on scene at 1519, S 27 10 minutes after the MAYDAY call, and conducted a visual inspection. ZA554's pilot had lowered the undercarriage such that it could be inspected and also to ensure that he did not forget to lower it should he succumb to shock prior to landing. [redacted] confirmed that the rear S 27 occupant and rear canopy transparency were missing, that there was damage to the base of the fin, and that the undercarriage appeared to be down and locked. [redacted] then took over search duties. [redacted] S 27 was joined by another F-15E ([redacted]) at 1522 and they continued to search for signs of the WSO. ZA554 returned to RAF Marham where it landed without further incident at 1524, from a normal full-flap 25° wing sweep approach. Witness 1, Annex X Witness 1 Annex X Witness 1, Annex R, W, Exhibit 7

16. Rescue / SAR Aspects. SAR helicopters from RAF Leconfield (RESCUE 128) and Wattisham Airfield (RESCUE 125), as well as a Norfolk Police helicopter from Norwich (POLICE 26B), had all been scrambled at 1510. A radar replay was requested by the Aeronautical Rescue Coordination Centre (ARCC) from LATCC (Mil) Distress and Diversion cell (D&D) to assist in locating a start point for the search. This gave a position approximately 2 miles north of the disused RAF airfield at Sculthorpe, consistent with the pilot's reported approximate Annex Z

[redacted]

position. A member of the public reported to RAF Marham that they had seen something falling from an aircraft. This sighting led to another potential location which was relayed to RESCUE 125 on VHF Guard. Initially the main parachute canopy was located by POLICE 26B, which was then investigated by RESCUE 128. RESCUE 125 then located aircraft canopy fragments. From this debris field a probable trajectory for the casualty was calculated. RESCUE 125 and 128 searched either side of this line. RESCUE 125 located the ejection seat head-box; thereafter, POLICE 26B located and subsequently directed RESCUE 128 to the WSO. RESCUE 125 then ferried a doctor (the Deputy Senior Medical Officer (DSMO)), an armourer and RAF Police (RAFP) from RAF Marham to the accident site. Exhibit 16 Annex Z Annex AA

17. **WSO.** At 1621 the WSO was identified by RESCUE 128. He was still strapped into the ejection seat, which was on a disused airfield at Egmere, Little Walsingham. The WSO was assessed as Triage Level 4. Thereafter, the DSMO, RAF Marham, arrived on scene and pronounced the WSO dead at 1710. Annex Y Annex E

18. **Recovery of Aircraft.** After landing the aircraft was brought gently to a halt once clear of the active runway and shut down with RAF Marham fire crews in attendance. The pilot requested an armourer, via a note held up for the fire crew, to assess the canopy and rear cockpit because he did not know the condition of the AAES. It took approximately 10 to 15 minutes for an armourer to get to the aircraft. Meanwhile, a member of the groundcrew plugged a headset into the aircraft and the pilot relayed his concerns concerning the safety of the AAES to the groundcrew, and asked that personnel did not get too close to the aircraft. When the armourer arrived he assessed the rear cockpit and stated that there was 'nothing to pin' indicating that there was nowhere for the rear ejection seat safety pin to be inserted because there was no ejection seat present. Therefore, the pilot elected to open the canopy using the normal system once all ground personnel were clear of the area. The canopy opened without incident. The pilot then unstrapped, vacated the cockpit and was taken to the RAF Marham medical centre. Thereafter, ZA554 was impounded pending subsequent investigation. Some wreckage was scattered on the runway when ZA554 landed at RAF Marham – this was collected and impounded. Witness 1 Annex G

19. **Search of Accident Site.** An MOD Incident Officer (IO) deployed from RAF Marham, and an Aircraft Recovery Officer (ARO) deployed from the Joint Aircraft Recovery and Transportation Sqn (JARTS), RAF St Athan. However, primacy over the accident site rested with Norfolk Constabulary who had deemed the area a Police Scene of Crime (SOC). Therefore, the IO and ARO, with their respective staffs, assisted and advised both the Norfolk Constabulary Senior Investigating Officer (SIO) and the Board. The accident site Annex F, G

was centred on the disused airfield at Egmere, Little Walsingham, and consisted of 2 main debris sites within an overall debris trail, which extended for approximately 3km, and covered an area of approximately 5 square km. The search area, which as a SOC was cordoned and guarded, consisted of: numerous hedgerows; soft soil arable fields consisting of a mixture of ploughed fields and sugar beet ready for harvesting; small copses; derelict farm buildings; domestic housing and gardens; old aircraft dispersal areas used for fly-tipping; ponds; and various scrubland. While access was relatively easy, searching for small components within such diverse and extensive terrain was extremely difficult. At times the recovery team totalled 120 personnel, and comprised not only JARTS but also personnel from RAF Marham and Civilian Police Specialist 'Fingertip' Search Teams. Additionally, Civilian Police divers were brought in to search ponds, and explosive-trained sniffer dogs were used in an attempt to locate the ejection gun primary cartridge. All wreckage recovered was mapped, labelled and quarantined as evidence by Norfolk Constabulary. The search was terminated on 23 Nov 07, when a joint decision between the Board and Norfolk Constabulary concluded that all reasonable efforts had been made to recover the evidence, albeit the Top Latch Plunger (TLP), TLP spring and ejection gun primary cartridge had not been recovered. Annex A

Degree of Injury

20. The Board found that:

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

b. **Civilian Personnel.**

(1) **Pilot.** There were no injuries to the pilot.

(2) **WSO.** The WSO suffered multiple fatal injuries. Annex E

Whether Personnel Involved Were on Duty

21. The Board found that the pilot and WSO were on BAE Systems duties at the time of the accident. Witness 7

Aircrew Escape Systems and Survival Aspects

22. **Rear Ejection Seat Sequence of Events.**

a. Ejection of the rear seat from the aircraft had not been initiated. Annex E

[redacted]

b. As the aircraft rolled inverted the rear ejection seat started to slide up its guide rails (downwards relative to the ground) under the 1.0g force of gravity, ultimately falling from the aircraft. Certain components and their associated cartridges were activated as a result of seat movement whereas others, as a result of the ejection not being initiated normally, were not. Annex E

c. As a normal ejection had not been initiated, the seat pan cartridge had not fired and, therefore, the gas-operated HPRU firing unit did not function. Similarly, there was no gas to operate the BTTDFU and therefore the primary and secondary ejection gun cartridges did not fire. These cartridges would ordinarily unlock the seat by raising the inner piston and also provide the initial thrust for the seat to clear the cockpit before the rocket pack fired. The initial seat movement activated the mechanically-operated rear canopy MDC system, firing the MDC and shattering the rear canopy. Further seat travel activated the drogue gun and Barostatic Time Release Unit (BTRU) via their static line trip rods, retracted the arm and leg restraint lines, and activated the ejection seat emergency oxygen system. As the seat dragged the inner piston out of the ejection gun the gas hose to the BTTDFU was sheared. The seat moved up the guide rails (at a significantly slower speed than during a normal ejection), and the upper two pairs of slippers disengaged from the guide rails, allowing the seat to be rotated backwards by the airflow. At this point the Remote Rocket Initiator (RRI) cable would have reached its maximum length of travel, activating the rocket motor and accelerating the seat towards the aircraft fin. The seat impacted the base of the fin and sustained considerable damage, shearing the main beam immediately above the HPRU. The 22" drogue had been deployed through the activation of the drogue gun, but the subsequent damage caused by impact with the fin arrested the continuation of the sequence and prevented the 22" drogue from pulling out the 5' drogue and afterwards the main parachute canopy. However, the disruption and damage to the main beam assembly and headbox caused the main parachute canopy to be ripped unsystematically from the headbox. It did not inflate, but streamed in the airflow no longer connected to any seat components. Although the BTRU had been operated by the static trip rod on first seat movement, further propagation of the ejection sequence was prevented as the fin impact had detached the BTRU, and the gas pipe leading to the drogue link shackle had sheared. From the moment of impact against the fin, with the resulting damage to the gas pipe work, the subsequent events of the ejection sequence and propagation of the gas pathways were arrested. The harness locks remained attached and man/seat separation did not occur. The ejection seat therefore fell to the ground with the WSO still strapped in. Annex E Exhibit 15h Exhibit 15g

[redacted]

[redacted]

23. **Survival Aspects.** It was probable that the WSO's fatal injuries were sustained by the impact with the fin at 1508. The damage to the WSO's Aircrew Equipment Assemblies (AEA) was consistent with the dynamic forces to which it had been subjected, and the force of impact was of such a magnitude that no AEA, of whatever design, could have made such an impact realistically survivable. Furthermore, the damage to the seat, sustained during the impact with the fin, prevented successful deployment of the parachute canopy. Because the rear ejection seat impacted the fin the accident was not survivable. Annex E, I

Damage to Aircraft, Public and Civilian Property

24. Aircraft.

a. **Airframe.** The aircraft suffered Category 2 damage with the following items requiring replacement: fin assembly; canopy assembly; pre-cooler intake and assembly; panels T211, T212 and R249; canopy arch assembly at X8000; frame at X12737; fin and spine Instrument Landing System (ILS) aerials; and the HF notch aerial. A total of [redacted] manhours were expended repairing the aircraft. The cost of repairing the aircraft was between £41,000 and £61,500. Annex D S 40 Witness 21

b. **Rear Ejection Seat and Ejection gun.** The rear ejection seat and ejection gun suffered Category 5 (Scrap) damage. The cost of this loss was £110,000. Annex E Witness 21

25. **Public Property.** There was no damage to public property. Annex F

26. Civilian Property.

a. **Accident Site.** There was no damage reported to civilian property at the accident site, and the environmental impact was minimal. However, the ejection gun primary cartridge has never been recovered. Annex E

b. **Flying Clothing.** The WSO's flying clothing, owned by BAE Systems, suffered Category 5 (Scrap) damage. The cost of this loss was approximately £15,000.

Loss of, or Damage to, Classified Material

27. There was no loss of, or damage to, classified material as a result of the accident involving ZA554.

[redacted]

[redacted]

Relevant Qualifications

28. **Aircrew.** The crew of ZA554 were appropriately trained and correctly approved by the Directorate of Flying (now TESD), and authorised by NETMA and BAE Systems to complete post maintenance flight tests. The pilot had completed post maintenance flight test training whilst on BAE Systems duties in Saudi Arabia. All currencies herein are expressed in relation to AvP67, which is the overall regulatory document for CMU Flight Operations, RAF Marham. AvP67 had no requirement for WSOs to maintain any form of flying currency, nor be trained or authorised specifically for post maintenance flight test duties. The pilot was in flying currency. The last Tornado GR4 emergency simulator for either crewmember was on 20 Jul 07, where they were crewed together; thus, the crew were simulator current under AvP67. The last formal ejection seat training for both crew was on 2 Jan 07. Although they had recently attended a brief which covered changes to the ejection seat as a result of Mod 02198, this did not satisfy the full currency requirements of formal ejection seat training as required under AvP67. Thus, the crew was out of formal ejection seat training currency by 1.5 months.

Witness 1
Annex S
Witness 1
Annex C
Annex AR, AS
Exhibit 13
Witness 1

29. **Engineering.** All personnel involved in the fitting of the rear ejection seat and associated vital and independent checks had been trained and authorised to undertake the work.

Exhibit 18, 19

Conclusions

30. The Board concluded that:

a. The flight was not authorised, albeit the crew believed that it was. — Annex AQ, Exhibit 7, Para 55

b. The flight was adequately briefed. — Witness 1, 7, 10, Annex AQ

c. The crew were competent to undertake the flight test. — Annex C, S, Exhibit 9, 10

d. The aircraft was declared airworthy and serviceable to undertake the flight. — Witness 8, 10, Exhibit 12

e. The weather was suitable for the flight. — Annex M

[redacted]

[redacted]

Civilian Police and RAF SIB Investigations

31. Primacy for conducting the criminal investigation of all deaths rests with the Chief Officer of the Home Department Police Force (HDPF) under whose jurisdiction the death occurs[22]. Furthermore, the HDPF has primacy in deciding whether a Board of Inquiry (BOI) can continue[23]. The HDPF for this accident was Norfolk Constabulary which was, following liaison with the Convening Authority (CA), Regional Legal Advisor (RLA) and the Board, content to permit the Board to continue its investigation into the accident. Nonetheless, Norfolk Constabulary applied the pre-conditions that the Board was to keep Norfolk Constabulary informed of the Board's findings and, if at any stage of the Board's investigation, it appeared that the matter may involve the commission of a criminal offence, to draw this immediately to the attention of Norfolk Constabulary (the Board's Terms of Reference (TORs) were not formally amended to reflect these requirements but the Board, nonetheless, appreciated its position). It should also be noted that Norfolk Constabulary appreciated that the Service was better-placed to identify the cause of the accident, and was keen for the Service to identify any relevant flight safety issues as quickly as possible, in order to mitigate against potential reoccurrence. Annex A

32. The Board was acutely aware of the onus on it to report immediately any potential commission of a criminal or disciplinary offence. Therefore, on 6 Dec 07, when the Board's investigations considered that there was prima facie evidence that such an offence may have been committed, and following RLA advice, the President adjourned the Board's proceedings pending CA, Deputy Director of Legal Services (DDLS), Senior RAF BOI Co-ordinator and RAFP consideration. On 10 Dec 07[24] the Board was stayed (suspended) by the CA in agreement with DDLS and Norfolk Constabulary, pending the outcome of further investigations for Gross Negligence Manslaughter by Norfolk Constabulary, and for any Service offences by RAF Special Investigations Branch (SIB). During the period of suspension, independent aircrew and engineering Subject Matter Experts (SMEs) were made available by Air Command to Norfolk Constabulary and RAF SIB. Annex A

33. Following the subsequent Norfolk Constabulary investigation and presentation to the Crown Prosecution Service (CPS), the CPS directed on 18 Apr 08 that there was insufficient evidence upon which to bring a prosecution in a civil court. The investigation was then ceded to RAF SIB jurisdiction for consideration of Service offences. RAF SIB closed the case 'no offence disclosed' on 13 Aug 08. Annex A

[22] QR J945 and QR Appendix 19.
[23] The Investigation of Deaths on Land or Premises Owned, Occupied or Under the Control of the MOD Protocol, dated 12 Sep 05.
[24] Although the BOI was formally suspended on 10 Dec 07, the CA directed the Board to finalise their Interim Report and read-in Norfolk Constabulary and RAF SIB to the Board's findings to date. Therefore Annex A, Diary of Actions, includes actions by the Board until 131200 Dec07.

[redacted]

Thereafter, following review by the Health and Safety Executive (HSE), RLA and the Station Commander, RAF Marham, it was determined there was no impediment to the Board being reconvened. The Board was subsequently reconvened on 20 Oct 08 at RAF Marham. During the period of the Board's suspension the aircraft was subsequently released back to the Service by Norfolk Constabulary, RAF SIB and the CA.

Diagnosis of Causes

Introduction

34. The Board was aided in its investigations by virtue of the fact that the aircraft survived the accident, along with the large amount of wreckage recovered by the search operation. The nature of the accident itself resulted in the rear ejection seat and associated debris being strewn over a large area, which necessitated a lengthy search. Fortunately, the Board developed a strong working relationship with the Norfolk Constabulary chain-of-command and deployed search team, which ensured that the maximum amount of evidence was recovered and made available to the Board. Nonetheless, despite extensive search, 2 key pieces of evidence, the TLP and TLP spring, along with the ejection gun primary cartridge and WSO Flight Crew Checklist (FCC)[25], pages N1 to N62, were never recovered. It was also fortunate that the pilot survived the accident and had clear recollections of the events up to, during and after the accident. These recollections and the recovered evidence – the aircraft, the rear ejection seat and recovered debris – plus detailed analysis from the Aircraft Accident Investigation Branch (AAIB), BAE Systems, Martin Baker Aircraft Limited (MBA) and the RAF Centre of Aviation Medicine (RAFCAM), led the Board to concentrate on AAES factors in determining the cause of the accident.

35. The initial technical investigation sought to identify those components or systems that could have had a bearing on the accident, in order to establish the most likely cause and associated flight safety implications. As well as the technical investigation, several other lines of inquiry were initiated in order to examine other factors relating to the accident. Therefore, in addition to the pilot's recollection of events and the physical evidence recovered, the Board also relied heavily on BAE Systems and AAMSS personnel's recollections of events surrounding the fitting and maintenance of the aircraft's AAES, and on the various agencies involved with the training of air and ground personnel. This work sought to establish the required detail on matters such as procedures, governance and training of personnel. These lines of inquiry required the Board to consult widely with a number of Service and civilian agencies and SMEs. Additionally, witness statements taken by Norfolk Constabulary and interviews conducted under the

[25] AP101B-4104-14A.

[redacted]

Police and Criminal Evidence Act (PACE) were made available to the Board[26]. The Board noted that the independent engineering SMEs provided to Norfolk Constabulary, during the period of Board suspension, were unable to conclude the cause of the accident. However, this was to be expected as they only had access to the aircraft, ejection seat, BTTDFU and photographs from the accident site, and not to the Board proceedings, nor to any of the interim or final reports from AAIB, BAE Systems, or MBA. Exhibit 15f, 15h

Available Evidence

36. **Evidence.** To assist the Board in its deliberations the following evidence was available:

a. The aircraft.

b. The rear ejection seat and recovered debris.

c. Pilot's statement.

d. Eyewitness statement.

e. Statements from engineering personnel who had worked on the aircraft and its AAES.

f. Statements from ejection seat training personnel.

g. ADR tape and data traces.

h. SME witness statements.

i. Maintenance documentation for ZA554.

j. AAIB report.

k. BAE Systems report.

l. MBA report.

m. RAFCAM Accident and Human Factors (HF) reports.

n. Norfolk Constabulary witness statements.

o. RAF SIB transcripts of Norfolk Constabulary taped PACE interviews.

p. BAE Systems aircrew training and authorisation

[26] Norfolk Constabulary released all witness statements and records of interview with permission of the respective witnesses (Ref 2007DIN02-151). These are entered into the evidence as Annex AP and Exhibit 15.

[redacted]

[redacted]

records.

q. Engineering personnel training and authorisation records.

r. SAR report.

s. Transcript of Air Traffic Control (ATC) radio log.

t. CMU Flying Order Book (FOB).

37. **Unavailable Evidence.** The following evidence was not available to the Board:

a. TLP and spring.

b. Ejection gun primary cartridge.

c. WSO FCC, Cards N1 to N62.

d. WSO flying logbook. Para 75a(5)

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

a. AAIB.

b. BAE Systems Airworthiness, Flight Test and Materials Departments.

c. RAFCAM Accident Investigator.

d. RAFCAM Aviation Psychologist.

e. MBA.

f. JARTS.

g. ADR Services, QinetiQ.

h. Norfolk Constabulary.

i. Weapon Training Section (WTS), RAF Marham.

Factors Considered by the Board

39. At an early stage the Board was able to discount weather, mid-air collision and birdstrike as factors in the accident. Witness 1, Annex M, X, Exhibit 16

[redacted]

40. The Board considered the following factors in determining the cause of the accident:

a. Failure of rear ejection seat following an initiated ejection.

b. Mechanical failure.

(1) Catastrophic failure of the TLP.

(2) Catastrophic failure of the TLP spring.

(3) Catastrophic failure of the rear ejection seat gun or its sub-components.

c. Installation of the TLP.

(1) TLP and/or TLP spring not fitted.

(2) TLP fitting handwheel left in-situ.

d. TLP incorrectly engaged.

(1) Ejection seat raised.

(2) Misalignment of the inner piston v-shaped grooves.

(3) Raised inner piston.

e. Ejection seat Mod 02198.

f. Events leading to raised ejection gun inner piston.

g. Fouling of BTTDFU.

h. Reintroduction of the TLP handwheel caused by fouling of the BTTDFU.

i. Maintenance procedures.

j. Training and authorisation of AAMSS personnel.

k. Working practices.

(1) Adherence to MPs.

(2) Recording of maintenance activities.

(3) Working practices on ZA554.

l. Unauthorised or unrecorded work on the AAES after the completion of independent checks.

m. Airworthiness trail.

n. Communication between CMU and AAMSS personnel.

o. Authorisation of sortie.

p. Post maintenance flight test schedule.

q. Aircrew orders.

r. Aircrew training.

s. Sabotage.

t. Seat and aircraft impact.

u. Human Factors.

(1) Pressure.

(2) Distraction.

(3) Fatigue.

(4) Environment.

(5) Supervision.

(6) Task situational awareness.

(7) Seat raise check.

(8) TLP checks.

Consideration of Factors

41. **Failure of Rear Ejection Seat Following an Initiated Ejection.** Ejection of the rear seat could only be initiated through either the pulling of its Seat Pan Firing Handle (SPFH) or, via the command ejection system, the pulling of the front SPFH[27]. Failure of the rear ejection seat to follow a normal ejection sequence following an aircrew-initiated ejection was discounted as a factor in the accident for the following reasons:

a. Examination of the rear ejection seat wreckage showed that the rear SPFH had not been pulled. — Annex E

b. The pilot had not initiated ejection. — Witness 1

c. The pilot had given no instruction to eject and stated that there was no reason for ejection to have been initiated. — Witness 1
Furthermore, the ADR trace and voice recording showed no indication of any problems with either the aircraft or diagnosed by the WSO, that would have been likely to result in ejection being initiated by the WSO. — Annex I, R, W

42. **Mechanical Failure.** Ejection seats are locked to the aircraft solely through the engagement, under TLP spring pressure, of the flat section of the ejection seat TLP with the flat surface of the top latch window on the ejection gun; the gun being firmly bolted to the aircraft. Therefore, the failure of the seat to be retained within the aircraft when it inverted must have resulted from a failure somewhere within this arrangement. The Board considered that there were 3 potential catastrophic failure cases that could have resulted in such a failure:

a. **Catastrophic Failure of the TLP.** Despite the TLP not being recovered, SME analysis of the top section of the inner piston, BTTDFU and ejection gun showed positive evidence of the TLP striking the ejection gun inner piston with force, and of the TLP being dragged over the top latch window. This could not have occurred had there been a catastrophic failure. — Annex I, J
Furthermore, there were no known occurrences of TLP failure[28]. — Witness 2
The Board concluded that catastrophic failure of the TLP was not a factor in the accident. — Annex K, Q

[27] Further detail on the generic operation of ejection seats can be found within Annexes I and O.
[28] The generic TLP mechanism has been fitted to approximately 50,000 ejection seats worldwide over a period of 50 years.

[redacted]

b. **Catastrophic Failure of the TLP spring.** Despite the TLP spring not being recovered, there were a number of reasons why the Board believed that failure of the spring did not occur:

(1) Witness marks on the top section of the inner piston indicate the TLP struck this item with force. This force could only have been applied by the TLP spring. — Annex H, I, J

(2) The outer, upper surface of the top latch window displayed evidence of a TLP being dragged over the top of the window at relatively slow speed and under spring pressure. — Annex J

(3) The most common failure mode of a spring would be fatigue caused by large numbers of compression/relaxation cycles. The TLP spring spends most of its life in a benign, semi-compressed static state. — Annex H

(4) The ejection seats had undergone enhanced bay maintenance[29] just before being installed into ZA554. This maintenance included a pass/fail check of the spring length[30] and an associated supervisor check.

(5) There had been no known TLP spring failures. — Witness 2

Thus, the Board concluded that failure of the TLP spring was not a factor in the accident.

c. **Catastrophic Failure of the Rear Ejection Seat Gun or its Sub-Components.** The rear ejection gun was still fitted to the aircraft; thus failure of the ejection gun attachment bolts was discounted. The top latch window of the ejection gun was intact and therefore failure of this item was discounted. The ejection gun intermediate piston was intact and retracted inside the ejection gun. However, the ejection gun inner piston was slightly extended and had sheared off where the aluminium inner piston breech joined the inner piston. Subsequent metallurgical examination identified the failure mechanism to be ductile static overload with distortion of the tube wall suggesting an element of bending; the Board concluded that this failure was caused by the action of the ejection seat falling from the aircraft and rotating as the top slippers disengaged. Furthermore, in this situation a sheared inner piston would not cause the top latch to become unlocked. Catastrophic failure of the ejection gun and/or its sub-components was therefore discounted by the Board as a factor.

Annex H, I, J
Annex J
Annex I
Annex H

[29] SNOW 4007MABAY030907.
[30] AP109B-0141-5F 2nd Edition Sect 2 Chap 1A Pulse B Card 34 Item 55.3.

[redacted]

[redacted]

43. **Installation of TLP.** With mechanical failure discounted as a factor, the Board, in close consultation and agreement with MBA and BAE Systems SMEs, considered there were 3 potential situations where the installation of the TLP may have resulted in, or contributed to, the accident:

a. **TLP and/or TLP Spring Not Fitted.** Neither of these items had been recovered. However, the Board believed they were both fitted for a number of reasons:

(1) Witness marks on the inner piston and top latch window proved that the TLP and TLP spring were present at the time of the accident. Annex H, I, Para 44c(4)

(2) The ejection seat had undergone an enhanced bay maintenance[31] and had also had the top block replaced[32] prior to being fitted to ZA554. These activities included certification that the TLP and TLP spring had been fitted.

(3) Failure to fit a TLP would have prevented the ejection seat from being locked to the ground seat stand, used for storage and transportation. Additionally, fitting the TLP handwheel, an inherent part of the seat fitting process both for fitment and removal from the seat stand and also for installation into the aircraft, would have been physically impossible.

(4) The lack of a TLP spring would have been obvious to both seat bay and AAMSS personnel because the associated lack of spring pressure would have made gaining purchase on the TLP with the handwheel, both for fitment and removal from the seat stand and also for installation into the aircraft, extremely difficult.

Consequently, the Board discounted the TLP and/or TLP spring not being fitted as factors in the accident.

b. **TLP Handwheel Left In-Situ.** The TLP handwheel was used during maintenance to disengage the TLP from the ejection gun. Thus, if the handwheel had been left in-situ, it was highly likely that the seat would not have been locked to the aircraft. However, leaving the handwheel fitted would be contrary to the instructions in the Mandatory Maintenance Procedure[33] (MMP). Moreover, the handwheel would have to have been missed by the tradesman (Witness 3), vital checker (Witness 4), independent checker (Witness 5) and the WSO. The handwheel was relatively

[31] SNOW4007MABAY030907.
[32] SNOW4008MABAY021107.
[33] DAP101B-4104-1EP MP 29-10/3 and MP 29-10/3A.

[redacted]

large and was of shiny brass construction; the shaft of the handwheel was approximately 8 cm long while the handwheel itself was approximately 7.5 cm in diameter and 1 cm deep. The armament toolkit was registered for one handwheel, which was accounted for in the toolkit, and 100% toolkit checks had been signed for in the days leading up to the accident. The Board discounted the handwheel being left in-situ as a factor in the accident. Annex AI

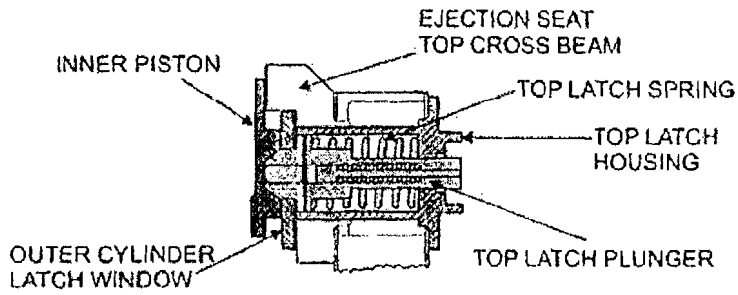
44. **TLP Incorrectly Engaged.** By discounting mechanical failure, TLP and TLP spring not fitted, and TLP handwheel left in-situ, the Board concluded that a serviceable TLP and TLP spring must have been fitted at the time of the accident. **Therefore, the only possibility remaining for the cause of the accident was that the TLP must have been incorrectly engaged in the top latch window.** The Board was able to prove that this condition existed on ZA554 at the time of the accident. To set out a verifiable evidence trail the Board initially examined the criteria required and process for checking for correct TLP engagement. The Board then looked at the mechanisms that could have led to the incorrect TLP engagement. Thereafter, material evidence was examined and trials completed to prove objectively that an incorrectly fitted TLP existed at the time of the accident. Annex H, I, J Annex AG Annex H, I, J, AG

a. **Correct TLP Engagement.** Correct engagement of the flat section of the TLP with the flat surface of the top latch window on the ejection gun was essential to lock the seat to the aircraft. For the TLP to be correctly engaged 2 conditions had to be met. Firstly, the ejection seat had to be fully lowered down its guide rails with the ejection gun inner piston sufficiently retracted into the ejection gun such that the inner piston breech groove aligned with the top latch window on the outer cylinder of the ejection gun. Secondly, the TLP, under TLP spring pressure, had to pass through the top latch window on the ejection gun and locate in the breech groove on the inner piston. This would place the TLP in a position whereby the flat surface of the TLP was situated against the flat surface of the top latch window, thus locking the seat to the ejection gun. The TLP consisted of the plunger element, which was the body of the TLP, and a spring-loaded spigot, which ran through the centre of the plunger. Correct indication of a properly locked ejection seat was via a 2-part TLP check: Annex I, P

(1) **Plunger Check.** The plunger was to be flush with or slightly below the top latch housing face on the seat.

(2) **Spigot Check.** The spigot was to be flush with or slightly proud of the threaded end of the TLP body.

Both parts of the TLP check had to meet their respective criteria for the check, as a whole, to be passed.



MBA Schematic of a correctly engaged TLP.

b. **TLP Checks.** According to the MPs extant at the time of the accident, the TLP check should be carried out at least 3 times in the process of installing the ejection seat, at least once by each of the tradesman, vital checker and independent checker. The tradesman carries out the maintenance or fitting task. The vital checker carries out vital checks, which are to be undertaken at pre-defined stages during the AAES installation (the vital checker must not have undertaken the maintenance task to which the vital check related but could be the supervisor of the maintenance task[34]). The independent checker is to provide final confirmation, via the independent check, that all AAES locking, routeing and installation processes have been carried out correctly on the assembly being checked (the independent checker must not have undertaken or assisted in, supervised or vital checked any part of the maintenance undertaken on that assembly[35]). Furthermore, a physical seat raise check is also performed by the vital checker with the aim of confirming that the seat is locked by attempting to lift it out of the aircraft by using a hydraulic crane. The Board confirmed that there were no credible scenarios where the TLP could have been incorrectly engaged such that the seat would not have been locked to the ejection gun without at least one indication of failure shown by at least one part of the TLP check. Annex P Annex K

c. **Possibilities for Incorrect TLP Engagement.** The Board considered the conditions that would prevent correct engagement of the TLP in the top latch window, and thus result in an unlocked seat. Three possible conditions were identified: Annex K

(1) **Ejection Seat Raised.** This condition would have occurred if the seat was not fully lowered down the ejection seat rails (eg if there was an obstruction under the seat), and would place the TLP on the top latch window housing, on the outer surface of the ejection gun, immediately above the window. This would give a correct spigot indication but an Annex K Annex K

[34] JAP 100A-01 Chapter 13.1.2.
[35] JAP 100A-01 Chapter 13.1.2

incorrect plunger indication, in that the plunger would be proud of the housing. With the seat in this condition the tradesman would have difficulty connecting and rigging the ejection seat trip rods and would be unable to connect the rear canopy MDC. Therefore, the problem would be identified even if the TLP check indications had been missed. Furthermore, the rear canopy MDC operated when the seat fell from the aircraft and, thus, must have been correctly connected. Therefore, the condition of a raised ejection seat preventing the locking of the seat to the aircraft, was discounted as a factor in the accident. Annex E, J

(2) **Misalignment of the Inner Piston V-Shaped Grooves.** The v-shaped grooves on the inner piston mate with a locating spigot on the inner surface of the seat top block. This ensures that the inner piston remains in position rotationally, allowing the BTTDFU to be screwed into position. Misalignment of the v-shaped grooves would mean that the locating spigot would sit on top of the inner piston, leading to a raised seat. This would also have left damage on the top of the inner piston. Misalignment of the inner piston v-grooves was discounted as a factor for the reasons as per a raised ejection seat, and also because of the absence of damage to the top of the inner piston. Annex K Annex J

(3) **Raised inner piston.** The Board identified a previously unknown condition where on a post-Mod 02198 seat, the inner piston could be raised to a position that prevented the correct engagement of the TLP, but allowed all other seat connections to be made; Mod 02198 is discussed in more detail at paragraph 45. Therefore, having discounted the other 2 factors that could have led to incorrect TLP engagement, the Board concluded that the third and final possibility, a raised inner piston, must have existed at the time of the accident. This was confirmed through examination of material evidence and replication trials, as detailed in the following paragraphs.

(4) **Material Evidence and Replication Trials.** Through the examination of material evidence and replication trials the Board proved conclusively that the TLP was not correctly engaged in the ejection gun top latch window and that a raised inner piston had existed at the time of the accident.

(a) **Material Evidence.** Metallurgical examination of ZA554's BTTDFU and inner piston showed witness marks on the top edge of the breech groove that matched with a TLP as well as a small indentation in the port v-groove commensurate with a TLP spigot. Annex I

[redacted]

During a normal ejection, or as part of any maintenance activity, the TLP would never make contact with these areas of the inner piston. SME opinion was that the positioning of the witness marks indicated that the TLP was not correctly engaged with the top latch window at the time the ejection seat left the aircraft. Annex J

(b) **Replication Trials.** Replication trials were conducted by the Board to verify its conclusion. The trials were undertaken in the WTS, RAF Marham, using a representative post-Mod 02198 ejection seat and the ejection seat training rig. Two WTS instructors completed the trials under the direction of the Board, witnessed by AAIB, BAE Systems, and MBA SMEs. The trials were conducted in the front cockpit to facilitate filming and observation; the processes undertaken would have been no different for the rear cockpit. The trials replicated the condition of a raised inner piston preventing the correct engagement of the TLP in the ejection gun top latch window. Initially, the ejection seat was correctly locked to the ejection gun. Then, for the purpose of the trials, the inner piston was raised by withdrawing the TLP from the top latch window (by using the handwheel). The inner piston was then raised to the maximum physical amount possible by gently pulling on the BTTDFU until the inner piston touched the top block; also proving the ease with which the inner piston could be raised. The handwheel was then removed allowing the TLP to move under spring pressure. However, the TLP could not engage correctly due to the misalignment of the inner piston breech groove with the top latch window. The plunger was clearly proud (ie a failed plunger check) and the spigot was slightly recessed. While in theory this indicated a failed spigot check there were, nonetheless, times during the trials when personnel present were unsure as to whether the spigot check had passed or failed; these perceptions may have been influenced by the knowledge that the plunger was in the unlocked condition or the angle from which the spigot was viewed. An attempt was made to move the seat vertically, using a Rotazoom (small crane), to simulate the actions that occurred under gravitational force when the aircraft inverted. The seat moved up the rails. As the seat moved, the plunger could be seen overcoming the breech groove and the ejection gun top latch window. As the seat moved further up the rails the top block struck the BTTDFU at the

Annex AG

Annex H, I, J, AG

Annex AG

Annex L

Annex AG

[redacted]

interface with the gas pipe (the point at which the gas pipe had sheared during the accident) causing the inner piston to be dragged upwards with the seat. The trial was halted at this point. Following removal of the BTTDFU and seat, the ejection gun top latch window and inner piston were inspected. Although the seat had been raised at a slower speed than would have occurred during the accident, the marks on the top latch window and inner piston were consistent with those on the respective items recovered from the accident. The trials were conducted 3 times with consistent results. Annex H, I, J, AG

(c) **Material Evidence and Replication Trials Summary.** The examination of material evidence and replication trials proved that:

(i) A normal ejection had not occurred during the accident.

(ii) The marks on the top latch window and inner piston were consistent with the accident.

(iii) The TLP and TLP spring were present and serviceable during the accident.

(iv) A raised inner piston could prevent correct engagement of the TLP, thereby leaving the ejection seat unlocked. This condition would fail the TLP checks, although the spigot check may be perceived as a pass.

(v) The ejection seat impacted the BTTDFU gas pipe at the point it had sheared during the accident.

(vi) The BTTDFU gas hose dragged the inner piston from the ejection gun.

The Board concluded that a raised inner piston existed at the time of the accident, preventing correct engagement of the TLP in the top latch window, and was therefore a causal factor.

The Board concluded that the cause of the accident was that the TLP was incorrectly engaged in the top latch window, as a result of a raised inner piston, which led to the rear ejection seat not being locked to ZA554. Annex H, I, J

[redacted]

45. **Ejection Seat Mod 02198.** Mod 02198 was designed to cater for the growth in mass of the ejection seat and AEA that had occurred because of a number of modifications, and a general increase in aircrew mass[36]. The modification (mod) is split into mods 02198A and 02198B. Mod 02198A introduces a new drogue withdrawal line and protective top flap. Mod 02198B introduces: a new parachute design; a gas-operated shackle and associated pipework; and a gas-fired BTTDFU and associated timing mechanism. Because Mod 02198 had recently been introduced (Aug 07) and affected components that interfaced with the TLP, the Board believed it warranted close investigation:

a. ZA554 was only the 10th RAF aircraft to be fitted with post-Mod 02198 ejection seats. At the time of the accident, 88 sorties totalling 65 hrs had been flown by RAF aircraft with post-Mod 02198 seats installed. Annex T

b. The introduction of Mod 02198 did not change any dimensions relating to the TLP, inner piston and/or TLP housing. Furthermore, the mod did not change in any way the checks for the correct engagement of the TLP, or make the checks harder to undertake. Witness 2 Annex K

c. The Board examined differences between pre and post-Mod 02198 seats that could have influenced the correct engagement of the TLP in the ejection gun top latch window. One major aspect was found:

(1) On pre-Mod 02198B ejection seats, the Board established that if a condition existed whereby the inner piston was raised such that the seat was not locked to the ejection gun (and this was not identified during the TLP checks, which would indicate a failure), the mechanical linkage to the BTTDFU could not be made. The Board believed that in such a case the efforts to make the mechanical linkage fit would have resulted in the depression of the raised inner piston and in the process, probably unknown to the tradesmen, the TLP would subsequently be correctly engaged in the top latch window. Thus, for a pre-Mod 02198 seat, even if the tradesman and vital checker (who complete their TLP checks before the BTTDFU mechanical linkage is fitted) had missed the fact that the TLP checks had failed, the unlocked condition could have been rectified in the process of fitting the BTTDFU without any realisation that the seat had, at some stage, not been locked. Coincidently, therefore, when independent checks were carried out on a pre-Mod 02198 seat (ie after all components had been fitted), the TLP could be in no other

[36] DAP101B-4104-2 June 2007 MOD 02198B.

[redacted]

[redacted]

condition but correctly engaged.

(2) The Board established that for a post-Mod 02198B seat the semi-flexible gas pipe connection to the gas-operated BTTDFU could be fitted with the ejection gun inner piston remaining in a raised position, thereby preventing engagement of the flat section of the TLP with the flat surface of the top latch window on the ejection gun, such that the seat was not locked to the aircraft. In this condition the TLP plunger check would fail by approximately 5.5 mm and the TLP spigot check would fail by approximately 0.69 mm, depending on machining tolerances. However, if the tradesman and vital checker had missed the failed TLP checks the unlocked condition would not be unknowingly rectified through the fitting of the BTTDFU (as it could be on a pre-Mod 02198 seat), and could only then be picked up by the independent check or aircrew check. Annex H, I, J Annex K, AG

d. Therefore, Mod 02198 introduced a condition whereby a seat could be fitted and armed with a raised inner piston, which would prevent the correct engagement of the TLP. Although the TLP would have indicated a failure, this was the condition (as already proved) that existed on ZA554. Annex H, J

The Board concluded that while Mod 02198 did not directly cause the accident, it made it more likely, and therefore was a contributory factor.

46. **Events Leading to Raised Inner Piston.** Having concluded that a raised inner piston was a cause of the accident, the Board then focussed on examining the events that may have led to the condition of a raised inner piston.

a. The Board, in consultation with SMEs, determined that there were 5 potential mechanisms that could have led to a raised inner piston:

(1) The inner piston could have been left slightly extended by the seat bay; albeit, the seat bay MP[37] requires the inner piston breech groove to be aligned with the top latch window.

(2) The inner piston could have moved during transportation. ZA554's final ejection gun was transported on the back seat of a general-purpose flatbed, crewcab vehicle (LDV). Witness 11, 13

(3) The inner piston could have been raised when Witness 11

[37] AP109C-0104-5F 2nd Edition Sect 2 Chap 1 Card 23 Amdt 2 Item 34.1 and 35.1.

[redacted]

[redacted]

removing the BTTDFU from the ejection gun prior to installation of the ejection gun into the aircraft. The BTTDFU should be screwed into the ejection gun for ground transportation; however, the Board was unable to determine whether this was the case with ZA554's final ejection gun.

(4) The inner piston could be raised if a trial fit of the BTTDFU was carried out with the seat lowered into position on the ejection gun, and with the handwheel still attached. During trials, the Board found that this was very easy to undertake and that the raising of the inner piston may not be noticed. Albeit, this action would be before the MMP called for the TLP checks, and hence the TLP checks should highlight the incorrect engagement of the TLP. Annex AG

(5) The inner piston could be raised if the handwheel was reintroduced to ease any difficulties experienced when fitting the BTTDFU. Reintroducing the handwheel would remove the TLP spring pressure from the inner piston and allow a slight amount of play which may enable the BTTDFU to be screwed in more easily. After this, the BTTDFU gas hose would be connected. In such a case the seat would be in an unlocked condition, and it would be very easy to unknowingly raise the inner piston slightly during connection of the gas hose. Because the seat would have been previously locked the installation team might not think it necessary to re-check the locking of the seat. Albeit, such reintroduction would be against the MMP. Annex Q, Annex AG

b. The Board became aware that one week after the accident, armament personnel from 56(R) Squadron, RAF Leuchars, were installing an ejection seat to the front cockpit of a Tornado aircraft, unrelated to this accident, when it failed the plunger check but was deemed to have passed both the spigot check and seat raise check[38]. Subsequent 56(R) Squadron investigation found raised inner pistons on both the front and rear ejection guns that had not been identified prior to the attempt to install the front ejection seat. Annex AF, Exhibit 17

c. Finally, the Board found that, on the whole, armament personnel were well-versed in the checks for v-groove alignment but were unaware of the need to check that the inner piston breech groove was aligned with the top latch window. Personnel assumed that the MMP instruction[39] *ensure correctly seated* for the inner piston tube referred solely to v-groove alignment with the guide rails. Therefore, a raised inner piston may go Witness 3, 5, 9, Annex AF

[38] Although the ejection seat was a post-mod 021988 seat, at this stage in the installation process there is no difference between pre- and post-mod seats.
[39] DAP 101B-4104-1EP, MP29-10/3A, Item 4.3.

[redacted]

unnoticed.

d. **Events Leading to Raised Inner Piston Summary.** The Board was able to determine that the possibility existed whereby an ejection gun with a raised inner piston could be provided for installation into an aircraft, and that not all personnel were aware of the method of ensuring that the inner piston was correctly seated in the ejection gun. However, the Board was unable to positively discount or directly attribute as a factor in the accident, any of the 5 potential mechanisms that may have led to the inner piston of the rear ejection gun of ZA554 being in a raised condition.

The Board concluded that the 5 potential mechanisms were possible contributory factors, at least one of which must have been a contributory factor.

47. **Fouling of BTTDFU.** The Board identified a number of instances of post-Mod 02198B BTTDFUs being difficult to fit because of physical fouling, probably due to machining tolerances, between the BTTDFU and the top block. On ZA554, fouling of the BTTDFU had caused delays to the installation of the rear ejection seat and resulted in trial fits of both an ejection gun and BTTDFU. The fouling also formed part of the collective decision of the seat fitting team and the seat bay to replace only the ejection gun prior to the final seat installation. Historically, ejection seats and guns were paired; however, the process of matching up the ejection seat, ejection gun and BTTDFU was not being conducted in the seat bay at the time of the final seat fits of ZA554. The fouling of ZA554's BTTDFU may have been resolved in the seat bay had the process of matching up ejection seats and guns been extant. The resolution of ZA554's BTTDFU fouling at the aircraft, rather than in the seat bay, resulted in the following:

Witness 11, 13, Annex AB

Witness 4, 11, 13

Witness 11, Annex AB

Annex J

a. Delays that protracted the installation of the seats on a priority aircraft, with the aircraft's associated time pressures, which therefore may have introduced an element of pressure to the seat fitting team.

Witness 4, 5, 6, 12, 11, Annex AP(ii)

b. Deviation from normal procedures, by both the seat bay and AAMSS personnel.

Witness 4, 13, Annex AP(i)

c. Distraction of AAMSS personnel during the period in which the TLP checks were undertaken.

Annex L

The Board believed that had the ejection seat been matched to its ejection gun and BTTDFU prior to fitment to the aircraft, the fouling found by AAMSS tradesmen may not have occurred. The Board considered that the pressure, deviation and distraction on the seat

Annex J

Annex L

[redacted]

fitting team during the final rear ejection seat installation would not have occurred without the fouling of the BTTDFU on the top block. **Therefore, the Board concluded that fouling of the BTTDFU was a contributory factor.**

48. **Reintroduction of the Handwheel caused by Fouling of the BTTDFU.** Where fouling of the BTTDFU occurs, reintroduction of the handwheel and the withdrawal of the TLP from the inner piston breech groove, thus removing lateral pressure from the inner piston, could make the fitment of the BTTDFU easier. However, as previously discussed, this would increase the risk of unintentionally raising the inner piston, and for the associated incorrect TLP engagement to go unnoticed because the TLP checks would have already been passed. Examination of the top latch window on ZA554's ejection gun showed a grease mark on the lower surface of the window, which suggested that a seat had been correctly locked to the ejection gun at some point. The MBA SME believed that the grease mark, which should have been removed by the seat bay prior to delivery, meant that the final ejection seat and gun had at some point been correctly locked to each other in ZA554. Furthermore, he believed there was a real possibility that in order to overcome difficulties in fitting the BTTDFU the handwheel had been reintroduced during seat arming, which would have been after the TLP checks. However, the Board noted that perceived time pressures on ZA554 may have resulted in the seat bay not being as thorough as they normally would have been in cleaning the gun, which is not specifically called for in the MP[40], and therefore on this occasion, the seat bay may not have cleaned the top latch window. Consequently, the grease mark may have been left by another seat that was fitted to the gun during a previous installation on another aircraft. Thus the Board could not conclude whether or not the grease mark proved that the rear seat of ZA554 had been locked to this gun, because the personnel involved in the seat fit stated that the handwheel had not been reintroduced, but the seat bay said that the ejection gun was cleaned. Hence, the Board could draw no conclusion as to whether the handwheel had been reintroduced to overcome BTTDFU fouling on ZA554.

Annex Q, Para 46a(5)
Annex J, Q
Annex Q
Witness 11, 13
Witness 3, 4, 6
Witness 13

49. **Maintenance Procedures.** The MPs[41] for the installation and reinstallation of ejection seats are Mandatory MPs (MMPs). MMPs require personnel to certify their work against each line of the MMP unlike MPs, which can be signed for as a whole[42]. WTS training taught that AAMSS personnel should take the MMP with them to the aircraft and read each line before completing the task pertinent to that line. The work should then be signed for immediately on completion of the tasks that have been undertaken for that MMP. The MP[43] for independent checks following installation of an ejection seat was not

Witness 14
Witness 5

[40] AP109C-0104-5F 2nd Edition Section 2 Chapter 1 Bay Maintenance Ejection Gun and Guide Rail.
[41] Installation DAP101B-4104-1EP MP 29-10/3, and reinstallation DAP101B-4104-1EP MP 29-10/3A.
[42] JAP 100A-01 Chapter 7.2
[43] DAP101B-4104-1EP MP 29-10/6.

[redacted]

[redacted]

an MMP but personnel were encouraged to follow it line by line while undertaking the checks. In its deliberations the Board considered the tasks and checks for the ejection gun inner piston and for the lowering and locking of the ejection seat for each of the tradesman, vital checker and independent checker. The Board identified that:

a. **Inner Piston Checks.**

(1) The ejection gun inner piston tube check[44] was open to interpretation, in that the wording *ensure seated correctly* did not describe the alignment of the inner piston breech groove with the top latch window. Therefore, the MMP check would not necessarily have led to the identification and correction of a raised inner piston. — Annex P, AF

(2) The check that the stud [locating spigot] on the ejection seat was to be located in the v-groove of the ejection gun inner piston[45] was open to interpretation in that personnel may have considered a passed v-groove check to be a valid indicator of a correctly seated inner piston. — Witness 2, 5 Annex L, P, AF

(3) There was no check to enable identification of a raised inner piston within the independent checks[46]. — Annex P

The Board considered that the lack of clear instruction in the MPs for inner piston checks may have led to the raised inner piston going unnoticed and hence uncorrected.

b. **MMP Deviation.** The requirement to remove the lifting sling prior to undertaking the seat raise check, as part of the vital checks[47], encouraged personnel to deviate from the MMPs. — Witness 14

(1) Personnel were taught to undertake the raise check using a Rotazoom which required the lifting sling, because executing the raise check via a manual lift contravened Manual Handling Regulations. As a result, the supervisor routinely undertook the vital check prior to the tradesman completing his check, contravening both the MMPs and JAP100A-01. This meant that the tradesman was either less likely to carry out his own check or would be anticipating the check to pass, which may have affected his perceptual judgement. — Witness 4, 14 Annex L

(2) It was common practice, and indeed taught at Phase 3 training (para 50a), for the supervisor, or vital checker, to — Witness 3, 4, 5, 9, 14

[44] DAP101B-4104-1EP MP 29-10/3 06/07 Items 12.11(i) and 14.10 (b); and MP 29-10/3A 02/07 Item 4.3(i). This also applies to AP109C-0104-5F 2nd Edition Section 2 Chapter 1 Card 23 Amendment 2 Item 34.1.
[45] DAP101B-4104-1EP MP 29-10/3 06/07 Item 15.13; and MP 29-10/3A 02/07 Item 5.13.
[46] DAP101B-4104-1EP MP 29-10/6 06/07.
[47] DAP101B-4104-1EP MP 29-10/3 06/07 Items 15.16 and 16.2; and MP 29-10/3A 02/07 Items 5.16 and 6.2.

[redacted]

[redacted]

remove the TLP handwheel; ie to physically lock the ejection seat to the ejection gun, a maintenance task. A vital checker must not undertake the maintenance task that he is 'vital checking'[48]. The reason why this practice had evolved was readily apparent; the supervisor was in charge of the seat lift into the aircraft and was therefore already located in position (ie at the aircraft cockpit) to lock the seat, unlike the maintainer who was generally on the ground operating the Rotazoom. The Board concluded that this practice was contrary to both the MMPs and JAP100A-01, and could lead to the TLP checks only being undertaken once – by the vital checker rather than by both the tradesman and vital checker. Annex L

These practices were both undertaken by the final rear ejection seat fitting team on ZA554, and therefore may have resulted in aspects of the tradesman and vital TLP checks being missed. Annex L

c. **Seat Raise Check.** The ejection seat raise check was subjective in that there were no measurable criteria against which to execute the check. Consequently, the seat raise check may not have indicated an unlocked seat. The trials carried out by the Board indicated that qualified personnel routinely applied significantly less force than the actual seat weight when attempting to lift seats to check they were locked in position. During the trials the ejection seat was lowered onto and correctly locked to the ejection gun. A mass spring balance was attached between the Rotazoom and seat sling and WTS instructors were tasked to undertake a seat raise check in accordance with the MMP. Once the instructors were satisfied that enough force had been applied to the seat to lift it from the aircraft if it was not locked, the reading on the mass spring balance was recorded. The readings recorded during the trials ranged from 75kg to 103kg, which were all significantly less than the mass of a seat on installation. For example, in the case of ZA554 the seat would have weighed just less than 120kg when the seat raise check was carried out, because it had all its safety equipment fitted. Therefore, the seat raise check may not have indicated a locked seat, and conversely could have given personnel the false impression that a seat was locked to the aircraft when it was not. Annex L Annex AG Annex AG Annex P

d. **TLP Checks.**

(1) The Note associated with the tradesman's check[49] of the TLP, detailing the 2 conditions to be met for a correctly engaged TLP, was valid. However, the check itself only stated a requirement to ensure that the top latch was correctly engaged; the note merely served as amplification Annex P

[48] JAP100A-01 Chapter 13.1.2.
[49] DAP101B-4104-1EP MP 29-10/3 06/07 Item 15.15; and MP 29-10/3A 02/07 Item 5.15.

[redacted]

[redacted]

of the check and therefore may not have been routinely referred to. Annex L

(2) The vital check[50] of the TLP merely instructed personnel to ensure that the top latch was correctly engaged. There was no amplification detailing the 2 conditions that had to be met when carrying out the check. This meant that the vital checker may not have been routinely exposed to the 2 aspects of the check. Annex P Annex L

The Board considered that the lack of clarity pertaining to the 2 aspects of the TLP check may have meant that personnel were not routinely exposed to the detail of both parts of the TLP check, thus leading to an increased likelihood of incorrect application. Annex L

The Board concluded that the unavoidable deviation from, and lack of clear instruction in the MPs made the accident more likely to happen; therefore, the MPs were a contributory factor.

50. **Training and Authorisation of AAMSS Personnel.**

a. Only appropriately trained and authorised armament personnel are permitted to undertake work on Tornado GR4 ejection seats. The training, known as Phase 2 and Phase 3 training comprised: at Phase 2, basic generic armament training and aircraft-specific armament training; and at Phase 3, further in-depth training on specific armament equipment comprising both theory and practical work. Both Phase 2 and Phase 3 training instructed personnel on the criteria of the TLP checks, ie how to identify correctly locked ejection seats. Authorisation of personnel to work on ejection seats was based upon successful completion of Phase 3 training. An open book, 6-monthly re-certification exam was then required to maintain authorised status. Exhibit 15i Witness 14 Exhibit 15i

b. All personnel involved in the fitting of ZA554's rear ejection seat and associated vital and independent checks were trained and authorised to undertake the work. However, the Board noted that the re-certification exam was theoretical and encouraged the use of the MPs to answer the exam questions – there was no practical test. Some AAMSS personnel thought that this was good practice, and appeared to view the 6-monthly exam as a verification of competence. However, the Board considered the exam was testing personnel's ability to read an MP, rather than their competence to undertake the maintenance activity therein. Consequently the Board believed there was significant scope for individual and collective false confidence in personnel's competence to undertake AAES work. The Board also noted that Exhibit 18, 19 Witness 4, 14 Witness 6

[50] DAP101B-4104-1EP MP 29-10/3 06/07 Item 16.1; and MP 29-10/3A 02/07 Item 6.1.

[redacted]

[redacted]

WTS instructors had no additional technical training to undertake their role and that consequently there was a lack of standardisation in the way personnel were taught to undertake maintenance activities. The Board believed that either AAES training, while it appeared sufficient, was not effective and/or, following AAES training, knowledge and/or engineering standards had reduced below the requisite standard for the following reasons: — Witness 14, Annex AD

(1) There was a widespread lack of knowledge of the requirement for breech groove alignment with the top latch window. — Witness 3, 5, 6 Annex AF

(2) A lack of knowledge of the criteria required by the TLP checks was demonstrated by some members of AAMSS, despite being presented with the MMP for reference. — Witness 3, 4, 9

(3) WTS training of personnel deemed it acceptable that the same person could undertake the lowering and locking of the seat (maintenance tasks) and the vital checks, contrary to regulations. — Witness 14

(4) The inappropriate working practices employed by AAMSS, identified and discussed in the section AAMSS Working Practices. — Para 51

Consequently the Board concluded that the training and authorisation process for AAMSS personnel may have led to personal and collective false confidence in engineering standards by failing to identify any developed behaviour patterns or erroneous mental models. Furthermore, the training and authorisation process did not ensure all AAMSS personnel displayed the expected level of knowledge of ejection seat operation and maintenance, particularly with respect to the inner piston and TLP checks. — Annex L

The Board concluded that the training and authorisation of AAMSS personnel was a contributory factor to the accident.

[redacted]

[redacted]

51. **Working Practices.** As a result of the Board's findings, the Board considered that the following aspects of the working practices employed by AAMSS personnel involved in the final installation of the ejection seats to ZA554 warranted close investigation.

a. **Adherence to MPs.** The tradesman, vital checker/supervisor and independent checker, who undertook the final rear ejection seat installation on ZA554, maintained they followed the MMPs and MP respectively, and had undertaken the checks to ensure correct engagement of the TLP. The independent checker signed for completing his task in accordance with the correct MP[51]. However, the tradesman and supervisor installing the rear ejection seat for the final time on ZA554 signed the incorrect MMP[52] for the task. The tradesman and supervisor used the MMPs relating to removal and reinstallation for access (MP29-10/2A and MP29-10/3A), which do not cover the fitting of the ejection gun to the aircraft, vice the removal and installation MMPs (MP29-10/2 and MP29-10/3), which do. Firstly, this meant that the removal, trial fit and replacement of the ejection gun was not recorded. Secondly, the tradesman and supervisor either did not realise they were using the incorrect MMPs and fitted the ejection gun without reference to the MMPs, or they referred to the correct MMPs and yet certified their work on the incorrect MMPs on completion of the task. As a result, failure to notice that the wrong MMPs had been used led the Board to doubt the thoroughness with which the tradesman and supervisor followed the MMPs. Furthermore a DQAFF agent present during the final rear ejection seat installation to ZA554 did not believe that the MMP was being followed line-by-line. This overall lack of adherence to MPs increased the likelihood that aspects of the MMP could have been missed, especially when allied with the previously discussed trained and routine deviation from the MMPs, and distraction caused by BTTDFU fouling. **Consequently, this increased probability that critical seat fitting checks were missed, or incorrectly applied, led the Board to conclude that non-adherence to the MMPs was a contributory factor.**

Witness 3, 4, 5, Annex P, AP(i), (ii), (iii), Exhibit 15a

Annex P

Witness 8

Annex L

Para 49b

b. **Recording of Maintenance Activities.**

(1) **Use of MOD Form 707B Main Card.** The overall removal and installation requirements for the ejection seats and canopy were raised on a pre-printed MOD Form 707B main card[53] which referred out to the relevant MPs/MMPs for each major task. In the case of MMPs, personnel were to certify the work carried out by signing on the relevant MMP

[51] SNOW0002ZA554240107 Sheet 5 Line 14.
[52] SNOW002ZA554240107 Sheet 24.
[53] PPMWO MAR/TOR/07/02 Issue 9.

[redacted]

[redacted]

(MOD Form 707MP). Once the whole of the MMP had been completed, completion was to be recorded on the MOD Form 707B. The MOD Form 707B also contained entries to certify that the vital checks (already certified on the MMP) and independent checks had been carried out. AAMSS personnel used the same MOD Form 707B to record all ejection seat removals and installations, and canopy work, relating to an aircraft going through CMU. The Board found that this method of recording the work made it extremely difficult to track what had taken place with respect to an aircraft's AAES. Moreover, when several removals and installations of AAES components had been carried out, the documentation became so complex that there was significant room for error. In the case of ZA554, this complexity may have contributed to the failure of AAMSS personnel to raise entries for, and subsequently certify completion of both the MDC rigging and canopy rocket motor cartridge installation, which the Board identified had not been recorded correctly. The failure also highlighted weaknesses in the pre-printed MOD Form 707B main card, which did not identify the requirement for these maintenance activities. Furthermore, the complexity of the MOD Form 707B may have made personnel more reluctant to record additional work such as faults. The Board also noted that several faults relating to ZA554's ejection seats and canopy were not recorded on the documentation. As a result of its investigations for ZA554, the Board concluded that AAMSS personnel, as a whole, were habitually failing to record all of the maintenance activities that they undertook on aircraft, in contravention of JAP100A-01.

Annex P, AH

Witness 4, 5, 6, Exhibit 20, 21

Annex AE

(2) **Use of DMS.** Following completion of the task, in addition to completing the documentation, AAMSS tradesmen are required to certify that their work is complete on DMS. DMS contains all of the planned and emergent maintenance activities required for an aircraft undergoing maintenance in CMU, and is the CMU system for tracking completed and outstanding work. An electronic signature on DMS certifies that the work has been completed in accordance with appropriate regulations. Therefore, correct application of DMS is critical to the issue of the FAC. The Board noted that there appeared to be some confusion within AAMSS on the interface between DMS and RAF F700 series documentation. The DMS entries did not reflect either the maintenance documentation or the LITS entries, nor did DMS contain all of the faults that had been found on ZA554. Consequently, the DMS certification could not be used, as it was intended to have been, as authoritative evidence of all maintenance that had been undertaken on the aircraft, or

Annex AD

Annex AE

Witness 3, 4, 5, 6

Annex AD

[redacted]

[redacted]

that tasks had been fully completed in accordance with the regulations.

(3) **Use of LITS.** The LITS entries for ejection seat and ejection gun fitment for both ZA554[54] and ZA613[55] did not correspond to the aircraft documentation. There were entries on LITS for each aircraft indicating that ejection seats and ejection guns were fitted but there was no corresponding maintenance documentation. Additionally, ZA613 also had documentation showing ejection seats had been fitted but no corresponding LITS entry. This served to further complicate the engineering sequence of events to the point where the Board could not rely upon LITS data to ascertain the AAES maintenance carried out on the aircraft. Annex AM

The Board concluded that the AAMSS personnel did not accurately record their maintenance activities and, while not a factor in this accident, rectification may prevent future accidents. Therefore, the incorrect recording of AAMSS maintenance activities was an other factor.

c. **Working Practices Found on ZA554.** As concluded previously: the tradesman and vital checker/supervisor displayed a lack of knowledge pertaining to the TLP checks; and the MMP was not followed line-by-line. The Board also found that the relevant documentation was not signed either at the time or immediately after completion of the seat installation. This was evidenced by the fact that the signatures for the maintenance and vital checks, which should have been entered into the documentation before the independent checks started, were entered afterwards, at least a full day after the seat installation was reportedly completed. Work was also carried out on the aircraft AAES that was not recorded; the independent checks were started at 1530 on 7 Nov 07 but failed for 3 faults: MDC go/no go test, CJRM lockwire and manual separation lockwire (front seat). However, neither these faults nor the independent check failure were recorded on the MOD Form 707B, although the resultant removal of the front ejection seat safety equipment to rectify the manual separation lockwire was. A second set of independent checks started at approximately 0800 on 8 Nov 07, which failed for a broken aircraft portion PEC in the front cockpit, although the remainder of the independent checks passed. These independent checks and the fault were also not recorded, although the removal of the aircraft portion PEC was. A PEC was then slaved into the aircraft (again unrecorded) to allow TEMPEST testing to go ahead. The final PEC was installed at lunchtime following completion of the TEMPEST testing; the PEC

Para 50, 51a, Witness 3, 4

Witness 4, 5, 6, 8, Annex AH

Witness 5, 6 Annex AH

Witness 5, 6

Witness 5, 6

[54] SNOW 0002ZA554240107.
[55] SNOW 3410ZA613080507.

[redacted]

[redacted]

was checked by the independent checker who then signed for undertaking the independent checks on both of the ejection seats and the canopy. According to JAP100A-01, and the seat installation MMP, the replacement of the aircraft portion PEC should have resulted in a vital check and a further full set of independent checks on the front ejection seat but neither of these occurred. Furthermore, there were a significant amount of entries in the AAMSS diaries for lost documentation and missing signatures. These aspects led the Board to consider that it was common practice for maintenance activities to either not be recorded whatsoever, or not be recorded immediately following completion of the maintenance task. Witness 5, 6 Exhibit 20, 21

d. **Working Practices Summary.** From the inconsistencies between interviews, DMS, LITS, maintenance documentation and AAMSS diary entries, the Board found that maintenance work was carried out on ZA554 and other aircraft that was not recorded correctly by AAMSS personnel on Mod Form 707 documentation, LITS and/or DMS. Furthermore, the Board was not satisfied that AAMSS personnel routinely adhered to the MMPs in the manner in which they had been trained, or that work was signed for either at the time, or immediately after the work was completed. Witness 3, 4, 5, 6, 8, Annex AE, AM, Exhibit 20, 21, 26

The Board concluded that, the working practices employed as a whole within AAMSS made the accident more likely; therefore the working practices employed within AAMSS was a contributory factor.

52. **Unauthorised or Unrecorded Work on the AAES after the Completion of Independent Checks.** Given the time between the independent checks and flight test, the pressure for the aircraft to meet its operational commitment, and the fact that the Board found that some AAMSS maintenance work had been completed but not recorded or had been inaccurately recorded, the possibility of unauthorised or unrecorded work being carried out on the ejection seats after the completion of the independent checks, although this would contravene JAP100A-01 and go against all training, had to be investigated. The Board did not identify any maintenance activities recorded on DMS that would have required the ejection seats to be unlocked from the aircraft, and there was no evidence to support any further work being carried out on the seats once the final (recorded) seat installations and independent checks were complete. Consequently, the Board believed it unlikely that the seats were unlocked after the final set of independent checks, and aircraft PEC replacement, had been completed on 8 Nov 07 and therefore concluded that unauthorised or unrecorded work on the AAES after the completion of independent checks was not a factor in the accident. Annex AH Witness 20

[redacted]

[redacted]

53. **Airworthiness Trail.** The process used by CMU to assess the airworthiness of an aircraft was not dissimilar to the process used by the RAF. The CMU process relied on: an understanding of the work being undertaken; use of appropriately trained and authorised personnel; the completion of the appropriate maintenance documentation to certify that the work had been carried out correctly and in accordance with regulations; and random quality checks to ensure that the correct procedures were being followed. Finally, a CMU check of the DMS and LITS systems ensured that all outstanding tasks had been completed prior to an aircraft being declared airworthy. The Board believed that this airworthiness process, in general, was valid. However, the Board considered that individual elements within the process for ZA554 justified investigation: Witness 10 Annex AD

a. **Compliance with the CMU Airworthiness Process.** The Board was content that DMS confirmed that all relevant maintenance tasks as identified in DMS pertaining to ZA554 had been completed prior to the aircraft being declared airworthy. However, on interrogating the quarantined LITS data, the Board found that the AAES maintenance tasks did not match the maintenance documentation or DMS entries and that there were some outstanding Short Forecast items including both LITS and MOD Form 700 quality checks. However, a cross-check with the aircraft MOD Form 700 showed that the Short Forecast (printed directly from LITS 4 minutes before the crew walked for the aircraft from CMU Flight Operations) was in date. Consequently, the Board was unable to positively identify which version of LITS data was correct. LITS in itself was not a factor in the accident because it would not have highlighted the rear ejection seat of ZA554 being in an unlocked position because only the top level activity was recorded, eg seat installation, and this was recorded as complete. While the Board did not undertake an F700 quality check, it noted that Mod 02196 and Mod 02198 (both ejection seat modifications fitted to ZA554) were not recorded on the MOD Form 703A1. Despite the fact that interviews and DMS chits suggested that the airworthiness process had been complied with, the anomalies found between the maintenance recording systems meant that the Board was unable to positively determine that this was the case. Annex AM Witness 19 Witness 8, 10, 19

b. **DQAFF Involvement with AAMSS.** In order to allow an aircraft to fly under DEFCON638 following CMU maintenance activity the DQAFF agent had to be assured by CMU under Defence Standard 05-100 that the aircraft was airworthy, this included amongst other aspects, *all normally dormant systems considered vital to the safety of the aircraft and/or aircrew had been functioned or tested during final inspection and immediately before flight, or following systems disturbance, and complied with the specified requirements.* CMU relied on the DMS signatures of

[redacted]

[redacted]

the AAMSS personnel for this assurance and did not carry out quality checks on AAMSS personnel. Hence, as shown in sub-paras c and d, CMU could not have assured the DQAFF agent as to the standard of AAMSS work. The only non-RAF quality checks that were undertaken on AAMSS personnel were conducted by the DQAFF agent himself, who audited elements of ZA554 as part of his risk-based surveillance audits, and thus the only Defence Standard 05-100 assurance, outlined above, had to come from the DQAFF agent. No CMU-specific DQAFF TORs or process maps relating to airworthiness assurance could be produced by the DQAFF agent who had been allocated to be present during the final seat installation to ZA554. Notwithstanding this, the DQAFF agent stated that the purpose of his DQAFF quality check was to ensure that the correct MP and procedures were being followed; albeit he also stated that his lack of armament experience meant that he only had basic knowledge of armament processes. Nonetheless, the Board considered that by undertaking a quality check on the rear ejection seat of ZA554, the DQAFF agent was assuring himself that the quality of the work that he had witnessed was to an acceptable standard and therefore, intentionally or not, this quality check must have formed part of the airworthiness chain. The Board ascertained that the incorrect MMP was used to certify the final seat installation and that the AAMSS seat fitting team deviated from the MMP whilst the DQAFF agent was present. The quality check, as undertaken by the DQAFF agent did not highlight either of these deficiencies. However, the Board was unable to find evidence that the DQAFF agent had been provided with sufficient guidance to undertake his responsibilities in CMU, especially with respect to AAMSS activities, and hence the Board was unable to ascertain whether he could or should have been reasonably expected to identify the above deficiencies. The Board concluded that the presence of the DQAFF agent at the final seat installation to ZA554 could not have assured the airworthiness of the aircraft as pertaining to the ejection seat installation, although the Board believed that by conducting the quality check it became, by default, part of the airworthiness process. Furthermore, the Board believed the presence of the DQAFF agent at the rear ejection seat fit may have given the seat fitting team a false confidence that they had a good working process in place.

Witness 8

Witness 8, Exhibit 15d

Para 51a

Witness 3, 4, 6, Annex L

c. **Assurance of AAMSS Activities.** The AAMSS seat fitting team for ZA554 were provided to CMU under GFx arrangements. Thus, the team worked under RAF regulations[56] vice CMU regulations[57]. From an airworthiness perspective, provided that the AAMSS personnel were appropriately authorised and the DMS entry had been closed, CMU was content that the seat

Annex AD Witness 10

[56] JAP100A-01, QR, and F700 series paperwork.
[57] AvP67, MAOS and DMS.

[redacted]

[redacted]

installation had been carried out to the required standards, and that minimal additional governance was required because this was encompassed under the RAF Quality Assurance (QA) system. While the Board noted that this arrangement should have provided sufficient confidence for CMU to believe that the AAES work was completed to an airworthy standard, CMU operated under Maintenance Approved Organisation Scheme (MAOS) regulations[58]. Under these regulations Mil-Reg 145.A.75 allowed CMU to arrange for maintenance to be carried out by another organisation that was working under its quality system. Nonetheless, while the BAE Systems MAOS Mil Part 145 Exposition Issue 4 response to Mil-Reg 145.A.75, dated Oct 07, covered this from a non-GFx perspective it did not cover GFx. Notwithstanding this, the Board considered that with overall airworthiness responsibility for the aircraft, CMU should have had oversight of GFx activities. With no oversight, CMU relied on the RAF system to identify and rectifiy any problems within the GFx operations. However, the inappropriate AAMSS working practices identified by the Board had not been previously recognized by the RAF and, consequently, this meant that the interface between the 2 organisations was not operating as intended. With neither the RAF nor CMU realising this, the airworthiness chain was essentially broken because the standard of work produced by AAMSS was not to the standard assumed by CMU to assure airworthiness.

Annex AU
Annex AD
Para 51,
Annex AN
Annex AD

d. **Utilisation of DMS for Airworthiness.** CMU had responsibility for the correct operation of DMS, and used it as a major part of the airworthiness assurance process. The Board noted that AAMSS personnel were unaware of their full responsibilities in terms of DMS and did not view it as a tool for assuring airworthiness. In addition, the fact that neither the Board nor the BAE Systems' SME were able to track with certainty the process of canopy and ejection seat removals and installations through DMS and the aircraft documentation, led the Board to query the robustness of the system. Therefore, the Board believed CMU reliance solely on DMS signatures for AAMSS activities was insufficient to assure airworthiness.

Annex AE
Witness 20

e. **Airworthiness Trail Summary.** The Board considered that: the inability to determine compliance with the CMU airworthiness process; the DQAFF involvement with AAMSS; the airworthiness assumption made by CMU pertaining to AAMSS activities; and CMU reliance on DMS signatures for AAMSS activities meant that the airworthiness chain was not complete in relation to ZA554.

[58] Def Stan 05-130.

[redacted]

[redacted]

The Board concluded that these deficiencies, taken as a whole, made the airworthiness trail an other factor.

54. **Communication between CMU and AAMSS personnel.** Even though unusual problems had been found during the ejection seat fits on 2 aircraft there was little communication either between AAMSS personnel or with CMU regarding these problems. Following investigation, the Board was unable to determine whether a robust system was in place for the reporting of maintenance issues both internally within AAMSS and also between AAMSS and CMU. Nonetheless, the Board concluded that, at the time of the accident, there was insufficient knowledge surrounding the cause to enable any information that may have prevented the accident to be communicated between CMU and AAMSS personnel. **Therefore, communication either within AAMSS or between AAMSS and CMU was an other factor.** Witness 3, 4, 6, 10, 12

55. **Authorisation of Sortie.** The sortie was not authorised because the WSO, who signed as the authorising officer, was not empowered to authorise sorties; therefore, the sortie should not have proceeded. AvP67 order 1301 stipulated that only pilots could authorise sorties in AvP67 regulated aircraft. The Board considered initially that the term *pilot* may be open to interpretation under this order and, therefore, sought clarification from TESD as sponsor of AvP67. TESD informed the Board the term *pilot* was not open to interpretation, and that no dispensation to this order had been issued by TESD for CMU Flight Operations, RAF Marham. Nonetheless, despite the fact that the BAE Systems AvP67 Head of Flying (Director Flight Operations) had no authority to delegate powers of authorisation to the WSO, he had done so, and the Board considered that the WSO believed he [the WSO] could authorise sorties. Furthermore, under AvP67, order 1202, the WSO was not a TESD approved Head of Flying[59] and therefore could not have had powers of authorisation conveyed to him. Additionally, the Board noted that the authorisation sheets did not include details of the flight test, or the LFAs. Despite all of the above, the Board believed that the WSO met all of the responsibilities required of an authoriser as detailed in AvP67, order 1304. Consequently, the Board concluded that these deficiencies in the flight authorisation did not contribute to the accident and therefore authorisation of the sortie was not a factor. Exhibit 7, Annex A, Annex AQ, Annex A

56. **Post Maintenance Flight Test Schedule.** Production Tornados operated by BAE Systems, flown under RTS conditions, were to be airtested under the MOD Tornado GR4/4A FTS. The accident sortie was being flown to a CMU test schedule, produced by Flight Test BAE Systems Warton, which contained all of the MOD FTS test points, using exactly the same wording, but placing them in a more time and Annex U, Witness 1, Exhibit 1

[59] *Head of Flying* was a clearly designated term under AvP67; however, although the WSO held the position of Head of Flight Operations Marham, he was not an AvP67 Head of Flying.

[redacted]

[redacted]

fuel efficient order. The Board considered, from the definition contained in JSP553 chapter 6, that the use of the CMU test schedule may have placed the sortie outwith the RTS; therefore, the Board sought clarification from the Design and Modification Support Division (DMSD) as sponsor of JSP553. DMSD informed the Board that despite any re-ordering of the 5M test points, the aircraft was still being operated within the RTS as none of the RTS limits had been exceeded. Therefore, the Board was content that ZA554 was being operated within the RTS. Furthermore, the CMU test schedule did not contribute to the accident because the test point in question was worded in exactly the same manner in both test schedules. The Board examined MOD FTS item E17e in detail, the same test point as CMU test schedule item 22e, which called for a loose article check. The manoeuvre was further described as *to be flown wings level while applying negative g (zero g approximately).* The contradictory advice (apply negative g at approximately zero g) on how to conduct the test point, led the Board to consider 2 aspects of the post maintenance flight test schedule: Annex A

a. **Purpose of Test Point.** Firstly the Board examined the purpose of the loose article check. The basis of the current MOD FTS was the original Panavia airtest schedule. Each test point in the Panavia airtest schedule was subdivided into Condition, Test and Requirement. It was readily apparent that the test point at paragraph 2.2.2.2 of the Panavia airtest schedule required an inversion for 17 seconds, or maximum time cleared, with the engine throttle settings at max dry. This test was to ensure that: an oil pressure warning occurred as designed; that there were no hydraulic or Integrated Drive Generator (IDG) warnings; and finally that the engine did not flame out. There was no mention of a loose article check. The BAE Systems schedule for Tornado IDS Shakedown Testing Following Servicing / Lay-up of Aircraft Operating under BAES Control used the same test method and outcomes as described in the Panavia airtest schedule above, and added a check for no loose articles in the cockpit. In contrast the MOD FTS mentioned only a loose article check that should be flown wings level and to approximately zero g. The pilot and WSO of ZA554 had discussed the MOD FTS loose article check and the pilot believed that the purpose of the loose article check was: to pick up all of the loose articles in the cockpit area; to allow the engineers to de-swarf the internal spaces of the aircraft when they removed panels post flight test; and to ensure that all components were correctly installed and did not move under negative g. Therefore, the pilot and WSO had decided that a level flight inversion and push to minus 1.0g was the most efficient manner of achieving the test because they had found bunting erect to zero g did not disturb the loose articles or allow any items found to be picked up. They had conducted flight tests in this manner successfully on previous aircraft. Annex U Witness 1

[redacted]

[redacted]

b. **Test Point Flight Profile.** Secondly the Board examined the flight profile for the loose article check split into the test point set-up and the test point manoeuvre itself.

(1) **Set-up.** The Panavia airtest and BAE Systems IDS Shakedown schedules both called for the aircraft to be flown at approximately 10,000ft and 400kts with 25° wing sweep for the level inversion. The MOD FTS stated that the aircraft was to be below Flight Level (FL)100, and ideally 5000ft – 1000ft. The test point immediately prior to the loose article check required 45° wing sweep and 400kts. It was immediately obvious that there was a typographical error (1000ft vice 10,000ft) in the MOD FTS, which had not been corrected since issue in Aug 00. The Board observed that the MOD FTS, when compared to the Panavia and BAE Systems schedules, would have reduced the recovery time available should a loose article cause a control restriction. Annex U

(2) **Test Point Manoeuvre.** The conflicting advice regarding the normal acceleration level in the MOD FTS led to a modified test technique being used by the crew. Although still technically wings level, an inversion was not called for in the FTS. Also, in order to achieve a loose article check some negative g needed to be applied in order to dislodge any loose articles and make them accessible for retrieval. The crew had discussed and tried differing methods, on previous sorties in other aircraft, to achieve what they believed to be the purpose of the loose article check. The level inversion method they used in this case was not incorrect; however, it did lead to the situation where an incorrectly locked rear ejection seat would fall from the aircraft. Witness 1

c. **Post Maintenance Flight Test Schedule Summary.** The Board believed that the lack of a clear purpose for the loose article check and the latitude given for execution in the MOD FTS, led to the crew conducting an inversion and push to minus 1.0g. The Board also believed that the crew's decision to fly the test point as such was not unsafe. Nonetheless, flying the loose article check under negative g led to the condition where an unlocked ejection seat could fall out of an aircraft.

The Board concluded that flying the loose article check under negative g was a contributory factor.

The Board also concluded that the lack of a clear purpose for the MOD Tornado GR4/4A FTS loose article check and the latitude given for the check's execution was an other factor.

[redacted]

[redacted]

57. **Aircrew Orders.** CMU aircraft were to be flown in accordance with the MOD Release to Service (RTS). The RAF aircrew documentation, specifically the Aircrew Manual (AM) and FCCs, describe and translate the RTS[60]. Consequently, the procedures within the AM and FCCs were to be used during CMU operations. In terms of the FCC and AM they are complementary with neither pertaining to be the master. Thus, direct read-across without contradiction would be expected from the AM to FCCs and vice versa, with the general expectation that the AM would provide the detail and background behind the checks contained in the FCCs. Exhibit 12 Annex N

a. At the time of the accident, the advice regarding the checks to ensure correct locking of the ejection seat to the aircraft in the FCCs differed from those contained within the AM:

(1) The FCCs stated *'Seat top latch.....ensure flush'*. Annex N

(2) The AM stated: *'Ensure that the seat is correctly locked to the ejection gun by checking that the top latch indicator spigot (inner plunger) is flush with or slightly protrudes from the end of the latch plunger and that the latch plunger is flush with or slightly recessed in the end of the housing'*. Annex O

b. The Board believed that the FCC check was open to interpretation in that it was singular and could at most cover only one part of the full TLP check which consisted of 2 parts, and that there was ambiguity in that the *'Seat top latch'* was the whole TLP (ie the plunger plus spigot). The check should have been referenced to both the *'latch indicator spigot'* and the *'latch plunger'*. Furthermore, should the interpretation of the FCC check be taken to mean to check the latch indicator spigot as flush, this would not reliably highlight an unlocked ejection seat because it has been determined an unlocked condition can exist where the TLP indicator spigot may be interpreted as flush. This was the condition that was believed to have existed on ZA554. Therefore, if the WSO used the FCCs as a reference for his before-flight ejection seat checks, vice the AM, the unlocked condition of the ejection seat may have been unobserved. Annex I, L, AF Annex H, J Annex L

The Board concluded that had the FCCs been used as reference the unlocked condition of the rear ejection seat may not have been diagnosed. Thus, this made the accident more likely and therefore, the ejection seat top latch check as worded in the FCCs was a contributory factor.

[60] Joint Service Publication (JSP)553 ch 6, para 25.

[redacted]

58. **Aircrew Training.** Aircrew training on ejection seats was a mandatory requirement for aircrew operating under AvP67. The Board noted the following:

a. Both crewmembers had received ejection seat training; however, this was not in accordance with AvP67 both in terms of subjects covered and periodicity. The crew's ejection seat brief currency had lapsed by 1.5 months at the time of the accident, although they had been briefed on the changes to the ejection seat as a result of Mod 02198; this brief did not cover the TLP checks. Consequently, the aircrew were not current for Ejection and Manual Separation Drills at the time of the accident despite being displayed as current on Pathfinder. — Exhibit 13, Witness 15, Witness 1, Exhibit 9, 10

b. The pilot was only aware of the TLP spigot check, and not the plunger check. Furthermore, he believed the WSO was only aware of the TLP spigot check. — Witness 1

c. The TLP checks were taught at the crew's last formal ejection seat briefing on 2 Jan 07, which they attended together. The Board believed there was a possibility that the checks were taught incorrectly in that the TLP spigot check may have been briefed as a flush or recessed spigot being a pass condition. Furthermore, although the plunger check was briefed correctly, the plunger shown on the demonstration seat was proud. While this anomaly was briefed, the Board believed that this incorrect visual cue might have contributed to an incorrect mental model. The Board considered the combination of these features might have led the WSO to have perceived that the rear seat TLP of ZA554, as presented at the time of the accident, was correctly engaged when it was incorrectly engaged. — Witness 15, Exhibit 13, Annex L

The Board concluded that the aircrew were out of ejection seat training currency and it was likely that the ejection seat training provided to the aircrew had not equipped them with the knowledge to effectively carry out the TLP checks. Therefore, the final check of the TLP prior to flight was potentially flawed in its execution, making the accident more likely, thus aircrew training was a contributory factor.

59. **Sabotage.** The rear ejection seat was installed on 6 Nov 07 and independent checks of the canopy and seats were completed on 8 Nov 07. The aircraft finally flew on 14 Nov 07 after other unrelated maintenance work on the aircraft was completed. Consequently, there were 6 days post the final recording of any ejection seat related work when sabotage could theoretically have been carried out. It was not apparent from the evidence obtained by the Civilian Police whether they investigated sabotage. The RAF SIB did not investigate sabotage. The Board believed that sabotage was highly unlikely

[redacted]

because all of the following factors would have been required:

a. **Knowledge.** Knowledge of the ejection seat system and of the required tools would have been necessary in order to unlock the seat. An unlocked seat could occur through only 2 conditions (if all other seat connections were made): either by leaving the seat in an unlocked position by disengaging the TLP; or through a raised inner piston which would in turn prevent the TLP from engaging correctly in the top latch window. For the first case, in order to disengage the TLP a handwheel would have to be applied. However, removal of the handwheel would then re-engage the TLP. Consequently, although armament personnel would have had the knowledge to disengage the TLP, it would not have remained disengaged unless the handwheel had remained attached; this would have been obvious, and therefore was discounted. For the second case, the handwheel would still need to be attached to disengage the TLP, then the inner piston would need to be raised such that the TLP was prevented from re-engaging when the handwheel was removed (in this case the TLP checks would fail). From formal and informal enquiries the Board believed that, at the time of the accident, armament personnel, including AAES trainers and Integrated Project Team (IPT) staff, were unaware that a post-Mod 02198B ejection seat could be installed into an aircraft with the inner piston in a raised position such that the seat was unlocked but all seat connections made. Consequently, the Board believed it extremely unlikely that the knowledge necessary to deliberately create an unlocked condition through raising of the inner-piston existed at the time of the accident.

Annex I
Para 43b
Annex AB
Witness 2
Exhibit 15e

b. **Access.** Access would have been required to both the aircraft and to the armament tool kit. In the period between the independent checks and the flight test the aircraft was being worked 24 hours a day, 7 days a week and was undergoing functional testing and associated recovery work. Consequently, opportunities to access the aircraft undetected to undertake an act of sabotage would have been limited. To unlock the seat, access would have been required to the armourers' tool kit (which contained the handwheel), which should have been controlled. However, the Board noted that the toolkit could have been left open in one area of the hangar while the armourers were working in another area of the hangar. Consequently, unauthorised access to the toolkit could not be ruled out. Nonetheless, the Board believed that opportunity for undetected access to both the aircraft and toolkit would have been limited.

Witness 12
Annex AP(i)

c. **Motivation.** Neither the Civilian Police, RAF SIB nor the Board identified any potential source of motivation for sabotage against the WSO or any potential rear seat occupant of the

[redacted]

[redacted]

aircraft.

Consequently, the Board concluded that sabotage was not a factor in the accident.

60. **Self-Sabotage.** The Board considered the issue of self-sabotage by the WSO. However, as per the reasons for sabotage by other persons, the Board did not believe the WSO possessed the knowledge, or had the required access to the aircraft or toolkit; although the WSO had free access to the rear ejection seat during crew-in, he did not interfere with the TLP mechanism. Furthermore, the Board found no evidence to support any motivation for self-sabotage and, thus, concluded that self-sabotage was not a factor in the accident. Annex V; Witness 1, Annex E

61. **Seat and Aircraft Impact**. Although ejection had not been initiated, the trip rods and lanyards that were pulled as the ejection seat left the cockpit should have been sufficient to complete the remainder of the ejection sequence including main parachute canopy deployment and man/seat separation. However, because ejection had not been initiated, the ejection gun primary cartridge did not fire. As per design the rear seat primary cartridge can only be fired through the pulling of either the front or rear SPFH – it is not fired through the mere motion of the seat, as are other components, because it is assumed the seat should never move without a normal ejection having been demanded. As a result there was only the force of gravity acting on the seat as it left the cockpit, which was insufficient to propel it clear of the aircraft and it subsequently impacted the aircraft spine and fin. The rocket pack fired as per design, but this was after the seat had left the cockpit and rotated through 90°, and thus the firing of the rocket pack merely served to accelerate the seat towards the fin. The impact with the fin fatally injured the WSO and substantially damaged the ejection seat. This damage stopped further automatic functioning of the AAES and ripped the parachute canopy and associated drogues from the main portion of the ejection seat and WSO. Thereafter, even if the WSO had survived the impact with the fin, a sufficiently arrested descent that would have enabled him to survive impact with the ground was impossible. **The Board concluded that the ejection seat impact with the fin rendered the ejection seat ineffective and therefore was an aggravating factor in the accident.** Annex E, H, I, J

[redacted]

[redacted]

Consideration of Human Factors

62. **Pressure.** ZA554 was required to meet an [redacted]. S 26 There was a belief that its [redacted] was at risk due to the S 26 amount of work outstanding on the aircraft; as a result a recovery plan was put into place. The problems encountered with the fitting of the BTTDFU to the rear ejection seat risked delaying 2 key events in the recovery plan - TEMPEST testing and the aircraft weigh. In addition, the aircraft was suffering from cabin pressurisation problems, which also had the potential to delay the aircraft and place pressure on AAMSS to complete the ejection seat installation in order to allow the canopy to be fitted. Whilst the personnel involved in the rear ejection seat installation said that they did not feel pressurised by CMU to complete their job, they were aware of the overall time pressure to finish the maintenance. The Board found that this time pressure was at least partially responsible for the decision to replace only the ejection gun rather than both the gun and the seat. Subsequent unorthodox practices may have contributed to some of the engineering anomalies found by the Board. The Board also believed that the desire to complete the task due to the time pressures may have affected the performance of the team including that of the independent checker. **Therefore, the Board concluded that pressure was a possible contributory factor.**

Witness 12
Exhibit 28
Witness 14
Annex AP(ii)
Witness 3, 4, 5, 6
Witness 13
Annex AH
Annex L

63. **Distraction.** The problems encountered with the fitment of the BTTDFU on the rear ejection seat meant that by the time the final seat installation took place the seat had been fitted to 2 aircraft and 3 ejection guns. At some point during this final installation a trial fit of the BTTDFU was undertaken. Although the Board was unable to ascertain from the personnel exactly when this happened, the Board believed that it was most likely to have happened either before or immediately after the handwheel was removed as it would be wasted effort to undertake further installation of the seat if the BTTDFU was not going to fit. Either way, the Board considered that the distraction caused by the BTTDFU problems may have affected the team's performance and attention during the seat fit process and that this may have affected the way in which the TLP checks were undertaken, especially given the priority nature of the aircraft. **Therefore the Board concluded that distraction of the seat fitting team was a possible contributory factor.**

Witness 6
Witness 4
Annex L

64. **Fatigue.** The tradesman had arrived back at work on 24 Sep 07 following approximately one month's post operational and annual leave. From the maintenance documentation, the tradesman had worked the previous Saturday (3 Nov 07), undertaking aircraft canopy-related work and had, therefore, only had one full day off in the previous 8 days at the time he was tasked to install the rear ejection seat in ZA554. However, the tradesman did not consider that he was suffering from fatigue because he was working fewer hours than he

Exhibit 19
Witness 3

[redacted]

had been on operations. There was no evidence to support fatigue of the vital checker, independent checker or the WSO. The Board did not consider fatigue to be a factor in the accident. Exhibit AP(i), (ii), Witness 1

65. **Environment.**

a. **Lighting.** The personnel involved in ZA554's final ejection seat installation thought that the standard of lighting in the hangar was good. It was a sunny day when the WSO conducted his before flight ejection seat checks. Although the light conditions were apparently good for the AAMSS personnel and the WSO, the ability of the personnel to distinguish a failed spigot indication may have been affected by the way the light and shadows were falling, because the visual check of the spigot relied on the shadow cast by the difference between the plunger and spigot faces. Witness 3, 4, 5, 6 Annex V Annex L

b. **Temperature.** The hangar heating had been unserviceable for some time. In addition the hangar doors were often open to allow exhaust fumes from mobile hydraulic and electrical rigs to vent because the hangar hydraulic and electrical systems were also unserviceable. It was therefore likely that the temperature in the hangar was little, if at all, higher than the outside air temperature. On the day of the final seat installation the outside air temperature ranged from 6.4ºC at 0850 to a high of 10.3°C by 1350 against a minimum workplace temperature requirement of 13°C. Consequently, at the time personnel were removing the seat, undertaking the trial fit of the ejection gun and installing the final seat, temperatures were likely to have been below the minimum workplace requirement. Physical judgement in the maintenance environment is primarily affected by temperature and therefore the cold conditions may have affected the way in which personnel undertook the tasks and perceived the TLP indications. Exhibit 27 Annex AT Exhibit 27 Annex L

The Board concluded that the environmental conditions were a possible contributory factor in the accident.

66. **Supervision.**

a. **Rear Ejection Seat Installation Team.** The ejection seat installation was carried out by a tradesman (SAC) and a supervisor (corporal); there was also a SNCO (sergeant) observing the seat installation and independent checks but who took no formal part in the proceedings. Because of undermanning, the shift compositions had been altered and the personnel were not working with their usual colleagues. The tradesman and supervisor had not worked together during the last 6 months during which time the tradesman had been deployed Witness 3, 6 Witness 3, 4, 6

[redacted]

OOA on non seat-related work for 4 months. The SNCO had not worked with either of the team before, being new in post and had not worked on ejection seats for approximately 2 years. The Board found no evidence to suggest that this lack of familiarity resulted in any changes to the way the supervisor undertook his role. However, the tradesman was relatively inexperienced and required the MMPs to be read to him as he completed the tasks, but the considerably more experienced supervisor did not read from the MMPs. Therefore he supported the tradesman in a manner more appropriate for a more experienced tradesman. This also meant the supervisor did not provide any additional instruction or supervision to the tradesman during the maintenance activity. As a result of the assumed skill level, the Board doubted the adequacy of the supervision provided during the seat installation. Additionally, the Board noted that despite both the tradesman and supervisor appearing confident in their abilities there was doubt over the level of knowledge possessed by the tradesman and supervisor on how the ejection seat TLP locking mechanism worked and the associated TLP checks for ensuring that the seat was locked to the aircraft. Therefore the supervisor may not have picked up any errors with the TLP checks. Overall, these discrepancies in working practice did not seem to have been identified by the seat installation team and the Board considered that this increased the probability of: the tradesman incorrectly interpreting an instruction; the supervisor reducing his supervision and potentially failing to detect and rectify an incorrect action; and/or the assumption that one of them had completed an item when they had not.

Witness 3
Witness 4
Witness 3, 4
Witness 3, 4, 6, Annex L
Witness 3, 4, 5, 6
Annex L

b. **Undermanning.** While AAMSS was not undermanned, a number of supervisors were OOA and the number of personnel qualified to undertake vital and independent checks was reduced such that work had to be delayed pending a qualified vital checker, and an independent checker had to be called from another section. This may have placed additional pressure on the qualified supervisors leading to reduced supervision and/or reduced checking and may have played a part in the engineering anomalies and inappropriate working practices already discussed. However, evidence suggested that the methods employed for recording maintenance may have been long standing and existed across AAMSS as a whole rather than particular to this aircraft, and may have been caused through supervisory pressure caused by a reduced number of supervisors.

Witness 5
Annex AP(ii)
Annex L
Annex AH
Annex AE
Exhibit 20, 21

c. **Supervision Summary.** The Board found that the supervision level applied to the tradesman was inappropriate and that this may have resulted in MMP stages being missed or incorrect actions going unnoticed. In addition, while the team was adequately constituted, they displayed over-confidence in their

[redacted]

[redacted]

own and the other seat installation team member's abilities. Furthermore, the supervisory pressure, caused by a reduced number of qualified supervisors, coupled with the time pressure, perceived or otherwise, to complete the maintenance on ZA554, may have contributed to the inappropriate working practices previously discussed. Para 62 Para 51

The Board concluded that supervision within the seat installation team coupled with the pressures associated with undermanning made the accident more likely, and thus supervision was a contributory factor.

67. **Task Situational Awareness.**

a. **Tradesman.** Reading directly from an MP, or reading an MP together with a supervisor, would provide a tradesman with greater task Situational Awareness (SA) such as task context and anticipation of future tasks. Task SA would be likely to be lower if a tradesman was both unfamiliar with the task steps and the task information was retained and drip-fed by a supervisor. Therefore, the fact that on ZA554 the tradesman was inexperienced and preferred the MMP to be read to him suggested that his task SA was low. This meant that the tradesman may have failed to detect any read-out errors, omissions and/or changes in task sequence. Furthermore, if the supervisor became hands-on during the task, as occurred during the rear ejection seat locking on ZA554, the tradesman could infer that this replaced his task responsibility. This may have resulted in the tradesman omitting the TLP check or misreading the TLP check indications. Annex L Witness 3 Annex L Witness 3, 4 Annex L

b. **Vital and Independent Checkers.** With only a theory-based 6-monthly re-certification test, and with irregular reference to the MMPs, it was unlikely, in general, that any technique errors developed by supervisors, including vital and independent checkers, would have been identified and rectified. Annex L

The Board concluded that the potential for the omission, or incorrect application of the TLP check and the lack of awareness that TLP check technique errors may have developed made the accident more likely. Therefore, task SA was a contributory factor.

68. **Seat Raise Check.**

a. With no specific criteria for the vital checker to follow it was likely that the quality of the seat raise check would be inconsistent between RAF armament personnel and between discrete applications of the check by an individual. This, coupled with the fact that the vital checker had never seen a failed check, would Annex L, Para 49c

[redacted]

[redacted]

have meant that his mental model of a passed seat raise check would be incomplete. In addition, supported by its trial and 56(R) Squadron evidence, the Board believed that on ZA554 the rear seat raise check was passed even though the seat was unlocked. The passed seat raise check would have enhanced the seat installation team's belief that the seat was locked. Witness 4 Annex AC, AF, AG

b. The practice, contrary to the MMP, of the vital checker lowering and locking the seat before checking the TLP and undertaking the raise check, in advance of the tradesman undertaking his TLP check, meant that it was much more likely for the tradesman to suffer from impaired perceptual judgement due to anticipation of a pass or even to decide that his TLP check was not required because the more-experienced vital checker had already passed both the TLP check and the seat raise check. This deviation from the MMP, not only negated the vital checker's TLP check but also increased the probability that the tradesman's TLP check would be missed or forgotten because the supervisor had gone beyond that stage of the MMP in order to undertake the seat raise check. This would have been exacerbated if the MMPs were not being followed closely. Annex L

Consequently, the Board concluded that the seat raise check was a contributory factor to the accident.

69. **TLP Checks.**

a. **MMPs.** HF analysis suggested that the use of the 'note' to provide details of the TLP checks for the tradesman may have resulted in the detail being missed because once a task has been conducted a few times personnel will tend to employ summary techniques where only the top-level task, ie the numbered item, is referred to rather than the 'note'. Furthermore, if the supervisor does not read the MMP line by line to the tradesman then, with the lack of any detail in the MMP for the vital check, the supervisor is also unlikely to be exposed to the detail of the check. This, together with the lack of illustrations to show the exact TLP check criteria, decreased the probability that any errors in AAMSS personnel's understanding of the checks would be rectified. Annex L Annex L

b. **Certification.** Personnel maintained that they rechecked the MMPs as they certified their work to check that they had not omitted any points. However, the recognised practice of signing by block rather than by item increased the probability that only the top-level items were referred to rather than the detail and therefore, that any inaccuracies in the checks would have been unlikely to be identified, as evidenced by the fact that the seat installation team certified the seat installation on the wrong MMP. Witness 3, 4 Annex L Para 51a

[redacted]

[redacted]

c. **TLP Physical Checks.**

(1) **Spigot.** In general, the personnel interviewed were much more aware of the spigot check than the plunger check. In the case of ZA554 the spigot was likely to have been recessed by approximately 0.69mm, depending on tolerances. In general, a failed spigot check should be easier to detect than a failed plunger check because of the adjacent nature of the face of the spigot with the face of the plunger, vice the plunger which is further away from the surface environment it is being compared to. However, because the spigot check relies on a subjective rather than objective assessment, a pass/fail diagnosis is based on perceptual judgement and is easier to diagnose if the spigot's position is either significantly proud or recessed. Where the pass/fail condition is on the boundary between the 2 conditions, diagnosis would be more difficult with personnel having to evaluate the amount of shadow, which would be dependent on the light conditions; a fairly common condition can exist where shadow is also present on a flush as well as a recessed spigot. Physical discrimination of a boundary condition could also be difficult to discern depending on how that discrimination was carried out (eg fingernail, thumb, etc) and environmental temperature. HF analysis suggested, backed up by the Board's findings during its trial and the report from 56(R) Squadron, that the recess on ZA554's spigot may not have been perceptually identifiable as indicating fail criteria because of: the scope for misreading the results caused by the way light and shadow may have been falling on the spigot; mistaken reading caused by lack of experience in distinguishing between different pass and fail criteria; and anticipation that it would pass based on the individuals' lack of previous exposure to failed spigot checks. Furthermore, anticipation could also lead to complacency in the way the checks were completed, leading to a further increase in the probability of a failed spigot check going undetected.

Witness 1, 3, 4, 9

Annex K

Annex L

Annex L

Annex L

Annex AG, AF

Annex L

Witness 5, 6

Annex L

(2) **Plunger.** The plunger check was less well known by the personnel involved. Additionally, through the course of its investigations, the Board found that, in general, aircrew canvassed were unaware of the plunger check. On ZA554 it was likely that the plunger was protruding by approximately 5.5mm, depending on tolerances. This should have made the resultant failed plunger check easily identifiable. However, HF analysis considered that, because it was common for the result of the first TLP check (spigot check) to be indicative of a corresponding result for the second TLP check (plunger), it was possible that personnel became

Witness 1, 3, 4, 9

Annex K

Annex L

Annex L

[redacted]

[redacted]

conditioned to use only the first check to determine correct engagement of the TLP. Furthermore, the lack of exposure to failed plunger checks may have meant that anticipation of a pass result affected their judgement such that the standard of the plunger check was not sufficient or the check was omitted. Annex L

d. **TLP Checks Summary.** The Board considered that the following may have contributed to the accident: Annex L

(1) The spigot/plunger 'note' for the tradesman's check was probably not routinely referenced.

(2) The subjective nature of the TLP checks and the fact that personnel had been routinely exposed to a non-failed TLP condition made both the maintenance personnel and aircrew vulnerable to anticipation, complacency and conditioning.

(3) The spigot check may have been used to infer the result of the plunger check.

(4) The spigot check may have been incorrectly diagnosed.

The tradesman, vital checker and independent checker maintained that they completed the TLP checks and that the seat was locked to the aircraft. However, human factors analysis proved, to a high degree of probability, that the TLP checks could have been incorrectly diagnosed despite the recollections of the individuals concerned. With the cause of the accident identified, the Board concluded that the tradesman, vital checker, independent checker and WSO did not identify the unlocked condition of the TLP. **Consequently, the Board concluded that the application of the TLP checks, as conducted by those personnel, was a contributory factor in the accident.**

[redacted]

Summary of Causes and Factors

70. **Cause.** The cause of the accident was that the TLP was incorrectly engaged in the ejection gun top latch window, as a result of a raised inner piston, which led to the rear ejection seat not being locked to ZA554. Para 44

71. **Contributory Factors.** The Board identified the following factors which did not directly cause the accident but made it more likely:

a. Ejection seat Mod 02198. Para 45

b. Fouling of the BTTDFU. Para 47

c. Lack of clear instruction within the MPs for positioning of the ejection gun inner piston, and for the checks to ensure correct engagement of the TLP and locking of the seat. Para 49

d. Non-adherence to, and deviation from the MMPs. Para 49, 51a

e. Training and authorisation of AAMSS personnel. Para 50

f. Working practices of AAMSS. Para 51d

g. Flying the loose article check under negative g-force. Para 56

h. FCC ejection seat top latch check. Para 57

i. Aircrew ejection seat training. Para 58

j. Supervision within the seat installation team. Para 66

k. Task situational awareness of the seat installation team. Para 67

l. Seat raise check. Para 68

m. Non-identification of the TLP being in the failure condition by the tradesman, vital checker, independent checker and WSO. Para 69

72. **Possible Contributory Factors.** The Board considered that the following factors may have made the accident more likely:

a. Ejection gun inner piston may have been left extended by the seat bay. Para 46a(1)

b. Ejection gun inner piston may have been raised or moved during transportation. Para 46a(2)

c. Ejection gun inner piston may have been raised during Para 46a(3)

[redacted]

BTTDFU removal prior to installation of the ejection gun.

d. Ejection gun inner piston may have been raised if a BTTDFU trial fit was undertaken with the handwheel still attached. Para 46a(4)

e. Ejection gun inner piston may have been raised if the handwheel was reintroduced to ease BTTDFU fitting after the TLP checks. Para 46a(5)

f. Pressure on the seat fitting team and independent checker. Para 62

g. Distraction of the seat fitting team. Para 63

h. Environmental conditions, light and cold. Para 65

73. **Aggravating Factor.** The Board identified that the impact of the rear ejection seat with the aircraft fin, rendering the ejection seat ineffective, did not directly cause the accident but aggravated the final outcome. Para 61

74. **Other Factors.** The Board identified the following other factors which, although they did not contribute to the accident, if rectified, might prevent future accidents:

a. Recording of maintenance activities. Para 51b

b. Airworthiness trail. Para 53

c. Communication between CMU and AAMSS personnel. Para 54

d. The lack of a clear purpose for the MOD Tornado GR4/4A FTS loose article check and the latitude given for the check's execution. Para 56

75. **Compliance with Orders and Instructions.**

a. **Aircrew.** The Board noted the following:

(1) **Authorisation.** Even though the Board considered that the WSO believed he had powers to authorise sorties he did not. Therefore, the WSO's actions in certifying the accident sortie as authorised was in contravention of AvP67 order 1301. Para 55 Exhibit 7

(2) **Authorisation Sheet.** The authorisation sheet did not contain sufficient sortie profile detail that would have enabled sortie reconstruction, such as reference to the MOD FTS, or details of the LFAs to be utilised during the sortie. Exhibit 7

[redacted]

[redacted]

Therefore, the authorisation sheet did not comply with AvP67 orders 1305 and 4115, and AvP67 order 4107 respectively.

(3) **Altitude for Loose Article Check.** The aircraft inversion on the accident sortie conducted for the purpose of the loose article check was flown at 5900 feet pressure altitude. Although this altitude was within the band stipulated in the MOD and CMU Test Schedules it was below the minimum height of 7000 feet AGL/AMSL stipulated for an Inverted Flight Check in the CMU FOB, Section 2, page 9, paragraph 11.

Annex R, W

Exhibit 1

Annex AQ

(4) **Survival and Training Drills.** The Ejection and Manual Separation Drill attended by the crew on 2 Jan 07 was not conducted in accordance with AvP67 Annex O and the periodicity tracked by Pathfinder was 385 days vice 9 months. The Board acknowledged that the crew had attended a brief, within 9 months of the accident, which covered changes to the ejection seat as a result of Mod 02198; however, this did not satisfy the full currency requirements of formal ejection seat training as required under AvP67. Therefore, the aircrew were not current for Ejection and Manual Separation Drills at the time of the accident despite being displayed as current on Pathfinder. Furthermore, the CMU Personal Training Folders and Pathfinder were not logging the survival and training drills as stipulated in AvP67 Annex O, both in terms of periodicity and drills requiring to be completed.

Witness 15

Exhibit 9, 10

Witness 1

Annex AR, AS, Exhibit 9, 10

(5) **Flying Logbooks.** The WSO was not maintaining a flying logbook because it was lost sometime prior to the accident. However, AvP67 order 1602 required all flying personnel to record and retain their flying hours on RAF Form 414 or 1767 with 3 monthly logbook checks to be conducted, in this case, by the BAE Systems Head of Flying.

Witness 7

b. **Engineering.** In electing to use the ejection seat removal and reinstallation for access MMPs (Digital Air Publication (DAP) 101B-4104-1EP MPs 29-10/2A and 29-10/3A), AAMSS personnel did not follow the MMP for, or certify completion of, the removal and installation of the main ejection seat guns. AAMSS personnel deviated from the installation MMP and the vital checker undertook a maintenance task before undertaking the vital check on the same maintenance task contrary to JAP100A-01 Chapter 13.1.2. Finally, AAES-related maintenance activities were also undertaken on the aircraft that were not recorded on the maintenance documentation contrary to JAP100A-01 Chapters 7.1 and 7.2.

Para 51a

Para 49b

Para 51b

[redacted]

[redacted]

Observations

76. The Board observed that:

a. The use of a multitude of diverse agencies to search the accident site, each with its own operating practices, required rapid development of new techniques and procedures. Memoranda of Understanding between these agencies covering post aircraft accident searches would have assisted the Board and should be considered. Para 19

b. Valuable assistance was provided throughout by the Civilian Police Authorities.

c. Notwithstanding the excellent working relationship developed between the Board and Norfolk Constabulary, a Memorandum of Understanding between the MOD and the HDPF covering post aircraft accident investigations would have significantly eased the Board's initial proceedings.

d. During a Board's suspension it is vital that an auditable evidence trail is maintained by the MOD, particularly in cases where the HDPF have not ceded primacy.

e. A parallel investigation, initiated by the Tornado IPT following the accident, interfered with the Board's investigation by drawing on the Board's time and resources. Annex A

f. One of the armament personnel assigned to assist the Board had recently worked on the ejection seat in question. Potential witnesses should not be assigned to post accident recovery duties.

g. Legal assistance was essential during the Board's proceedings.

h. A formal sortie brief was not required under AvP67.

i. The ejection seat checks in the FCC as a whole were inconsistent with the AM, Part 2, Chapter 1.

j. The ZA554 BAE Systems flight test schedule developed by BAE Systems Flight Test, Warton for CMU was created to ensure that the flight test flowed in a more time and fuel efficient manner than the MOD FTS. The MOD FTS should be reviewed to ensure that the MOD FTS is, as far as possible, efficient in the use of flying time. Para 56

k. There was a lack of emphasis in the MPs, APs and training

[redacted]

[redacted]

to highlight the danger to life if the TLP is not engaged correctly in the ejection gun top latch window.

l. JAP100A-01 Chapter 13.1.2 required personnel to call up and certify vital checks on the MOD Form 707 series documentation. This was in addition to personnel signing for the vital checks on the MMP. Notwithstanding the JAP 100A-01 Chapter 13.1.2 requirement, the Board did not believe that the presence of the vital checks on the MOD Form 707B in addition to the certification on the MMP, provided any greater assurance that the maintenance had been completed appropriately and, in fact, believed that it added to the complexity of the MOD Form 707B. The Board recommends that this practice be reviewed. Para 51b(1)

m. AP109B-0141-5F 2nd Edition Sect 2 Chap 1A Pulse B Card 34 Item 56.1 appeared to refer to incorrect maintenance activity and should be reviewed to ensure that it refers to the correct maintenance activity.

n. The MDC System Rigging MP (DAP101B-4104-1EP MP 29-21/9) requires the ejection seats to be removed and reinstalled with the canopy installed on the aircraft. However, the ejection seats cannot be removed and reinstalled using the Rotazoom (the accepted method for a complete ejection seat) while the canopy is installed. Therefore, this MP should be reviewed.

o. Some aircrew and engineering personnel were aware that there were deficiencies in the aircraft document set, but had not highlighted these through the appropriate channels.

p. The diagrams on page 13 of the Tornado Maintenance School AAES course notes showed the inner piston v-groove aligned incorrectly and should be amended to show the inner piston in its correct alignment.

q. The photographs showing the TLP in the DCAE Cosford W14 Phase CN1204 AAES Training Booklet and the Tornado Maintenance School AAES course notes did not provide sufficient clarity regarding the condition of the TLP.

r. At the time of the accident armament personnel authorisations were 6-monthly, although the authorisation printouts had an annual periodicity. The Board believed that this was most probably due to the database being updated prior to official authorisation being granted for annual checks. Nonetheless, authorisation records should be checked to ensure that personnel have been correctly authorised.

[redacted]

[redacted]

s. The SNCO observing the rear ejection seat fit and subsequent independent check, while holding an authorisation for vital checks on AAES did not hold relevant Q or X competencies. Whilst not contravening regulations the Board questions the interface between, and possible duplication or contradiction of, training in the Tornado Maintenance School for the Q competency and the WTS for local authorisations.

t. Whilst holding overall continuing airworthiness responsibilities, CMU did not undertake any oversight role of GFx activities in order to ensure that the physical standard of GFx work met the standards required for CMU to be able to declare an aircraft airworthy. The process for assuring airworthiness across the GFx boundary should be reviewed. Para 53c

u. No CMU-specific DQAFF TORs or process maps could be produced by the DQAFF agent.

v. The pilot completed post accident actions in a calm and thoroughly professional and courageous manner.

Recommendations

77. The Board recommends that:

a. Mod 02198B is reviewed in light of the potential for post-mod 02198B ejection seats to be fully installed with a raised inner piston, which could lead to an unlocked condition. Para 45

b. Armament personnel are alerted to the risk introduced by ejection seat Mod 02198B whereby an ejection seat can be installed and armed with the inner piston in a raised condition leading to the TLP being incorrectly engaged in the ejection gun top latch window. Para 45, 46

c. An assessment is undertaken of ejection seat Mod 02198B to identify and rectify the cause of BTTDFU fouling. Para 47

d. The process of matching the ejection seat, ejection gun and BTTDFU is undertaken in the seat bay to minimise the possibility of BTTDFU fitting problems occurring at an aircraft. Para 47

e. The MPs associated with the installation, reinstallation and independent checks of the ejection seats are reviewed to address the following: Para 49

(1) The lack of clear instruction for inner piston checks. Para 46, 49a

(2) The MMP order of events and tasks undertaken by the Para 49b

[redacted]

[redacted]

tradesman and vital checker during seat lowering and locking to ensure it can be followed in sequence.

(3) The validity and lack of objectivity of the seat raise check. — Para 49c

(4) The lack of clarity pertaining to the 2 aspects of the TLP for the tradesman and vital checker. — Para 49d

f. The training of armament personnel relating to the lowering and locking of ejection seats should be reviewed to ensure that both the tradesman and supervisor undertake their appropriate actions in the correct sequence, particularly the TLP checks. — Para 49b, 68

g. The training and authorisation of armament personnel with respect to ejection seats should be reviewed. — Para 50

h. The armament 6-monthly re-certification exam should be reviewed to ensure that engineering standards and practices are maintained; a practical element should be considered. — Para 50b

i. The practical and theoretical elements of armament technical instruction relating to ejection seat maintenance activities should be defined and standardised to ensure best practice and the maintenance of standards. — Para 50

j. An independent audit and review should be conducted into the working practices of AAMSS. — Para 51

k. A review should be undertaken of the method of recording ejection seat and canopy removal and installation on the AAES main card, MOD Form 707B (PPMWO MAR/TOR/07/02 Issue 9) with a view to simplification and to ensure the correct recording of maintenance, the results of maintenance activity checks (both pass and fail) and faults. — Para 51b(1)

l. Personnel of both CMU and GFx organisations are made fully aware of their responsibilities with respect to, and understand the working practices of, both organisations. — Para 51, 53, 54

m. A review is undertaken into the process used for the updating of LITS within CMU to ensure that the airworthiness trail is maintained. — Para 51b(3), 53a

n. A review is undertaken of the final assurance procedure used to ensure airworthiness prior to flight. — Para 53

o. BAE Systems and the Tornado IPT undertake a review of the systems within CMU for recording and checking aircraft — Para 53

[redacted]

[redacted]

maintenance activities to ensure continued airworthiness.

p. A review is undertaken to ensure that all emergent maintenance work is recorded on DMS.	Para 53d
q. The validity and set-up for the MOD FTS loose article check, item E17e, should be reviewed to ensure that it is necessary, and if so it is within safe limits, and that the test point itself gives a clear description of test point objectives and accurately defines the aircraft parameters and manoeuvres required to achieve the stated objectives.	Para 56
r. The wording of the TLP check contained within the FCC should be amended such that it contains the full checks for the plunger and spigot, and is consistent with the AM.	Para 57
s. A review is undertaken into aircrew ejection seat training to ensure that it is unambiguous and emphasises the correct TLP checks.	Para 58, 69
t. BAE Systems ejection seat training complies with AvP67 requirements.	Para 58
u. A study is undertaken into automatic initiation of ejection in the event of the ejection seat failing to remain secured within the aircraft, with a view to introduction of such a system.	Para 61
v. The supervisory responsibilities held by Non-Commissioned Officers (NCO) within AAMSS are reinforced, particularly with regard to human factors implications.	Para 62, 63, 66, 67
w. Personnel are made aware of the human factors which can lead to mis-diagnosis, omission, complacency, anticipation and conditioning relating to the TLP checks.	Para 62, 63, 65, 69
x. A study is undertaken to ascertain whether an easier method can be identified to ensure that an ejection seat is locked to an aircraft.	Para 69

[redacted]

[redacted]

President [redacted] Wg Cdr S 40

Members [redacted] Sqn Ldr S 40

[redacted] Sqn Ldr S 40

Date: 15 Jan 09

Observer [redacted] BAE Systems S 40

I am signing this report in my capacity as an employee of BAE Systems (Operations) Limited ('the Company') invited to participate as an observer to the Board of Inquiry pursuant to JSP551, Vol 1, Edition 1, Change 5, Section 205, Annex C, paragraph 21. While acknowledging (through such signature) agreement in principle with the findings of the report, I must point out on behalf of the Company that it nevertheless reserves the right to make its own observations with regard to the detailed content of the report when it is formally issued to the Company.

Date: 15 Jan 09

[redacted]

[redacted]

The Board considered that Witness 3, might be affected by its findings and, in accordance with QR 1269(1), he was informed that he could, if he so wished, be present during the remainder of the sittings of the Board or at such times as the convening authority or the President may specify, and, if he so wished it, could also be represented at his own expense. He was warned that the proceedings were privileged and were not to be disclosed to third parties except in the circumstances set out in QR 1272. He was also informed that he was entitled to cross-examine the witnesses, to give evidence, and to call witnesses to give (further) evidence on the matters which may affect him. He accordingly read the evidence of Witnesses 1, 2 and 4, but he declined to cross-examine. He also read his own statement. Witness 3 elected not to be present at the remainder of the inquiry.

The Board considered that Witness 4 might be affected by its findings and, in accordance with QR 1269(1), he was informed that he could, if he so wished, be present during the remainder of the sittings of the Board or at such times as the convening authority or the President may specify, and, if he so wished it, could also be represented at his own expense. He was warned that the proceedings were privileged and were not to be disclosed to third parties except in the circumstances set out in QR 1272. He was also informed that he was entitled to cross-examine the witnesses, to give evidence, and to call witnesses to give further evidence on the matters which may affect him. The evidence of Witnesses 1 to 3 was accordingly read over to him. He elected to recall Witness 3 for cross-examination. He also read his own statement. Witness 4 elected not to be present at the remainder of the inquiry. He elected to give further evidence.

The Board considered that Witness 5 might be affected by its findings and, in accordance with QR 1269(1), he was informed that he could, if he so wished, be present during the remainder of the sittings of the Board or at such times as the convening authority or the President may specify, and, if he so wished it, could also be represented at his own expense. He was warned that the proceedings were privileged and were not to be disclosed to third parties except in the circumstances set out in QR 1272. He was also informed that he was entitled to cross-examine the witnesses, to give evidence, and to call witnesses to give further evidence on the matters which may affect him. The evidence of Witnesses 1 to 11, including appropriate amendments, was accordingly read over to him. He also read his own statement. The Board stated that the Convening Authority had confirmed that Witness 5 would be allowed to read the full proceedings of the Board when the Board of Inquiry had completed. In light of this Witness 5 elected not to be present at the remainder of the inquiry. He elected to give further evidence.

[redacted]

[redacted]

The Board considered that Witness 15 might be affected by its findings and, in accordance with QR 1269A(3), he was informed that he could, if he so wished, be present during the remainder of the sittings of the Board or at such times as the convening authority or the President may specify, and, if he so wished it, could also be represented at his own expense. He was warned that the proceedings were privileged and were not to be disclosed to third parties except in the circumstances set out in QR 1272. He was also informed that he was entitled to cross-examine the witnesses, to give evidence, and to call witnesses to give further evidence on the matters which may affect him. The evidence of Witnesses 1 to 17 was accordingly read over to him. He also read his own statement. Witness 15 elected not to be present at the remainder of the inquiry. He elected to give further evidence.

[redacted]

PART 1.3
REMARKS BY UNIT OR FORCE COMMANDER

[redacted]

BOARD OF INQUIRY IN THE ACCIDENT INVOLVING ZA554 – STATION COMMANDER'S COMMENTS

I accept the findings and recommendations of the Board of Inquiry into this tragic event. It is clear that the Board has conducted a most thorough and comprehensive Inquiry and I would like to commend the members for their efforts. The pilot concerned should also be recognised and applauded for his professional and calm manner following the immediate aftermath of the accident, despite the obvious shock of such a sudden and unexpected occurrence. In addition, I must acknowledge the valuable assistance provided by the Norfolk Constabulary during the Inquiry.

The Board has identified the cause of the accident as being the incorrect engagement of the TLP in the top latch window as a result of a raised inner gun piston that prevented the rear seat from being locked in position. Whilst many events conspired to complete the chain that led to this previously unknown condition (and thus an incorrectly engaged TLP), it appears that the introduction of Mod 02198, which calls for the replacement of mechanical linkages on pre-mod seats with the flexible gas hoses on post-mod seats, has unwittingly removed a defence that prevented the fitting of an ejection seat with the inner gun piston in a raised position. This does lead to the possibility that an unnoticed raised inner gun piston may have been a common occurrence during the fitting of pre-mod seats, but was unconsciously rectified in the fitting process. The identification of 2 such conditions during seat fitting at RAF Leuchars supports this view. I therefore strongly support the recommendation that Mod 02198 be reviewed in light of the potential for an ejection seat to be installed with a raised inner piston, along with an analysis of the cumulative effect of a number of machine tolerances. In the interim, all armament personnel within the Tornado GR Force (TGRF) have been alerted to this risk.

In considering the fouling of the BTTDFU, it would be easy to underestimate the additional pressures this placed upon those who work in CMU and I agree with the Board's assertion that fouling of the BTTDFU was a contributory factor and that the cause of fouling should be investigated as part of the full review of the modification which introduced the new design. To alleviate such pressures occurring in the future, I strongly support the matching of ejection seats, guns and BTTDFUs as standard practice, and this procedure has been implemented in the seat bay at RAF Marham.

Turning to the suitability of documentation, I agree that the lack of clear instruction within the procedures relating to ejection seat fitting was a contributory factor. As such, a full review of the associated procedures and FCCs has been conducted and forwarded to higher authority, and it is requested that formal AP amendments are incorporated once the Inquiry's findings are officially endorsed. The Board has identified non-adherence to, and deviation from, the procedures as being contributory to the accident. However, I also note the Board's suggestion that the deviation from the procedures relating to the order in which the seat raise check is carried out was unavoidable because the procedures previously could not physically be followed in the listed sequence. Furthermore, it is of note that those involved in Phase 3 training deemed such deviation from procedures acceptable and that an almost identical error occurred within a few days at another Main Operating Base. Indeed, not one of the 4 persons involved in the seat fitting, including the DQAFF agent, questioned the process. This leads me to the conclusion that non-adherence to, and the deviation from, procedures were system induced. These issues highlight the importance of training and ensuring procedures are followed or challenged and then amended where inappropriate. More robust training, and hence a thorough understanding of the importance of the mechanical function of the TLP by all concerned, may have prevented the non-identification of the TLP in the failure condition. As such, a full review of all armament personnel and RAF/BAES aircrew training pertinent to ejection seats has been conducted and changes implemented (for example, a previous 3-hour exam has been amended to a 3-day re-authorisation course including visual recognition of

[redacted]

[redacted]

TLP failure). This has also ensured an improved task situational awareness. The training and authorisation of AAMSS personnel and the working practices of AAMSS, which were identified as contributory factors, have also been amended at Station level such that the recommendations pertinent to RAF Marham have been implemented.

Looking wider, I have also considered the workload pressure and appropriate supervision at RAF Marham. The output of aircraft from the Depth maintenance facility is critical to the sustainment of the TGRF and whilst individuals have stated that pressure was not a factor, it is likely that working under pressure has, to an extent, been normalised. I have, therefore, emphasised to supervisors at all levels that there is a fine balance between productivity born of pressure versus failure because of pressure. The Board's recommendation relating to reinforcement of supervisory responsibilities held by NCOs is fully supported. At a local level, this has been implemented and an additional post of senior supervisor has been established and manned to manage the AAMSS team in order to reinforce the importance of supervision and support to the RAF armament team in Depth Support Wing (DSW).

In sum, the Board has identified multiple areas for improvement, particularly in respect of procedural and training elements, and I have implemented all of the changes within my purview; namely, 77b, 77c, 77d, 77f, 77g, 77h, 77i, 77k, 77l, 77p, 77t and 77v. Where higher authority to implement the remaining recommendations is required, engagement with the appropriate agencies has commenced.

In addition to the points above and having considered the Human Factors element in this accident, I also request the full inclusion of all DSW activities and personnel within the HQ Air Command 'Can Do Safely' campaign. I further believe that the AE&S and Tornado IPTs should consider whether the ejection seat raise check remains valid and strongly recommend the use of an objective measurement to ensure that seat is locked to an aircraft. Certainly, as an interim procedure, the use of the mass spring balance to measure the lifting force applied to the seat raise check should be implemented. Equally, AE&S are strongly recommended to consider a more robust and objective checking process for ensuring that the TLP is correctly fitted during seat installation, rather than relying on the naked eye.

In concluding my comments I would like to take the opportunity to offer my personal condolences to Mike Harland's immediate family.

C BASNETT
Group Captain
Station Commander
RAF Marham

[redacted]

[redacted]

COMMENTS BY STATION COMMANDER RAF MARHAM IN RESPONSE TO THE ADDITIONAL STATEMENTS MADE BY CT [redacted], CPL [redacted] AND SAC [redacted] S 40

I have reviewed the statements made under QR1269 by CT [redacted], Cpl [redacted] and SAC [redacted] S 40 and offer the following additional comments. The questions raised in CT [redacted]'s statement, especially regarding the height of the inner piston and tolerances of the seat assembly, are valid. If we are to restore the confidence of all operators and maintainers who deal with ejection seats, the questions posed by CT [redacted] need to be answered, if only to remove the potential to chase S 40 shadows in the future. The Convening Authority may therefore wish to formally address the issues raised before the findings of the Board of Inquiry are forwarded to Higher Authority.

[redacted] S 40

C BASNETT
Group Captain
Station Commander
RAFMarham

14 Apr 09

[redacted]

[redacted]

COMMENTS BY STATION COMMANDER RAF MARHAM IN RESPONSE TO THE SECOND SET OF ADDITIONAL STATEMENTS MADE BY CT [redacted], GPL [redacted] AND SAC [redacted] S 40

I have reviewed the additional statements made under QR1269 by CT [redacted], Cpt [redacted] and SAC [redacted] and have questioned why issues are still being raised so late in the proceedings of this Board of Inquiry. The answer given is that, although all three have been afforded access to the relevant documentation, they had been unable to examine the Board of Inquiry's conclusions set against the body of evidence until the first round of disclosure - a point I can readily accept. S 40

Whilst the counter-questions, photographs and tables included in the statements serve to illustrate the point that CT [redacted], Cpl [redacted] and SAC [redacted] currently-do not feel that their initial concerns have been adequately addressed, I concur that some of the issues raised by them are worthy of deeper investigation, if only to tie-off the loose ends that still exist. True confidence in the ejection-seat and the procedures used to install it into the aircraft can only be restored when the issues still open to debate have been addressed, and the possibility of such an accident happening again has been reduced to the bare minimum, Therefore, in acknowledging the duty of care we have to all our operators and maintainers, the Convening Authority may wish to address these outstanding issues before the findings of the Board of Inquiry are forwarded to Higher Authority. Should the Board of Inquiry be reconvened, I would like to see the acknowledged ejection-seat subject matter experts from within the TGRF included as interviewees

[redacted] S 40

C BASNETT
Group Captain
Station Commander
RAF Marham **27 May 09**

[redacted]

30 SEP 09 ADDENDUM TO BOARD OF INQUIRY INTO THE ACCIDENT INVOLVING TORNADO ZA554 - COMMENTS BY STATION COMMANDER RAF MARHAM

I have reviewed the fourth round of statements made under QR1269, together with the Board of Inquiry Addendum Report dated 30 Sep 09, and consider that the questions raised by Chf Tech [redacted], Cpl [redacted] and SAC [redacted] following earlier S 40 disclosures have now been thoroughly and formally analysed. As a result, I fully support the findings and recommendations of the Board, although I provide some revision on the need to review Modification 02198.

Whilst on the balance of probability it has been shown that Top Latch Plunger incorrect engagement ultimately caused this accident, I, like the Board, recognise that this was due to a combination of factors. As the Board has identified, the implications and unintended consequences introduced through the embodiment of Modification 02198 were not fully realised at the time. There is no doubt that this modification, which was introduced to increase aircrew survivability on ejection, remains a significant contributory factor. It unwittingly introduced a series of consequences, including the removal of a defence mechanism, which, at the time, were not understood fully by ejection-seat specialists across the Service and Industry. The Chief Engineer's report into the review of the modification is a key piece of evidence in this regard. However, tragically, this accident did highlight those issues with the modification that have since been rectified by better training and revised procedures. Therefore, I accept the expert advice that the modification is 'fundamentally' safe now that we have a better understanding of the modification and its implications on seat fitment procedures. As such, the review into Modification 02198 per se is no longer necessary; what is needed, however, is a review of how the modification was tested and accepted to ensure that we do not repeat such an error in the future.

This Inquiry has been a protracted and painful process, particularly for the family of Mr Harland, but also for the tradesmen involved in the maintenance of his seat. The attention that has been paid by the Board, the engineering support team and the individual tradesmen has allowed us to pursue every avenue of investigation in order to ensure that we have left no stone unturned. I commend them all for their tenacity and fortitude through what has been a very difficult time for all. Whilst this report has been a long time in coming, I am absolutely certain that we resolved the immediate issue to rectify any failings extremely quickly and that we have fully explored every subsequent facet of this tragic event. It is important to learn all the lessons from this, especially those pertaining to Human Factors, and allow those individuals most affected to move on with their lives and careers. I will ensure that the maintenance personnel involved are taken through the Board's report fully so that they may better understand their part in it. In consultation with DE&S, I will ensure that all other recommendations and observations are fully understood and incorporated.

I am grateful to the Board for their professional approach to this Inquiry. I believe that all possible causes of this accident have been considered and that, very early on in their work, we quickly restored confidence in the ejection seat and the procedures used to maintain and install the system into the aircraft. Most importantly, I remain

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conscious of the very real personal impact of this accident on Mrs Harland and her family and I offer them my personal condolences and fullest support.

[redacted] S 40

C BASNETT
Group Captain
Station Commander RAF Marham / Tornado Force Commander
07 Dec 09

[redacted]

From Group Captain S P Rochelle OBE DFC ADC MA RAF

Royal Air Force Marham
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Tel: [redacted]
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DFTS: [redacted] S.40
DFTS Fax: [redacted]

13 January 2010

[redacted] S.40

Reference: Your letter MFTR/70/21 (297) dated 23 December 2009

Following receipt of Reference A, I can confirm that disclosure of the report in t ZA554 took place on 11 January 2010 to Chief Technician [redacted], Corporal and Senior Aircraftsman [redacted]. All three declined to make a statement.

Hard copies of the disclosure certificates are attached.

Yours Aye

Rocky

PART 1.4
REMARKS BY
CONVENING AUTHORITY

[redacted]

BOARD OF INQUIRY TORNADO GR4 ZA554 - BOARD COMMENTS IN RESPONSE TO STATEMENTS MADE UNDER QR1269(7) FROM CHIEF TECHNICIAN [redacted] AND SENIOR AIRCRAFTSMAN XXX

[redacted] S 40

References:

A. MFTR/70/7/1 (297) dated 1 May 09. S 40
B. Statement dated 2 Apr 09 from Chief Technician [redacted] iaw QR1269(7).
C. BAE-WPM-MN-TOR-B&P-226 dated 12 Feb 08 (pages 1 to 6) (copy attached).
D. Statement dated 2 Apr 09 from Corporal [redacted] iaw QR1269(7). S 40
E. Statement dated 2 Apr 09 from Senior Aircraftsman [redacted] iaw QR1269(7).
F. E-mail 170406MAY09 from Mr [redacted] of Martin-Baker Aircraft (copy attached).
G. DE&S(AIR)(WYT)/100400/4/3/7 dated 29 Apr 09 (copy attached). S 40

1. **Introduction.** The Board of Inquiry (BOI) into the accident involving Tornado GR4 ZA554 on 14 Nov 07 was re-convened (Ref A) to review the statements and further evidence provided at Refs B, C, D and E. The Board has reviewed the points raised and the further evidence provided, and confirms that the findings, recommendations and observations of its BOI report dated 15 Jan 09 remain extant. The points raised are discussed in turn by the Board within the following paragraphs.

2. **Raised Inner Piston.** The Board finds that the points raised at Ref B Para 3a are covered in Part 2, Annex K. With regard to Ref B Para 3b the Board confirmed during its replication trials that automatic realignment did not occur for an inner piston raised to the maximum physical amount possible . As stated in Part 2, Annex H, the replication trials undertaken by the Board raised the inner piston to the maximum amount possible; which was measured at 4mm. The perceived discrepancy of the extreme positions was because of the differing methods and references used by BAE Systems and AAIB to measure the inner piston at its extreme raised position; AAIB made a manual measurement, whereas BAE Systems used CAD drawings. Thus, the Board considered the difference between the 2 figures was irrelevant to its findings; what was relevant was that for an inner piston raised to the maximum extent, no automatic realignment occurred, and personnel were not checking for a raised inner piston[2]. There are 5 further comments raised within Ref B Para 3, which are covered below:

a. The Board considered the degree to which the inner piston was raised on ZA554; however, it was not possible to positively identify the definitive height that the inner piston was raised. More importantly the Board concluded that the inner piston on ZA554 was raised to such an extent that automatic realignment did not occur.

b. The Board considered that the maximum height the inner piston could be raised was not critical to the Board's findings.

c. Part 2, Annex K determines how tolerance or tightness issues affect the likelihood of automatic realignment. The Board considered that further investigation over and above that contained in Annex K would not have affected its findings.

[1] Part 1.2, Para 44c(4)(b).
[2] Witnesses 3, 4 and 5

[redacted]

[redacted]

d. As per Para 2a, the Board did not determine the maximum or minimum height that the inner piston needed to be raised to prevent correct TLP engagement. The Board's recommendation at Part 1.2, Para 77a should lead to further investigation of this matter.

e. The replication trials proved the seat could be fully rigged while retaining the inner piston in a raised condition, without automatic realignment. Part 1.2, Para 45d states *'Mod 02198 introduced a condition whereby a seat could be fitted and armed with a raised inner piston, which would prevent the correct engagement of the TLP'.*

3. **TLP Indication with Raised Inner Piston.** Ref B Para 4a(3) raises an apparent conflict between SMEs. Of the 2 'groups' of SMEs referred to, one produced Part 2, Annex K which discusses the pure geometrical TLP indications as shown by CAD drawings, whereas the second 'group' observed the physical TLP indications in realistic environmental conditions. These indications have to be taken in context, particularly with regard to Human Factors (HF) as covered in Part 2, Annex L and Part 1.2, Para 69c. The Board concluded that while the spigot check could fail the 'correctly seated' test in absolute terms, in terms of HF it could be perceived as a pass; ie, it is what the human element may interpret. The suggestion regarding use of quantitative assessment at Ref B Para 4b is covered by the Board's recommendation at Part 1.2, Para 77x.

4. **Examination of Factors.**

a. **Correctly Locked Ejection Seat Becoming Unlocked During Flight.** The Board had considered the possibility of a correctly locked ejection seat becoming unlocked during flight. Although not recorded in the formal proceedings, the Board had concluded that this was not a factor in the accident for the following reasons:

(1) The Board in consultation with the Martin Baker Aircraft (MBA) SME confirmed that neither the horizontal nor vertical forces required to overcome a correctly locked and functioning TLP mechanism could occur during normal aircraft operation[3]. Therefore, the in-flight manoeuvres conducted by ZA554 would not have led to a correctly locked ejection seat becoming unlocked.

(2) **Lateral Acceleration and Ejection Seat Component Tolerances.** During its deliberations the Board considered whether Mod 02198 had affected the tolerances of the TLP mechanism. Both the Harrier, Jaguar and Survival IPT and MBA confirmed there had been no changes to the TLP mechanism tolerances as a result of Mod 02198, and therefore the operation of the TLP mechanism was unchanged. In addition, MBA confirmed that the worst cumulative effect of tolerances would not have affected correct locking of the ejection seat. In particular, the point raised at Ref B Para 5 regarding *'greater than anticipated movement of the inner piston'* was discussed with the MBA SME during the Board's initial deliberations, and it was confirmed that lateral movement of the inner piston due to wear could not have unlocked the ejection seat[4]. Furthermore,

[3] The MBA SME has subsequently confirmed in writing (Ref F) that the Post-Mod 02198 ejection seat is stressed for 13g vertical, 34g forward and 11.9g lateral.
[4] This has subsequently been confirmed in writing (Ref F).

[redacted]

[redacted]

as the components in question had recently undergone an enhanced bay maintenance they had been checked and replaced where necessary[5].

(3) **Historical Evidence.** The generic TLP mechanism, which has remained unchanged by Mod 02198, has been fitted to approximately 50,000 ejection seats worldwide over a period of 50 years with no reported failures of the mechanism.

(4) **Examination of Further Evidence.** Further evidence was provided to the Board on 06 May 2009 in the form of a copy of the meeting notes of BAE Systems Chief Engineer's Review of Modification 02198 (Ref C). Ref C states that the review was '*to confirm the integrity of the modification, re-assess the modification and clearance process taken (in light of the recent issues[6]), and identify any potential gaps/lessons that can be learnt for future reference*'. In summing up the review the Chief Engineer concluded that: '*he is satisfied with the integrity of the design and that the modification is fundamentally safe*' and '*that the UTIs[7] support the immediate Airworthiness of the platform*'. The Board noted that both the Tornado and Survival and Aerial Delivery (SAD) IPTs supported the review and both IPTs had representatives at the meeting. Nonetheless, the Board examined the meeting notes in detail and concluded that there was no information raised by the meeting notes, pertinent to the accident, which was unknown to the Board during its original investigations.

5. **Examination of Scoring and Witness Marks.** The report referred to in Ref B Footnote 16 was undertaken by an NDT expert with no knowledge of the accident or ejection seat experience. His recommendation to the Board was carried out in consultation with SMEs; firstly, through the Board's replication trials AAIB, MBA, BAE Systems and RAFCAM stated that the witness marks seen on ZA554's ejection gun and the trial ejection gun were consistent, and indicated a slow-speed extraction. Secondly, during its deliberations the Board examined several in-Service ejection guns and while there was ejection gun scoring this was dissimilar to the witness marks made during the replication trials and found on ZA554's ejection gun. The only way that scoring of the nature seen on ZA554's ejection gun could have occurred, outwith the accident, would have been if a seat had failed its seat raise check during a fitting to this gun. However, according to Witnesses 3, 4, 5 and 6 the ejection seat fitted to ZA554 had not failed its seat raise check. Furthermore, during its deliberations the Board could not find any individual who had ever witnessed a failed seat raise check. The Board therefore considered it improbable that the ejection gun fitted to ZA554 had previously failed a seat raise check prior to its installation in ZA554. The Board was therefore content that the witness marks on ZA554's ejection gun were atypical, being consistent with a slow speed extraction and not as a result of a normal ejection sequence or maintenance activities.

6. **Mandatory Procedures.** The Board did not believe that it should direct the Independent Check Maintenance Procedure to become mandatory and believed this was a decision for higher authority as part of the staffing of the Board's findings. The Board notes that this is being considered by the AES TL (Ref G).

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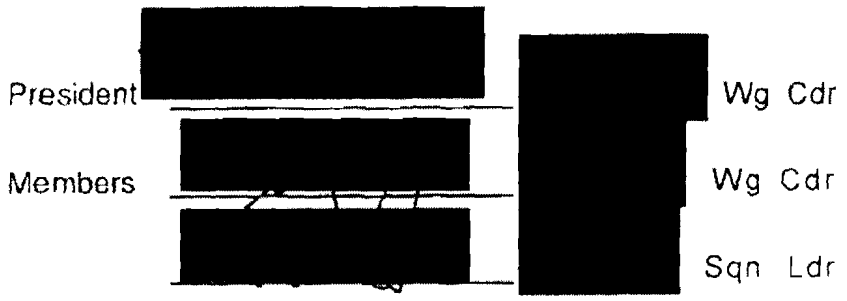
[5] Part 1.2, Para 42b(4).
[6] This refers to 2 recent issues: the first was a fouling of the BTTDFU on the top cross beam member; and the second was a fouling of the BTTDFU Gas Adaptor Pip Pin on the BTTDFU castellations.
[7] Urgent Technical Instruction.

[redacted]

[redacted]

7. Summary. The Board acknowledges the points raised at Refs B, D and E and thanks the individuals for their comments. Furthermore, the Board notes the recommendations from the AES TL (Ref ^, which further validate the Board's comments above. The Board has reviewed all of the points raised and the further evidence provided, and confirms that the findings, recommendations and observations of its BOI report dated 15 Jan 09 remain extant.



Date: 11 May 09

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70/7/1(297)

13 Mar 09

BOARD OF INQUIRY TORNADO ZA554 PART 1.4 – REMARKS BY CONVENING AUTHORITY AD AIR SYSTEMS TEST AND EVALUATION SUPPORT DIVISION

1. **Introduction.** I believe that the Board of Inquiry (BOI) into the Tornado ZA554 accident on 14 Nov 07 has carried out a thorough and detailed investigation into this accident. In particular, the Board's consideration of the wider circumstances and analysis of the more systemic, underlying factors which had a bearing on the accident is to be commended. My comments below follow in outline the Summary of Causes and Factors, Paragraphs 70 to 76, and Recommendations, Paragraph 77, of the Report; these should be read in conjunction.

2. **Cause.** I agree with the Board that the cause of the accident was that the Top Latch Plunger (TLP) of the ejection seat was incorrectly engaged in the ejection gun top latch window, as a result of a raised inner piston, which led to the rear ejection seat not being locked to the aircraft. Thus, when the aircraft was inverted, the seat was not secure and left the aircraft.

3. **Contributory Factors.** I agree with the Contributory Factors identified by the Board, and would make the following additional comments. Additional recommendations arising from these comments are summarised in Paragraph 8 below.

a. **Ejection Seat Mod 02198.** The Station Commander (Stn Cdr) has summarised the Board's findings in this regard[1] and I concur with his views. I note that all armament personnel within the Tornado GR Force have been alerted to the risk of a raised inner piston; it is of course imperative that *armament personnel of all organisations* using an ejection seat with Mod 02198 embodied (including civilian companies under MoD contract dealing with ejection seat-fitted aircraft) or a modification of a similar type understand the implications of the modification, and I recommend that this is achieved as a priority. There is a wider point concerning the hazard and risk analysis that is undertaken when an aircraft modification is introduced (this analysis being undertaken to make sure as far as possible that the introduction of a modification does not unwittingly introduce a potential new hazard, as in this case). I believe it would be valuable to review the processes carried out when an aircraft modification is introduced, particularly in the area of the potential for new risks or new hazards to be introduced unwittingly, to provide assurance that these processes are as robust as we can make them; this is of direct relevance to the continuing airworthiness of an aircraft platform through life. In this instance, and with the benefit of hindsight, had the possibility of a remaining raised inner piston been identified, once the new seat connections (from Mod 02198) were complete, mitigating checks could have been put in place or the checks already in place could have been amended to take account of the new issues.

b. **Ejection Seat and Gun Matching.** I agree with the Stn Cdr's decision to re-implement the matching of seat, gun and BTTDFU[2] in the ejection seat bay at RAF Marham. In line with the comment above, I recommend that this policy should be considered for implementation as standard practice for all organisations using aircraft with ejection seats.

c. **Maintenance Procedures.** The Board identified a number of inter-related factors concerning lack of clear instruction, non-adherence to procedures and maintenance procedures that were impossible to fulfil as written (these leading to unavoidable deviation from the required process) (Paragraphs 49 and 51). I agree with the Stn Cdr that together these led to 'system-induced' questionable practices and wholeheartedly agree that we must

[1] At Part 1.3 of the Board's proceedings
[2] Breech Type Time Delay Firing Unit

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instil in our maintenance personnel the need to challenge all badly written or impossible to fulfil procedures and not just accept local 'work-arounds' as standard practice. This message should be reinforced at all levels of engineering training and qualification; it is highly unlikely that these particular ejection seat-fitting procedures are the only maintenance procedures currently in use that are not possible to undertake as written, or are not being followed as standard. In a similar fashion, experience tells us that it is unlikely that Marham AAMSS is the only unit where it might be possible to find incorrectly signed for MMPs, or incorrect MPs being used for maintenance activities. While the Stn Cdr has addressed these issues at a local level and has also identified changes to be made in the supporting publications, there is a need to take wider action across all air platforms. I recommend that the issue is tackled in 3 ways: firstly, education of all engineering specialisations regarding the importance of challenging badly written or incorrect procedures. Secondly, an open invitation across the engineering community for submission of known issues with current publications and, to ensure that such issues are captured appropriately in the future, the putting in place of an effective mechanism for the reporting and tracking of such problems. Thirdly, any issues raised must be corrected in a timely fashion.

d. **Loose Article Check.** The Board noted the differences in the description of and requirements for the test point (at which the seat separated from the aircraft) between the MoD Flight Test Schedule and the industry (ie BAES – based on the original Panavia) air test schedule. While I agree with the recommendation for a review of the MoD test point (as written it does not enable a loose article check) it is worth noting that there is no confusion over the purpose of the test point from industry's perspective, or over the manner in which it is to be flown. The crew of ZA554 aimed to fly the test point (inverted level at -1 g) in accordance with BAES standard operating procedure, which should confirm correct functioning of systems, plus allowing an opportunity to capture any cockpit loose articles and, post landing, to check for any disturbances within the rest of the airframe. There is a further point: industry clearly believes that there is a need for a loose article check. However, this could be taken to imply a failing in maintenance procedures, as correct procedures would not require a loose article check (notwithstanding there may well be other valid reasons for an inverted check, as industry believe). I recommend that the review of the requirements for the test point should be widened to include all MoD air test schedules that have a requirement for a loose article check.

e. **Top Latch Plunger (TLP) Checks and Aircrew Ejection Seat Training.**

(1) **Aircrew Checks.** The Board rightly examines the issue of the TLP checks in the Flight Crew Checklist and as conducted by aircrew. It is sobering to realise that this basic check of the integrity of the ejection seat (it is after all the only check which shows that the seat is fixed to the aircraft) is, or was up to the time of the accident, not fully understood by a large proportion of pilots canvassed by the Board (Paragraphs 58 and 69.c), including the pilot of the accident aircraft. This is despite the mandatory seat training carried out every 9 months by all pilots and the detailed initial training when first introduced to ejection seat operations. In this regard, I do not believe that the fact that the crew of ZA554 were out of currency for this training by one and a half months had any bearing on the accident, the lack of understanding regarding the TLP check is (or was) widespread and long term. I strongly support the recommendation (Paragraph 77.s) that aircrew ejection seat training be reviewed to ensure that it is unambiguous and emphasises the correct TLP check. This review must cover the whole MoD community including flying training units, front line units and MoD contractors.

(2) **Maintenance Checks.** It is instinctively difficult to understand how an unlocked seat was passed by 3 separate maintenance personnel; the Board's discussion and analysis of Human Factors is valuable and relevant here, and I agree with their

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conclusions and recommendations. One further point: it is entirely possible that the more checks mandated for an item the less safe or the less reliable the overall check could be, as every level can assume (albeit at times probably subconsciously) that a higher level will pick up any failing, or that if something was wrong, it would already have been picked up by a lower level check. There is an argument to be made for the most important checks to be done once only, by someone who is in no doubt that they are solely responsible for that check, particularly when that check has life and death implications. I recommend that this issue is given further study by human factors specialists in order to identify the optimum level and manner of checking during aircraft maintenance.

f. **Seat Raise Check**. The Board correctly identifies the seat raise check (using the Rotazoom crane) as a Contributory Factor in that it appears to show beyond doubt (and did so on ZA554) that a seat is locked to the aircraft, when in fact the procedure as currently undertaken cannot confirm this. The use of this apparently robust check in the process for fitting a seat is likely, I believe, to make the other checks less reliable – there is likely to be the perception, albeit subconsciously, that the TLP checks (ie carried out by maintenance personnel) are perhaps not so important as the seat has been physically shown (*apparently*) to be locked. There are several points to be made:

(1) **Purpose of Check**. The only purpose for this physical check would be if it was believed that the TLP checks (plunger and spigot) as laid down could not be relied upon to truly show whether or not a seat was correctly locked. Or, if it was believed that maintenance personnel would so often mistake the laid down TLP checks that a further physical check was required. Neither of these statements is true.

(2) **Conduct of Check**. The Board is to be commended for investigating the check in some detail, and for demonstrating by practical means that the check as currently practised, with no way to measure the force applied to the seat, was unlikely ever to show an unlocked seat (all personnel asked to conduct the check failed to apply enough force to overcome the weight of the seat). However, if the practice was amended such that the force is sufficient to show an unlocked seat, that force may cause damage to the lifting lugs on the seat or even possibly to the TLP mechanism itself.

(3) **Recommendation**. If the seat raise check was only nugatory it would not be particularly important if it was continued. However, the fact that it is likely to give the opposite indication (locked when not locked), that it is likely to weaken the conduct of the human TLP checks, that it may inadvertently damage the seat, and is in itself unnecessary, all lead inescapably to the conclusion that this check should be discontinued immediately. Indeed, it is somewhat surprising that over a year after it was identified that this check was a contributory factor to a fatal accident *it has still not been amended or removed from the process.* It is recommended that the seat check as currently conducted is removed from the process for seat fitment.

4. **Possible Contributory Factors and Aggravating Factor**. I agree with the Possible Contributory Factors and Aggravating Factor identified by the Board, and the recommendations resulting from them. In particular, I endorse the recommendation to investigate the potential for ensuring that if under any circumstances an ejection seat was to begin to detach from the aircraft it would operate (ie effectively a fail-safe mode).

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5. **Other Factors.** I agree with the Other Factors identified by the Board, and would make the following additional comments.

a. **Recording of Maintenance Activities.** The Board members were rightly surprised that given the well-understood requirement for recording all maintenance activity on an aircraft, and the availability of modern computer-based recording systems, it was not possible to ascertain with confidence what parts had been fitted to which aircraft at what time, or what items had been fitted then removed, and then (possibly) re-fitted. The Board identifies a number of AAMSS working practice issues, and I support its conclusions and recommendations in this regard. However, I would add that the simultaneous use of 3 separate recording processes (and associated IT systems) namely MOD F707B, DMS and LITS, was likely to make it almost inevitable that maintenance activities would show significant anomalies or differences between the different records. I strongly support the recommendation at Paragraph 77(o) which recommends a review of the multiple systems used by the Combined Maintenance and Upgrade facility (CMU) for recording and checking aircraft maintenance activities, with the aim of improving the process to assure aircraft airworthiness. I wish to further expand this particular recommendation to ensure that the wider air Project Team community is made aware of the need to keep to a minimum (ideally one) the number of different recording processes.

b. **Airworthiness Trail.** There is much meat in this section (Paragraph 53), and I recommend that the MoD Airworthiness Regulator[3] consider the findings of this Board once complete in order to identify and apply the key airworthiness-related lessons. In addition, there are important issues that should be considered by Project Team Leaders[4] planning other platform CMU-type arrangements. Again, I recommend that the relevant observations and recommendations of the Board be carefully considered prior to the setting up of future contracts with industry. In particular, the issue of whether or not, or to what degree, a contracted Company is responsible for monitoring or assuring itself of the standards and competence of a MoD-supplied (GFx) organisation or workforce must be addressed. My own view is that the contracted Company always retains a level of responsibility for any organisation conducting activity under that Company's contract, and contracts should not be constructed so as to sign away this responsibility. This issue may be equally applicable in the Land and Sea domains.

6. **Compliance with Orders and Instructions.** I concur with the Board's conclusions in this section.

7. **Observations.** I agree with the Observations made by the Board, and the recommendations that follow from them. I would make the following additional comments.

a. **Parallel Investigation.** The Board notes that a parallel investigation, initiated by the (then) Tornado IPT following the accident, caused some difficulty for the Board's investigation by drawing on the Board's time and by utilising scarce specialist support which was then not immediately available to the Board. While there is no impediment to a Project Team initiating its own investigation following an accident, any such investigation must not draw on the Board's time and resources or prevent resources being made available to the Board for the conduct of the safety inquiry. It is recommended that appropriate direction be included in JSP832 (Service Inquiries) and the Military Aviation Regulatory Document Set to ensure that Service Inquiries are afforded the priority that is required and that the amendments should also reflect that all such activity should be formally channelled through the Convening Authority.

[3] Within the Directorate of Safety and Engineering, DE&S; formerly the Continuing Airworthiness Support Division.
[4] Formerly IPT Leaders

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b. **Flight Test Schedule.** The recommendation to review the Tornado MoD Flight Test Schedule in the light of potential best practice developed by the aircraft designer and manufacturer is fully supported. However, this should be extended to MoD flight test schedules for all platforms, as in many cases the MoD schedules are likely to suffer from the same problems identified by the Board for the Tornado MoD Schedule.

8. **Recommendations.** I agree with and fully endorse the recommendations made by the Board. In a significant number of cases, the recommendations and key lessons are applicable to many platforms, not just Tornado, and to many units, not just CMU at RAF Marham. Once the Board's proceedings are complete, the Convening Authority will address this challenge through the Command Action Letter dealing with the actions arising from the Board's findings and the subsequent review process. In addition to the recommendations made by the Board, the following recommendations are made:

a. **Ejection Seat Mod 02198.** It is recommended that armament personnel of all organisations using an ejection seat with Mod 02198 embodied (including civilian companies with MoD contracts dealing with ejection seat-fitted aircraft) or a modification of a similar type are made aware of the implications of the modification. (Paragraph 3a)

b. **Introduction of an Aircraft Modification.** It is recommended that the processes carried out when an aircraft modification is introduced are reviewed to ensure that they are as robust as possible, particularly in the area of the potential for new risks or new hazards to be introduced unwittingly. (Paragraph 3a)

c. **Ejection Seat and Gun Matching.** It is recommended that the matching of seat, gun and BTTDFU in the ejection seat bay should be considered for implementation as standard practice for all organisations operating aircraft with ejection seats. (Paragraph 3b)

d. **Engineering Training.** It is recommended that the need to question and challenge badly written, inappropriate or impossible maintenance procedures be reinforced at all levels of engineering and maintenance qualification training. (Paragraph 3c)

e. **Identification of Issues with Publications/Procedures/Processes.** I recommend that an open invitation is issued to the engineering community for submission of known issues with current publications and, to ensure that such issues are captured appropriately in the future, an effective mechanism for the reporting and tracking of such problems is put in place. Any issues raised must be corrected in a timely fashion. (Paragraph 3c)

f. **Loose Article Check.** I recommend that the review of the requirements for a loose article check test point, and manner in which it should be flown, should be widened to include all MoD flight test schedules that have a requirement for such a check. (Paragraph 3d)

g. **Maintenance Checks and Human Factors.** It is recommended that a study be carried out into the underlying rationale for the need for multiple checks to be carried out of the same item during aircraft maintenance. (Paragraph 3e2)

h. **Seat Raise Check.** It is recommended that the seat raise check as currently conducted is discontinued immediately. (Paragraph 3f3)

i. **Airworthiness Issues.** It is recommended that the MoD Airworthiness Regulator review the proceedings of this Board to ensure that airworthiness lessons identified are applied as necessary pan-platform, in particular (and together with Project Team Leaders) as

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they might apply to future contractor-led maintenance activities. The following issues warrant special attention and I recommend that:

(1) Guidance and, if necessary, direction is provided with regard to the recording processes for maintenance activities. (Paragraph 5a)

(2) Guidance and, if necessary, direction is provided with regard to the responsibilities of the contracted Company for the oversight of organisations conducting any activity in support of that contracted Company. These responsibilities must accord with the requirements of the regulations that are conditions of the contract. The work in this area should be communicated to the appropriate authorities in the Land and Sea domains. (Paragraph 5b)

j. **Parallel Investigation.** It is recommended that appropriate direction be included in JSP832 (Service Inquiries) and the Military Aviation Regulatory Document Set to ensure that Service Inquiries are afforded the priority that is required and that the amendments should also reflect that all such activity should be formally channelled through the Convening Authority. (Paragraph 7a)

k. **Flight Test Schedules.** It is recommended that the review of the Tornado MoD Flight Test Schedule in the light of industry best practice be extended to cover MoD flight test schedules for all platforms. (Paragraph 7b)

l. **HQ Air Command 'Can Do Safely' Campaign.** The Stn Cdr recommends the inclusion of all Depth Support Wing activities and personnel within the HQ Air Command 'Can Do Safely' campaign, and I support this recommendation.

m. **Classified Material.** The Board states that no classified material was lost; however, I note that the Flight Crew Checklist belonging to the WSO was never recovered. This publication was classified RESTRICTED. It is recommended that the implications of this be considered by the appropriate authority.

9. **Further Remarks.**

a. **Cost Data.** The provision of cost data in terms of an accident is standard practice for a BOI. However, given that these costs relate to CMU man-hours (BOI Report Part 1.2 Paragraph 24) they should be viewed as at least 'share price sensitive' and probably Commercial in Confidence. It is strongly recommended that these costs are redacted from the Report when it is distributed to the wider, non-MoD, audience.

b. **MoD Airworthiness and Flight Test Regulator (MAFTR) BOI.** Immediately following the accident it became apparent that the previous understanding of the processes and functions of a MAFTR BOI (as opposed to a Single Service BOI) had weakened over time, this led to a delay in the provision of personnel for the Board. This has now been addressed through discussion and formal amendment to JSP551 and should not be an issue for the future.

c. **Pilot Actions and Norfolk Constabulary.** I concur with the observations made by the Board and noted by the Stn Cdr regarding the professionalism of the pilot immediately following the accident and the assistance given to the Board by the Norfolk Constabulary.

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10. Conclusion. There is much to be learned from this accident, and the relevant findings of the Board should be communicated to all in positions of management and supervisory authority, both engineer and aircrew. In particular, it is imperative that the wider lessons identified (in maintenance procedures, airworthiness management, aircrew and engineering training and human factors) are understood and applied robustly, pan-platform, and where required, pan-domain, in order to ensure that the likelihood of such problems occurring in the future is minimised.

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Group Captain
AD Air Systems - TESD

Boscombe Down Ext [redacted] S 40

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FORMAT FOR RECORDING QR 1269(7) ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Chief Technician [redacted] was invited to read the proceedings and make a statement in accordance with QR 1269(7). Chief Technician [redacted] elected/~~declined~~/ to make a statement which is at page(s)1-3.(*). S 40

(*) Delete as applicable.

(AL39,Mar 00)

FORMAT FOR RECORDING QR 1269(7)
ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Corporal [redacted] was invited to read the proceedings and make a statement in accordance with QR 1269(7). [redacted] elected/~~declined~~/ to make a statement which is at page(s) 1-3 . (*).

(*) Delete as applicable.

(AL39, Mar 00)

FORMAT FOR RECORDING QR 1269(71
ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Senior Aircraftsman [redacted] was invited to read the proceedings and make a statement in accordance with QR 1269(7). Senior Aircraftsman [redacted] elected/~~declined~~/ to make a statement which is at pagel. (*). S 40

[redacted] S 40

(*) Delete as applicable.

(AL39, Mar 00)

QR1269 COMMENTS ARE PROVIDED IN PART 2 OF THE PROCEEDINGS AT SECTION 2(a)

FORMAT FOR RECORDING QR 1269(7) ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Chief Technician [redacted] was invited to read the proceedings and make a statement in accordance with QR 1269(7). Chief Technician [redacted] elected/~~declined~~/ to make a statement which is at page(s)1-3.(*).

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(*) Delete as applicable.

(AL39, Mar 00)

QR1269 COMMENTS ARE PROVIDED IN PART 2 OF THE PROCEEDINGS AT SECTION 2(a)

FORMAT FOR RECORDING QR 1269(7) ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Corporal [redacted] was invited to read the proceedings and make a statement in accordance with QR 1269(7). Corporal [redacted] elected/~~declined~~/ to make a statement which is at page(s) 1-3. (*). S 40

(*) Delete as applicable.

(AL 39 Mar 00)

QR1269 COMMENTS ARE PROVIDED IN PART 2 OF THE PROCEEDINGS AT SECTION 2(a)

FORMAT FOR RECORDING QR 1269(7)
ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Senior Aircraftsman [redacted] was invited to read the proceedings and make a statement in accordance with QR 1269(7). Senior Aircraftsman [redacted] elected/~~declined~~/ to make a statement which is at page(s) 1-3. (*).

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(*) Delete as applicable.

(AL39, Mar 00)

QR1269 COMMENTS ARE PROVIDED IN PART 2 OF THE PROCEEDINGS AT SECTION 2(a)

FORMAT FOR RECORDING QR 1269(7)
ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Chief Technician [redacted] was invited to read the addendum report into ZA554 proceedings and make a statement in accordance with QR 1269(7). Chief Technician [redacted] elected/~~declined~~/to make a statement/ which is at page(s) ..... (*).

(*) Delete as applicable.

(AL39, Mar 00)

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QR1269 COMMENTS ARE PROVIDED IN PART 2 OF THE PROCEEDINGS AT SECTION 2(a)

FORMAT FOR RECORDING QR 1269(7)
ACTION IMA UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Corporal [redacted] was invited to read the addendum report into ZA554 proceedings and make a statement in accordance with QR 1269(7). Corporal [redacted] elected/~~declined~~/to make a statement/ which is at page(s)
..... (*)

(*) Delete as applicable.

(AL39, Mar 00)

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QR1269 COMMENTS ARE PROVIDED IN PART 2 OF THE PROCEEDINGS AT SECTION 2(a)

FORMAT FOR RECORDING QR 1269(7)
ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(1) Senior Aircraftman [redacted] was invited to read the addendum report into ZA554 proceedings and make a statement in accordance with QR 1269(7). Senior Aircraftman [redacted] elected/~~declined~~/to make a statement/which is at page(s) ..... (*).

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(*) Delete as applicable.

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QR1269 COMMENTS ARE PROVIDED IN PART 2 OF THE PROCEEDINGS AT SECTION 2(a)

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Dec 09

BOI TORNADO ZA554 • CONVENING AUTHORITY (CA1 PART 1.4 FURTHER COMMENTS

1. **Introduction.** The Board of Inquiry (BOI) into the aircraft accident involving Tornado ZA554 submitted its report on 15 Jan 09[1], and the first 2 levels of staffing, by Stn Cdr RAF Marham and the Convening Authority (CA),[2] were completed on 13 Mar 09. In accordance with QR 1269(7), Chief Technician (CT) [redacted], Cpl [redacted] and SAC [redacted] were S 40 given the opportunity to read the proceedings and make statements. There have now been a total of 4 rounds of disclosure under QR 1269(7); this has included the re-convening of the BOI on 2 occasions, with a separate 'additional' BOI report produced on each occasion. Issues raised by CT [redacted] (and supported by Cpl [redacted] and SAC [redacted]) on each S 40 occasion
have been examined in great detail.

2. **QR 1269(7) Issues.** The totality of the subject matter expert (SME) advice received, together with the 2 additional BOI Reports and supporting evidence, has satisfied me as CA that all the issues raised by the RAF Marham personnel in the 4 separate rounds of disclosure under QR 1269(7) have been properly addressed.

3. **Issues Raised by Stn Cdr RAF Marham during QR 1269(7) Process.** Since the last CA comments recorded in the Proceedings,[3] the Stn Cdr RAF Marham has made comments following each of the 4 rounds of disclosure. I am content that the comments made following the 1st, 2nd and 3rd rounds of disclosure have been addressed by the BOI in their 2 additional reports, supported by SME advice from the HST PT and other sources as documented in the Proceedings. In his comments following the 4th round of disclosure, the Stn Cdr focuses on Ejection Seat Mod 02198. However, an ejection seat may fail to lock on fitting for any number of reasons. The Stn Cdr's recommendation that a review is carried out into how Mod 02198 was tested and accepted, and the wider implications for other such testing, is covered by the recommendation at para 8b of the original CA Part 1.4 Comments.[4]

4. **Additional Recommendations.**

a. I fully support the further recommendation made by the Aircrew Escape and Survival SME[5] (and disclosed to[6] and acknowledged by[7] the RAF Marham individuals previously), namely:

"It is recommended that the relevant authority consider the value in giving the Independent Checks post-ejection seat fitting the status of Mandatory Maintenance Procedures (MMPs). This consideration should apply to all ejection seat-fitted platforms."

[1] RAF Form 412A dated 15 Jan 09.
[2] Reference MFTR/70/2/1(297) dated 13 Mar 09.
[3] CA Comments Part 1.4 dated 13 Mar 09
[4] CA Comments Part 1.4 dated 13 Mar 09
[5] And endorsed by the Tornado IPT
[6] At MFTR/70/7/1 (297) - 20090727-BOI ZA554 QR1269 Second Statements Final Staffing dated 27 Jul 09.
[7] At the Third Statement by CT [redacted] dated 12 Aug 09 S 40

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b. I fully support the further recommendation made by the Board in their Addendum Report,[8] namely:

"The Board recommends that further investigation is undertaken to ascertain whether there is a flight safety hazard associated with scoring/damage to ejection gun top latch windows."

5. Conclusion. I am content that the Findings, Recommendations and Observations of the BOI original report (and clarified by the additional 2 BOI reports) remain valid. I am also content that the additional Findings, Recommendations and Observations of the Stn Cdr RAF Marham (at Part 1.3 of the Proceedings) and of the CA (at Part 1.4 of the Proceedings) remain valid. Finally, in closing, I offer my deepest personal sympathy to Mrs Harland and her family for their loss.

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Group Captain
MOD Flight Test Regulator

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[8] which arose from their further investigations but was not related to the accident under the BOI

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ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(7) Chief Technician [redacted] was invited to read both the comments by Stn Cdr RAF Marham following the 4th round of disclosure, and the CA further comments and make a statement in accordance with QR 1269(7). Chief Technician [redacted] declined to make a statement.

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SIGNED [redacted] S.40

RANK Chief Technician

NAME [redacted] S 40

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AP3392 Vol 4
Leaflet 1507
Appendix 2
to Annex A

FORMAT FOR RECORDING QR 1269(7)
ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(7) Corporal [redacted] was invited to read both the comments by Stn Cdr RAF Marham S 40 following the 4th round of disclosure, and the CA further comments and make a statement in accordance with QR 1269(7). Corporal [redacted] declined to make a statement.

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RANK Corporal

NAME [redacted] S 40

DATE 11 - Jan -2010

AP3392 Vol 4
Leaflet 1507
Appendix 2
to Annex A

FORMAT FOR RECORDING QR 1269(7) ACTION IN A UNIT OR BOARD OF INQUIRY

Having already been advised of his rights under QR 1269(7) Senior Aircraftsman [redacted] was invited to read both the comments by Stn Cdr RAF Marham following the 4th round of disclosure, and the CA further comments and make a statement in accordance with QR 1269(7). Senior Aircraftsman [redacted] declined to make a statement. S.40

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DATE 11-01-10

PART 1.5
REMARKS BY
REVIEWING AUTHORITY

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Part 1.5 Remarks by Reviewing Authority

REMARKS BY CHIEF OF MATERIEL (AIR)

1. I commend the members of this Board of Inquiry for conducting a comprehensive investigation into the circumstances surrounding this tragic accident. Whilst key elements of physical evidence were not located, despite an extensive search, I am satisfied that the Board has assembled and collated a cogent body of evidence that has allowed them to identify the most likely cause of the accident and to provide an extensive range of recommendations that should avoid recurrence of such a tragic event. I agree with the Board's analysis of the cause and contributory factors identified in its initial report and amplified in its subsequent comments. This has been a regrettably lengthy investigation, involving a number of adjournments to satisfy legal process issues and also to address fully the issues subsequently raised by personnel involved. The Board has made a number of recommendations and some of these have been specifically commented on by the Station Commander and the Convening Authority. I agree with most of these recommendations, findings and observations, but I comment below on a number of the key issues raised where I feel that additional remarks are needed or a different course of action is merited to that recommended.

2. I accept that the cause of the accident was that the Top Latch Plunger (TLP) was not correctly engaged to lock the rear ejection seat in place, allowing the seat to exit the aircraft during the inverted negative 'g' manoeuvre while conducting the Loose Article/Negative g check. The TLP and spring assembly has not been recovered. However, the evidence compiled by the Board is sufficient for them to conclude that mechanical failure of these components was not a cause of the accident and led the Board to determine that the TLP was serviceable, but was not correctly located in the locked position during seat installation. The Board also concludes that a correctly applied TLP check should have identified an incorrect fitment state. I agree with these conclusions. The Board has identified a chain of events and

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possible contributory factors that may have combined to allow the TLP to be in an unlocked condition prior to the post maintenance flight check on ZA554. I commend the thoroughness with which the Board has sought to identify the variety of human factors and other issues which may have combined, in whole or in part, to allow the chain of events to occur. The Board has identified evidence of shortcomings with our aircrew and groundcrew training, which appear to have existed for many years, leading to a partial understanding of what constituted a correct TLP locked check. The necessary surety has been rapidly re-established. The Board has identified some lack of clarity in the maintenance procedures associated with the task and the relevant corrections have been introduced. The Board has also identified a number of procedural and human factors that increased the likelihood of such a maintenance error occurring. Any break in the chain of such possible contributory factors may well have prevented this accident occurring and I believe the Board has identified the remedial actions required to address such factors and actions against these have been taken. Those actions that have broader relevance, which relate mostly to the management of the airworthiness chain within the Partnered Support organisation at RAF Marham, are being addressed as part of a wider review. This seeks to adopt best practice from across the range of such operations now in place between Contractors and the MoD with other platforms. The Convening Authority is ensuring that those issues which have applicability to other Ministry of Defence aircraft types have been advised to the operating authorities concerned.

3. The Martin-Baker Aircraft (MBA) generic TLP assembly has been successfully used for just over 50 years in service world-wide, on over 55,000 ejection seats, during which time it has performed successfully in over 5,000 ejections. In RAF service alone, between 1971 and 2002, over 10 million ejection seat flight hours were logged without a mishap. As the mechanism that not only secures the ejection seat to the aircraft, but also allows the seat to instantaneously unlock itself from the aircraft when required in order to enable successful ejection - a demanding set of criteria – it has been a highly successful design. The TLP 'check' has also been reviewed by the designer

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and manufacturer, Martin Baker, the aircraft Design Authority, BAE Systems, and the Ministry of Defence Engineering Authority, and all consider it to be fit for purpose as long as its fitment is taught and practised correctly. As mentioned above the training has been reinforced, but I accept we should study whether it is practicable to incorporate a design change to make the locking indication more immediately apparent, without adding complexity which would compromise its functioning when required.

4. The Station Commander has commented on the contribution to the chain of events that was played by the introduction of Mod 02198B, an essential safety modification needed to deal with the revised parachutes introduced to handle greater all up weights of aircrew equipment assemblies. Inner piston misalignment would most probably have been identified on a pre-modification 02198B seat. However, ensuring that the inner piston has been positioned such that the TLP is correctly engaged has never been a function of fitting the BTTDFU. I therefore do not consider that the design of Mod 02198B is deficient in meeting accepted design requirements for aircraft systems, albeit some minor tolerancing issues have required subsequent minor changes to the design. Appropriate amendments to training, maintenance procedures and technical publications have been made to reinforce the need for correct alignment of the inner piston. I therefore do not support the recommendation for further review of the design of Mod 02198B. I also do not support the Board's suggestion of the need to study the introduction of a system to automatically initiate ejection should a failure of the locking system occur. Having examined this proposal with the engineering authorities, I have concluded that the additional features of such a system are likely to result in greater overall safety risk if implemented. I believe the measures put in place from the other recommendations made by the Board will ensure future safe operation. Also, the seat-raise check has been deleted as this has been demonstrated to provide no confirmation of correct TLP engagement, and hence provided a false sense of security.

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6. In concluding my remarks, I would concur with the Station Commander's comments regarding the pilot's professionalism in the immediate aftermath of the accident under what must have been the most distressing of circumstances. Finally, I too would like to offer my condolences to Mike Harland's family.

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K J LEESON 9 Feb 10

Air Marshal
Chief of Materiel (Air)
Defence Equipment and Support

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