Defence
Safety Authority

Service Inquiry

Loss of Hawk T Mk1 XX189 from 736 Naval Air Squadron, RNAS Culdrose

25 March 2021

Defence Safety Authority

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PART 1.1

Covering Note & Glossary

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PART 1.1 – COVERING NOTE

DSA/SI/02/21/HAWK

18 Jan 22

DG DSA

SERVICE INQUIRY INVESTIGATION INTO THE LOSS OF HAWK T MK1 AIRCRAFT XX189 FROM 736 NAVAL AIR SQUADRON, RNAS CULDROSE, ON 25 MARCH 21

1. The Service Inquiry Panel assembled at MoD Boscombe Down on the 07 Apr 21, by order of the DG DSA, for the purpose of investigating the accident involving Hawk T Mk1 XX189 on 25 Mar 21 and to make recommendations in order to prevent reoccurrence. The Panel has concluded its inquiry and submits the report for the Convening Authority's consideration.

2. The following inquiry papers are enclosed:

Part 1 REPORT Part 1.1 Covering Note and Glossary Part 1.2 Convening Orders & TORs Part 1.3 Narrative of Events Part 1.4 Findings Part 1.5 Recommendations Part 1.6 Convening Authority's Comments	Part 2 RECORD OF PROCEEDINGS Part 2.1 Diary of Events Part 2.2 List of Witnesses Part 2.3 Witness Statements Part 2.4 List of Attendees Part 2.5 List of Exhibits Part 2.6 Exhibits Part 2.7 List of Annexes Part 2.8 Annexes Part 2.9 Schedule of Matters Not Germane to the Inquiry Part 2.10 Master Schedule

PRESIDENT

[Signature]

[redacted]
President
Hawk XX189 SI

MEMBERS

[Signature]

[redacted]
Engineering Member
Hawk XX189 SI

[Signature]

[redacted]
Engineering Member
Hawk XX189 SI

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GLOSSARY

Abbreviation	Term
AAIB	Air Accident Investigation Branch
AAES	Aircraft Aircrew Escape System
ACDT	Air Commodities Delivery Team
ACNS (A&CS)	Assistant Chief of Naval Staff (Aircraft and Carrier Strike)
ADH	Aviation Duty Holder
ADS	Air System Document Set
AEA	Aircrew Equipment Assemblies
AERO	Aviation Engineering Routine Orders
AMM	Aircraft Maintenance Manual
AMO	Approved Maintenance Organisation
AMSL	Above Mean Sea Level
AOC	Air Officer Commanding
ARM	Accident Route Matrix
AS	Air Safety
ASAP	As Soon As Possible
ASI	Air Safety Investigation
ASIMS	Air Safety Information Management System
ASMS	Air Safety Management System
ATC	Air Traffic Control
ATSB	Australian Transportation Safety Bureau
Babcock	Babcock International UK Aviation
BAE	British Aerospace
BFJT	Basic Fast Jet Flying Training
BRd	Book of Reference (Digital)
CAw	Continuing Airworthiness
CAME	Continuing Airworthiness Management Exposition
Cdr	Commander
CO	Commanding Officer
CoE	Control-of-Entry
CVR	Cockpit Voice Recorder
CWP	Central Warning Panel
DA	Danger Area
DAIB	Defence Accident Investigation Branch
DAPs	Digital Air Publications
DASORs	Defence Air Safety Occurrence Reports
D&CP	Devon & Cornwall Police
DDH	Delivery Duty Holder
DE&S	Defence Equipment and Support
DFS	Duty Flying Supervisor
DG DSA	Director General Defence Safety Authority
DH	Duty Holder
DOs	Design Organisations
DP	Duty Pilot

EA	Engineering Authority
EFDC	Early Failure Detection Cell
EGR	Engine Ground Run
EGHQ	Cornwall Airport Newquay
Eng Docs	Engineering Documents
EPLB	Emergency Personal Locator Beacon
EQA	External Quality Assurance
E2E	End to End
F	Form
FACS	Future Aircrew Clothing System
FBA	Fighter Bomber Attack
FJ	Fast Jet
FL	Flight Level
FOST	Fleet Operational Sea Training
FRCs	Flight Reference Cards
F2FP	Failure To Follow Procedure
FW	Fixed Wing
FWF	Fixed Wing Force
g	Acceleration (1g is 1 x the force of gravity)
GDAS	Graphical Data Analysis Software
GF	Guard Force
GPS	Global Positioning System
HAM	Head of Aircraft Maintenance
HDT	Hawk Delivery Team
HF	Human Factors
HFACS	Human Factors Analysis Classification System
HMS	Her Majesty's Ship
HP	High Pressure
IA	Immediate Action
iaw	In Accordance With
ICP	Incident Control Point
IMC	Instrument Meteorological Conditions
IPG	Immersion Protection Garments
IQA	Internal Quality Audit
JARTS	Joint Aircraft Recovery & Transportation Squadron
JSP	Joint Service Publication
kg	Kilogram
km	Kilometre
kts	Knots
LH	Left Hand
LOA	Letter of Agreement
LSJ	Life Saving Jacket

MAA	Military Aviation Authority
MAM-P	Manual of Airworthiness Maintenance - Processes
MAOS	Maintenance Approved Organisation Scheme
MAS	Manual of Air Safety
MCD	Magnetic Chip Detector
MCVR	Multi-Channel Voice Recorder
MDC	Miniature Detonation Cord
MEMS	Maintenance Error Management System
Mil	Military
Mil CAM	Military Continuing Airworthiness Manager
MOD	Ministry of Defence
MPFR	Multi-Purpose Flight Recorder
MRP	Military Regulatory Publication
MSD	Minimum Separation Distance
MWO	Maintenance Work Order
NAO	Naval Aviation Order
NAS	Naval Air Squadron
NB	Not Below
NM	Nautical Miles
NoK	Next of Kin
ODH	Operating Duty Holder
OF3	Lieutenant Commander / Major / Squadron Leader
Ops	Operations
OOP	Out of Phase
OSA	Organisational Safety Assessment
OSD	Out of Service Date
PCM	Post-Crash Management
PCMIO	Post-Crash Management Incident Officer
PFL	Precautionary Forced Landing
PPMWO	Pre-Printed Maintenance Work Order
psi	Pounds per Square Inch
Pt 145	Part 145 Accredited Organisation
PU	Polyurethane
PVA	Process Verification Audit
QA	Quality Assurance
QMS	Quality Management System
QSEC	Qualified, Suitably Experienced and Competent
QSO	Quality System Owner
RA	Regulatory Article
RAF	Royal Air Force
RAFAT	Royal Air Force Aerobatics Team
RAFCAM	RAF Centre of Aviation Medicine
RAG	Red, Amber, Green
RH	Right Hand
RN	Royal Navy

RNAS	Royal Naval Air Station
RNFSC	Royal Navy Flight Safety Cell
RPAS	Remotely Piloted Air System
RPM	Revolutions Per Minute
R-R	Rolls Royce
RTS	Release to Service
RTSA	Release to Service Authority
RW	Rotary Wing
SAR	Search and Rescue
SAT	Surface Attack
SE	Survival Equipment
SES	Survival Equipment Section
SET	Survival Equipment Technicians
SI	Service Inquiry
SME	Subject Matter Expert
SO	Senior Operator
SOP	Standard Operating Procedure
SQEP	Suitably Qualified and Experienced Personnel
Sqn	Squadron
sS	Single Service
SSOs	Squadron Standing Orders
STANEVAL	Standards & Evaluation
Stn	Station
TAA	Type Airworthiness Authority
TG	Trade Group
TRiM	Trauma Risk Management
UA	Unit Authenticator
UKMFTS	United Kingdom Military Flying Training System
1PA	First Party Audit

PART 1.2

Convening Order & TORs

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DSA DG/SI/02/21 – CONVENING ORDER FOR THE SERVICE INQUIRY INTO THE LOSS OF HAWK T MK1 AIRCRAFT XX189 FROM 736 NAVAL AIR SQUADRON, RNAS CULDROSE, ON 25 MAR 2021

1. In accordance with Section 343 of Armed Forces Act 2006 and JSP 832 – Guide to Service Inquiries (Issue 1.0 Oct 08), the Director General, Defence Safety Authority (DG DSA) has elected to convene a Service Inquiry (SI).

2. The purpose of this SI is to investigate the circumstances surrounding the incident and to make recommendations in order to prevent reoccurrence.

3. The SI Panel will commence administrative briefing at 1200 on Wednesday 7 Apr 2021 at DAIB, B120 at MOD Boscombe Down, and will be formally convened by the DG DSA at 1400.

4. The SI Panel comprises:

President: [redacted] [redacted] **ROYAL AIR FORCE**

Members: [redacted] **ROYAL NAVY** [redacted]
[redacted] **REME** [redacted]

5. The legal advisor to the SI is [redacted] (DSA-HQ-Legad) and technical investigation / inquiry support is to be provided by the Defence Accident Investigation Branch (DAIB). The nominated mentor for this SI is [redacted] **RAF** (DSA-DAIB-Air-Eng4).

6. The SI is to investigate and report on the facts relating to the matters specified in its Terms of Reference (TOR) and otherwise comply with those TOR (at Annex A). It is to record all evidence and express opinions as directed in the TOR. An Initial Report on the commencement of the investigation is to be submitted on 21 Apr 2021.

7. Attendance at the SI by advisors / observers, unless extended by the Convening Authority, is limited to the following:

Head DAIB – Unrestricted Attendance.
DAIB SO1 Air – Unrestricted Attendance.
DAIB Investigators in their capacity as advisors to the SI Panel – Unrestricted Attendance.
Human Factors specialists in their capacity as advisors to the SI Panel – Unrestricted Attendance.

8. The SI Panel will initially undertake induction training at the DAIB facility at MOD Boscombe Down immediately after convening. Thereafter, permanent working accommodation, equipment and assistance for the nature and duration of the SI will be requested at a location decided by the SI President in due course.

9. Reasonable costs will be borne by the DG DSA under UIN D0456A.

Original Signed

S C Gray CB OBE FREng
Air Marshal
DG DSA – Convening Authority

Annex:

A. Terms of Reference for the Service Inquiry into loss of Hawk T Mk1 aircraft XX189 from 736 Naval Air Squadron, RNAS Culdrose, on 25 Mar 2021.

Annex A to
20210407-DSA DG/SI/02/21 – CONVENING ORDER FOR THE SERVICE INQUIRY INTO THE LOSS OF HAWK T MK1 AIRCRAFT XX189 FROM 736 NAVAL AIR SQUADRON, RNAS CULDROSE, ON 25 MAR 2021-OS

7 Apr 2021

TERMS OF REFERENCE FOR THE SERVICE INQUIRY INTO THE LOSS OF HAWK T MK1 AIRCRAFT XX189 FROM 736 NAVAL AIR SQUADRON, RNAS CULDROSE, ON 25 MAR 2021

1. As the nominated Inquiry Panel for the subject SI, you are to:

a. Investigate and, if possible, determine the cause of the accident, together with any contributory, aggravating and other factors and observations.

b. Establish the level of training, relevant competencies, qualifications and currency of the individuals involved in the incident.

c. Identify if the levels of planning and preparation were commensurate with the activity's objectives.

d. Determine the state of serviceability of the aircraft and other relevant equipment.

e. Review the levels of authority and supervision covering the task during which the incident occurred.

f. Examine what policies, orders and instructions were applicable and whether they were complied with.

g. Investigate and comment on the relevant fatigue implications of the individuals' activities prior to the matter under investigation and on any Human Factors that may have played a part in this incident.

h. Ascertain if aircrew escape and survival facilities and equipment assemblies were fully utilised and functioned correctly.

i. Determine whether the Post-Crash Management procedures were complied with and were adequate, and review whether the post incident actions, including immediate medical attention and ongoing care, were appropriate, adequate and carried out correctly.

j. Determine and comment on any broader contributary organisational and / or resource factors.

k. Report and make appropriate recommendations to the DG DSA.

2. The investigation should not seek to attribute blame and you should use JSP 832 - Guide to Service Inquiries and DSA 03.10 as guidance for the conduct of your inquiry. You are to report immediately to the DG DSA should you have cause to believe a criminal or Service Offence has been committed.

3. If at any stage the Panel discovers something they perceive to be a continuing hazard presenting a risk to the safety of personnel or equipment, the President should alert DG DSA without delay to initiate remedial actions. Consideration should also be given to raising an Urgent Safety Advice note.

PART 1.3

Narrative of Events

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TABLE OF CONTENTS – PART 1.3

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PART 1.3 – NARRATIVE OF EVENTS

All times Local

Synopsis

1.3.1. On Thursday 25 Mar 2021 at 09:37, a 736 Naval Air Squadron (NAS) Hawk Trainer Mark 1 (T Mk1) crashed approximately 4 nautical miles (NM) to the east of Royal Naval Air Station (RNAS) Culdrose, Cornwall. The Pilot and Passenger ejected before the aircraft was destroyed on impact with the ground.

1.3.2. The aircraft was operated from RNAS Culdrose where 736 NAS is the Royal Navy's (RN) maritime adversary squadron (Sqn). It was also [redacted] based at RNAS Culdrose. The Sqn was tasked with providing support to the Fleet Operational Sea Training (FOST) exercises by simulating enemy aircraft and missiles conducting attacks on ships at sea. The Sqn also provided training for airborne RN Observers[1] in the fighter control role.

1.3.3. The crew who consisted of a 736 NAS Instructor Pilot[2] and the Passenger[3], were tasked as the subordinate element in the second pair of the day conducting FOST tasking. At the top of the climb, an OIL caption illuminated on the Central Warning Panel and a return to base was initiated. Approximately nine minutes later the aircraft suffered a mechanical failure of the engine and after shutting down the engine, the crew elected to eject at low-level. The Pilot sustained a major injury[4] whilst the Passenger suffered no significant injuries.

Background information

1.3.4. **Aircraft.** The Hawk T Mk1 (Figure 1.3.1), tail number XX189, was a BAE Systems Hawk which held a valid Military Airworthiness Review Certificate. Exhibit 1

[1] An RN Observer is a commissioned crew member responsible for navigation, system operation and weapon control.

[2] Instructor Pilots are qualified to instruct certain phase 3 skill sets, versus Qualified Flying Instructors who hold a Central Flying School accreditation to teach phase 2 and 3 skills.

[3] A Fast Jet holdover student awaiting the commencement of Advanced Fast Jet Flying Training.

[4] The Military Aviation Authority Master Glossary includes within the reportable definition of a major injury: a fracture or admittance to hospital for more than 24 hours.

Figure 1.3.1 - Hawk T Mk1 of 736 NAS.

1.3.5. **736 NAS.** 736 NAS was re-commissioned on 6 Jun 2013 at RNAS Culdrose and replaced the units formerly known as Fleet Requirements and Aircraft Direction Unit and RNAS Yeovilton Hawkdet. It was manned by RN aircrew and Survival Equipment Technicians, Babcock International UK Aviation engineering and support staff and was commanded by an RN OF3 (Lieutenant Commander). A small squadron of approximately [redacted] 736 NAS formed the [redacted]

1.3.6. **RNAS Culdrose.** RNAS Culdrose was home to the RN Merlin HM Mk2 Force[5] and the RN Fixed Wing Force[6] comprising of Avenger, Hawk and RPAS aircraft.

Pre-flight events

Preceding month's flying and maintenance

1.3.7. **Aircraft flying.** During the preceding 30-day period, XX189 had flown a total of 20 hours and 15 minutes. Exhibit 5

1.3.8. **Maintenance.** XX189 underwent 145 hours and 45 minutes of routine maintenance during the month preceding the accident. On two occasions oil related Exhibit 6

[5] Consisting of 814, 820 and 824 Squadrons.

[6] Consisting of 700X, 736 and 750 Squadrons.

issues were recorded in the Ministry of Defence (MOD) F707A. Those are detailed as follows: Exhibit 8

a. 09 Mar 2021 – OIL caption illuminates immediately on pushing negative g – Oil pressure relay (EH4[7]) replaced.

b. 15 Mar 2021 – OIL caption repeatedly illuminates after two to three seconds of negative g – Engine Control Unit pressure switch replaced. Exhibit 5

1.3.9. XX189 had flown 3 hours and 55 minutes since the last reported oil related issue and had a total of 8,908 hours and 5 minutes airframe flying time.

1.3.10. **Incident reporting.** There were no Defence Air Safety Occurrence Reports raised on XX189 in the preceding month.

Preceding week's flying and maintenance

1.3.11. **Aircraft flying.** XX189 had flown a total of 3 hours and 15 minutes during the working week preceding the accident. Exhibit 5

1.3.12. **Aircraft maintenance.** XX189 underwent 2 hours and 30 minutes of routine maintenance[8] during the week preceding the accident. Maintenance included the aircraft being placed into and out of maintenance and the carrying out of Out of Phase (OOP) maintenance code A10 – Engine Magnetic Chip Detector (x3) replaced for Early Failure Detection Cell Analysis. This procedure was carried out on the night prior to the accident sortie. Exhibit 6 Exhibit 7

Day of the accident - 25 Mar 21

1.3.13. **Aim of sortie.** The flight was in support of FOST tasking as part of the 'Thursday War'[9]. The aircraft, using the callsign [redacted][10], was number 4 of 4 aircraft which launched as 2 separate pairs approximately 50 minutes apart. The tasking area was to the south of Plymouth and east of the Lizard Peninsula as shown in Figure 1.3.2. Exhibit 32

[7] EH4 is the low-pressure warning relay that connects power to the Centralised Warning Panel when the oil pressure falls below a set value and illuminates the OIL caption.

[8] Excluding flight servicing activities.

[9] Routine maritime training exercise.

[10] [redacted]

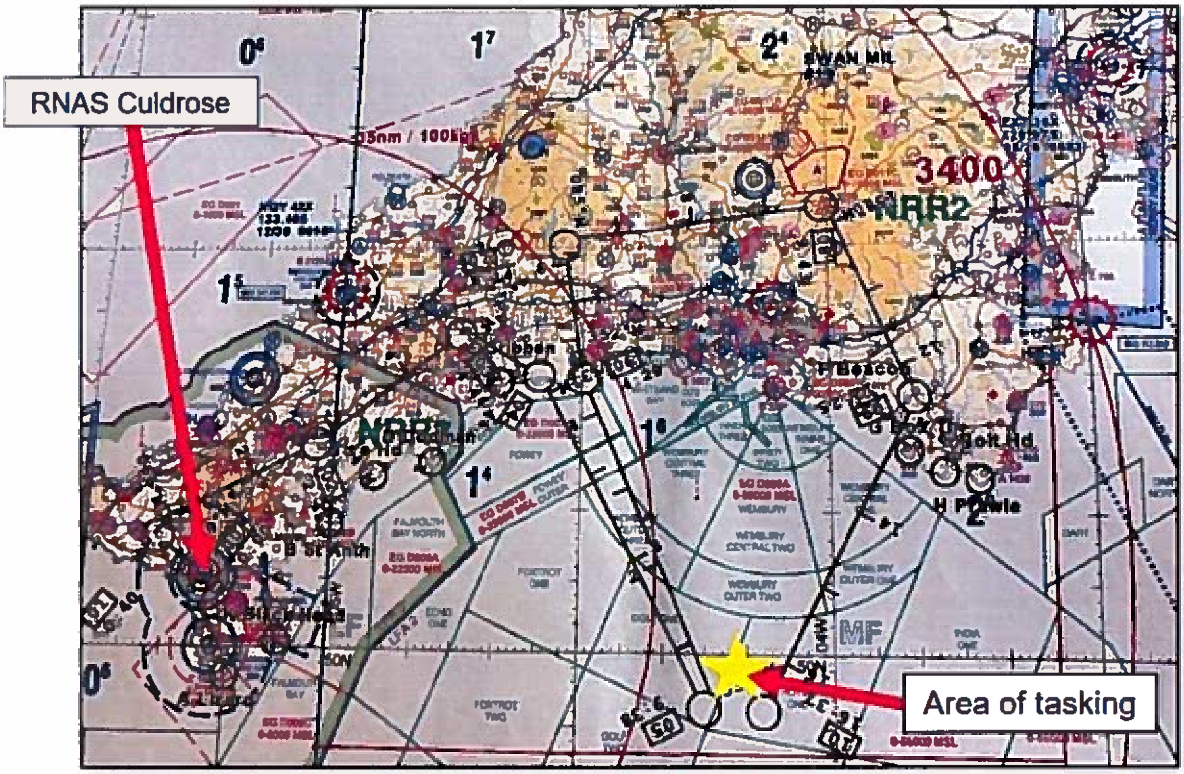

Figure 1.3.2 - Map of Tasking area as planned on the Hawk Advanced Mission Planning Aid - 24 Mar 21.

1.3.14. **Planning.** Most of the mission planning was conducted the day prior to the accident by the nominated 'War Lead'. Finer aspects of the sortie planning, such as the fuel and weather-related considerations, were conducted on the morning of the accident by the crews flying the sortie. Witness 1

1.3.15. **Published weather forecast.** RNAS Culdrose was under an occluded front with moderate rain expected throughout the day. A strong south westerly flow with gusts up to moderate gale were also expected[11]. The max temperature of the day was expected to be approximately 10°C.

1.3.16. The terminal airfield forecasts covering the period of flying were: Exhibit 9

a. On 25 Mar issued at 08:10, valid between 09:00 and 18:00, wind 220 degrees at 12 knots (kts) gusting up to 25kts, visibility 7 kilometres (km) with light showers of rain. Cloud scattered[12] at 1000ft, broken[13] at 1800ft, becoming between 09:00 and 11:00, visibility greater than 10km, nil significant weather, cloud few[14] at 2000ft. Temporarily, between 11:00 and 18:00, visibility 7km, light showers of rain, cloud few at 1000ft and broken at 2000ft. Temporarily

[11] Gust warning issued 250800 to 251800 gusts up to 25kts during the morning increasing to 30 kts by late afternoon.

[12] Scattered is 3-4 OKTAS cloud coverage. OKTAS is the unit for cloud coverage given in eighths.

[13] Broken is 4-7 OKTAS cloud coverage.

[14] Few is 1-2 OKTAS cloud coverage.

between 16:00 and 18:00, visibility 4000 metres with moderate showers of rain, cloud scattered at 500ft, broken at 1600ft with towering cumulous.

Exhibit 16

1.3.17. **Actual weather.** The actual weather at the time[15] of the crash was:

a. Wind: 220 / 11kts Gust 18kts.

b. Visibility: 29km.

c. Significant Weather: Nil.

d. Cloud: Few 500ft, Few 2000ft, Sct 6000ft.

e. QFE[16]: 1009.

f. QNH[17]: 1019.

g. Temperature: +11°C.

h. Relative Humidity: 89%.

1.3.18. **Airfield status.** The airfield, as annotated by the Duty Pilot (DP), was operating on runway 29. Primary Radar was on maintenance. The Instrument Landing System was Serviceable. The Precision Approach Radar to Rwy 29 was unserviceable. The diversion airfield, Cornwall Airport Newquay (EGHQ[18]), was annotated as fully serviceable. The RNAS Culdrose air traffic department was at a reduced manning level due to on-going COVID-19 restrictions; however, a trainee and supervisor were manning Culdrose Approach as part of the trainee's work-up. Also, in the room was a radar supervisor.

Exhibit 10
Witness 3

1.3.19. **Briefing.** The Pilot and Passenger attended the sortie brief at 07:30 followed by 'Sqn Shares[19]' at 07:50. The sortie was briefed from a standard format used for all 'Thursday War' missions. Sqn Shares followed the same format every day. The pertinent points relating to weather, aircraft status, crew status, passenger status, Notice To Airmen (NOTAMs), emergency of the day, diversion airfield, diversion fuel requirements and sortie profile were briefed and re-iterated in the out brief, which also followed a standard format.

Witness 1
Witness 2
Witness 10

1.3.20. **Sortie.** [redacted] took-off at 08:35 for their specific tasking. [redacted] departed RNAS Culdrose in a streamed formation take-off at 09:24 for theirs.

Exhibit 11
Witness 1
Witness 2

1.3.21. **Start-up, taxi, and take-off.** The start-up, at 09:15, taxi, and take-off were uneventful from the perspective of the Pilot, Passenger, and ground crew. After a short taxi the formation was ready for departure and did so without any abnormal

Witness 1
Witness 2
Witness 12

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[15] Recorded at 0939.

[16] Barometric pressure setting causing an altimeter to read airfield elevation in relation to the ground at the point where the airfield is situated.

[17] Barometric pressure setting causing an altimeter to read airfield elevation in relation to sea level.

[18] International Civil Aviation Organisation Code for Cornwall Airport Newquay.

[19] A daily meeting where Sqn matters are discussed.

indications. During the latter stages of the climb-out the Passenger was handed control by the Pilot. The aircraft was levelled off at 15000ft. At the top of the climb the formation leader reduced speed as the formation was ahead of their intended timeline. At approximately 09:27 the OIL caption and attention getters[20] flickered on momentarily and then extinguished. Within seconds the caption and attention getters returned, and the caption remained on in a steady state for the remainder of the flight.

1.3.22. **Immediate actions.** The Pilot took back control and correctly completed the Flight Reference Card (FRC) Immediate Action (IA) associated with the OIL caption (from memory) and set 83% Revolutions Per Minute (RPM)[21]. The intention to return to RNAS Culdrose was communicated to the formation lead. [redacted] offered to accompany [redacted] back to RNAS Culdrose, but the offer was declined by [redacted]. At 09:28 the Pilot initiated a gentle right-hand turn, declared a 'PAN PAN'[22] call out to Plymouth Military (Mil) Air Traffic Control (ATC) and began a descent back to the airfield. At the time the caption illuminated [redacted] was approximately 10NM from Newquay, which was also the nominated diversion of the day, and 20NM from RNAS Culdrose. Witness 1 Witness 2

1.3.23. **Descent.** During the descent the Pilot told Plymouth Mil to standby. During this time the Passenger, confirmed the OIL IA had been completed correctly, reading out the subsequent actions along with the associated warnings, directly from the FRCs. The Pilot concurrently contacted the 736 NAS DP and Duty Authoriser to inform them of the situation and intentions to conduct a fixed power straight in approach back to RNAS Culdrose. Witness 1 Witness 2 Witness 10

1.3.24. During the time when Plymouth Mil was waiting for the Pilot to recontact them, a landline call was made to Culdrose Approach notifying them of the situation. The Distress and Diversion Cell (based at Swanwick) was also informed of the situation. Witness 4

1.3.25. At 09:31:16 [redacted] was handed over from Plymouth Mil to Culdrose Approach and checked in with the continued declaration of a 'PAN PAN'. Shortly after the handover, and while routing through the overhead of RNAS Culdrose at approximately 8000ft, the Duty Authoriser contacted the Pilot and informed the Pilot that the duty engineering officer had confirmed that during the preceding day's engineering work a magnetic chip detector change had been conducted on the engine of XX189. Exhibit 14 Witness 1 Witness 10

1.3.26. At 09:32:12 the Culdrose Approach trainee informed the Pilot of the status of D005A, the danger area surrounding Predannack Airfield. The Pilot asked more specifically what height D005A was active up to, but as the controller was unaware of the height or position of the Remotely Piloted Air System operating within the area, the trainee's supervisor responded that the area was active up to 8000ft as NOTAM'd. The Pilot responded to this information that they may encroach. The Pilot Witness 1 Witness 4 Exhibit 14

[20] Attention getters were flashing buttons that sit under the cowling in both cockpits of the Hawk.

[21] RPM represented the High-Pressure shaft speed on the Hawk T Mk1.

[22] An urgent condition concerning the safety of the aircraft but did not require immediate assistance.

altered the aircraft's vector away from D005A and positioned towards runway 29 centre line heading away from the airfield on a reciprocal heading to the runway while the descent was continued.

1.3.27. At 09:34:56 the Pilot experienced rumbling, vibrations, and a 'snatch-down' of the engine RPM and declared a 'MAYDAY'[23] call to Culdrose Approach. The call was acknowledged and at 09:35:07 the Pilot manoeuvred towards the coast on the eastern side of the Lizard Peninsula to position for an over water ejection. The Pilot rolled out the aircraft on an easterly heading and at 09:35:40, after approximately 30 seconds, the engine indications returned to normal. The Pilot elected to turn back towards RNAS Culdrose to continue the approach. This involved a turn back of approximately 270 degrees onto a north westerly heading. [redacted] was now 'coasting in' at a height of 900ft with approximately 7NM to run to the runway. Witness 1 Witness 2 Exhibit 14 Exhibit 34

1.3.28. At 09:36:27, more severe engine vibrations were felt, and a mechanical failure was diagnosed. The IA was carried out, in accordance with the FRCs, and the engine shut down at 09:36:41. [redacted] was approximately 4NM from the airfield, so the Pilot pointed the aircraft away from all known built-up areas and farm buildings towards the Helford River Valley. At 09:36:54, the Pilot called for the initiation of the command ejection[24], which was initiated by the Passenger in the rear cockpit while the aircraft was at a height of 650ft. Witness 1 Witness 2 Exhibit 14 Exhibit 34

1.3.29. The aircraft crashed onto a woodland clear of any farms a few seconds after the Pilot and Passenger ejected (Figure 1.3.3 and Figure 1.3.4).

[23] A condition of being threatened by serious and / or imminent danger and of requiring immediate assistance.

[24] A system in which the pilot of an aircraft or the occupant of the other ejection seat(s) initiates ejection, resulting in the automatic ejection of all occupants.

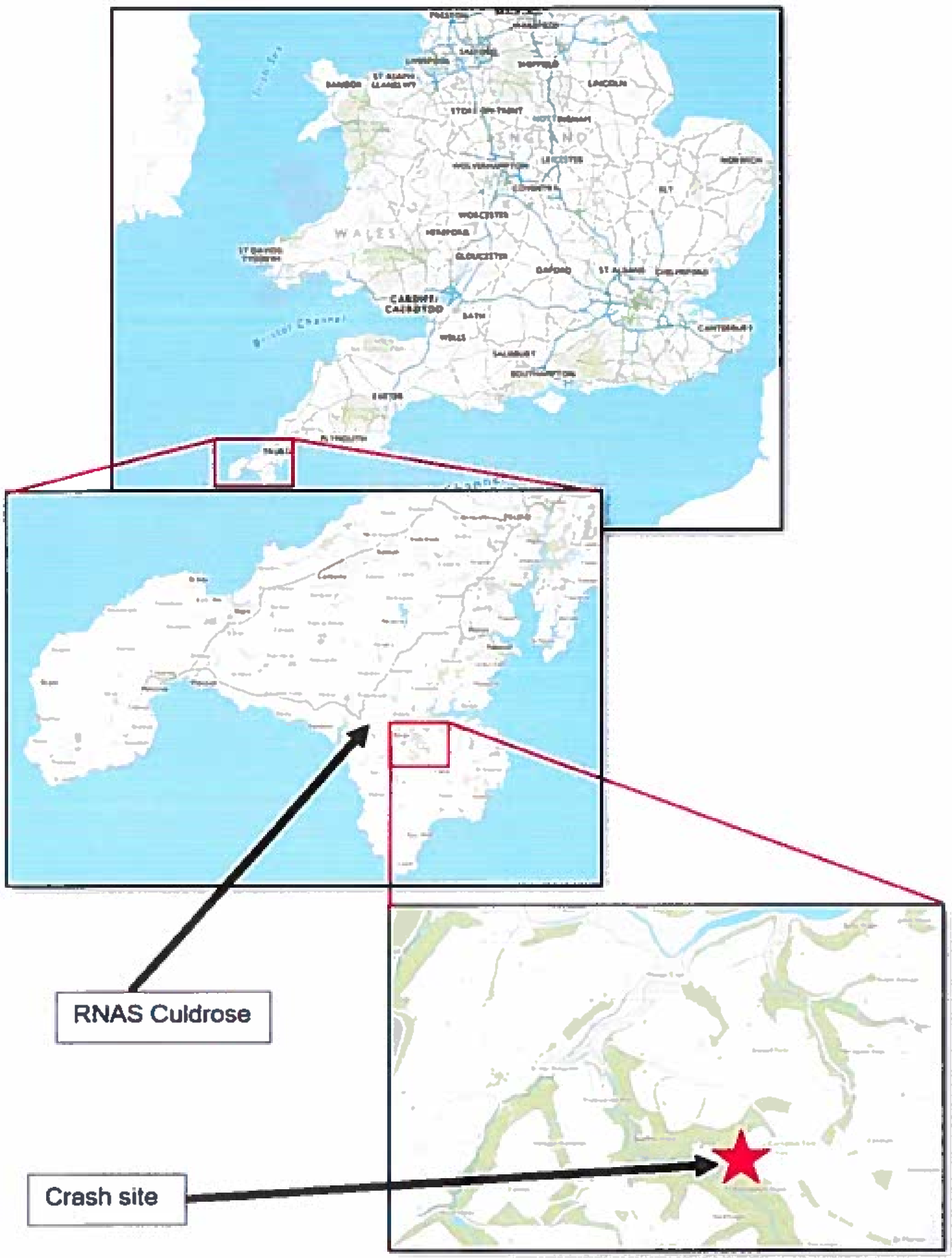

Figure 1.3.3 - Maps highlighting the crash location.

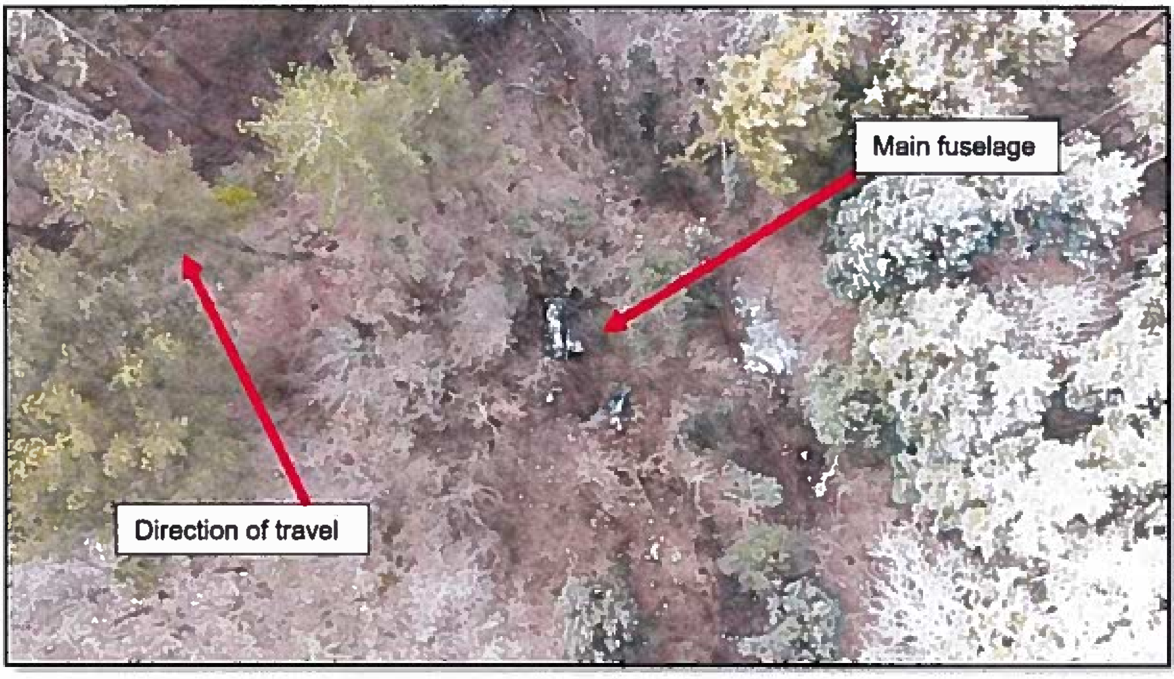

Figure 1.3.4 - XX189's resting place post impact with the Cornish Hedge.

Escape and survival

1.3.30. The Pilot and the Passenger ejected safely with all aspects of the ejection seat, parachute, and automatic lowering of the personal survival pack working as expected. Witness 1 Witness 2 Exhibit 122

1.3.31. **Post ejection.** The Passenger, who ejected first as per the design of the command ejection system, checked the parachute canopy was inflated, inflated the Life Saving Jacket (LSJ) and noted that the oxygen mask had been 'ripped' from their face, however, the visor had remained locked in place. An assessment of the descent indicated a potential to land in trees, so a decision was made to try and steer the parachute away from the trees. Subsequently, the Passenger approached the front face of a wood line with the parachute snagging the trees and the descent coming to a stop approximately 6 inches from the ground. The Passenger stepped out of the parachute harness and tried to identify where the Pilot was going to land. Witness 2

1.3.32. The Pilot ejected with their hands on their knees, and after confirming the parachute canopy was inflated, immediately noticed a pain in their back. The LSJ was activated but this deflated after the initial inflation. The Pilot also noted that the helmet visor had been lifted and the oxygen mask had been removed from their face during the ejection sequence. A parachute landing position was adopted appropriate to the direction of descent and a landing in a rearward motion in a field occurred. In response to the back pain felt, the Pilot remained still. Witness 1

1.3.33. The Passenger approached the Pilot and offered the inflated LSJ as a neck rest to provide some comfort while waiting for aid. The Passenger was carrying a mobile phone and used this to contact their partner, the Pilot's partner and 736 NAS Operations (Ops). The landowner quickly arrived and provided a post code which Witness 1 Witness 2

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was passed by the Pilot to 736 NAS Ops and by the landowner to the emergency services to assist their response.

Post-accident events

1.3.34. **Initial response and activation.** The Duty ATC Officer initiated an Emergency State 1[25] after communications were lost with the Pilot. Actions were initiated by ATC and Ops staff in accordance with the Culdrose Defence Aerodrome Manual. Culdrose guardroom staff also called 999 at 09:43, alerting the civil emergency services. Witness 4 Exhibit 17

1.3.35. The Maritime & Coastguard Agency Search and Rescue (SAR) aircraft at Newquay was scrambled and reported en-route by the Aeronautical Rescue Coordination Centre. At 09:49 the Deputy Chief of Defence Staff Duty Officer was informed and the Post-Crash Management Incident Officer (PCMIO) recalled. At 09:53, RNAS Culdrose self-activated its PCM plan. The SAR aircraft arrived on scene at 10:12, located both crewmembers rapidly, and transported them to [redacted] Hospital.

1.3.36. Culdrose guardroom staff commenced a full PCM recall (Emergency Routine 22) at 09:58 and this action was completed by 10:25. The RAF Regional Liaison Officer (south west) was contacted at 10:00. Following discussion between ATC controllers and the Duty Flying Supervisor (DFS), the Culdrose Crash Combine (comprising of a Rapid Intervention Vehicle and Ambulance) was despatched off airfield towards the scene. The Airfield was declared BLACK[26] (due to the lack of suitable airfield rescue and firefighting cover to recover other aircraft), and airborne aircraft diverted to their alternate. At 10:19, the Crash Combine arrived on scene and the Fire Crew doused the wreckage with fire-retardant aqueous film forming foam due to the very strong smell of aviation fuel. Exhibit 17

1.3.37. The duty PCMIO arrived on base at 11:10 and, after briefing and taking stock, deployed to the scene of the crash at 12:18 for an initial reconnaissance, accompanied by the PCMIO assistant / scribe, Aircraft Incident Support Officer, and Health, Safety and Environmental Protection Advisor. The Culdrose Command Element was briefed on the emerging situation by the DFS / Station Incident Officer and further direction and guidance for the full implementation of the Culdrose response was given. Exhibit 17

1.3.38. **Airborne aircraft.** On recovery to RNAS Culdrose while checking in on the Culdrose Approach frequency, [redacted] heard the ongoing emergency; they performed an orbit to provide lateral distance to [redacted] and to observe the weather over the diversion airfield, Newquay. After determining their fuel load, ATC requested they fly over the suspected crash area to search for signs of impact or survivors. After a short time searching both aircraft recovered to Newquay on 'fuel Witness 3

[25] State 1 – Aircraft Accident: A crash on or seen from an aerodrome.

[26] Airfield is unusable for reasons other than clouds or low visibility.

priority' having reported no signs of the crash or any indications the crew had ejected.

1.3.39. **Accident site laydown and location.** The aircraft crashed just west of Caervallack Farm (Grid Reference SW245725), hitting a tree in the hedgerow between two fields. The aircraft impacted the ground in the corner of the field, demolishing part of a Cornish Hedge[27] (Figure 1.3.5) between the field and a wooded slope leading down to a stream. The bulk of the wreckage came to rest on the wooded slope above the stream (Figure 1.3.6). The stream fed Mawgan Creek that, in turn, fed the Helford River, a site of special scientific interest and a Marine Conservation Zone. The two ejection seats landed approximately 1km further north-east: one in a field by Mudgeon Farm, and the other in a nearby hedgerow ditch. One of the crew's parachutes was snagged in a row of trees east of the seats. Plexiglass, from the shattered canopy following miniature detonation cord initiation, was found in the farmer's fields by the ejection seats. Exhibit 17

[27] A Cornish Hedge is a wall constructed with stone and earth often covered in vegetation.

Figure 1.3.5 - The Cornish hedge at the top of the slope.

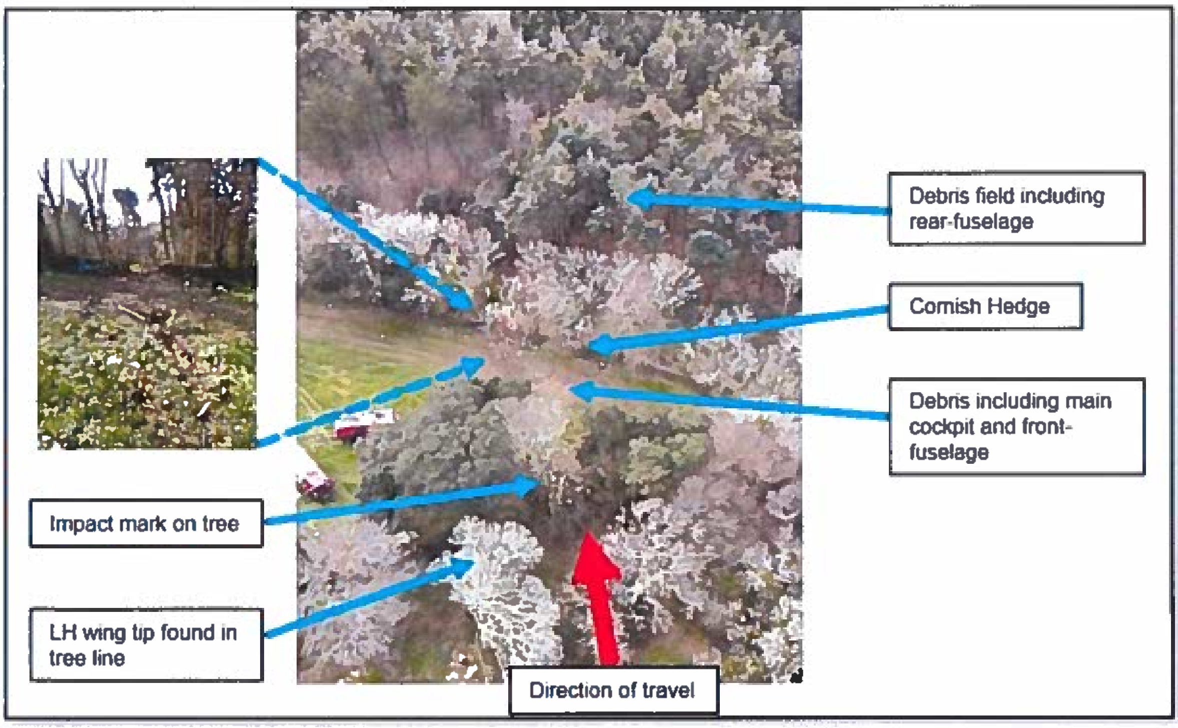

Figure 1.3.6 - Drone captured photo of the impact area.

1.3.40. **Deployment to the accident site.** Although only 5-6 miles by road from RNAS Culdrose, the small and narrow Cornish lanes made access for larger vehicles difficult. Following the on-site recce and discussion with the Devon and Cornwall Police (D&C Police) On-Scene Commander, an inner and outer cordon, and Incident Control Point (ICP) (Figure 1.3.7) and Forward ICP placement was agreed for the crash site and area where the crew landed, and a Media area outside the cordon close to the ICP agreed. The Culdrose Guard Force (GF) consisted of fifteen personnel and the GF commander was deployed at 16:00. The GF posture adopted comprised: two guards at the outer cordon / Control-of-Entry (CoE) point, at the field entrance; two guards deployed at the inner cordon, at the bottom of the field; two guards at the inner cordon, on a nearby logging track; and a further two guards deployed to the secondary site, where the ejection seats and other elements of Aircraft Assisted Escape Systems (AAES) were located.

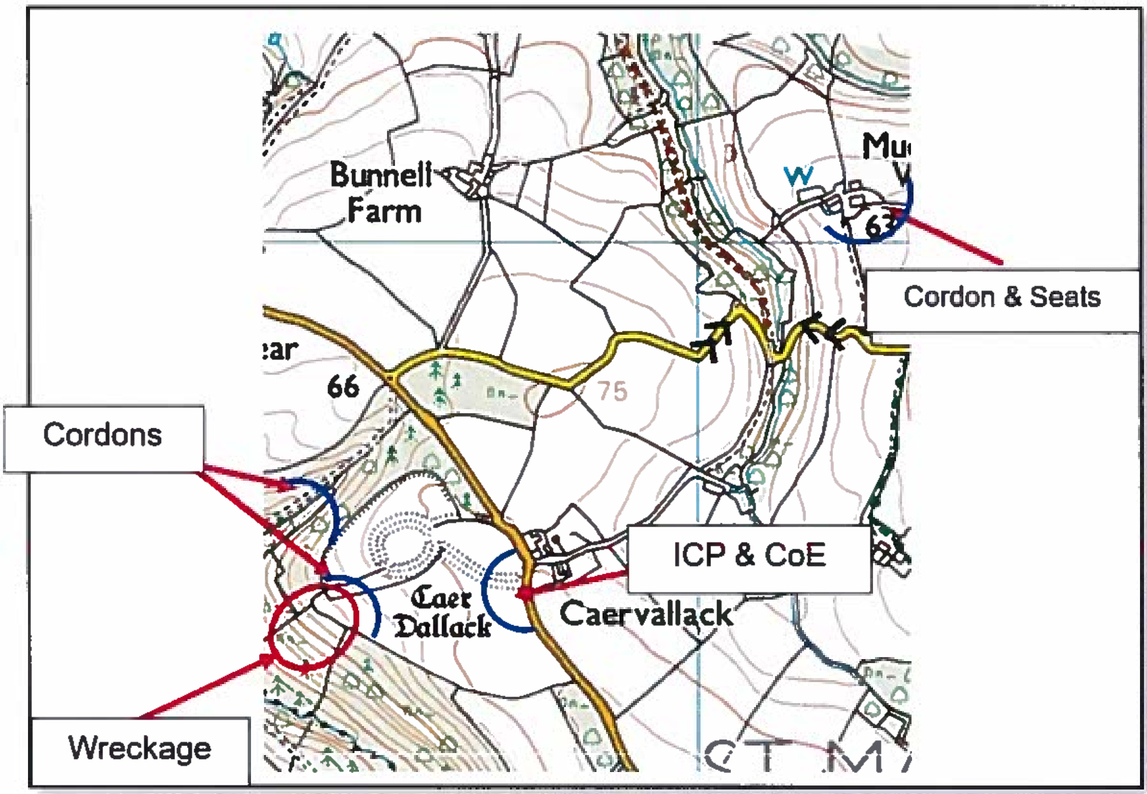

Figure 1.3.7 - Initial response laydown.

1.3.41. Support accommodation and generators were deployed to the wreckage site and responsibility for both sites (aircraft wreckage and ejection seats) was formally handed over by the D&C Police on scene commander to the PCMIO, acting on behalf of the MOD, at 19:28. Exhibit 17

1.3.42. Members of the Defence Accident Investigation Branch, Air Accident Investigation Branch and a Safety Inspector from Rolls-Royce were on scene by 17:00 on the day of the accident. Exhibit 78

1.3.43. External support agencies were quickly on scene, with the Joint Aircraft Recovery and Transportation Sqn Aircraft Recovery Officer arriving in the early evening. The RAF Centre of Aviation Medicine AAES and Environmental Health teams were all on site by 08:30 on 26 Mar 2021, followed by the RN Southern Diving Unit Explosive Ordnance Disposal Team and 3 Mobile Catering Sqn later in the afternoon. Exhibit 17

Next of kin notification

1.3.44. The 'KINFORMING'[28] process occurred informally when both the Pilot and Passenger used the Passenger's mobile phone to contact their partners. This was followed up by a phone call by CO 736 NAS and the Duty Authoriser. A well-intentioned individual within the RNAS Culdrose Medical Centre also initiated KINFORMING via the Joint Compassionate Coordination Cell (JCCC) when they were made aware of the media coverage of the accident and the fact that both crew members involved had been flown to hospital by helicopter. JCCC received the notification of casualty from RNAS Culdrose and began the process of KINFORMING. After a brief conversation with [redacted] Hospital, it became apparent that the Pilot's wife was already present, so no further actions were taken in trying to contact her. The Passenger's partner was, however, contacted and [redacted] by the notification that came several hours after the accident.

Witness 1
Witness 2
Witness 8
Witness 10
Exhibit 23
Exhibit 24
Exhibit 25
Exhibit 26
Exhibit 27
Exhibit 28
Exhibit 29
Exhibit 35
Exhibit 53

[28] The military phrase for the notification of next of kin.

PART 1.4

Analysis and Findings

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TABLE OF CONTENTS – PART 1.4

PART 1.4 – ANALYSIS AND FINDINGS

All times Local

Introduction

1.4.1. On 25 Mar 2021 at 09:37 a Hawk Trainer Mark 1 (T Mk1), registration XX189, was involved in an accident to the east of Royal Naval Air Station (RNAS) Culdrose on the Lizard Peninsula in Cornwall (Figure 1.4.1). The accident occurred after the OIL caption illuminated. The engine was shut down after the Pilot diagnosed a subsequent Engine Mechanical Failure approximately nine minutes after the initial caption. The Pilot and the Passenger ejected safely, and the aircraft crashed into a wooded area. The Defence Accident Investigation Branch (DAIB) deployed to the site and the Director General of the Defence Safety Authority (DG DSA) convened this Service Inquiry (SI), on 7 Apr 2021, to investigate the circumstances surrounding the accident and to make recommendations to prevent reoccurrence.

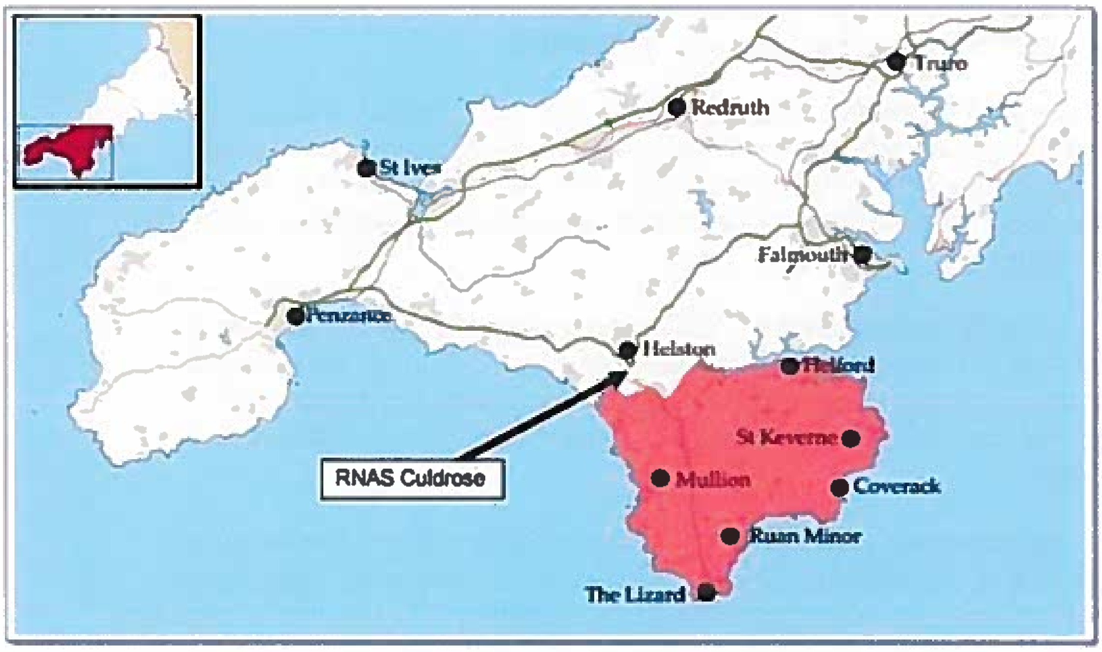

Figure 1.4.1 - Lizard Peninsula, Cornwall.

1.4.2. XX189 was a military registered aircraft and held a valid Military Airworthiness Review Certificate. The maintenance of the aircraft was under the management of British Aerospace (BAE) Systems (Operations) Limited (BAE) who were an Approved Maintenance Organisation (AMO)[1]. Babcock International UK Aviation (Babcock) were responsible for the provision of human resource for the aircraft maintenance activities and preparation of the aircraft in support of 736 Naval Air Squadron's (NAS) mission. Babcock were

Exhibit 1

Exhibit 48

[1] UK Military Aviation Authority (MAA).145.1009.

sub-contracted by BAE[2] to fulfil the delivery requirement at RNAS Culdrose. The Babcock workforce consisted of 77% ex-military personnel.

1.4.3. The crew were Royal Navy (RN) personnel who provided an account of the accident sequence. Although the aircraft was largely destroyed by the impact, it was fitted with a Multi-Purpose Flight Recorder (MPFR) which was undamaged. As a result, the MPFR was used to provide evidence of the circumstances of the accident. The Hawk T Mk1 did not have a Cockpit Voice Recorder (CVR).

1.4.4. The Panel **observed** that a recommendation from a previous Hawk SI (XX179) recommending the fitting of a CVR was still open[3] at the time of writing[4].

Methodology

Accident factors

1.4.5. Once an accident factor had been determined to have been present it was then assigned to one the following categories:

a. **Causal factor(s).** 'Causal factors' are those factors which, in isolation or in combination with other causal factors and contextual details, led directly to the incident or accident. Therefore, if a causal factor was removed from the accident sequence, the accident would not have occurred.

b. **Contributory factor(s).** 'Contributory factors' are those factors which made the accident more likely to happen. That is, they did not directly cause the accident. Therefore, if a contributory factor was removed from the accident sequence, the accident may still have occurred.

c. **Aggravating factor(s).** 'Aggravating factors' are those factors which made the outcome of the accident worse. However, aggravating factors do not cause or contribute to the accident. That is, in the absence of the aggravating factor, the accident would still have occurred.

d. **Other factor(s).** 'Other factors' are those factors which, whilst shown to have been present played no part in the accident in question but are noteworthy in that they could contribute to or cause a future accident. Typically, other factors would provide the basis for additional recommendations or observations.

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[2] Maintenance Approved Organisation Scheme (MAOS) UK MAA.145.0910.

[3] XX179 Rec No 03 / 11 / S I / XX179 / 1.5.3c.

[4] CVR incorporation is underway under the Hawk Capability Sustainment Programme.

e. **Observations.** Observations are points or issues identified during the investigation that are worthy of note to improve working practices, but which do not relate to the accident being investigated and which could not contribute to or cause future accidents.

Accident factors modelling

1.4.6. The Panel recognised that accidents are usually the result of individual acts or omissions, or technical events, however, these can occur in the context of a complex operational system with established defences against accidents. In investigating the broader factors influencing the accident the Panel has exploited the work of Prof James Reason, known colloquially as the 'Swiss Cheese' model[5], adapted by the Australian Transport Safety Bureau (ATSB), in its analysis of the accident assessing evidence across the following categories:

a. **Individual (unsafe) acts or technical events.** Unsafe acts are errors or violations which can be task-related or personal factors but can only be defined in relation to the presence of a particular hazard. Errors comprise slips, lapses and mistakes and are grouped as follows:

(1) **Unintentional acts**

(a) **Slips.** Error by commission, where a well-practiced skill, requiring little cognition, is carried out incorrectly.

(b) **Lapses.** Error by omission, where a well-practiced skill, requiring little cognition, is not carried out.

(2) **Intentional acts**

(a) **Mistakes.** Deficiencies in judgement and / or failing to formulate the right plan based on flawed knowledge and / or incorrect comprehension of rules.

(b) **Violations.** Deliberate and conscious departures from established rules / procedures, although often with no intent to cause harm.

b. **Local Conditions.** Local conditions are those events or circumstances which may lie dormant in any organisation, or which may contribute to the accident on a particular day. They influence the efficiency and reliability of performance in a particular working context. Examples may include fatigue, perceived or actual pressure on individuals, poor weather, inappropriate crewing, etc.

c. **Organisational influences.** Organisational influences are those factors over which an organisation, at a high level, could reasonably be

[5] Managing the Risks of Organizational Accidents, James Reason 1997 (ISBN 13: 978 1 84014 105 4).

expected to exercise some measure of control. The 'organisation' in this context is the strategic entity, which is responsible for designing, equipping, and managing the working environment and for providing defences-in-depth against foreseeable organisational hazards. In the military context, examples of organisational influences may include vehicle design, regulations, orders, hazard identification or safety management systems, etc.

d. **Risk controls.** Risk controls relate to lower level means of creating defences, usually as part of the day-to-day operation of the organisation but are affected by organisational influences. For example, training, local rules, or procedures (such as flying order books or Military Transport orders), authorisation processes and supervision each generate barriers against an accident happening.

ATSB Investigation Analysis Model

1.4.7. The ATSB Model (Figure 1.4.2) was used for the SI because of the complex interaction between a number of factors, the technical nature of the investigation and the importance of the sequence of events. The Model is an adaptation of James Reason's[6] Swiss Cheese Model. It presents the components of the Model as a series of levels of potential safety factors. The Model was broadly implemented from the bottom to top during the investigation, asking a series of questions for each level.

[6] Reason, J. (1990). Human Error. New York: Cambridge University Press.

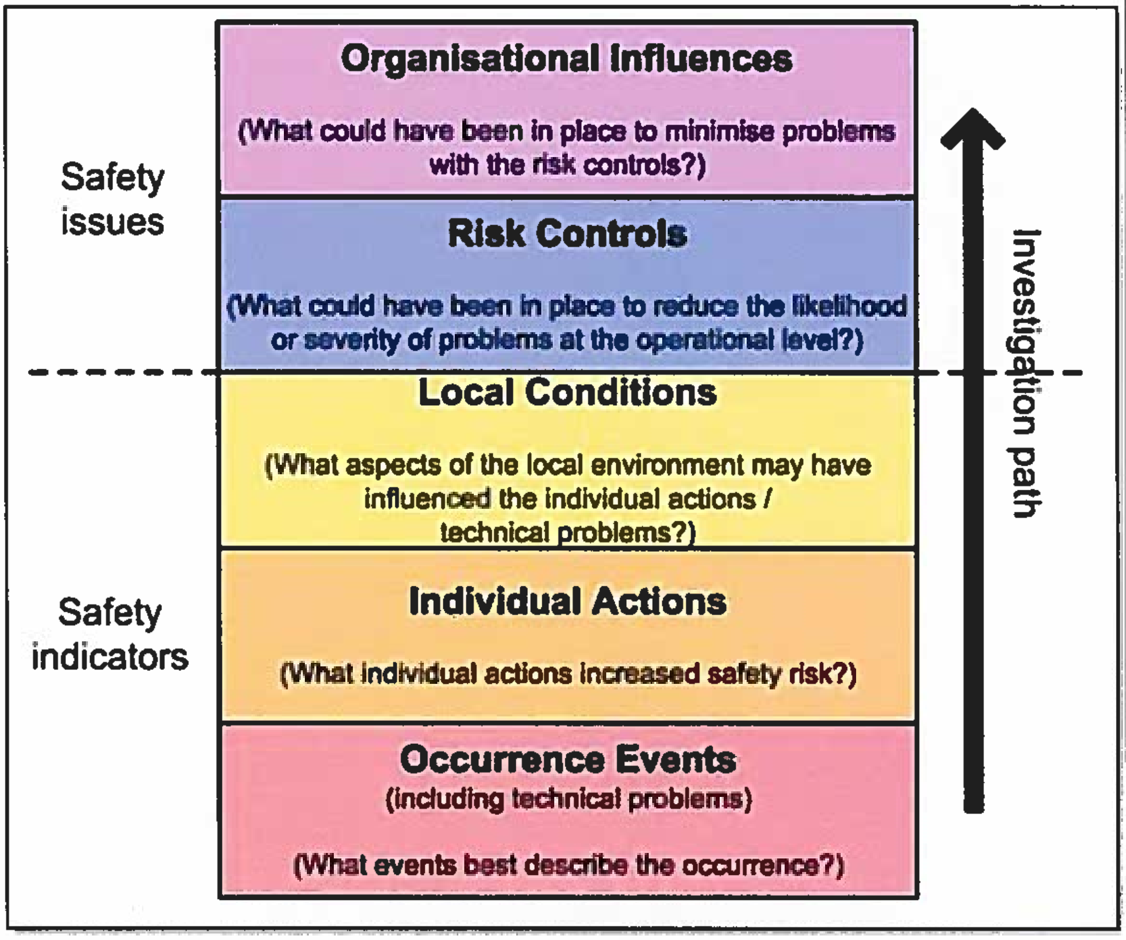

Figure 1.4.2 - ATSB Investigation Analysis Model[7].

1.4.8. Occurrence events are the key events that describe 'what happened' and include technical events. Individual actions are the observable behaviours of operational personnel, which include aircrew, crew members and maintenance personnel. Local conditions are those conditions which exist in the immediate context or environment in which the event occurred. Risk controls are the measures put in place to facilitate and assure safe performance of the system and can be considered barriers in a 'bow tie analysis'[8]. Organisational influences are those conditions that establish, maintain, or otherwise influence the effectiveness of an organisation's risk controls. Examples of safety factors at each level are detailed in Figure 1.4.3.

[7] Figure 1.4.2 was sourced from: https://www.atsb.gov.au/media/27767/ar2007053.pdf.

[8] Bowties are commonly used to aid in the identification and management of risks and barriers to prevent event occurrence.

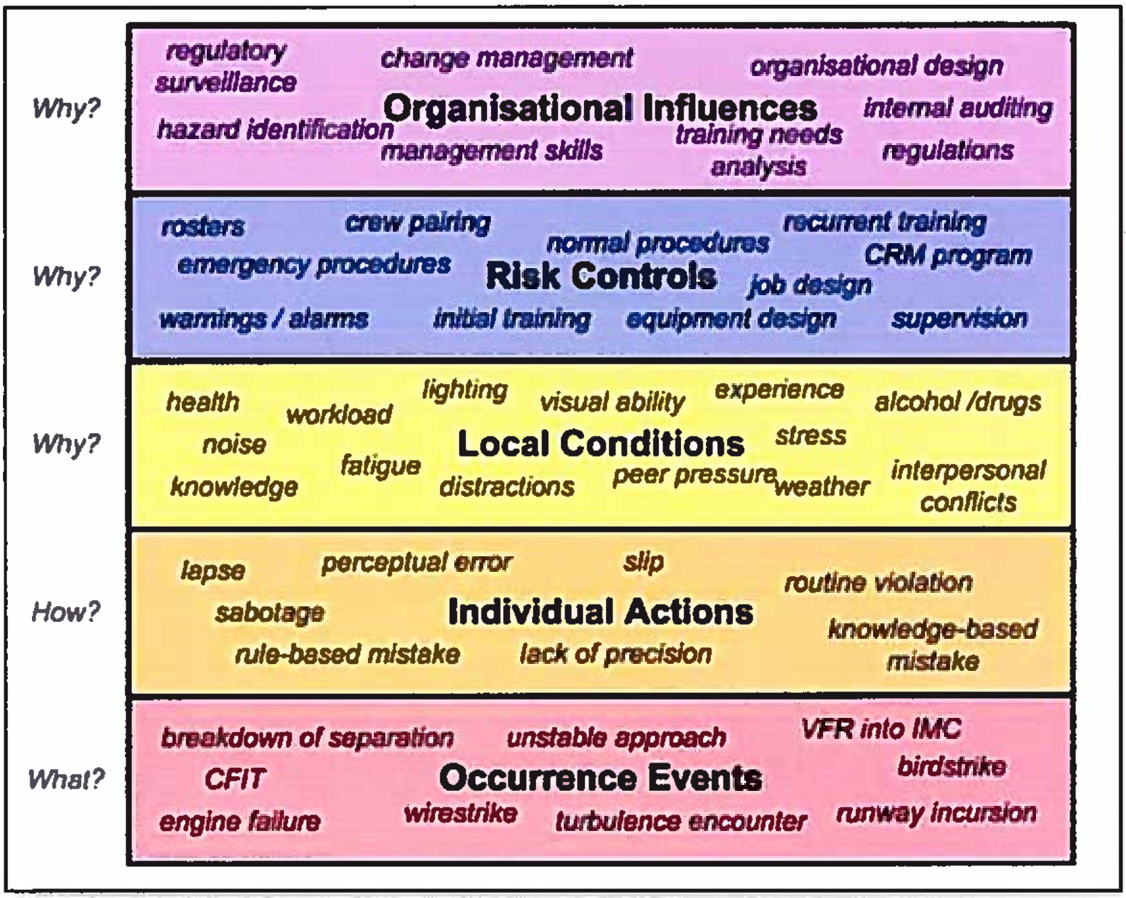

Figure 1.4.3 - ATSB investigation safety factors[9].

[9] Figure 1.4.3 was sourced from: https://www.atsb.gov.au/media/27767/ar2007053.pdf.

Probabilistic language

1.4.9. The probabilistic terminology detailed in Figure 1.4.4 clarifies the terms used in this report to communicate levels of uncertainty within the report.

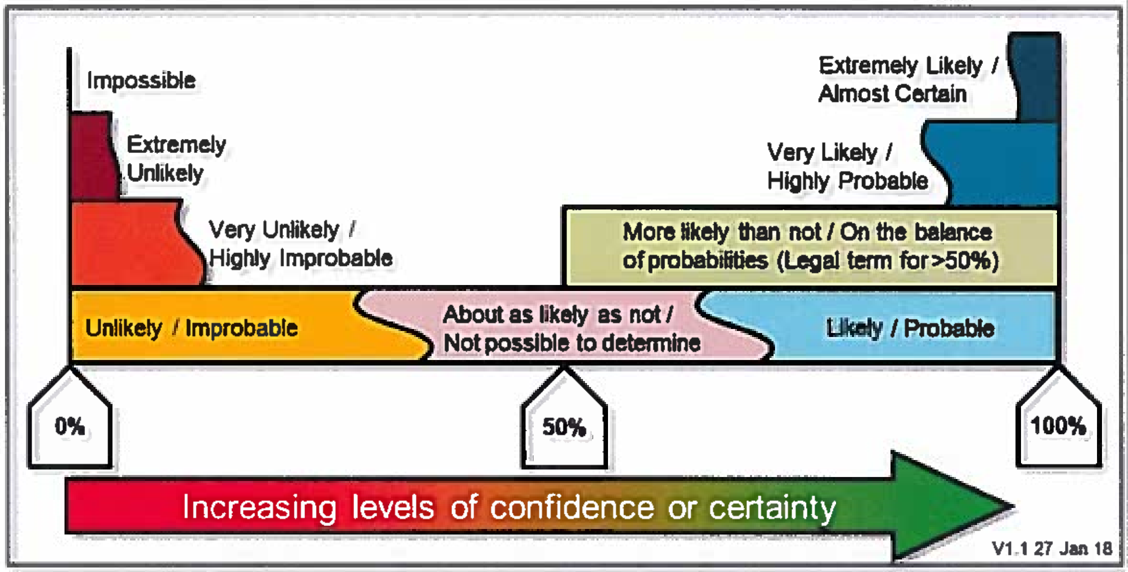

Figure 1.4.4 - DAIB verbal probability expressions.

Human Factors (HF) modelling

1.4.10. Specialist advice was provided by the Royal Air Force Centre of Aviation Medicine (RAFCAM) to ensure that HF aspects were suitably considered. This advice was provided based on the Accident Route Matrix (ARM) approach. The ARM was developed by RAFCAM based on the systematic and validated framework of the Human Factors Analysis Classification System (HFACS), which is based on James Reason's Swiss Cheese Model, and experience of providing HF advice to over seventy accident and incident investigations.

1.4.11. RAFCAM adapted HFACS for use during the investigation, by analysing the type of HF issues, the sequence of effects, and the impact of the issues in the accident sequence. The aim of the ARM was to identify which issues, and at which point each issue, increased the risk of hazard entry, recovery, escape, and survival. The approach used in the SI considered a broad range of HF contributors to aviation accidents including Organisational Factors; the nature of the supervision and tasks undertaken; the equipment used; the operating environment as well as individual actions and the condition of operators involved in the accident. The conclusions from the HF report were incorporated into the broader investigation.

Available evidence

1.4.12. The Panel had access to a significant amount of evidence which included:

a. **Interviews.** Seventeen witnesses were interviewed during the investigation. Witnesses included:

(1) The Pilot and Passenger.

(2) The Duty Pilot (DP).

(3) The Duty Authoriser.

(4) The Chain of Command.

(5) 736 NAS Babcock maintenance personnel.

(6) 736 NAS Survival equipment personnel.

(7) RNAS Culdrose Air Traffic Control (ATC) personnel.

(8) The Hawk T Mk1 Standards and Evaluation (STANEVAL) / User Authenticator (UA).

1.4.13. **Aircraft data.** The Hawk T Mk1 MPFR was rudimentary and did not include a CVR. Information pertaining to the engine; aircraft speed, attitude, and altitude; lateral and vertical g[10]; and heading were recorded by the MPFR.

1.4.14. **Photographic imagery.** Images taken by the rescue and recovery services, accident investigators, the Panel and RNAS Culdrose Post-Crash Management (PCM) organisation.

1.4.15. **Publications.** A range of publications including policy documents, flying logbooks, and other documents within the Air System Document Set (ADS), and Rolls-Royce (R-R) manuals.

1.4.16. **Aircraft Wreckage.** Physical examination of XX189 at the crash site, and once recovered, within a secure area.

1.4.17. **Equipment and facilities.** Physical examination of ground support, servicing equipment, aircraft, and facilities.

1.4.18. **Aircrew Equipment Assembly (AEA).** The available AEA harvested from the scene of the crash underwent detailed examination by RAFCAM, 1710 NAS and Survitec, the Original Equipment Manufacturer. Some of the AEA was unavailable for inspection[11].

1.4.19. **Visit to engine manufacturer.** The Panel visited the R-R Air Safety Investigation (ASI) department for a detailed discussion relating specifically to the Adour Mk151 engine. R-R provided a Technical Report following in depth testing and analysis of the engine and components from XX189.

[10] 1g is 1 x the force of gravity.

[11] The passenger's helmet, oxygen mask, parachute and one leg restraint were unaccounted for, stolen from the scene.

1.4.20. **Specialist reports.** The Panel received the following reports:

a. DAIB provided Triage and Technical Reports. Exhibit 78

b. 1710 NAS provided forensic, scientific, and engineering reports which included detailed analysis of the engine fluids, bearings, and analysis of the Life-Saving Jacket (LSJ) worn by the Pilot. Exhibit 60 Exhibit 65 Exhibit 103 Exhibit 133

c. RAFCAM provided a HF Report and Subject Matter Expert (SME) advice into the Aircraft Aircrew Escape Systems (AAES) and AEA. Exhibit 114 Exhibit 115

d. RNAS Culdrose PCM Incident Officer (PCMIO) provided a PCM Report. Exhibit 122 Exhibit 17

e. Joint Aircraft Recovery Transportation Squadron (JARTS) provided a Response and Recovery Report. Exhibit 57

f. R-R provided an Engine Report. Exhibit 77

g. The Defence Equipment and Support (DE&S) Air Commodities Delivery Team (ACDT) provided information and responses to two Urgent Safety Notes issued by DG DSA. Exhibit 159

1.4.21. **Graphical Data Analysis Software (GDAS).** GDAS is a visualisation tool constructed from various primary evidence sources. These included radar plots, ATC tapes and MPFR data. Together they produced a visual representation of the final flight of XX189. Exhibit 142

1.4.22. During the construction of the GDAS product QinetiQ noticed that some timings did not match. After scrutiny it was discovered that the RNAS Culdrose Multi-channel Voice Recorder (MCVR) clock was exactly one minute out. The Panel **observed** that a procedure to confirm the correct timing of the MCVR clock on a regular basis would prevent timing errors from reoccurring. The Panel finds that the MCVR clock timing was **not a factor**.

1.4.23. **Recommendation. The Delivery Duty Holder should instigate a process whereby the Multi-channel Voice Recorder clocks are regularly checked in order to ensure that it remains synchronised.**

1.4.24. **Expert advice.** The Panel consulted the following specialists:

a. RAF Hawk T Mk1 Standards and Evaluation Pilot.

b. Rolls-Royce Chief Pilot – Defence Aerospace.

1.4.25. **Air Safety documentary material.** Access to all flight safety related material extracted from the Military Aviation Authority (MAA) Manual of Air Safety (MAS), Air Safety Information Management System (ASIMS) and Defence Air Safety Occurrence Reports (DASORs). Maintenance Approved

Organization Scheme (MAOS) and Royal Navy Flight Safety Cell (RNFSC) audit reports were also analysed.

Services

1.4.26. The Panel was assisted by the following personnel and agencies:

a. Duty Holders / Aircraft Operating Authority.

b. Defence Accident Investigation Branch.

c. Royal Air Force Centre for Aviation Medicine.

d. 1710 Naval Air Squadron.

e. Rolls-Royce.

f. Survitec.

g. Hawk T Mk1 Standards and Evaluation Pilot.

h. QinetiQ.

i. Hawk Delivery Team.

j. Air Commodities Delivery Team.

k. Babcock.

l. Royal Air Force Aerobatics Team.

m. 100 Squadron, Royal Air Force.

n. Royal Air Force Release to Service Authority.

o. Military Aviation Authority.

p. Royal Naval Air Station Yeovilton / HMS Heron.

q. Royal Naval Air Station Culdrose / HMS Seahawk.

r. HMS Gannet.

s. 736 Naval Air Squadron.

t. 846 Naval Air Squadron.

u. 659 Squadron, Army Air Corps.

v. Defence Aircrew Publications Squadron.

Background

Context

1.4.27. The Hawk T Mk1 and Mk1A are tandem-seat trainer aircraft (Figure 1.4.5) with a low wing of moderate sweep, conventional tail surfaces and a single Adour Mk151[12] un-reheated axial flow twin-spool by-pass engine[13]. The Hawk T Mk1 could be configured for either the Flying Training Role (modification 285 embodied – removal of armament equipment) or the Weapons Training Role. The Hawk T Mk1A, introduced by modification 717, had provision for Sidewinder AIM-9 missiles and a tele brief system. The aircraft attached to 736 NAS were in the Flying Training Role fit.

Figure 1.4.5 - RN Hawk T Mk1 conducting Fleet Operational Sea Training (FOST) tasking.

1.4.28. **Design Organisation.** The Design Organisations (DOs) for the major elements of the aircraft are listed below:

a. Air Vehicle: BAE Systems, Brough.

b. Engine: R-R, Filton.

1.4.29. The original design of the Hawk T Mk1 was produced by Hawker Siddeley Aviation and entered military service in 1976 and was subsequently taken over by their successor British Aerospace then BAE Systems. Both BAE Systems and R-R are Ministry of Defence (MOD) Design Approved Organisations.

[12] The Adour Mk151-01 was used by the RN / RAF training aircraft fleet, Adour Mk151-02 was used by RAFAT.

[13] Variants of the Adour engine have flown with 20 different armed forces reaching a total of over 8 million flying hours.

1.4.30. **Aircraft utilisation.** The usage of Hawk T Mk1 / 1A has been reviewed by the Duty Holder and Type Airworthiness Authority (TAA) within the roles and fleets as detailed below:

a. Refresher, Qualified Weapon Instructor and UK Orientation training.

b. Central Flying School.

c. Target facilities - 100 Squadron and 736 NAS.

d. RAFAT.

e. RAFCAM.

1.4.31. **Military Continuing Airworthiness Manager.** The Military Continuing Airworthiness Manager (Mil CAM) was responsible to the Delivery Duty Holder (DDH) for the management of all Continuing Airworthiness (CAw) activities[14], on all platforms at RNAS Culdrose[15]. Exhibit 137

1.4.32. **Aviation Duty Holders.** The Aviation Duty Holders (ADH) construct for 736 NAS was relatively simple, the Station (Stn) Commanding Officer (CO) was the DDH and the Director Force Generation (Dir FGen) the Operating Duty Holder (ODH). However, the Hawk T Mk1 fleet has historically had a complex ADH construct, with multiple users across two Services under the command of separate Senior Duty Holders (SDH)[16]. Air Officer Commanding (AOC) 1 Gp was the ODH for Royal Air Force Aerobatics Team (RAFAT) and 100 Sqn, with RN Hawk sitting under Dir FGen. As noted in the Hawk T Mk1 MAA End to End (E2E) Audit (Dec 2019) this complex DH construct had hampered the modernisation and improvement of the fleet and reduced effective communication across the different ADH chains. Having a single TAA for the Hawk fleet (both T Mk1 and 2) allowed important engineering information to be effectively co-ordinated and disseminated to all users via a single point of contact. The Panel determined that the ADH construct across the Hawk T Mk1 fleet had been unnecessarily complex but assess the recent improvements and the use of a single TAA across all Hawk Mks as a good risk mitigation procedure. The Panel finds that the Hawk ADH construct was **not a factor**. Exhibit 45 Exhibit 39

1.4.33. **Type Airworthiness Authority.** The Hawk Delivery Team (HDT) TAA was the responsible individual accountable for the Air System Type Design[17]. The airworthiness of the Adour Engine was managed by delegation of airworthiness authority[18] to the Adour Engineering Authority (EA). Operating

[14] Regulatory Article (RA) 4947 – Continuing Airworthiness Management – Military Regulatory Publication (MRP) Part M Sub Part G.

[15] CULDROSE AESOs 1700(2) - KEY PERSONNEL TERMS OF REFERENCE (2021 Edition).

[16] First Sea Lord for RN and Chief of the Air Staff for RAF.

[17] RA 1015 - Type Airworthiness Authority – Roles and Responsibilities.

[18] RA 1003 - Delegation of Airworthiness Authority and Notification of Air Safety Responsibility.

within the United Kingdom Military Flying Training System (UKMFTS), the HDT managed the type airworthiness of the Hawk T Mk1, on behalf of the ADH chain. The HDT TAA had delegated airworthiness authority from DE&S Director Combat Air. The HDT TAA was responsible for the maintenance contract with BAE Systems as the Part 145 Accredited Organisation (Pt 145)[19].

1.4.34. **Release To Service.** The Release to Service (RTS) was the document that authorises service flying on behalf of both of the responsible SDHs[20]. The RTS defines the limits for the Air System and were based on the Air System Safety Case and RTS Recommendations delivered by the TAA. The Hawk T Mk1 RTS was managed by the RAF Release to Service Authority.

1.4.35. **External assurance activity.** 736 NAS had recently undergone various levels of assurance:

a. Naval Flying Standards Flight – Feb 2021. Exhibit 37

b. BAE Systems Ltd MAA Audit Report[21] – Oct 2020. Exhibit 38

c. Fleet Air Arm Command Flight Safety Officer Report – Dec 2020. Exhibit 41

d. Hawk T Mk1 MAA E2E Audit[22] – Dec 2019. Exhibit 39

e. MAA 19 CAMO 0030 Aircraft Product Sample Report 01 – Dec 2019. Exhibit 40

1.4.36. 736 NAS were assessed as 'GOOD' by the Naval Flying Standards Flight with only minor points of pick-up. The E2E report criticised the wider Hawk enterprise. However, many of the points of note were in the process of being addressed and corrected.

[19] Part 145 is the European Union Aviation Safety Agency standard for the approval of organisations that perform maintenance on aircraft and aircraft components. (www.easa.europa.eu/the-agency/faqs/part-145).

[20] RA 1300 Series – Release to Service.

[21] Covering RAF Valley, RNAS Culdrose and RNAS Yeovilton.

[22] Covering Brough, Abbey Wood, RAF Cranwell, High Wycombe, Leeming, Scampton, Valley, and RNAS Culdrose.

Analysis of Factors

Aircrew experience and crew composition

1.4.37. **Crew composition.** The crew consisted of an experienced pilot, who was captain of the aircraft, and a passenger. The Pilot was also an instructor pilot[23]. The Passenger was a RN Fast Jet (FJ) holdover student who had recently completed Basic FJ Flying Training (BFJT) in the Tucano at RAF Linton-on-Ouse and was waiting for the commencement of Advanced FJ Flying Training at RAF Valley on the Hawk T Mk2. The Passenger had been awarded their wings at the completion of BFJT and was a Qualified Service Pilot.

Exhibit 3
Exhibit 4
Exhibit 11

1.4.38. **Pilot.** The Pilot had 18 years flying experience with a total of 2,574[24] hours flying. Of those, 1,731 hours were fixed wing (1400 of which were Hawk T Mk1 hours) and 842 were rotary wing hours. He also had a further 442 hours of simulated flight time, of which 116 were Hawk T Mk1 simulator hours. The Pilot flew 12 hours during the preceding month and 3 hours 45 minutes during the preceding seven-day period. The Pilot was not a member of 736 NAS[25] but as Deputy Fixed Wing Force (FWF) Commander, had a commitment to fly with the Sqn approximately twice a week.

Exhibit 3
Exhibit 15

1.4.39. **Passenger.** The Passenger had a total of 229 flying hours with 24 hours and 50 minutes of those in the Hawk T Mk1. Nine hours had been flown in the preceding month and 3 hours and 35 minutes during the preceding seven-day period. All Hawk hours had been logged as Passenger hours.

Exhibit 4
Exhibit 15

1.4.40. **Passenger flying.** The term passenger was defined in MAA Regulatory Article (RA) 2340. The Passenger met that criteria and was suitably experienced to fly on the sortie. He was also trained to use all the Survival Equipment (SE) and AAES. Passengers without the same experience would not be permitted to fly on a 'Thursday War'[26] sortie even though the RA defines all passengers the same. The Panel acknowledged that passengers may be locally disqualified from flying on certain sorties due to the demanding nature of the sortie, however, this should be better defined in the RA to provide clear and consistent guidance to units flying passengers. Flying passengers with experience[27] on more demanding sorties was of great benefit to the passenger and should be encouraged, when appropriate. The Panel determined that the experience of the Passenger was beneficial to the Pilot during the emergency and that passenger flying is of value and should not be constrained by the outcome of this accident. The Panel finds that flying with a passenger was **not a factor**. The Panel **observed** that a review of the RA could further define

Exhibit 131
Witness 10

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[23] The pilot was not a Central Flying School accredited Qualified Flying Instructor. His instructor category was locally awarded after the relevant work-up and check flight.

[24] Hours rounded up to the nearest whole hour.

[25] But had previously been a member of 736 NAS.

[26] Routine maritime training exercise.

[27] Aircrew under training or trained as Qualified Service Aircrew.

flying with a passenger with experience or who is qualified aircrew but unable to meet the definition of supernumerary crew[28].

1.4.41. **Aircrew qualification and currency.** The Pilot was qualified and current at the time of the accident. CO 736 NAS had deemed the carriage of the Passenger on this sortie essential to the Passenger's development; the Passenger was in date for an aircrew medical, escape system operation, parachute, and dinghy drills. The Passenger was also correctly authorised as a frequent flying passenger[29] by Commander (Cdr) FWF and the 736 NAS Duty Authoriser. Exhibit 45 Exhibit 11 Exhibit 12 Exhibit 13 Witness 8

1.4.42. **Assessment of ability.** A recent STANEVAL check sortie with the RAF Hawk T Mk1 STANEVAL Pilot had been conducted and the Pilot had been assessed as [redacted] The Pilot's most recent assessment on the Form 2020G[30], 3 Sep 2020, indicated that they had been assessed[31] as [redacted] by CO 736 NAS. Exhibit 49 Exhibit 50

1.4.43. **Aircrew fatigue.** The Pilot and the Passenger stated during interview they were well rested, having achieved at least eight hours of sleep the previous evening[32], and did not feel fatigued prior to embarking on the sortie. Witness 1 Witness 2

1.4.44. The serial due to be undertaken by the Pilot and Passenger was routine business for the RN FJ pilots based at RNAS Culdrose. There was nothing unusual about this sortie and the Pilot and Passenger had flown together on previous occasions. While considering the carriage of a passenger in a FJ, the Panel agreed that given his experience, the Passenger enhanced situational awareness in the cockpit and aided the Pilot during the handling of the emergency. The qualifications and currencies of the Pilot were all in date and his experience level was appropriate for the task. The Panel finds that the experience, currency, crew composition and fatigue were **not factors**.

Sortie planning and preparation

1.4.45. **Task.** The sortie was a frequently flown 'Thursday War' mission tasked by Joint Services Air Tasking Organisation in support of FOST. The area of operations was south of Plymouth and was a familiar tasking area for pilots who flew with 736 NAS. Exhibit 30 Exhibit 31

1.4.46. The sortie was planned the day prior by the allocated 'War Lead'. On the morning of the sortie, after confirming the weather and diversion requirements of the day, the pilots added final details to the plan. The Witness 1 Exhibit 45 Witness 10

[28] RA 2340 Issue 8 – Released 30 Sep 2021, now includes new definitions and categories.

[29] Authorisation given to fly on more than one sortie, often granted to holdover pilots awaiting further training.

[30] Annual Assessment of Flying Ability.

[31] As assessed by the unit CO.

[32] Book of Reference (digital) (BRd) 767 Naval Aviation Order (NAO) 2345 – Aircrew and Aircraft Controller Crew Rest Period.

nominated diversion for the sortie was Cornwall Airport Newquay, Visual Flight Rules, but with the additional requirement to Carry Fuel for Radar[33].

1.4.47. The meteorological conditions on the day were suitable for the required task and the crews dressed according to their assessment of the sea state and sea temperature. Exhibit 9

1.4.48. A telephone brief had been conducted with Draken[34] to discuss all details of the sortie including the expected profiles, routing, and contingency plans. The mission profile involved the Draken aircraft as the adversary, whilst the Hawk aircraft simulated the weapons systems. Draken aircraft were also fitted with an array of equipment that could simulate adversary electronic warfare techniques and adversary radars. The briefing was conducted and recorded in accordance with 736 NAS Squadron Standing Orders (SSOs) Annex B to Chap 3. Exhibit 42

1.4.49. The Panel determined that the level of planning and preparation performed by the crews of [redacted] formation was commensurate with the mission. While planned as a four aircraft mission, the sorties were to be flown as two pairs reducing the complexity of the task. The planning by a single entity reflects the routine nature of the FOST tasking and perceived complexity by the pilots. The Panel finds that the planning, preparation, and nature of the task was **not a factor**.

Aircrew authorisation and supervision

1.4.50. Authorisations on 736 NAS were routinely conducted by the Duty Authoriser. All flights were authorised in accordance with RA 2306 and powers of authorisation, including limitations and powers of self-authorisation, granted in accordance with Naval Aviation Order (NAO) 2306. Where possible, authorisations should be conducted by the DP. On 25 Mar 2021 the DP was not a qualified authorising officer, so a Duty Authoriser was appointed to provide flight authorisations. The DP conducted all the administrative tasks, e.g. checking of the weather, booking of the diversion airfields, trawling aircrew currencies, allocating aircraft, checking Notice to Airmen. These were confirmed as correct by the Duty Authoriser prior to the daily brief which the Duty Authoriser attended in accordance with 736 NAS SSOs. Exhibit 43 Exhibit 44 Witness 10

1.4.51. The authorisation sheets were correctly annotated and signed by the Duty Authoriser and aircraft captains. The passenger carriage form was signed by the Duty Authoriser, authorising carriage of the Passenger for two sorties planned that day. The authorisation codes in the authorisation sheets were as follows: Exhibit 11 Exhibit 52

[33] Carry Fuel for Radar is often a requirement when using a civilian airfield as a diversion. It allows sufficient fuel for sequencing with civil radar traffic even though the weather might be suitable for a Visual Flight Rules approach.

[34] Draken International, LLC was a provider of contract air services including adversary functions for the RN.

a. **C - Surface Attack (SAT).** Air to Surface profiles flown in accordance with relevant 736 NAS Tac SOP minima.

b. **D - Formation.** Close or tactical formation including details of other aircraft involved and amplifying details (i.e. Draken DA20 NB (Not Below) 250ft Minimum Separation Distance (MSD). Note: Formation flying within a constituted and briefed 736 NAS formation of three aircraft or less is implicitly authorised.

c. **P - PAX flight.**

d. **M - Tactical Maritime Sortie.** Instrument Meteorological Conditions (IMC) Descent below 3000ft for simulated anti-ship attack profiles (including missile and Fighter Bomber Attack (FBA) profiles) authorised. IMC descent below Safety Altitude to and subsequent flight at 500ft Above Mean Sea Level (AMSL) or MSD (whichever is higher) subject to minima in SSOs 0221 authorised.

1.4.52. The Panel determined that the level of authorisation was in accordance with all applicable rules and regulations. The Duty Authoriser was qualified and attended the briefing as required in SSOs providing the correct level of understanding required prior to authorising the sortie. The Panel finds that the aircrew authorisations were **not a factor**.

Aircrew supervision

1.4.53. The Cdr FWF was the RN Hawk T Mk1 Senior Operator (SO) for the DDH. CO 736 NAS was responsible to Cdr FWF for the safe operation of Hawk T Mk1 at RNAS Culdrose. CO 736 NAS delegated supervisory responsibilities to the most senior pilots. There were five pilots granted supervisory duties, four of whom were members of 736 NAS and one worked in the Force Headquarters. Witness 8

1.4.54. CO 736 NAS was responsible for the safe operation of the Hawk T Mk1 to Cdr Air and Navy Fixed Wing Standards Flight. Exhibit 45

1.4.55. As described in paragraph 1.4.50, the supervisory duties were sometimes undertaken by other personnel on the Sqn in order to free up capacity of the few supervisors present, this also allowed for training and exposure for potential supervisors. On the day of the accident this was the case.

1.4.56. The small group of supervisors were extremely experienced and very familiar with the Sqn's operations, the pilots and personalities on the Sqn and the nature of the tasks undertaken daily. The Panel determined that there was a good level of supervision on the Sqn with a good level of understanding of the supervisory needs of the more junior aircrew. The mentoring of the aircrew across the Sqn was of a good standard. The Panel finds that supervision of the aircrew was **not a factor**.

Training and authorisation of engineering personnel

1.4.57. The Manual of Airworthiness Maintenance-Processes (MAM-P) details that engineering staff needed to be authorised, in line with their position, to conduct maintenance on military aircraft. Engineering personnel conducted formal training before being granted authorisations. All training and authorisations were retained in the individuals Personal Experience Verification Log. On 736 NAS, this consisted of completing a type specific equipment course and continuation training with completion of 'on the job' task books. The task books contained multiple maintenance tasks specific to their trade and the assessment was finalised by a competency interview with the 736 NAS Head of Aircraft Maintenance (HAM). Of note, the 'on the job' task book contained the Out Of Phase (OOP) A-10 Magnetic Chip Detector (MCD) change procedure. However, engineering personnel who were already working on the Hawk for Babcock, prior to the introduction of the 'on the job' task book scheme were given 'grandfather rights' and were not required to undergo the formalised training syllabus introduced in 2015. Both the Fitter and the Supervisor who carried out the engine maintenance on the XX189, the night prior to the accident, had 'grandfather rights' and neither had completed task books.

Exhibit 138
Exhibit 129
Exhibit 130
Witness 6

1.4.58. The Hawk Aircraft Maintenance Manual (AMM) required different levels of supervision depending on the task. These varied from 100% supervision, independent inspections, stage checks and self-supervision at appropriate points during tasks. The correct understanding of the level of supervision required for each task was confirmed by the witnesses during interview.

Witness 12
Witness 13

1.4.59. All engineering personnel who were involved in the maintenance of XX189 immediately preceding the accident, and other personnel reviewed during the investigation, were found to hold the correct authorisations for their role.

Exhibit 129
Exhibit 130

1.4.60. Most of the engineering team were extremely experienced and very familiar with the aircraft maintenance requirements and procedures. The Panel determined that there was a good level of training and assessment of competence, with a perceived good level of understanding of the maintenance tasks associated with maintaining the Hawk T Mk1. The process of authorisation was compliant with the regulations and was considered appropriate. The Panel judged the use of 'grandfather rights' was an effective way to recognise previous experience. However, it also had the potential to overlook training shortfalls. The Panel finds that engineering training and authorisation was an **Other Factor**.

Witness 15

The Accident

1.4.61. XX189 crashed after the Pilot and Passenger ejected from the aircraft. Before doing so the Pilot diagnosed a mechanical engine failure and shut down the engine in accordance with the Flight Reference Cards (FRCs). Despite the level of damage to the airframe, the engine remained largely intact and undamaged. Due to the information regarding the Pilot's diagnosis of the fault, the DAIB investigators identified the engine and the oil components as key evidence. The engine oil filter was examined, and a lack of oil was identified. Further inspection noted that the Yellow MCD was not located in its housing. This early evidence enabled the Panel to identify and pursue lines of inquiry, to determine the cause of the accident.

Witness 1
Exhibit 78

Sequence of events

1.4.62. The accident sequence of events was reconstructed using the primary radars at Plymouth and Newquay, MPFR data and ATC voice recordings. These were analysed by QinetiQ and a GDAS product was presented to the Panel for analysis. The Passenger created an audio recording of his recollection of events while in hospital. This was given to the DAIB triage investigators as access to the hospital was limited due to the COVID-19 restrictions. The Pilot was interviewed by telephone. The raw MPFR data with annotations can be found at Figure 1.4.6. The GDAS derived track is shown at Figure 1.4.7. A tabular sequence of events is at Table 1.4.1.

Exhibit 34
Exhibit 85
Exhibit 111
Exhibit 142
Exhibit 147
Exhibit 148
Exhibit 149
Exhibit 150
Exhibit 151
Exhibit 152
Exhibit 173
Exhibit 174

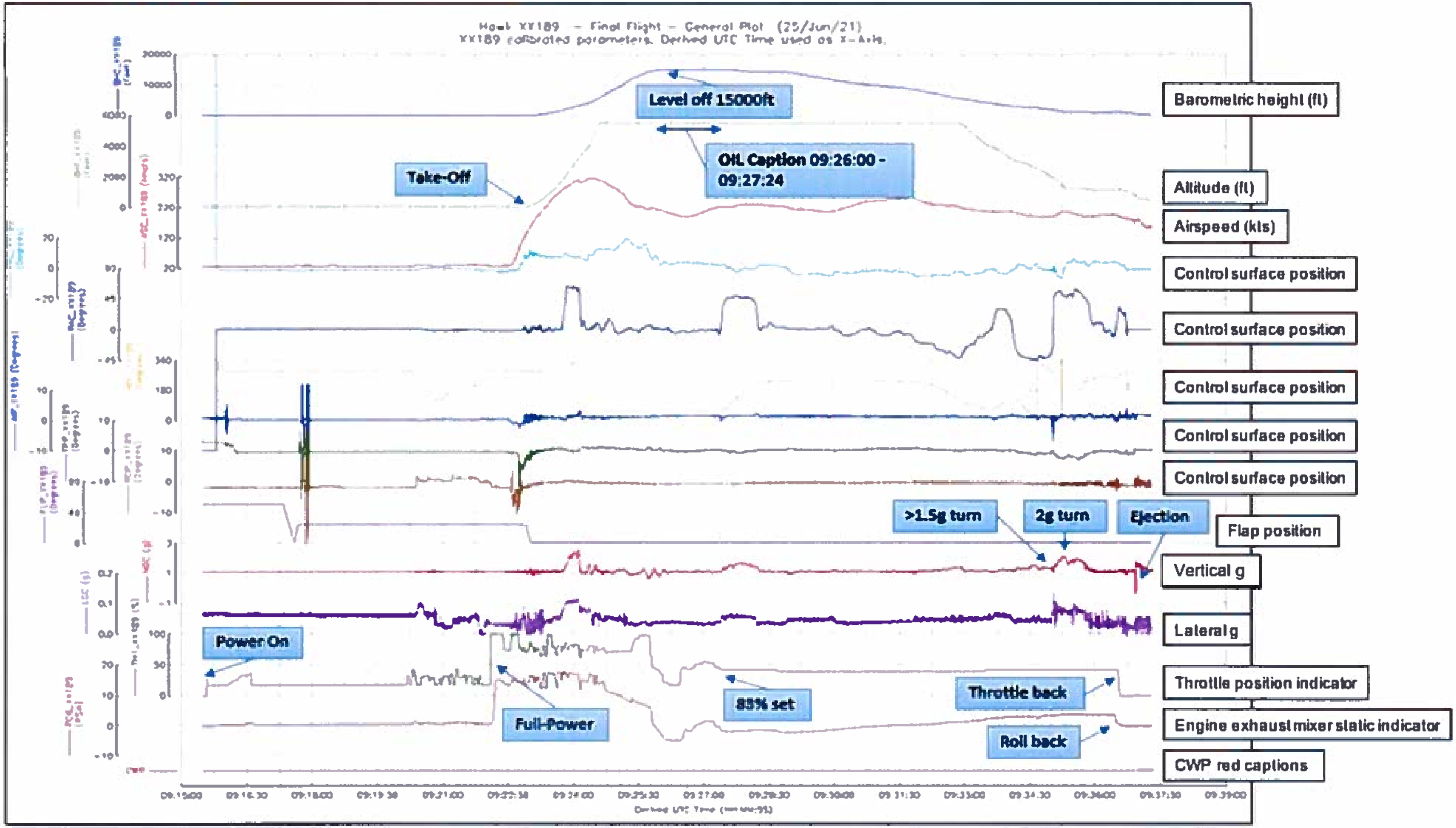

Figure 1.4.6 - Annotation of MPFR events – complete flight.

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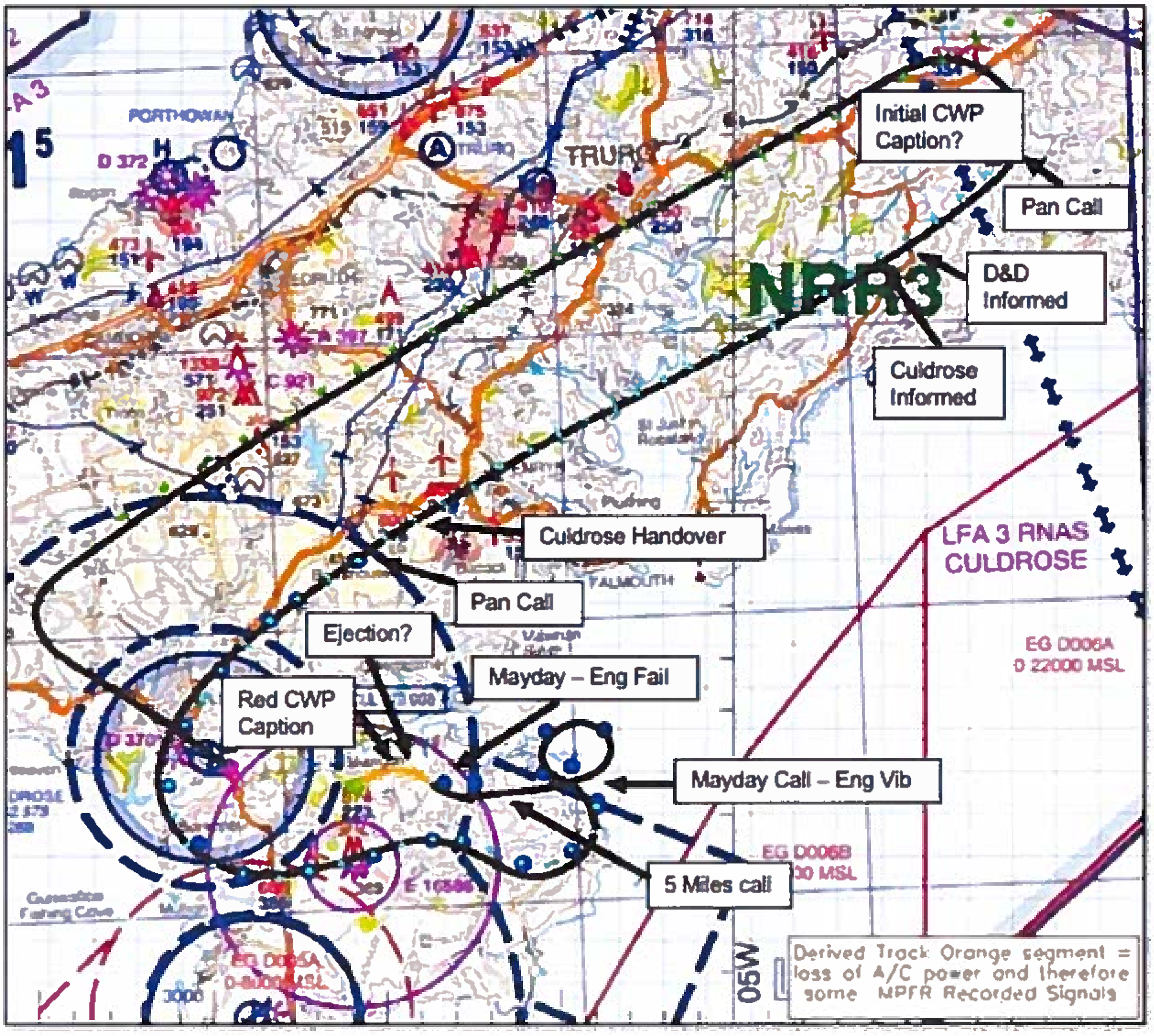


Figure 1.4.7 - Derived aircraft track plot from MFPR and radar data (dots).

Date / Time	Event	Evidence
25 Mar 2021 – 09:15:28	Power ON (MPFR starts) / Engine Start	MPFR
09:22:06	Full power applied (take-off run)	MPFR
09:22:54	Take-off	MPFR
09:26:00	Levelled off @ ~ 15000ft	MPFR
09:26 – 09:27:24	OIL Caption flickers then illuminates	Witness
09:27:24	83% Fixed power set	MPFR
09:28:06	'PAN PAN'[35] declared	Plymouth ATC
09:34:56	'MAYDAY'[36] declared 'SERIOUS ENGINE FLUCTUATIONS'	Culdrose ATC
09:35:00	Tight turn commences (>1.5g for 40 secs)	MPFR
09:35:15	'g' peaks at 2.08g for 8 secs	MPFR
09:36:27	Engine rolls back – MECH FAIL diagnosed	MPFR
09:36:33	MECH FAIL drill actioned - Pilot shuts down engine	MPFR
09:36:40	Further 'MAYDAY' – 'ENGINE FAIL'	Culdrose ATC
09:36:54	Command Ejection initiated	MPFR
09:37:20	MPFR recording stops	MPFR

Exhibit 34
Witness 1
Exhibit 111
Exhibit 173
Exhibit 174
Exhibit 14

Table 1.4.1 - Accident sortie timeline of events.

1.4.63. **Accident site.** The aircraft wreckage had been removed from the site of the accident ahead of the Panel being convened. However, the wreckage had been mapped and logged prior to being recovered to a secure facility at MOD Boscombe Down. Figure 1.4.8 shows the wreckage plot and the areas where wreckage was collected. The high-velocity debris field was scattered over an area 150m long and 60m wide located just west of Caervallack Farm (Grid Reference SW245725). The aircraft was travelling at approximately 160 knots (kts) when the MPFR stopped recording, eventually impacting a substantial tree line, and finally coming to rest in a thickly wooded area.

Exhibit 58
Exhibit 78
Exhibit 34
Exhibit 57
Exhibit 161

[35] A condition concerning the safety of the aircraft but does not require immediate assistance.

[36] A condition of being threatened by serious and / or imminent danger and of requiring immediate assistance.

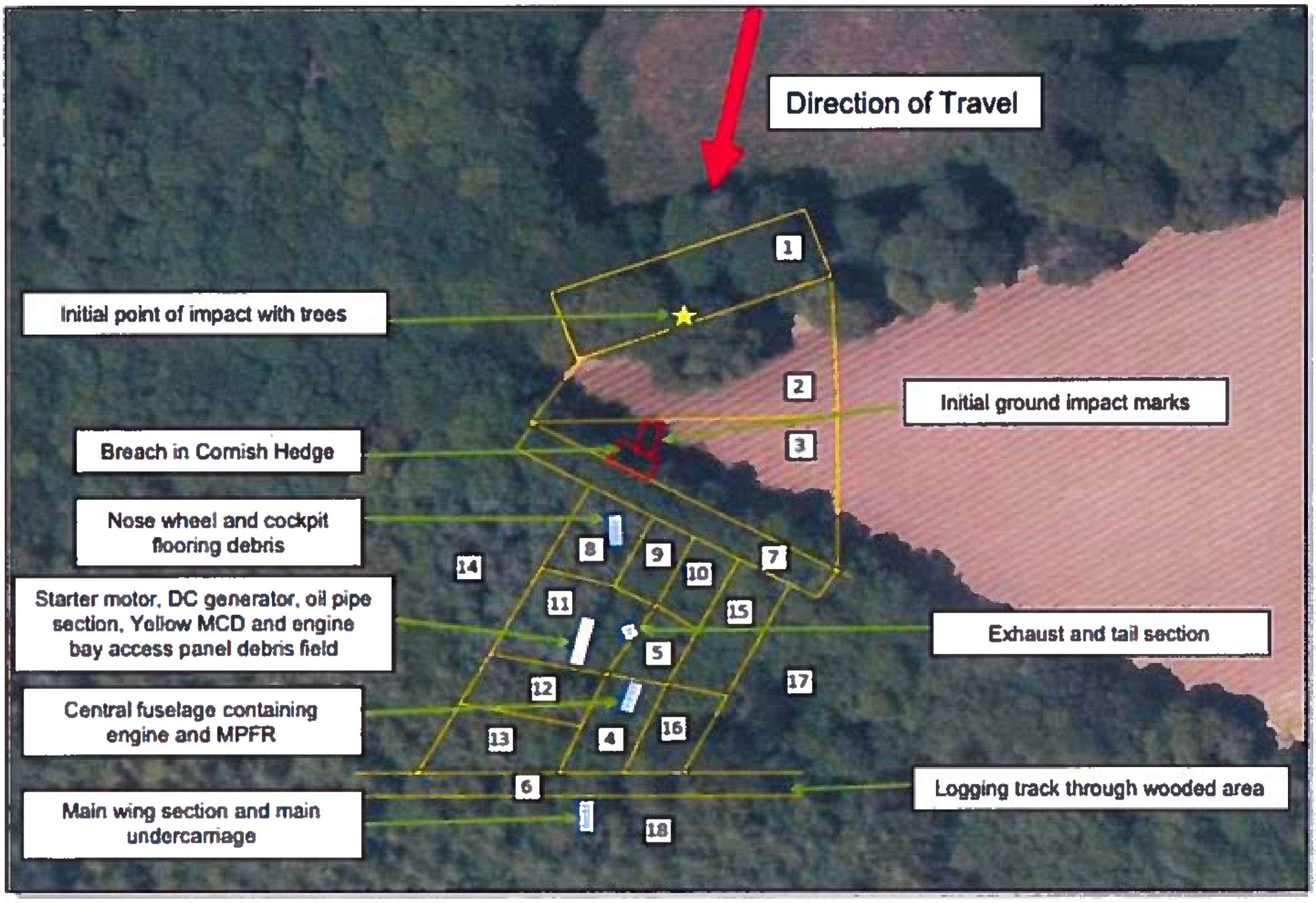


Figure 1.4.8 - Wreckage plot of the crash site.

1.4.64. The collision with the Cornish Hedge[37] (Figure 1.4.9 and Figure 1.4.10) significantly reduced the velocity of the aircraft and caused substantial damage to the airframe. Exhibit 162 Exhibit 163

[37] A Cornish Hedge is a hedge constructed using stone and earth, often found covered in vegetation.

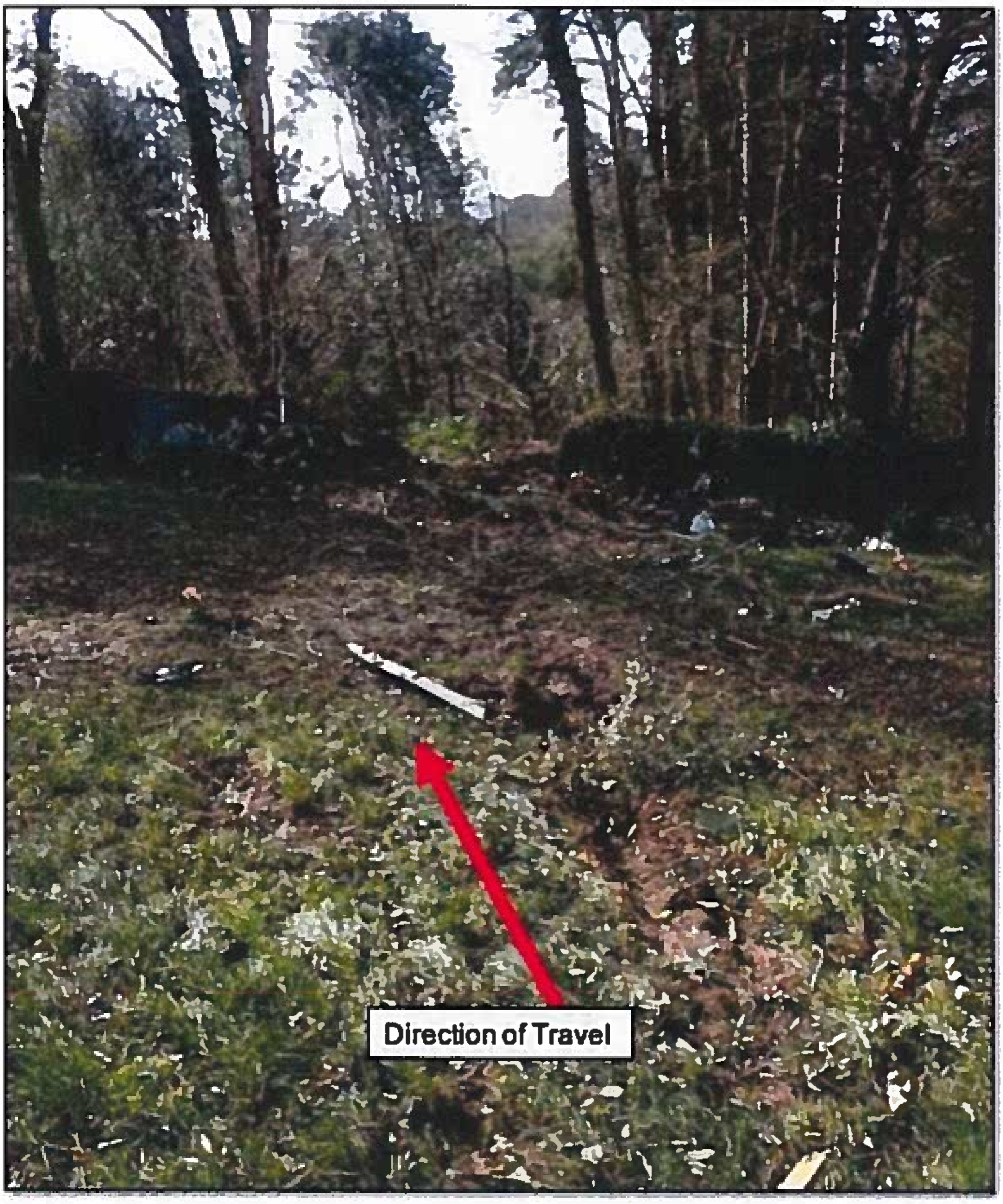


Figure 1.4.9 - Initial ground strike marks with direction of travel.

Figure 1.4.10 - Damage to the Cornish Hedge with direction of impact.

1.4.65. Members of DAIB, R-R, and JARTS combed the area for parts of the wreckage (Figure 1.4.10). On initial inspection of the main components of the engine it became apparent at an early stage that the Yellow MCD was missing from its housing, however, the Blue and Red MCDs were still fitted. Exhibit 57 Exhibit 78

1.4.66. Environmental experts were quickly brought onsite due to the large amount of fuel that spilled as a result of the crash. The pilot stated that, at the time of the accident, there was approximately 1,100kg of fuel remaining; much of this fuel seeped into the ground. This was apparent in the water course towards the bottom of the slope and further downstream. Mid-way down the slope was a logging track which provided good access for the PCM team and JARTS (Figure 1.4.11). Witness 1 Exhibit 61 Exhibit 164

Figure 1.4.11 - Removal of the fuselage via the logging track mid-way down the slope.

The accident sortie

1.4.67. XX189 was declared serviceable at 08:00 ahead of the sortie on 25 Mar 2021. The first indication of an issue was the OIL caption[38] displayed to the Pilot, shortly after levelling off from the take-off climb. This occurred at approximately 09:27; the Pilot responded by taking back control of the aircraft from the Passenger and setting a fixed engine Revolutions Per Minute[39] (RPM) of 84.7% (83% recorded on the MPFR) at 09:27:24. The Pilot initiated a right-hand turn whilst declaring a 'PAN PAN' call at 09:28:06. No additional captions were observed or recorded throughout the sortie[40]. They experienced increasingly severe engine fluctuations accompanied by loud mechanical noises and vibrations from 09:34:56. The engine was assessed to have mechanically failed at 09:36:27, prior to being manually shut down by the Pilot at 09:36:33.

Exhibit 47
Exhibit 34
Witness 12
Witness 1
Exhibit 142
Exhibit 111
Exhibit 173
Exhibit 174
Exhibit 77

Main technical lines of inquiry

[38] An AMBER Central Warning Panel (CWP) caption.

[39] RPM is measured as the speed of the high-pressure compressor.

[40] The MPFR only records RED CWP captions.

1.4.68. The engine and all ancillary components were recovered from the crash site, systematically stripped, and inspected by R-R to ascertain the root cause of the engine failure (Figure 1.4.12). The engine was disassembled into its constituent modules (Figure 1.4.13) by R-R under the observation of DAIB investigators. Exhibit 77 Exhibit 78

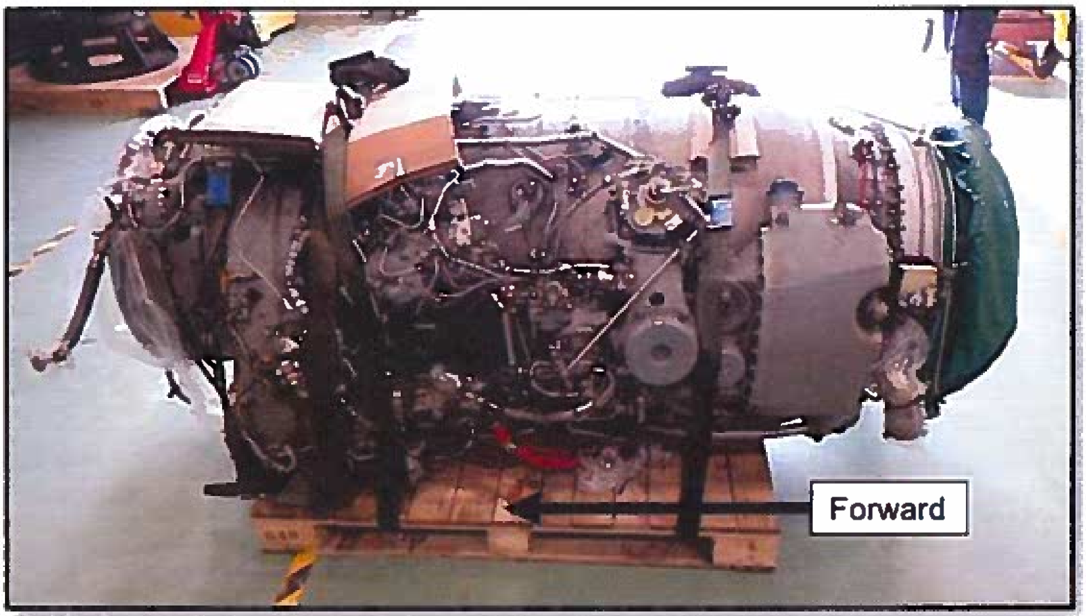


Figure 1.4.12 - View of the bottom of XX189's Adour Mk151 engine (Serial 5100) as delivered to R-R ASI workshop.

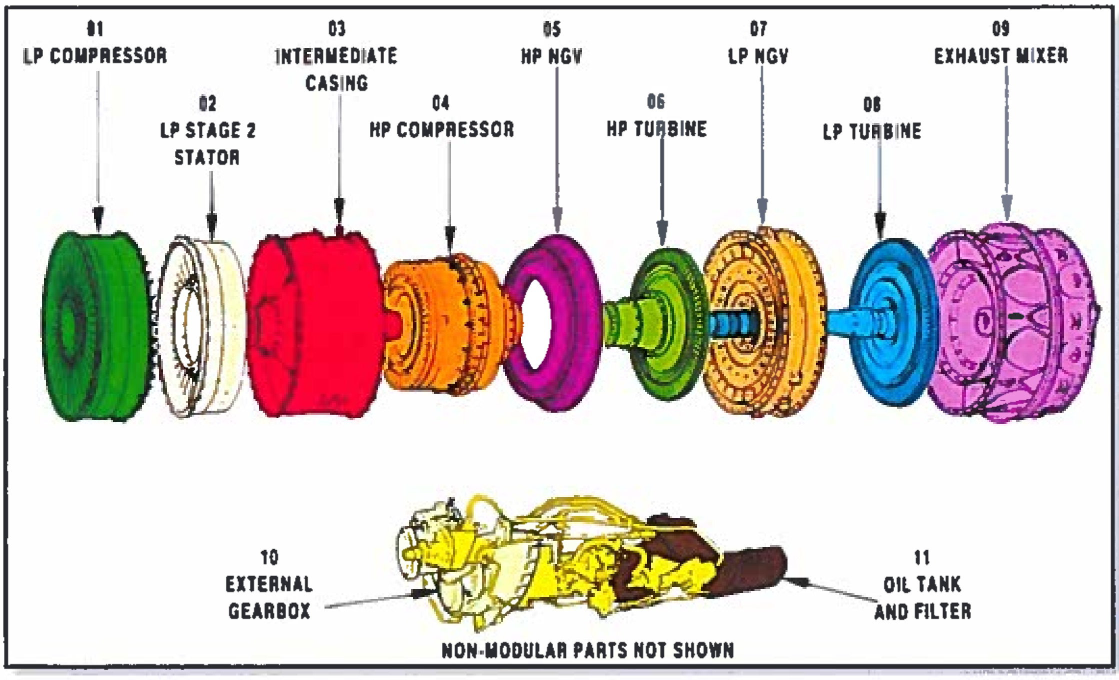


Figure 1.4.13 - Break down of engine modules.

1.4.69. The external gearbox, oil pump and oil distribution block were uninstalled by R-R then stripped and inspected by Safran, the DO for those components.

Cause of engine failure

1.4.70. The Panel determine that the damage to the engine and its components, with the exception of the High Pressure (HP) Compressor Location Bearing located in Module 03, was attributable to the crash. Evidence confirmed that the engine was not producing thrust but was 'windmilling' at the time of impact. This was consistent with witness reports and MPFR data. The 'windmilling' confirmed that the engine components were free to rotate. The Panel concluded that there were no failures in any part of the engine apart from those found in Module 03. The Panel finds that modules 01-02 and 04-11 were serviceable and were **not a factor**.

Exhibit 77
Exhibit 34
Witness 1

1.4.71. Prior to the sortie, the fuel quantity was confirmed to be 1,340kg. R-R were unable to find evidence of fuel starvation or problems with fuel delivery to the engine. A fuel leak was also discounted due to the large quantity of fuel located at the crash site. The MPFR did not record any fuel related CWP captions. Similarly, there was no evidence to indicate an electrical fault, during the accident sequence, with no electrical related CWP captions being recorded by the MPFR. The Pilot also reported both the fuel and electrical systems were operating normally. The Panel concluded that the fuel and electrical systems were serviceable. The Panel finds that the fuel and electrical systems were **not a factor**.

Exhibit 47
Witness 1
Exhibit 61
Exhibit 77
Exhibit 34

Oil system

1.4.72. The oil system (Figure 1.4.14) was designed to primarily provide cooling to all system components as well as providing lubrication for the bearings, gears, and splines.

Exhibit 78

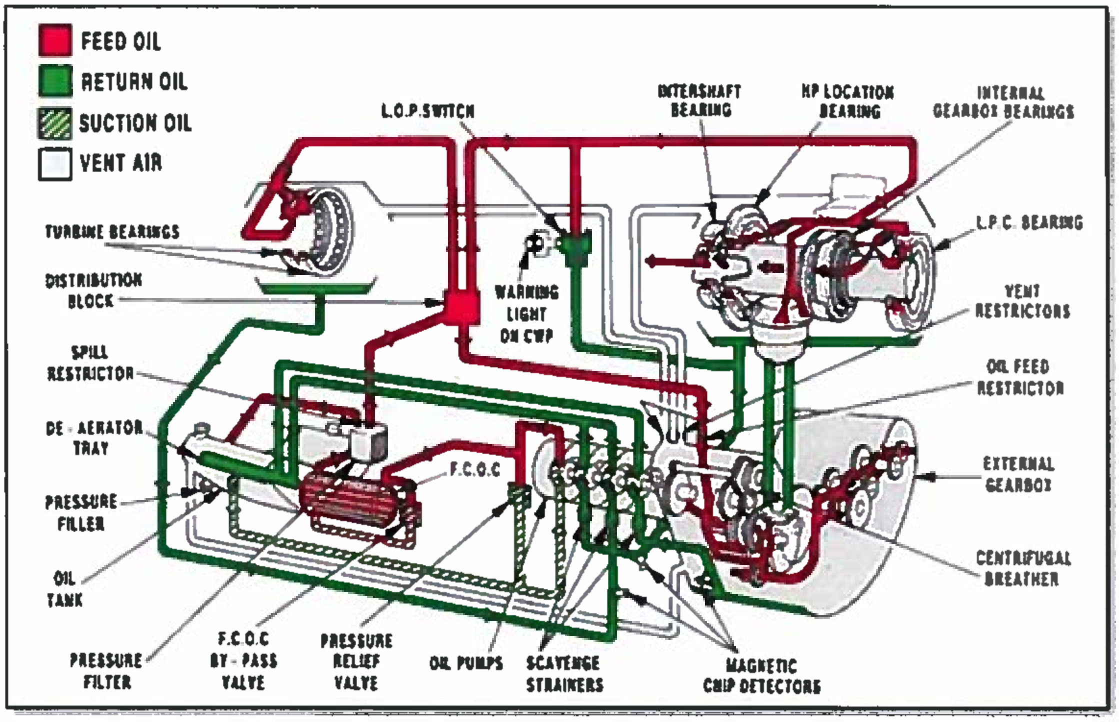


Figure 1.4.14 - Oil System schematic.

1.4.73. The oil temperature was managed using a fuel cooled oil cooler. Oil was also used to reduce engine vibration by 'squeeze film damping effect' in the engine bearings.

1.4.74. The oil system components sent to Safran were stripped and inspected. All components, including the gears, quill shaft and drive keys were assessed to be serviceable. The MCDs, strainers, filters, distribution block and pipework were free from significant debris. However, some small debris, including a washer-like object, was present in the oil pump. Safran determined this was highly likely to have entered the pump as a result of the crash as there was no evidence of damage to the gear teeth which would almost certainly have occurred if the debris was present during system operation. The external gearbox and its accessories were also assessed to be fully serviceable. The Panel concluded that there were no failures within these components in the oil system. The Panel finds that the oil system functionality was **not a factor**.

Exhibit 54
Exhibit 55
Exhibit 56
Exhibit 77

1.4.75. Records show that the oil system was last replenished on the 18 Mar 2021. Based on historic oil consumption, the engine was calculated to have had approximately 10.5 pints of oil remaining at the start of the accident flight, one week later. No evidence was found to suggest that the oil had been affected by high temperatures. Analysis of the oil by 1710 NAS showed no significant degradation or contamination. The oil was confirmed to be of the correct type. The Panel concluded that the condition of the oil was within specification and therefore the Panel finds that the condition of the oil was **not a factor**.

Exhibit 33
Exhibit 76
Exhibit 77

Module 03

1.4.76. Inspection by R-R identified that the HP Compressor Location Bearing within Module 03 had been significantly damaged by heat stress and mechanical friction (Figure 1.4.15).

Exhibit 77
Exhibit 78

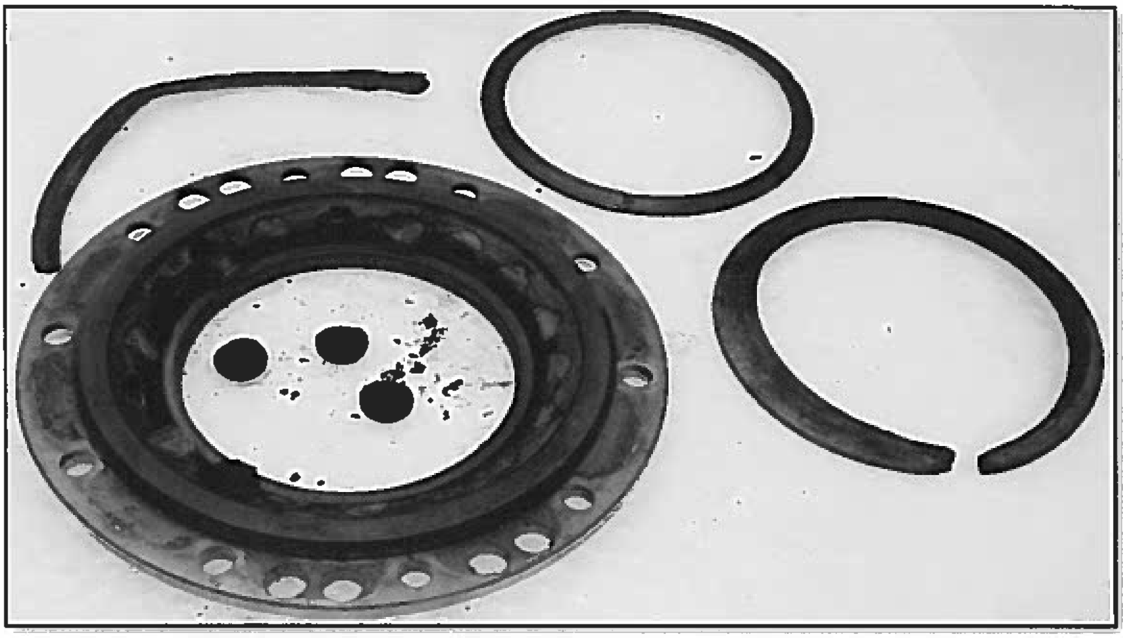


Figure 1.4.15 - Damaged HP Compressor Location Bearing, cage, and race.

1.4.77. Evidence showed that the galling, abrasion, and subsequent overheating, which led to the bearings experiencing a loss of dimensional tolerance, was caused by the loss of cooling and lubrication from the oil system. A rapid loss of oil was indicated by the localised debris from the bearing breakdown. The oil would have been the medium to transport the debris around the oil system. However, as there was a significant and rapid loss of oil, this did not occur. Exhibit 77 Exhibit 78

1.4.78. The Panel concluded that there was insufficient oil in the system to support the cooling and lubrication of the bearing, this resulted in the HP Compressor Bearing overheating and failing which resulted in the mechanical failure of the engine. The Panel finds that the rapid loss of oil from the system was a **Contributory Factor**. The Panel also concluded that in the absence of any damage to the engine other than that found within Module 03, the failure of the HP Location Compressor Bearing led to the subsequent failure of the engine. The Panel finds that the failure of the HP Compressor Location Bearing was a **Contributory Factor**.

Cause of oil loss

1.4.79. **Replenishment.** The oil system had been replenished to the correct level on the 18 Mar 2021 and had flown 3:15 hours, prior to the final sortie. A review of the oil replenishment / sampling record (MOD Form (F)737) confirmed the engine's oil usage was within limits. The oil tank sight glass was intact, free of staining, any permanent marks and was confirmed as serviceable. At the accident site there was a light film of oil on engine components and the fuselage wreckage. In particular the gull-wing panels under the engine were found to be coated in oil indicative of an oil spray from the engine (Figure 1.4.16). Exhibit 33 Exhibit 5 Exhibit 77 Exhibit 78

Figure 1.4.16 - Oil splatter visible on the interior of the gull wing doors.

1.4.80. R-R tested the pressure switch and confirmed it operated correctly. This confirmed that the OIL caption functioned as designed and was not spurious. During the strip down by R-R, sooting was evident on module 07, the Low-Pressure Nozzle Guide Vane, indicating a minor leak on the bearing chamber seal. R-R confirmed that this was a known in-service issue for Adour engines. However, the quantity and rate of the oil loss in the accident could not be attributed to this minor leak. There were no other internal oil leaks identified and no plausible internal mechanism that could explain the rate and quantity of oil loss. R-R calculated that during the 11 minutes 32 seconds between engine start and the OIL caption illuminating the oil system had lost approximately 7 pints of oil[41]. The Panel concluded that the oil level at the start of flight was within limits and there was no major internal loss of oil. The Panel finds that replenishment or internal loss of oil was **not a factor**.

1.4.81. **Blockage.** There was no significant debris found on the MCDs, strainers, filters, distribution block, tank or connecting pipework. The system was clear and did not display any blockages that would have prevented the oil from circulating. The Panel determined that all damage to the components and pipework was attributable to the impact. The Panel concluded that there were no blockages in the system and therefore finds that blockage of the oil system was **not a factor**.

Exhibit 54
Exhibit 55
Exhibit 56
Exhibit 77
Exhibit 78

[41] R-R assessment demonstrated an oil loss rate of 0.4 pints per minute at idle and 1 pint per minute at full power.

1.4.82. **Yellow MCD.** The Yellow MCD (Figure 1.4.17) was eventually found five days later on the accident site away from where the engine came to rest. Exhibit 58 Exhibit 78

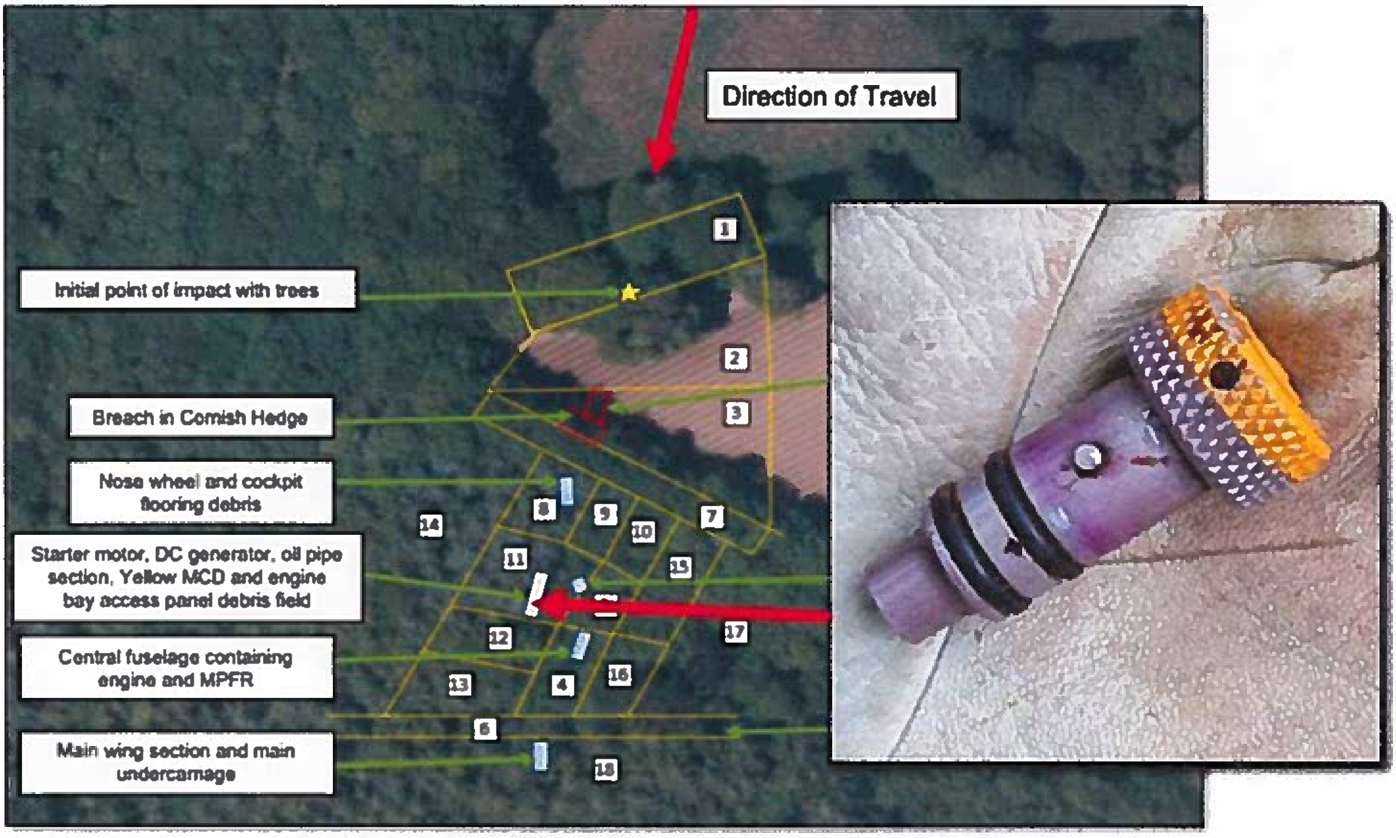


Figure 1.4.17 - Yellow MCD as found at crash site 31 Mar 2021.

1.4.83. The Yellow MCD was discovered approximately 10m west of the engine and main fuselage in the vicinity of the air starter motor, generator and the engine bay access panels that had detached from the airframe and engine during the crash sequence (Figure 1.4.17). Both Red and Blue MCDs were still in their respective housings (Figure 1.4.18). Exhibit 78

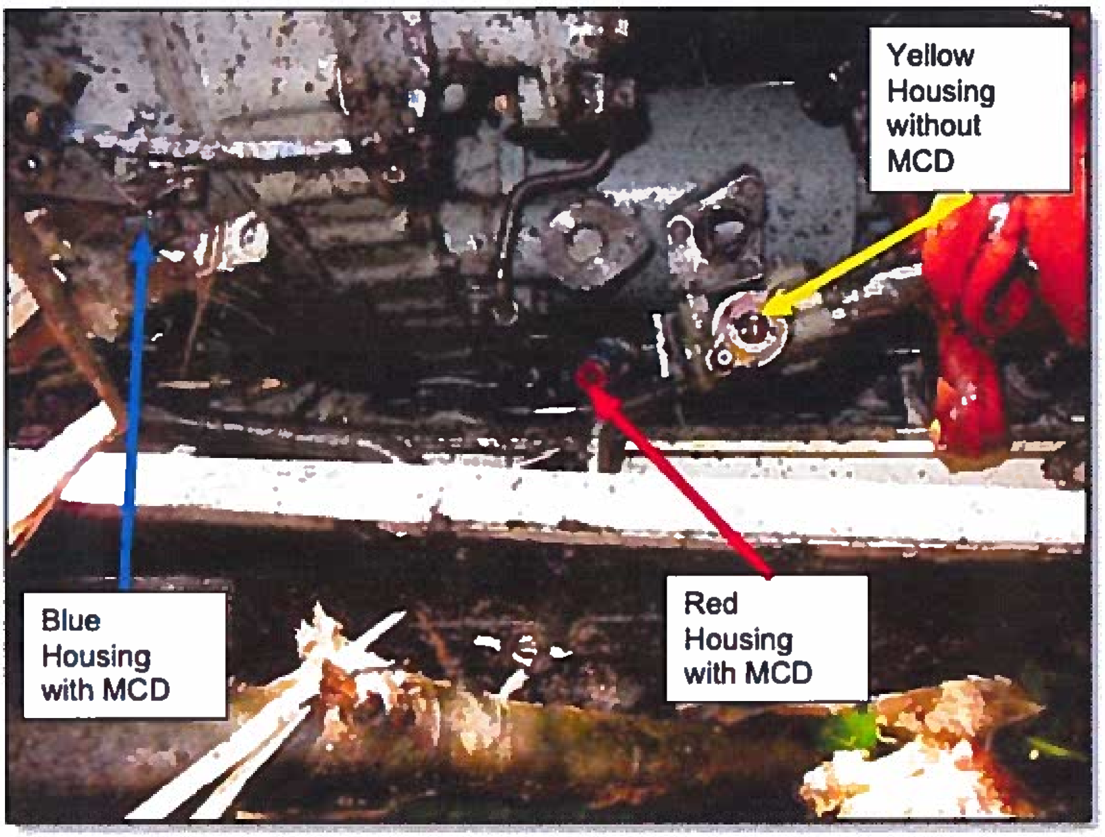


Figure 1.4.18 - MCD configuration on arrival of DAIB to crash site.

1.4.84. **MCD separation.** Components and surrounding structure (air starter motor, direct current generator, and engine bay access panels) exhibited impact damage consistent with being violently separated from the aircraft during the crash sequence. Detailed analysis of the Yellow MCD and housing did not identify any impact damage. Minor scuffing was evident on the MCD head and housing. However, R-R reported that, had the Yellow MCD been forcibly separated as a result of the crash sequence, significant deformation and damage would have been present on the MCD and its housing[42] (Figure 1.4.19). Exhibit 77 Exhibit 78

[42] A push, twist and pull action was required to remove a serviceable MCD from its housing.

Figure 1.4.19 - Yellow MCD and MCD housing inspection.

1.4.85. Through analysis of the technical evidence presented, the Panel concluded that the Yellow MCD was not fitted in its housing prior to the impact with the ground. Exhibit 77 Exhibit 78

1.4.86. **Yellow MCD loss.** With an MCD correctly fitted (Serial 1, Table 1.4.2) and the oil system pressurised, the system pressure holds the MCD in the housing under all flying conditions. R-R testing demonstrated that when not correctly fitted, with the oil system pressurised, the oil pressure was sufficient to eject the MCD from the housing. Testing demonstrates that when an MCD was not fitted the self-sealing valve contained within the housing should prevent any noticeable oil loss. The results of the test and analysis are at Table 1.4.2 and Figure 1.4.20. Exhibit 77 Exhibit 78

Serial	MCD position (Figure 1.4.20)	Outcome on engine start
1	Inserted and fully rotated into bayonet fitting.	Oil system pressure fixes MCD into bayonet fitting under all flight conditions.
2	Inserted and fully rotated but not pulled back into bayonet fitting.	Oil system pressure engages MCD into bayonet fitting and fixes it in position under all flight conditions.
3	Inserted but not fully rotated past the bayonet 'lip'.	Oil system pressure exerts pressure on MCD and with airframe vibrations MCD will either engage into bayonet fitting or be ejected from the housing.
4	Inserted and not rotated.	O-seal rings will hold MCD in position until engine start. Oil system pressure ejects MCD from housing.

Table 1.4.2 - MCD configuration analysis.

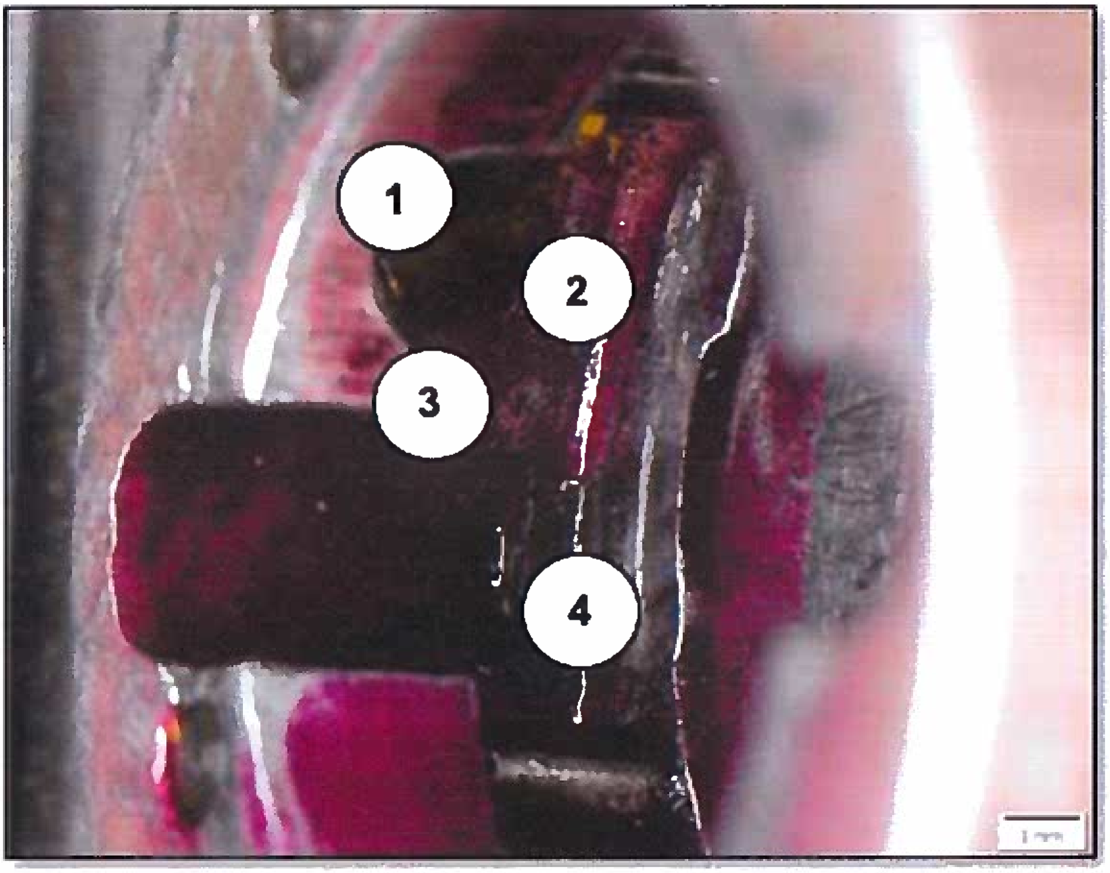


Figure 1.4.20 - MCD test positions as described in Table 1.4.2.

1.4.87. The Panel deduced that the removal of the Yellow MCD did not occur during the crash sequence. The Panel concluded that the separation of the Yellow MCD occurred prior to the impact most likely as a result of the MCD being in either position 3 or 4 post maintenance (Figure 1.4.20).

1.4.88. Documentary evidence and witness statements stated the MCD was fitted correctly during the MCD change procedure carried out on 24 Mar 2021. However, the technical analysis determined that the MCD was almost certainly not fitted correctly. The Panel judged the assertion of the tradesperson and the supervisor that the MCD was correctly fitted could be explained as a HF issue[43]. The task of changing the MCDs was conducted every 25 flying hours and was viewed by the witnesses as a simple, repetitive maintenance procedure. Simple, repetitive, low arousal, low stimulation tasks are recognised conditions where human errors are more likely.

Exhibit 7
Witness 12
Witness 13
Exhibit 77
Exhibit 79

1.4.89. The engine accessory gearbox and its components (including the MCDs) were located at the rear underside of the engine. Access to the MCDs, although good with the access panels open, still requires the tradesperson and supervisor to work below the aircraft. Access between the hangar floor and the bottom of the aircraft was limited. At all three sites maintaining Hawk T Mk1, the Panel witnessed a variety of wheeled boards and half seats, to aid comfort whilst working beneath the aircraft. Although witnesses described the operation as straight forward and simple, the ergonomics of access caused the potential for maintainers to operate in a position of discomfort which may be distracting. The Panel **observed** that the potential for discomfort during the fitting of the MCDs could be linked to the incorrect fitting and supervisory checks of the MCD on XX189.

1.4.90. Correct fitment of the Yellow MCD would have prevented oil loss from the system. The Fitter and Supervisor carried out two MCD changes on two separate aircraft on 24 Mar 2021 (6 MCDs in total). The MCD change on the other aircraft was completed with no reported issues. The AMM states that the procedure is to be carried out by a fitter and with a supervisor conducting stage checks and at times providing 100% supervision (the supervisor must be present for and check the correct fitting of the MCD by touch and sight). During interview, when recalling the process, no reference was made, by the Supervisor, to visually checking the MCD bayonet pins were located in the witness holes. The Panel determined that a visual check was either not conducted at all or was conducted but the position of the pins was not actually observed to confirm the MCD was correctly fitted. The Panel concluded that the Yellow MCD was incorrectly fitted and was forcibly ejected by oil system pressure. The Panel finds that the incorrect fitting of the Yellow MCD was a **Causal Factor**.

Witness 12
Witness 13
Exhibit 7
Exhibit 79
Exhibit 90

1.4.91. **Recommendation. Director Royal Navy Safety should conduct promotional messaging for a Royal Navy audience to highlight the importance of conducting visual checks correctly.**

1.4.92. **Recommendation. Inspector of Flight Safety (Royal Air Force) should conduct promotional messaging for a Royal Air Force audience to highlight the importance of conducting visual checks correctly.**

[43] XX189 and XX200 had the same MCD procedure on the 24 Mar 21, activities took place towards the end of a 12-hour shift.

1.4.93. **Recommendation. Deputy Chief of General Staff should conduct promotional messaging for an Army audience to highlight the importance of conducting visual checks correctly.**

1.4.94. Figure 1.4.21 shows the operation of the MCD and its interaction with the plunger within the housing.

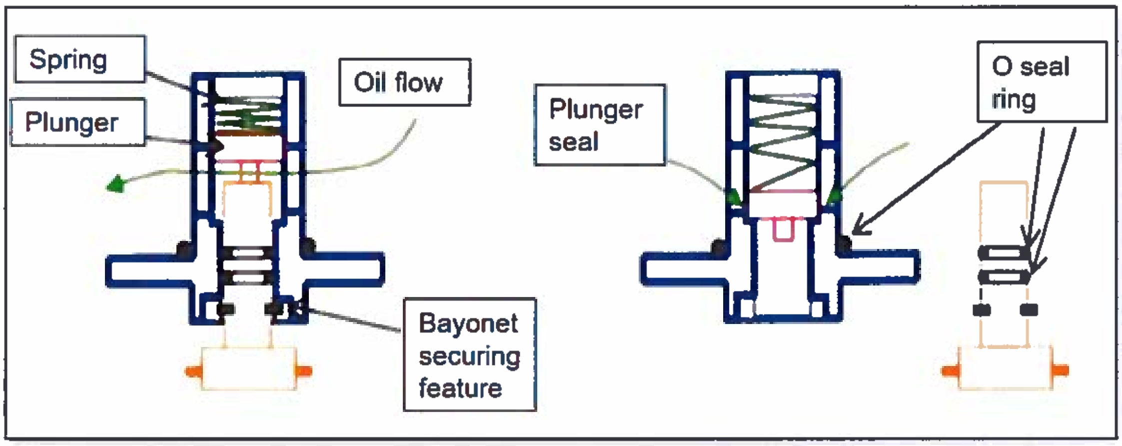


Figure 1.4.21 - Schematic of the MCD operation.

1.4.95. **Yellow MCD Housing.** The only component within the oil system that was found to be in an unserviceable condition was the Yellow MCD housing (Figure 1.4.22). The self-sealing valve was found to be jammed in the partially open position (Figure 1.4.23). Exhibit 78

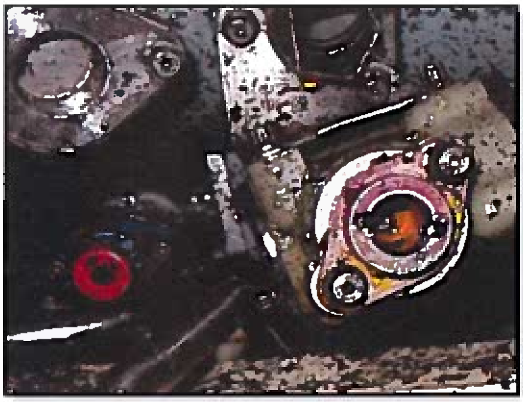


Figure 1.4.22 - Yellow MCD housing as found by DAIB investigators.

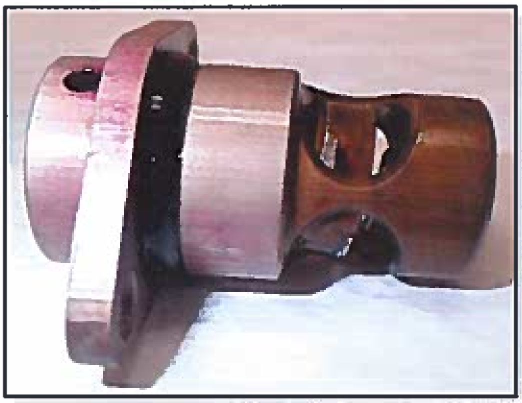


Figure 1.4.23 - Yellow MCD housing as removed for inspection.

1.4.96. Test and evaluation by R-R identified that a valve jammed in a partially open condition would suffer the oil loss rates experienced during the accident flight. Exhibit 77 Exhibit 78

1.4.97. Detailed inspection of the Yellow MCD housing and plunger by R-R identified significant fretting and wear (Figure 1.4.24) around the plunger and its housing where it had functioned as the MCD had been repeatedly inserted and Exhibit 77 removed for routine sampling. The Panel determined that the MCD housing plunger became jammed leaving the valve in the partially open position. There was no evidence to support a foreign object holding the valve open. The Panel determined that the valve became jammed post MCD maintenance on XX189 on 24 Mar 2021, highly likely due to the wear noted in Figure 1.4.24, otherwise an oil leak would have been apparent during maintenance (when the MCD was out of its housing). When combined with the missing MCD this condition allowed oil to escape from the engine. The resultant lack of oil caused the HP Location Compressor Bearing to overheat and the engine to fail. The Panel concluded that the failure of the MCD self-sealing valve caused the loss of oil which led to the failure of the engine. The Panel finds that the failure within the self-sealing valve was a **Causal Factor**.

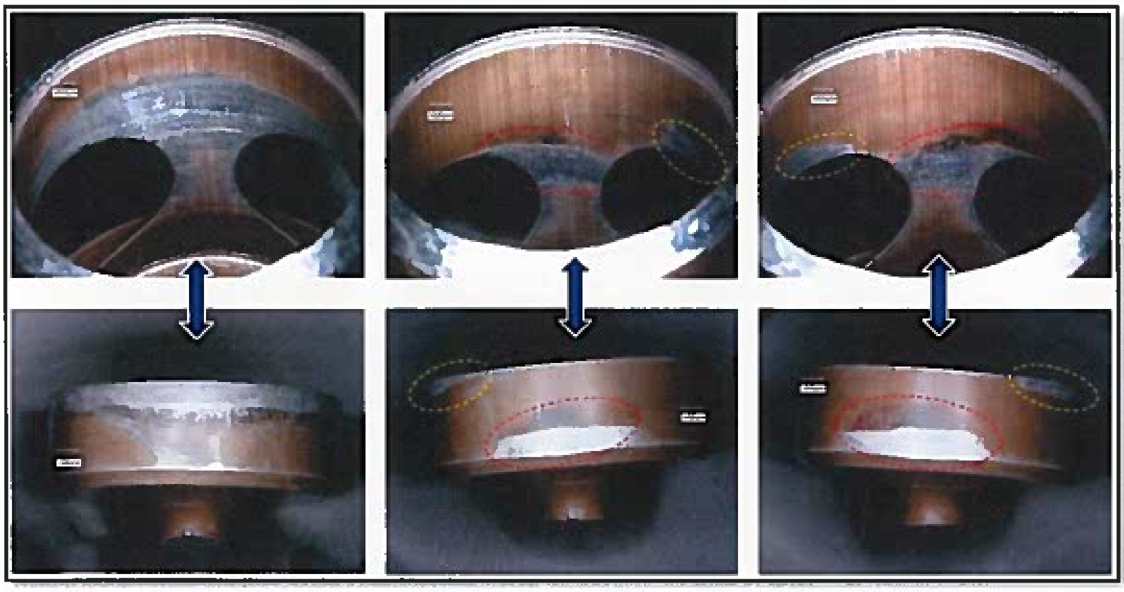


Figure 1.4.24 – Wear on inside of housing with corresponding wear on the plunger.

1.4.98. There is no requirement to inspect self-sealing valves and MCD housings during routine maintenance. Had there been a preventative inspection regime, it is highly likely that the damage to the self-sealing valve would have been identified at an earlier stage, thus preventing the accident from occurring. The Panel concluded that the lack of inspection regime for self-sealing valves and MCD housings meant that neither R-R nor the end users could be aware of the condition of an important safety barrier, preventing a loss of oil. The Panel finds that the lack of an inspection regime on the MCD housing was an **Other Factor**. Exhibit 77

1.4.99. Wear was also present on the contact point (Figure 1.4.25) where the plunger interacts with the MCD on insertion and removal. This wear was at an angle that matched the wear of the housing and seal edge. It was more likely than not that the plunger snagged on the MCD housing due to its canted angle when travelling in the housing (Figure 1.4.26). Exhibit 77

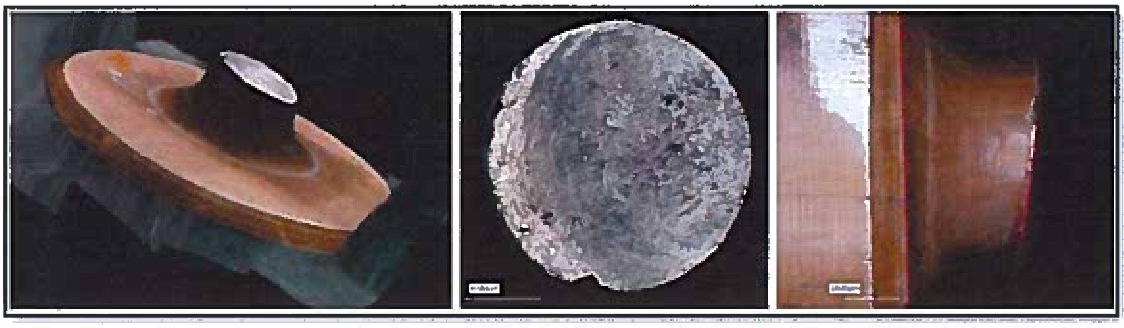


Figure 1.4.25 – Wear to the end face of the plunger from contact with the MCD.

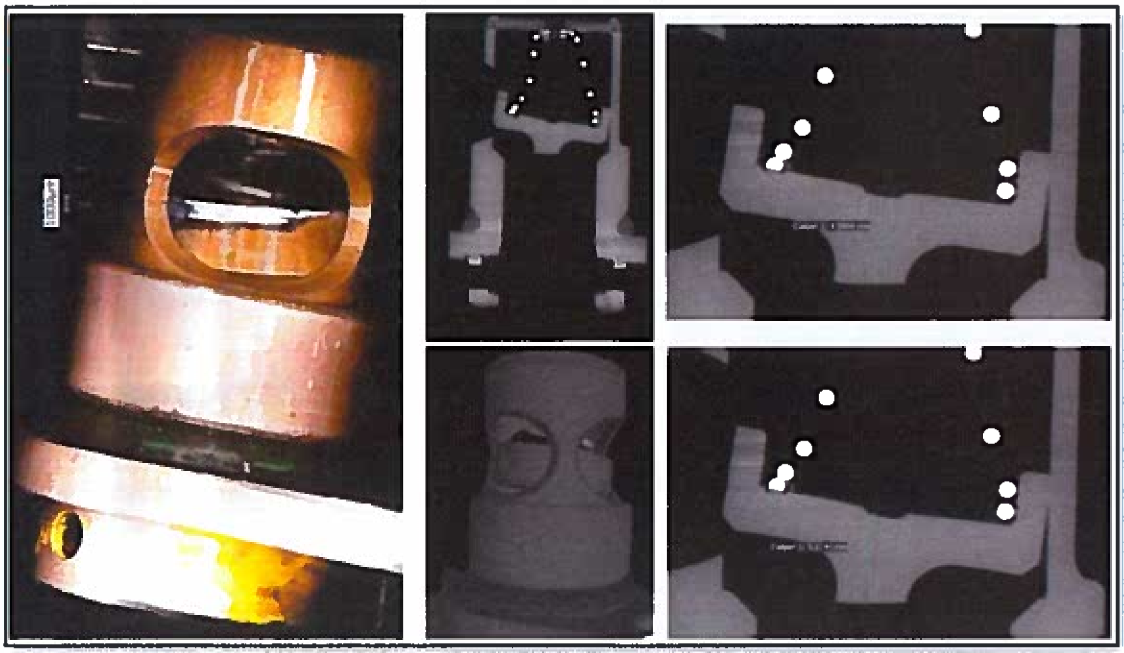


Figure 1.4.26 – Photograph and CT scan of Yellow MCD showing canted angle of the plunger.

1.4.100. **Recommendation. The Hawk Type Airworthiness Authority should implement a robust process to ensure Magnetic Chip Detector housings are serviceable in order to prevent unserviceable housings from being used.**

Prolonging the engine running time

1.4.101. **Engine 'low oil state' running timings.** R-R do not provide guidance on 'dry running time' of the engine post oil loss. Due to the large number of variables in these events (oil loss rate, engine & aircraft conditions, etc.) it was difficult to predict an expected 'dry running time' before failure. However, a gas turbine engine left running without oil will fail. R-R certify that the engine should run for 15 minutes in a 'low oil state'. However, in-service experience and further testing indicated that a time of between 5 and 10 minutes post OIL caption was more likely to be an accurate duration before engine seizure. As the Hawk T Mk 1 MFPR did not record amber CWP captions, the time that the OIL caption illuminated has been estimated to be Exhibit 77 Exhibit 88 Exhibit 89 Exhibit 34 between 09:26 and 09:27:24[44]. Applying the duration provided by R-R would give a maximum run time to 09:41:24, but more realistically a failure was almost certain to have occurred between 09:31 and 09:37:24. XX189 suffered an engine mechanical failure at 09:36:22.

1.4.102. **Aircrew guidance.** Aircrew documentation did not provide any guidance on time from OIL caption to engine failure, with nothing taught or tested by any Hawk unit. Times to failure may have been anecdotally discussed and information regarding previous incidents and engine run times were easily accessible to crews who choose to trawl previous incident reports or ASIMS. The only certainty was that once oil has been lost from the engine, the path to failure was inevitable. Therefore, getting the aircraft on the ground as soon as possible was the only way to prevent an accident. Exhibit 81 Exhibit 83 Witness 1 Witness 17

1.4.103. Figure 1.4.15 shows the damage caused to the HP compressor location bearing after the loss of oil had occurred. Without oil the HP Compressor Location Bearing would have been running at a temperature sufficient to cause it to operate in a molten condition. The molten condition may have been relatively stable at fixed power setting and in straight and level flight. This would have allowed the bearings and turbines to continue to turn, but any increased loading on the shaft or bearings would expedite the failure of the engine. An increased load would occur during any deviation from 1g or as altitude decreased and air density increased. Exhibit 77

[44] Level off to Pilot's response.

Oil pressure low caption

1.4.104. **Transition to level flight.** The various methods of levelling off the aircraft were discussed with the witnesses, those being a throttle back allowing the nose to lower; a roll and pull to level flight; or a negative 'g' push to level off. Both the Pilot and Passenger confirmed that the throttle was reduced, and the nose gently lowered to reduce the climb and level off at 15,000ft. Analysis of MPFR showed an absence of any significant amount of positive or negative g during the level-off. The Panel concluded that the levelling off of the aircraft was not the cause of the illumination of the OIL caption. The Panel finds that the transition to level flight was **not a factor**. Witness 1 Witness 2 Exhibit 34

1.4.105. **Throttle position.** Setting a fixed power should allow continued running of the engine and will reduce the loading of the bearings already under stress due to the loss of lubrication and cooling. The Hawk T Mk1 FRCs (Figure 1.4.27) contain the following actions for the OIL caption. Exhibit 81

OIL PRESSURE LOW

OIL

1. **Throttle . . . . Smoothly set between 78 - 87%**
2. RPM . . . . Monitor and maintain with smooth, progressive throttle movements
3. Maintain 1g nominal
4. Land . . . . ASAP

WARNING 1: Loss of oil pressure will result eventually in engine seizure

WARNING 2: Bearing loads increase as altitude reduces

WARNING 3: Increasing vibration is indicative of early failure

WARNING 4: The optimum RPM range to prolong engine life is 80-85%

Hydraulics
JPOHT
Oil
E-13

Figure 1.4.27 - Excerpt from Hawk T Mk1 FRCs Issue 6, Aug 2012.

1.4.106. The Pilot carried out the IA as highlighted in the FRCs in bold (Figure 1.4.27) and moved the throttle to a position correlating with 84.7% RPM. The MPFR data confirmed the pilot's actions although, recorded a setting on 83% RPM. The Panel noted that the FRCs and Aircrew Manual contained two different throttle ranges, 78-87% and 80-85%. The latter is the optimum range to prolong engine life. R-R have stated that the former band was most likely for use in 'operational circumstances'. As the Hawk was used by the MOD predominantly as a training aircraft, the Panel determined that the inclusion of two bands left room for interpretation and potentially allowed pilots to fly with the RPM outside of the optimal 80-85% range. The Panel concluded Witness 1 Witness 2 Exhibit 34 Exhibit 81 Exhibit 82 that having two different RPM parameters could lead to unnecessary damage to the engine. The Panel **observed** that the inclusion of the two different bands in the ADS likely resulted from directly quoting R-R's documentation, even though R-R cater for a wide range of customers, some of whom use the Hawk operationally.

1.4.107. **Notes, cautions, and warnings.** This nomenclature was used to add additional information to FRC drills and Aircrew Manual explanations to ensure pertinent information was highlighted to users and the potential severity of ignoring that information was fully understood. The definitions of each term were as follows: Exhibit 145

a. **Notes** – A 'Note' was inserted to clarify the reason for a limitation.

b. **Caution** – A 'CAUTION' was inserted when the consequence of not respecting a limitation might be damage to the Air System or equipment.

c. **Warning** – A 'WARNING' was inserted when the consequence of not respecting a limitation might be death and / or injury.

1.4.108. As stated at WARNING 2 in the FRC OIL Pressure Low actions, bearing loads increase as altitude reduces. This was a WARNING, meaning that by reducing altitude the consequence might be death or injury, however, altitude must be reduced to land the aircraft – especially when step number four of the drill was 'Land – ASAP'. The Panel determine that this should have been entered as a CAUTION, informing pilots that there is an increased likelihood of expediting engine failure, with a reduction in altitude inferring that altitude should be maintained for as long as possible. The guidance in the ADS was widely understood to be poorly phrased and disjointed across the various documents. The Panel **observed** that there was a consensus that the documentation was not as good as it could be. The Panel judged that little had been done to improve the current ADS as there was a perception that the work was nugatory since the Hawk T Mk1 was due to go out of service imminently. Therefore, the effort required to solve the discrepancies was greater than the benefit. The Panel conclude that a lack of appropriate reporting via MOD F765X or DASOR existed across the Hawk T Mk1 fleet and this indicated to the Panel that a cultural acceptance of sub-optimal documentation existed. Exhibit 81 Witness 17

1.4.109. 'WARNING 4' (Figure 1.4.27) referred to the optimum range of 80-85%. As a 'WARNING' this indicated that operating outside of this range, but still within the FRC range of 78-87%, injury or death could occur. This adds further confusion to the ranges indicated across the ADS. The Panel determined the definitions from the RTS (Notes, CAUTIONS, and WARNINGS) have been used incorrectly across the Hawk T Mk1 ADS. The incorrect use of the definitions could lead to an incorrect action due to a misunderstanding of the intended meaning of the phrase. For example, 'WARNING 4' is an amplification of the range prescribed at step one of the drill, and therefore should be a Note. The Panel concluded that the use of the nomenclature in the Hawk ADS was confusing, not in accordance with the RTS definitions, and in Exhibit 145 the Panel's opinion, likely to lead to incorrect actions due to a misunderstanding of the intended meaning.

1.4.110. Step three of the FRC drill (Figure 1.4.27) was: 'Maintain 1g nominal'. The Pilot of XX189 and several other witnesses stated that manoeuvring a fast jet aircraft at 1g, was in the circumstances experienced during this accident, almost impossible. This suggested that the FRC actions required pilots to conduct an almost impossible action whilst recovering an aircraft during this emergency. The Aircrew Manual stated that 'Engine seizure is delayed by the following: 'Minimising throttle movements, Maintaining 1g Flight' – these conflict with the requirement to 'Land - ASAP'. Discrepancies within the two documents should not occur. The FRCs require a pilot to 'maintain 1g nominal', but the Aircrew Manual is worded more as a 'WARNING' providing advice as to how to delay the impending failure of the engine. The Panel **observed** that the requirement to maintain 1g in the circumstances of this accident was an almost impossible requirement. Placing an almost impossible demand into the FRC emergency action could lead to a sub-optimal recovery.

Witness 1
Witness 17
Exhibit 81
Exhibit 83

1.4.111. **Nominal.** This word is not defined in the ADS or the MAA glossary. However, in the Oxford English Dictionary, nominal 'is something in name only, and not in reality'. Several witnesses were asked for their understanding of the word nominal, but none could give an exact answer. In the context of Oil Pressure Low actions, no-one could state a g range that would be deemed acceptable. One witness understood the word to mean 'about'. The RTS did use the term 'within acceptable limits' without defining what would be acceptable. When the limitation was so important to the continued running of the engine, the Panel **observed** that the limit in question should be clearly defined. For the purposes of this investigation, the Panel understood nominal to be 'as close to as possible, but without a specific range'. The R-R Technical Report states that 'it is likely that the sustained turn further increased the loads on the already distressed and overheated bearing. This may have exacerbated the bearing deterioration and reduced the overall time to engine seizure'. The Panel concluded that the use of the word nominal and the inconsistencies across the ADS provided room for interpretation and could cause confusion amongst pilots. The Panel finds that the wording used across the ADS was an **Aggravating Factor**.

Witness 1
Witness 17
Exhibit 82
Exhibit 132
Exhibit 77

1.4.112. **Recommendation. Delegated Release to Service Authority (Royal Air Force) should review the use of the word nominal and include a definition in the glossary in order to ensure aircrew have clear and specific guidance.**

1.4.113. Additionally, the Panel **observed** that the Hawk T Mk1 RTS contained a large amount of aircrew advice, which would be better placed in the Aircrew Manual and not in the limitations document.

Exhibit 145

1.4.114. **Urgency of the need to land.** The following terms, as defined in the Hawk T Mk1 FRCs, were used to give guidance. However, they were not intended to be precise definitions nor preclude relevant airmanship actions such as performing a low-speed handling check when the integrity of the airframe is suspected.

a. **Land ASAP.** Land at the nearest airfield with a runway suitable for a safe landing. Exhibit 81

b. **Land as soon as Practicable.** Land at the nearest airfield where you can land safely and expect practical assistance for your particular aircraft type.

1.4.115. The Oil Pressure Low drill step four stated 'Land ASAP' which the Panel assess as appropriate for the nature of an issue with an engine in a single engine aircraft.

1.4.116. **Rotary wing versus fixed wing definitions.** In rotary wing (RW) aviation the definitions of the urgency to land are different from those in fixed wing (FW) aviation. The following were the definitions of the urgency to land from the Apache AH1[45] FRCs: Exhibit 84

a. **'Land immediately'.** Land at once even if, for example, the outcome is ditching or landing in trees. The consequences of continued flight are likely to be more hazardous than those of landing at a site normally considered unsuitable.

b. **'Land ASAP'.** Do not continue flight for longer than is necessary to accomplish a safe but unhurried landing at the nearest site.

c. **'Land as soon as practicable'.** Land at the nearest aviation location, or if one is not reasonably close, at a safe landing site selected for subsequent convenience.

1.4.117. The Pilot's experience was a mix of RW and FW flying, although the majority was FW. During interview the Pilot stated that the emergency was 'not a land immediately drill', leading the Panel to believe there may have been some confusion between land immediately and the two definitions of Land ASAP. Notably the Apache helicopter definition of Land ASAP uses the word 'unhurried'. The Pilot's approach to the airfield overhead was expeditious, the subsequent routing away from the airfield extended the flight time, by approximately two minutes more than it would have taken to fly a Forced Landing (FL) pattern and required the engine to operate for longer. Had the Pilot maintained in the overhead and continued with a FL pattern they may have landed the aircraft prior to the engine failing and from the 'High Key'[46] position do not require thrust from the engine. Of the other incidents[47] reviewed by R-R and the Panel, where a loss of oil was experienced, none resulted in an Exhibit 3 Witness 1 Exhibit 85

[45] The pilot had flown Apache AH1 operationally during a previous tour.

[46] One of the recognised entry positions to a Forced Landing pattern.

[47] Twelve globally since 1984 (4 Jaguar incidents, 4 ground incidents, 4 airborne Hawk incidents).

accident. In the Panel's opinion, where the serviceability of the only engine within a single engine aircraft is in question, the importance of maintaining a position whereby glide back to RNAS Culdrose in the event of an engine failure was possible, becomes important. Exhibit 165 Exhibit 80 Witness 10 Witness 17

1.4.118. The Panel were unable to determine if either the mixed flying background of the Pilot and / or different definitions of the urgency to land caused any confusion in the mind of the Pilot. The Panel are of the opinion that Pilots with a mixed type background could 'revert to type' during stressful circumstances. The use of the word unhurried removes the sense of urgency from the situation and since moving RN pilots between RW and FW fleets is routine, exposure to this definition on FW aircraft is likely. The Panel **observed** that the inconsistencies of the 'Land ASAP' definition across fleets introduces the potential for misinterpretation and increased risk. The Panel **observed** that the practise of switching between rotary wing and fixed wing types has the potential to introduce HF hazards which may not be fully evident or understood.

Aircraft routing

1.4.119. When reacting to the emergency, the Pilot had the choice of two airfields, Newquay and RNAS Culdrose. Newquay was closer and on the nose of the aircraft; it had a significantly longer runway (9,000ft vs 6,000ft) but the Pilot's decision to use RNAS Culdrose was, in the Panel's opinion, justified within the leeway provided in the FRCs 'not intended to be precise definitions nor preclude relevant airmanship actions'. The Pilot's decision to return to RNAS Culdrose was based on the following logic: Witness 1 Exhibit 81

a. The availability of a barrier to assist stopping.

b. The knowledge of ATC to understand the priority and requests.

c. The ability of ATC to position appropriately for a Radar Precautionary Forced Landing (PFL) if required.

d. The familiarity of the emergency services with the Hawk T Mk1.

e. The knowledge that they would not have to sequence in with civilian traffic under the control of Newquay which may require an alteration to the fixed power setting.

1.4.120. The Panel, in consultation with witnesses, including Test Pilots, assessed the logic of the Pilot to be reasonable and understood the decision-making process, especially when there was a significant amount of height and speed to lose with a fixed throttle position. The additional track miles to RNAS Culdrose also aided the requirement to fly a gentler than normal approach as the need to pull high g loads was avoided when flying wider turns using less g over a greater ground track. Witness 10 Witness 17

1.4.121. The routing of the aircraft from the original position when the caption illuminated was as direct as it could be up to the point the aircraft approached the overhead. Routing through the overhead gave the Pilot the chance to fly a Forced Landing should the engine have failed at any point during the descent. The Pilot had already decided to fly a fixed power approach and had communicated this intention with ATC and the Authoriser. The Pilot's logic for departing the overhead and positioning for the fixed powered approach was mainly based on the continued output of the engine and the strong crosswind which would have almost certainly resulted a barrier engagement, something the Pilot was keen to avoid. A fixed powered approach also ensured a slower more controlled approach to the airfield and a slower threshold speed at touch down reducing the likelihood of a barrier engagement.

Exhibit 86
Exhibit 106
Witness 4
Witness 1

1.4.122. The positioning for this, however, was not as expected by the ATC controllers and not as per the guidance in the Pilot's Guide (Figure 1.4.28). To position for a fixed power approach the expectation would be that the Pilot would fly to intercept the extended centre line at a suitable point as indicated in Figure 1.4.28. This was what Culdrose ATC expected the Pilot to do, however there was no discussion of routing between ATC and the Pilot. To position for a PFL a pilot would be expected to fly to the overhead and maintain in the overhead while conducting a spiral descent to 'High Key'. During the manoeuvring throughout a PFL, pilots would be expected to stay close to the proximity of the airfield in case of an engine failure. In this case, after the pilot routed to the overhead, and with no indications of an imminent engine failure; a cross wind component that would have provided little in the way of retardation; the fear of landing long of the aim point, with a higher speed than required during a fixed powered approach, and the potential to take the aircraft into the barrier with hot brakes, the Pilot elected to continue to position for a fixed power approach. Figure 1.4.28 highlights the need to establish on the extended centreline and the Pilot was positioning to intercept this known pattern.

Exhibit 14
Exhibit 165
Witness 4

1.4.123. During interview, the Pilot discussed a history of pilots not conducting PFLs correctly resulting in accidents, and more recently an incident involving a RAFAT pilot flying a PFL resulted in the aircraft crashing and the passenger suffering fatal injuries. The Panel determined that there was a reluctance to fly a procedure that may result in ejection if not correctly flown versus flying a fixed power straight in approach which is more controlled and allows for a slightly slower approach speed.

Witness 1

1.4.124. Following the crash of Hawk T Mk1 XX204 at RAF Valley on 20 March 2018 the SI found the cause of the crash was the aircraft stalling with insufficient height to recover. This led to a recommendation that urgent investigations be undertaken into the incorporation of an Artificial Stall Warning System (ASWS) on the Hawk T Mk1, to provide sufficient warning to pilots during low-speed low-altitude manoeuvring. This position was further supported by the Coroner of inquiry into the crash of XX204, who issued a Regulation 28 Prevent Future Deaths Report (PFDR) to the Secretary of State for Defence, which specifically stated concern to resolve the lack of ASWS on Hawk T Mk1.

1.4.125. In his response to the PFDR the Secretary of State for Defence confirmed that the incorporation of a combined ASWS and Angle of Attack (AoA) gauge to enhance stall mitigation was feasible, proportionate and would be fitted to the remaining RAFAT Hawk T Mk1 aircraft. In addition, the ADH chain stated that the requirement to practise 'live' Forced Landings (FL) would be constantly reviewed, in-line with the development of a combined ASWS / AoA gauge and as future RAFAT Hawk T Mk1 synthetic developments are realised. At the time of writing the FL review was ongoing.

1.4.126. Figure 1.4.29 shows the expected flightpath, as drawn by a witness during interview, of [redacted] with a comparison to the actual flight path flown.

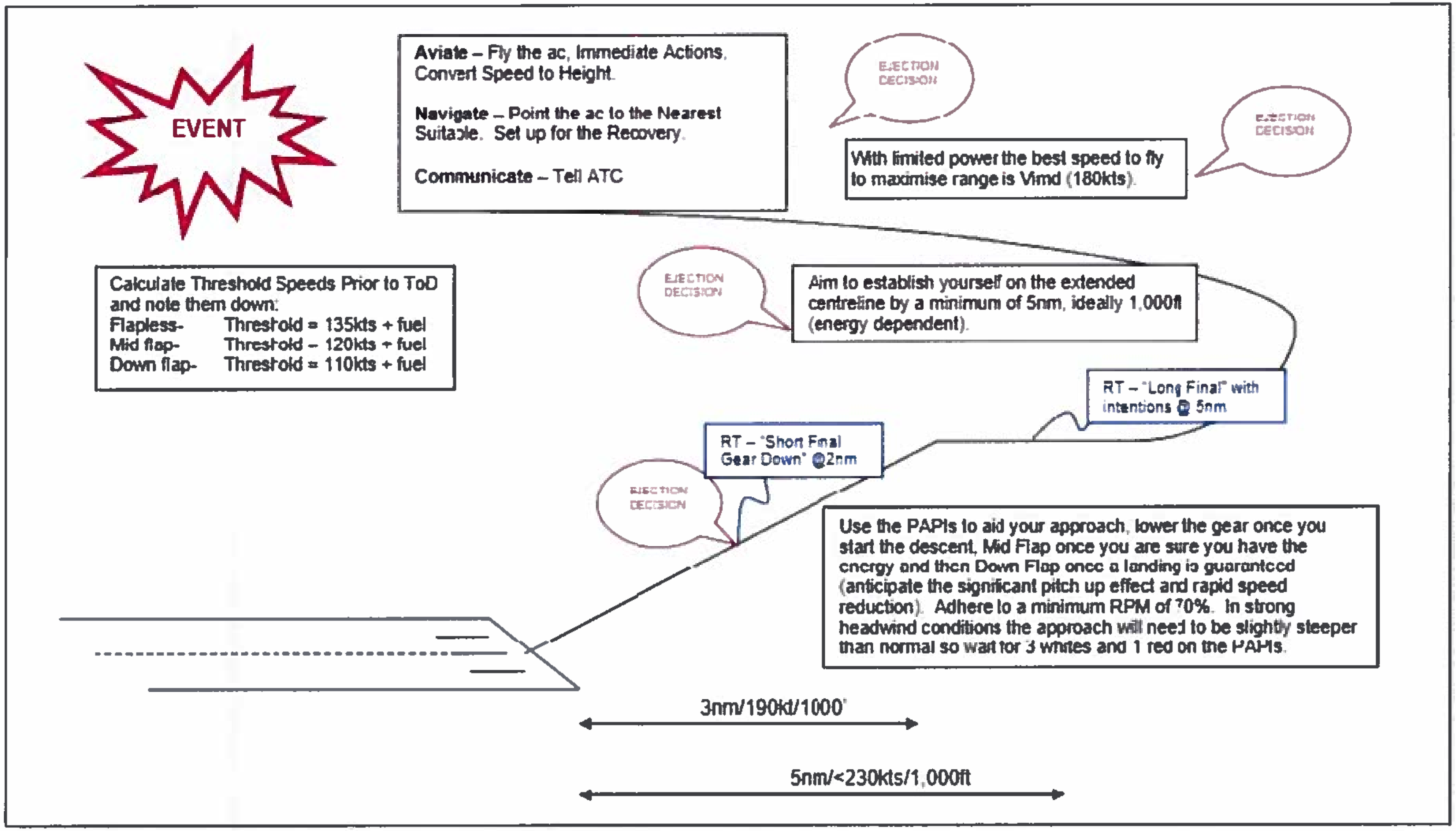


Figure 1.4.28 - Limited power straight-in approach from Hawk Pilot's Guide.

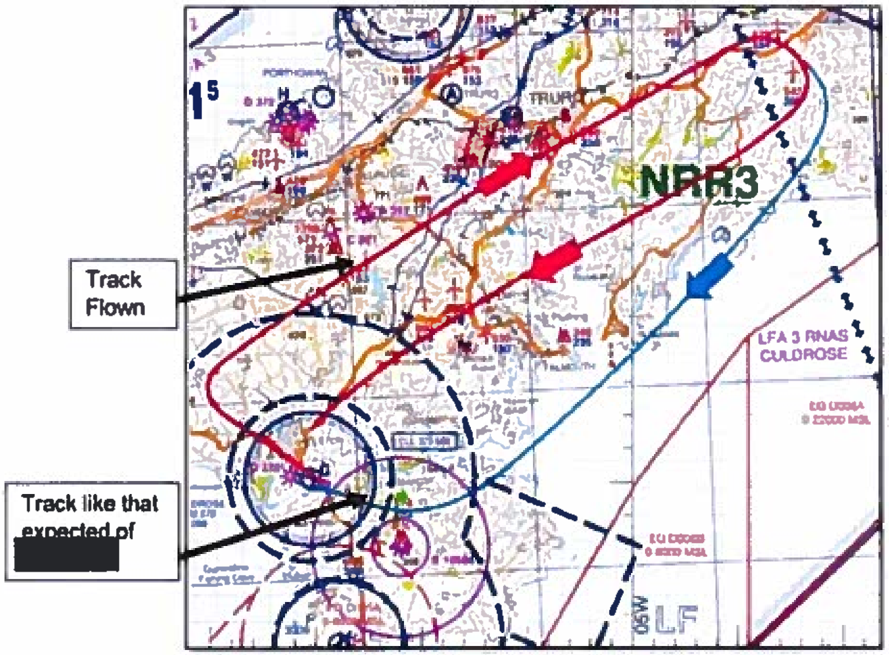


Figure 1.4.29 - Track flown (red) vs expected track (blue).

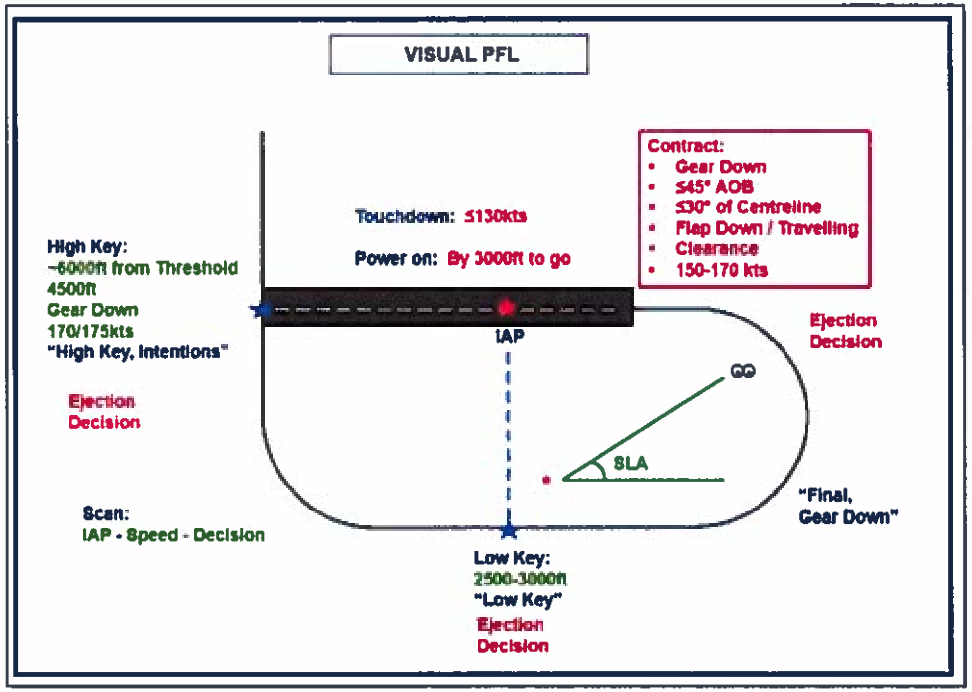


Figure 1.4.30 - Academic visual PFL pattern from Hawk Pilot's guide.

1.4.127. Throughout the descent the Pilot called for a visual straight in approach routing through the overhead. The ATC controller, consumed with maintaining the pointer on the radar return under an increasingly high workload situation, did not question the routing nor confirm the Pilot's intentions when it was noticed the routing was not as expected (Figure 1.4.29). Doing that may have highlighted at an earlier stage that the Pilot was intending to transit through the overhead close to D005A[48], with the potential to enter the active danger area, prior to departing the overhead and turning back in for the straight in approach. Exhibit 14 Witness 4

1.4.128. Once established in the overhead (Figure 1.4.30) the ATC controllers expected the Pilot to call 'visual to tower' which would have offloaded [redacted] from their frequency and freed up capacity to receive [redacted] who were 'pre-noted' by Plymouth ATC. When the Pilot did not call 'visual to tower' and maintained on frequency, the controllers were now at capacity and did not have additional capacity to make a call to the D005A Remotely Piloted Air System (RPAS) operators to ascertain the position of the RPAS that was flying there. This meant accurate positional, or height information was not available to pass to [redacted] for deconfliction purposes. The absence of effective communication between ATC and the Pilot confirming the routing contributed to the avoiding action required for D005A. Witness 4

1.4.129. The Letter of Agreement (LOA) between the Wind Racers[49] and RNAS Culdrose stated that D005A users must monitor the Frequentis Communications System[50] and maintain robust communications with the RPAS operator during RPAS activities. Culdrose ATC should have contacted the Wind Racers to inform them of the inbound emergency aircraft and request they land or clear the area. Due to the limited capacity of the controller, tracking [redacted] on the radar screen and liaising with the Duty Air Traffic Control Officer, none of the controllers contacted the D005A users to ensure they were aware of the inbound emergency aircraft. The Pilot appeared to be aiming for D005A, so the student controller passed the information that D005A was active. When probed by the Pilot for the height the danger area was active up to, the screen controller[51] responded that it 'was active'. The Pilot further queried this by asking what altitude the RPAS was operating at. The screen controller this time responded that the danger area 'was active up to an altitude of 8,000ft' as the position and height of the RPAS was unknown. The RPAS was not fitted with a transponder which would have given a height readout and, as the primary radar was on maintenance, ATC could not provide accurate positional information to the Pilot. The Pilot was planning on entering D005A below 8,000ft so now had to take avoiding action to ensure safe separation from the RPAS. Exhibit 87 Witness 4

[48] D005A is the Danger Area around Predannack airfield.

[49] A civilian organisation operating RPAS out of D005A.

[50] A system that allows internal communications, external phone communications and communication via radio telephony means.

[51] An instructor in air traffic control.

1.4.130. The Pilot had to alter his course and subsequently found that the aircraft was departing the overhead on a reciprocal heading to the runway whilst maintaining a descent. The subsequent flight path was not as per either of the academic options, both of which had been previously demonstrated by the pilot on numerous emergency simulator sorties. The Pilot had also recently flown with the STANEVAL Pilot and was presented with a similar scenario, albeit with an engine that 'failed' in the descent, which was actioned in accordance with the academic Forced Landing Pattern (Figure 1.4.30). Once in the overhead, the Pilot should have maintained within gliding range of the airfield, where there were several forced landing pattern options available, in case the engine had failed. This would have allowed the Pilot to fly a recognised approach using a familiar set-up. Maintaining position in the overhead would have also avoided the need to take avoiding action for the RPAS activity in D005A.

Witness 1
Exhibit 85
Witness 10
Witness 17

1.4.131. The Panel concluded that the ambiguity over the routing of [redacted] experienced by the ATC controllers, during the descent, and the uncertainty over the status of the RPAS within D005A, was due to the absence of effective communication between all parties. This affected the routing of the Pilot, thus prolonging the time taken to land. The Panel finds that safe recovery of [redacted] was affected by the absence of effective communication and this was an **Aggravating Factor**.

1.4.132. **Recommendation. The RNAS Culdrose Delivery Duty Holder should review the use of D005A in order to ensure that all risks, especially those associated with emergency procedures, are As Low As Reasonably Practicable and Tolerable.**

1.4.133. As previously discussed, the ATC controllers were unable to provide the Pilot with the position or altitude of the RPAS as the primary radar was undergoing maintenance and the RPAS was not fitted with a transponder. The lack of primary radar feed was often mitigated by using the primary radar feed from Plymouth. On the day of the accident, however, the primary radar located in Plymouth was unserviceable. The Panel concluded that operating without a primary radar feed reduced the situational awareness of non-transponder equipped aircraft. The Panel finds that the reduced situational awareness in the radar control room that would have normally been provided via a primary radar feed was an **Other Factor**.

Witness 3
Witness 4

1.4.134. **ATC staffing levels.** Staffing at RNAS Culdrose ATC was reduced due to COVID-19 restrictions. However, staffing levels in ATC were already reduced and the section was noted to be carrying several gaps prior to the implementation of COVID-19 restrictions. The gaps reduced the ability to train new personnel as the most experienced of the controllers had been drafted to shipborne appointments. Where additional staff were available, personnel were kept out of the radar control room to ensure distancing was provided to meet COVID-19 restrictions. The separation of the personnel removed the ability for the controllers to request assistance. Assistance was required with the handling of [redacted] and only occurred when one of the controllers, who was on a

Witness 3
Witness 4

OFFICIAL - SENSITIVE

break, passed the open door to the radar control room catching the attention of the radar supervisor. The additional controller took [redacted] to a separate frequency. This left the approach frequency free for [redacted] and freed up the capacity of the radar supervisor to deal with the ongoing emergency situation.

1.4.135. The Panel concluded that better co-ordination between available ATC staffing and the daily flying task should occur. This should ensure that the latter is commensurate with the former, and adequate personnel are available to handle potential emergency situations. Where this was not possible, the flying task should have been adjusted to meet the staffing levels available on the day. Had staffing been adequate the controllers would have been able to contact the D005A users and ensure the RPAS was deconflicted. This would have allowed the Pilot to fly a gentler turn. As the Pilot had to take avoiding action for D005A the Pilot was now on the centreline heading the wrong way while still in a descent. This meant a tight 'tear drop' (where higher g would be experienced) was required to re-position for the long final approach. The higher g would have also reduced the low oil running time available. The Panel finds that the restricted capacity in the radar control room was an **Aggravating Factor**.

1.4.136. **Recommendation. The RNAS Culdrose Delivery Duty Holder should ensure the co-ordination of Air Traffic Control staffing levels with the planned flying activity in order to ensure that adequate capacity is available to respond to aviation emergencies.**

1.4.137. **Positional awareness.** Hawk T Mk1 pilots primary navigation method was using map and stopwatch techniques; however, most pilots would also fly with a SkyMap II Global Positioning System (GPS) which was fitted onto the cockpit coaming sitting just under the gunsight. The GPS provided navigational information such as speed, timing, heading, and track relating to pre-set waypoints. Areas to avoid, such as D005A could also be preloaded to the GPS. The Pilot flew with a SkyMap II on the day of the accident, however, this failed early in the flight and was unable to provide any positional awareness to the Pilot during the recovery to the airfield. The fault precluding the correct operation of the GPS was linked to the power source and the Pilot 'gave the cable a wiggle' but seemed unphased by the unserviceability which was eluded to as a common occurrence. There had only been nine DASORs relating to failures of the GPS on 736 NAS since 2011, and only four of those directly related to the failure of the GPS unit. The lack of reporting using DASORs as a result of an incident, in the Panel's opinion, demonstrated a cultural issue regarding reporting; particularly as the lack of a serviceable GPS during the accident sortie directly related to the infringement of D005A.

Witness 1

Exhibit 160

1.4.138. Had the Pilot informed ATC that his GPS was not serviceable, ATC would have been able to provide vectors to aid in [redacted] recovery. The Panel judged that there was a lack of positional awareness and this was partially due to the unserviceable GPS. The interaction with ATC regarding D005A affected the positioning of the aircraft and delayed the time taken to land. The Panel concluded that both issues caused a delay in landing. The Panel finds the unserviceable GPS and the interaction with ATC regarding D005A caused a delay in landing and were an **Aggravating Factor.**

1.4.139. **Aircraft track.** The Pilot got into an unfamiliar situation given the limitations of the OIL emergency. The Pilot was not flying a PFL (Figure 1.4.30) or flying what was expected for a fixed power approach (Figure 1.4.28). Whilst heading outbound from the overhead the descent also continued whilst quickly increasing the track miles to touchdown. The engine was, at this point still working, so a level off or a climb, utilising what thrust the engine was producing, could have been introduced to better the aircraft position in terms of glide back performance. The pilot arrived in the overhead where a forced landing could have been flown at 09:32. The additional 16 track miles flown over the next five minutes consumed more of the available 'low oil running' time. The Panel concluded that had the forced landing approach been flown from the initial entry to the overhead, it was highly likely that the aircraft would have landed within three minutes. The Panel finds that the extended track flown by the Pilot and the additional airborne time was an **Aggravating Factor**. Exhibit 51

Decision points

1.4.140. When the initial OIL caption occurred, the Pilot declared a 'PAN PAN' and made the decision to return to base. At this stage the intent was to return to the overhead and conduct a fixed power approach to RNAS Culdrose. Witness 1

1.4.141. With the initial onset of major engine vibrations at 09:34:55, the Pilot upgraded the 'PAN PAN' call to a 'MAYDAY'. The Pilot, who was extremely concerned about built up areas, decided to turn towards the coast and head out to sea, anticipating an engine failure. This would have resulted in an ejection and a subsequent ditching. At this point the aircraft was still heading away from the airfield and the height was still decreasing. Had the Pilot considered turning inbound to the airfield they would have been on short final approach at the point the engine vibrations reduced facilitating the potential for a safe landing. The Panel determine that if the decision had been made to turn inbound from the position 6 Nautical Miles (NM) away from the airfield where the vibrations were first experienced, the aircraft may have landed at RNAS Culdrose approximately three minutes later, albeit with a serious engine fault. The possible recovery to RNAS Culdrose would have been more likely as the subsequent 1.5-2g continuous turn would have been avoided, potentially extending the engine running time. Witness 1 Exhibit 14 Exhibit 142

1.4.142. Whilst turning out to sea the vibrations ceased. At approximately 09:35, the Pilot elected to continue the turn back inbound to the airfield. The recovery of RPM, reduction in vibrations and noise, and continued thrust output from the engine potentially gave hope that a successful recovery could be made. The turn back was made using 1.5g which was pulled for approximately 40 seconds, with the g peaking at 2.08g. In the Panel's opinion, given the wording in the FRCs (maintain - 1g nominal), the use of 1.5g may be appropriate under the circumstances. Witness 1 Exhibit 14 Exhibit 34 Exhibit 142

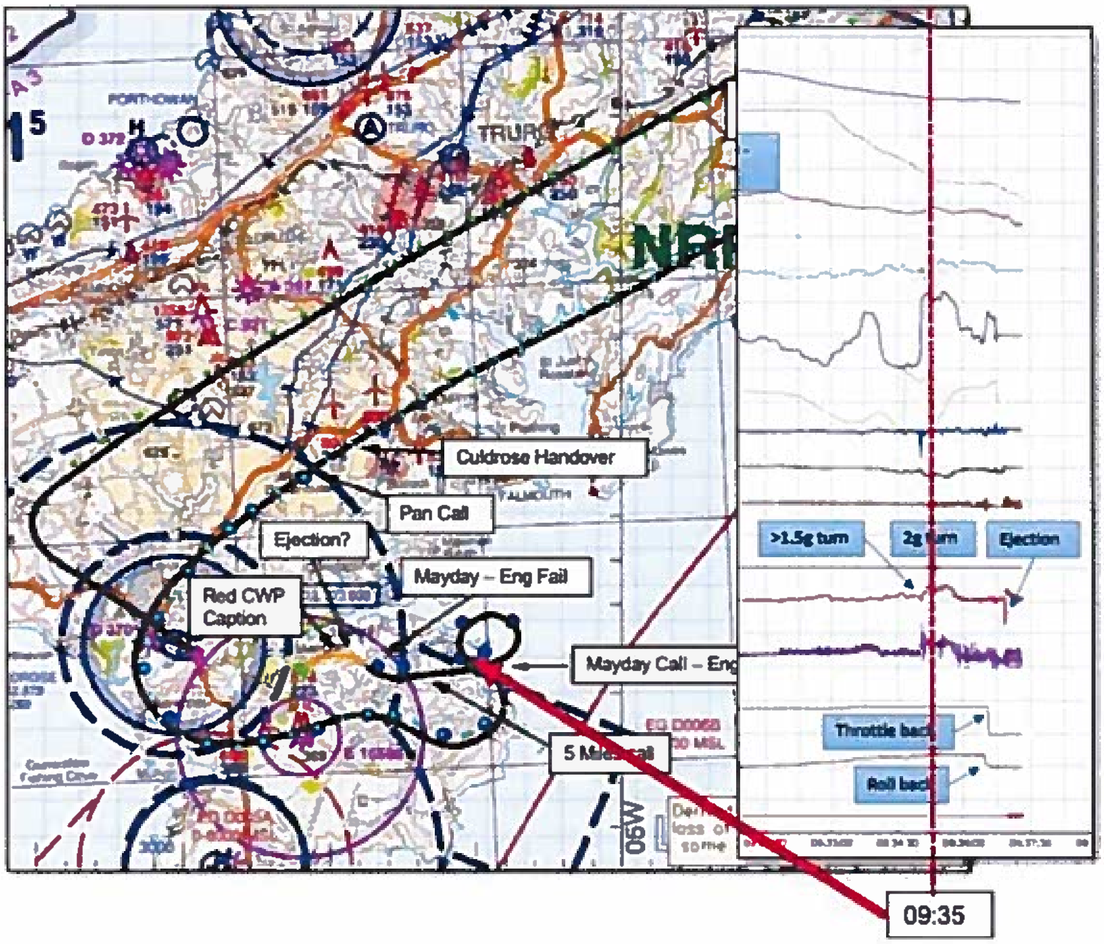


Figure 1.4.31 - Derived ground track from the MFPR data with corresponding MPFR data.

1.4.143. After rolling out of the turn on a westerly heading (Figure 1.4.31), tracking towards the airfield, the engine vibration and noise re-occurred at a higher intensity. The RPM 'rolled back' completely and the Pilot diagnosed a mechanical failure, shutting down the engine in accordance with the FRCs. An additional 4 to 5NM had now been flown since the decision to turn out to sea had been made. The point of impact from the airfield was approximately 4NM from the threshold of the runway in use. The Panel concluded that had the 270 degree turn not been flown the potential to land the aircraft at RNAS Culdrose may have been improved.

Witness 1
Exhibit 34
Exhibit 85
Exhibit 142

Radio telephony

1.4.144. **'PAN PAN' vs 'MAYDAY'.** The Pilot of [redacted] declared a 'PAN PAN' when reporting the issue with XX189 at 09:28:06. Civil Aviation Publication 413 defined states of emergency as: Exhibit 123

a. **Distress** – 'MAYDAY' (x3) – 'A condition of being threatened by serious and / or imminent danger and of requiring immediate assistance'.

b. **Urgency** – 'PAN PAN' (x3) – 'A condition concerning the safety of the aircraft or other vehicle, or some person on board or within sight, but does not require immediate assistance'.

1.4.145. The Panel agreed that the initial use of 'PAN PAN' was appropriate. However, knowing that D005A was active and potentially in the way of the Pilot's intended ground track, the use of 'MAYDAY' may have afforded the Pilot more priority. This may have also afforded ATC the time and capacity to pre-empt the issue with the RPAS and contact the D005A users instructing them to land, move clear, or provide adequate situational awareness to the controllers of their position aiding in the deconfliction.

1.4.146. In the opinion of the Panel the use of 'MAYDAY' would have been entirely appropriate when considering any malfunction with the engine of a single engine aircraft. The priority afforded by the use of 'MAYDAY' should reduce interaction outside of the cockpit during the latter stages of the approach. It could also positively affect aircraft routing / time taken to land, as was seen during this accident. Exhibit 82

1.4.147. The Panel concluded that the Pilot's choice of 'PAN PAN' was not a factor in the accident, however, judged that the use of 'MAYDAY' at an earlier stage in the recovery of the aircraft may have afforded a greater degree of priority from supporting agencies throughout the recovery to RNAS Culdrose. The Panel finds that the Pilot's decision to use 'PAN PAN' was **not a factor**.

Hawk T Mk1 vs Hawk T Mk2

1.4.148. The airframe and avionics between the variants of Hawk differ significantly, however, the engine was very similar, with the Hawk T Mk2 using the Adour Mk951, an engine based on the Adour Mk151 with the addition of a Full Authority Digital Engine Control system. The oil system components were also very similar, however, the MCD housings and MCDs were of a different modification state[52] (Figure 1.4.32). The MCDs on the Adour Mk951 had 'Tommy Bars' fitted; this aided the confirmation of correct fitment by demonstrating the correct orientation. However, references to an MCD with 'Tommy Bars' were included in the Hawk T Mk1 ADS even though that particular MCD was not cleared for use on the Hawk T Mk1. The illustrations of MCDs with 'Tommy Bars' were incorrectly included in the Mk1 ADS and eluded to a non-existent safety barrier. The Panel concluded that the Hawk T Mk1 ADS contained references to equipment not cleared for use on that mark. The Panel **observed** that the incorrect references to 'Tommy Bars' should have been noted and corrected prior to publishing but also noted by R-R and Hawk T Mk1 users. Exhibit 90 Exhibit 91 Exhibit 77

[52] Internal insert of new MCD housing is made from steel rather than aluminium.

h

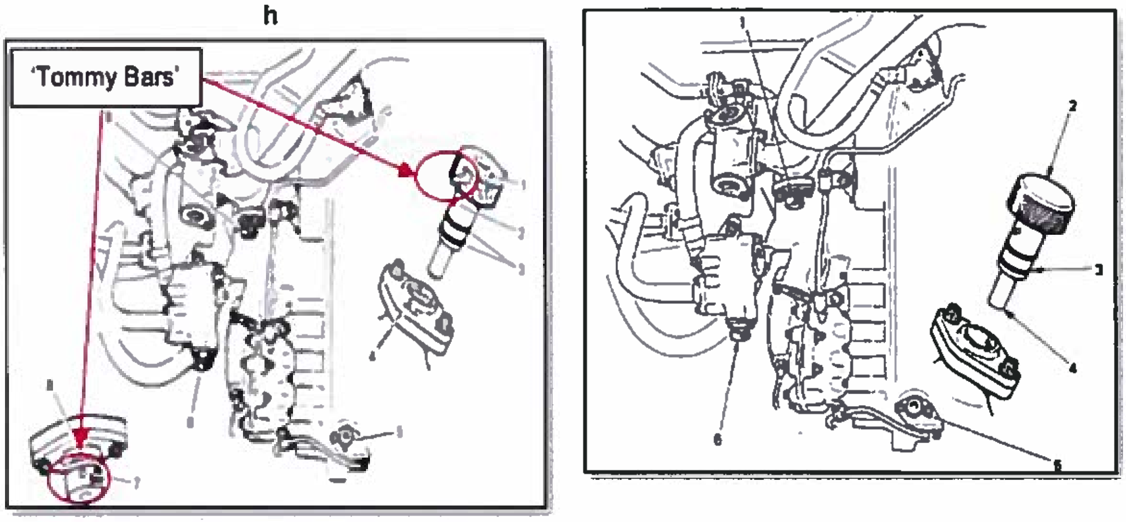


Figure 1.4.32 - MCDs with 'Tommy Bars' from the AMM (left) compared to Adour 151 MCDs without 'Tommy Bars' from the R-R Engine Test Servicing Manual (right).

1.4.149. **Recommendation. The Hawk Type Airworthiness Authority should review the Air System Document Set in order to ensure they correctly reflect the configuration of the aircraft.**

1.4.150. **Recommendation. The Hawk Type Airworthiness Authority should determine whether the risk associated with the use of Magnetic Chip Detectors is fully understood in order to ensure their use remains As Low As Reasonably Practicable and Tolerable.**

1.4.151. Given the similarities between the two engine variants, there was an expectation the MCD maintenance procedures would be common. However, there are noticeable differences across the marks and across the R-R, BAE Systems and RAF document sets. The Panel concluded that the MCD maintenance procedures for the Mk951 engine are significantly improved and in the opinion of the Panel, provided clearer guidance. The Panel finds that differing quality and clarity of the MCD maintenance procedure across the engine types was an **Other Factor**.

1.4.152. **Recommendation. The Hawk Type Airworthiness Authority should standardise Magnetic Chip Detector maintenance procedures across all Adour marks in order to ensure commonality of standards across the fleet.**

1.4.153. The Panel judged that the wording in the T Mk1 FRCs was ambiguous, ill-defined and didn't instil the sense of urgency required with an issue of this nature. The wording in the T Mk2 FRCs, in the opinion of the Panel, corrected the faults of the T Mk1 FRCs and provided pilots with much clearer wording and guidance, that would ensure a pilot understood the severity of the emergency. It is the opinion of the Panel, that an opportunity had been missed to improve the Hawk T Mk1 FRCs (Figure 1.4.33).

Exhibit 81
Exhibit 94

OIL PRESSURE LOW

OIL

1. Throttle .... Smoothly set between 78 - 87%
2. RPM .... Monitor and maintain with smooth, progressive throttle movements
3. Maintain 1g nominal
4. Land .... ASAP

WARNING 1: Loss of oil pressure will result eventually in engine seizure

WARNING 2: Bearing loads increase as altitude reduces

WARNING 3: Increasing vibration is indicative of early failure

WARNING 4: The optimum RPM range to prolong engine life is 80-85%

OIL PRESSURE

OIL

1. Throttle .... Set 78-87% RPM
2. Maintain RPM using slow, smooth throttle movements
3. Land ASAP
4. Note:
   - Increased vibration and sudden decreases in RPM may be observed
   - Engine may seize. Minimising RPM changes, throttle movements and maintaining 1g flight may delay seizure
5. Engine .... After landing, shutdown ASAP

Figure 1.4.33 - Hawk T Mk1 Oil Pressure Low Drill vs Hawk T Mk2 Oil Pressure Low Drill.

1.4.154. Defence Aircrew Publications Squadron confirmed that their role was to assure the ADS of both the Hawk T Mk1 and T Mk2. Both ADS were assessed as Green[53] with the exception of the T Mk1 Operating Data Manual which was assessed as Amber[54]. Unit Authenticators (UA), in conjunction with the TAA were responsible for amendments to the ADS. Exhibit 93 Exhibit 112 Exhibit 146

1.4.155. The Panel **observed** that at no point had rectification activity taken place to incorporate the improvements made in the T Mk2 ADS into the T Mk1 ADS leaving multiple issues remaining in the T Mk1 ADS that had been addressed elsewhere. It also appeared that the T Mk1 UA may not have been aware of the improvements made to the T Mk2 ADS. Therefore, they could not have assessed their suitability for incorporation into the T Mk1 ADS. The Panel concluded that had the Pilot been presented with the words and actions in the Hawk T Mk2 FRCs they may have flown a more expeditious approach resulting in the aircraft landing, albeit, with a major engine issue. The Panel finds that the wording of the Hawk T Mk1 ADS was an **Other Factor**.

1.4.156. **Recommendation. The Hawk Type Airworthiness Authority should compare the Hawk T Mk1 and Hawk T Mk2 Flight Reference Cards and Aircrew Manuals to identify good practice and generate amendments in order to ensure all documents contain standardised, concise, and accurate advice.**

1.4.157. **Recommendation. The Hawk Type Airworthiness Authority should review the Hawk T Mk1 Air System Document Set in order to remove ambiguity and ensure that the most up-to-date advice is available to aircrew in all documents, and that the vital information contained is standardised.**

[53] Defence Aircrew Publications Red, Amber, Green (RAG) analysis in accordance with Defence Aircrew Publication's local orders - Green was considered 'fit for purpose'(FFP).

[54] Defence Aircrew Publications RAG - Amber is considered as containing deficiencies which degrade FFP.

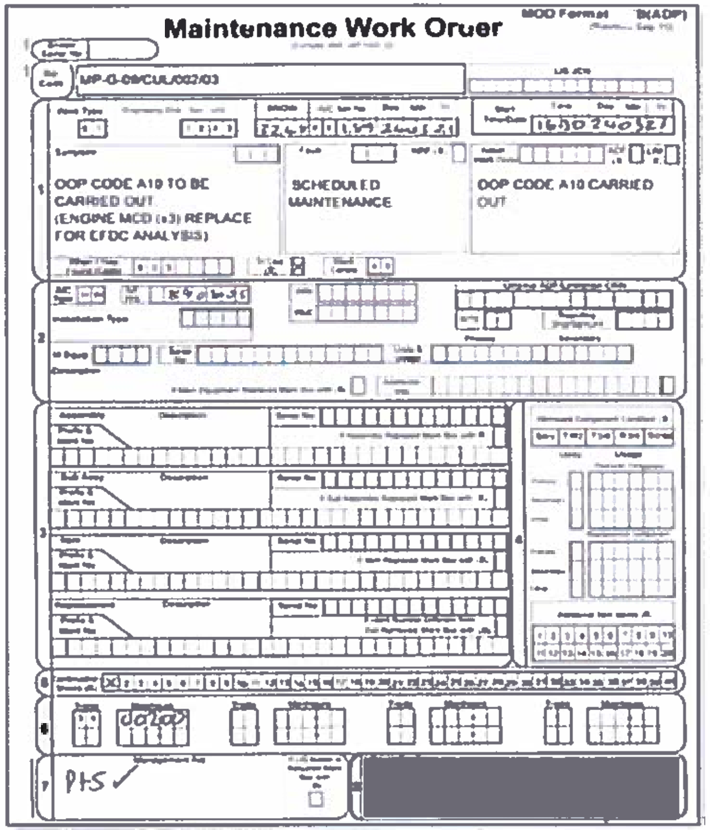
Out of Phase Maintenance Procedure A10 (MCD Change)

1.4.158. The procedure for changing the MCDs was laid down in the AMM and called for a routine removal and replacement of the MCDs every 25 flying hours. This procedure required clean MCDs to be fitted on each occasion and the old detectors to be securely packaged and dispatched to an appropriate examination centre. The examination centre, as annotated in the title of the A-10 procedure (Figure 1.4.34) to be an Early Failure Detection Cell (EFDC), would check the MCDs for debris, analyse any debris found, and then service them ready for re-issue. 736 NAS Engineering department were using a Pre-Printed Maintenance Work Order (PPMWO) (Figure 1.4.34) to document the maintenance process. The locally produced PPMWO correctly reflected the work content required in the AMM.

Exhibit 90
Exhibit 7

1.4.159. Engineering personnel were certifying the work on the PPMWO but were not conducting the procedure in accordance with either the PPMWO or the AMM. They were not using an EFDC for analysis. Instead, they were removing and determining the amount of debris from the MCDs before attaching the debris to a locally produced form. This form was then sent to 1710 NAS. 1710 NAS would then analyse the debris and report back on the findings, effectively performing the analysis role of the EFDC but crucially not servicing the MCD. 1710 NAS held the appropriate authorisations and equipment to conduct the procedure in the same manner as an RAF EFDC.

Exhibit 7
Exhibit 90
Exhibit 95
Witness 12
Witness 13



Maintenance Work Order

MOD Form 707A(ADP)

MP-G-09/CUL/002/03

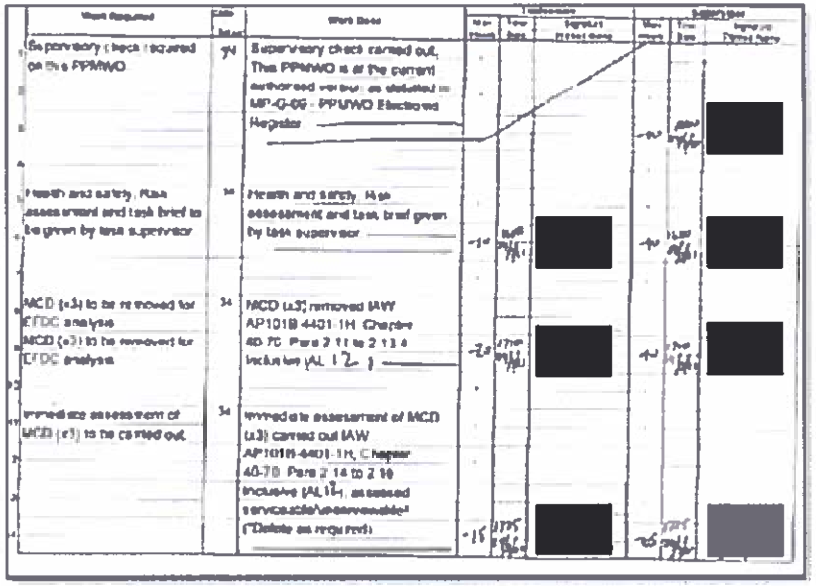
1 OOP CODE A10 TO BE CARRIED OUT (ENGINE MCD (x3) REPLACE FOR EFDC ANALYSIS)

SCHEDULED MAINTENANCE

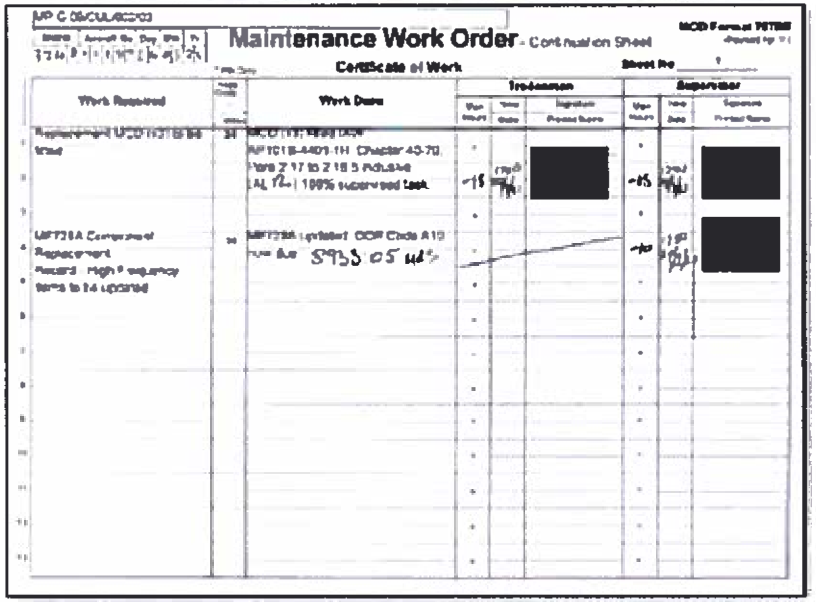
OOP CODE A10 CARRIED OUT

PHS ✓

[redacted]



Work Required	Work Done	Tradesman	Supervisor
Supervisory check required on this PPMWO	Supervisory check carried out. This PPMWO is at the current authorised version as detailed in MP-G-09 - PPMWO Electronic Register		[redacted]
Health and safety, Risk assessment and task brief to be given by task supervisor	Health and safety, Risk assessment and task brief given by task supervisor	[redacted]	[redacted]
MCD (x3) to be removed for EFDC analysis. MCD (x3) to be removed for EFDC analysis	MCD (x3) removed IAW AP101B-4401-1H Chapter 40-70 Para 2.11 to 2.13.4 inclusive (AL 12)	[redacted]	[redacted]
Immediate assessment of MCD (x3) to be carried out	Immediate assessment of MCD (x3) carried out IAW AP101B-4401-1H, Chapter 40-70 Para 2.14 to 2.16 inclusive (AL 12), assessed serviceable/unserviceable* (*Delete as required)	[redacted]	[redacted]



MP-G-09/CUL/002/03

Maintenance Work Order - Continuation Sheet

MOD Form 707B

Certificate of Work

Work Required	Work Done	Tradesman	Supervisor
Replacement MCD (x3) to be fitted	MCD (x3) fitted IAW AP101B-4401-1H Chapter 40-70 Para 2.17 to 2.18.5 inclusive (AL 12) 100% supervised task	[redacted]	[redacted]
MF728A Component Replacement Record - High frequency items to be updated	MF728A updated. OOP Code A10 next due 5953.05 hrs		[redacted]

Figure 1.4.34 - Scan of MWO used to initiate MCD change on XX189 (3 images).

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1.4.160. The Panel examined the OOP A10 maintenance procedure further and discovered other issues, those were:

a. Not following the correct procedure.

b. Signing the Maintenance Work Order (MWO) for the correct procedure which did not reflect the work carried out.

c. Conducting initial assessments of the MCDs without the correct authorisation.

d. Conducting the initial assessments of the MCDs without the approved equipment.

e. Not utilising an EFDC as per the AMM.

f. Not conducting magnetism checks (as per the EFDC).

g. Using 1710 NAS instead of an EFDC without an authorised deviation.

1.4.161. The MCDs were being refitted after unqualified inspection instead of being replaced with clean serviceable MCDs as required by the procedure.

1.4.162. These unauthorised deviations had been occurring for a period of time in excess of 15 years and went undiscovered by the many first, second and third party audits. The process used by 736 NAS was also different to the R-R procedure. The actual process used closely reflected that employed on rotary platform gas turbine engines; many personnel had considerable rotary experience. However, the reason for the deviation was detailed in the MAM-P where it was described the that different sS needs may result in slightly differing Early Failure Detection (EFD) procedures. The procedure followed by 736 NAS was in-line with the RN approach to EFD but was still a deviation from the procedure authorised in the AMM for MCDs on the Hawk T Mk1.

Exhibit 133
Exhibit 48

1.4.163. The fact that these deviations had been undetected for such a long period highlighted to the Panel problems with the assurance regime. Although outside the scope of this Inquiry, the Panel judges that because of QA process issues, it is likely that similar deviations from the AMM (approved process) might exist on 736 NAS. QA is further explored in para 1.4.259.

1.4.164. 736 NAS personnel used the 'inspect and repair as necessary'[55], whereas the EFDC used engineering 'best practice' when conducting the o-seal ring inspection and replacement. This meant that the MCD o-seal rings could be continually used without replacement, with a serviceability check being conducted at squadron level. The replacement MCDs issued from the

Witness 12
Witness 13
Exhibit 154

[55] 'Ensure seals are serviceable and fitted correctly. Inspect the seal rings for signs of swelling, splitting, distortion and abrasion. Replace if found to be in poor condition'.

EFDC had their o-seal rings replaced as part of the maintenance prior to issue. The Panel finds that the deviation while conducting the MCD change on XX189 was an **Other Factor**.

1.4.165. **Recommendation. The RNAS Culdrose Delivery Duty Holder should re-iterate the importance of adhering to procedure in order to ensure a reduction in deviation from authorised process.**

1.4.166. **Recommendation. The RNAS Culdrose Delivery Duty Holder should ensure that the correct mechanism for challenging or changing engineering related processes is understood in order to prevent future unauthorised deviations.**

1.4.167. **Recommendation. The RNAS Culdrose Delivery Duty Holder should review the conduct of all Hawk maintenance procedures in order to ensure compliance with the Aircraft Maintenance Manual.**

1.4.168. **Recommendation. The RNAS Culdrose Quality System Owner should review the effectiveness of aviation related audit processes to ensure that latent problems are detected and eliminated in order to improve Air Safety.**

Policy

1.4.169. The MAA RAs devolved maintenance responsibilities to single Services (sS) to interpret and apply. However, where multiple services were operating the same aircraft type this has allowed differing practices to evolve across the fleet. This was the case with Hawk working under three ADH chains and differing sS policies. As highlighted in the Hawk E2E report, there was no single source of risk to life ownership within the Hawk duty holding construct. Additionally, operating practices were varied across the fleet. There was no effective mechanism to identify and standardise best practise across the entire Hawk fleet. However, the DH construct has now been simplified with only two ADH chains existing, presenting a more aligned and less complex construct. The Panel **observed** that a fleet operated under multiple ADHs led to a complex in-service operating model which did not allow for standardised delivery.

Exhibit 39

1.4.170. The Panel considers that many of the issues identified during the investigation into this accident could have a read across to other aircraft types.

1.4.171. **Recommendation. Head Defence Equipment and Support Airworthiness Team, should ensure that other Type Airworthiness Authorities consider the read across of technical recommendations from this Service Inquiry in order to prevent similar occurrence on other platforms.**

Post-Accident Events

The failure of the lifesaving jacket

1.4.172. Post ejection, while descending under the parachute canopy, the Pilot of XX189 manually inflated their Mk42M Lifesaving jacket (LSJ) only for it to deflate almost immediately. Fortunately, the ejection was over land, however, had the ejection been over the sea, as per the Pilot's intentions after the first set of engine vibrations, serious injury or death would have been highly likely. The failure of the LSJ, a piece of equipment relied upon by aircrew to provide lifesaving protection in the water after the abandoning of a stricken aircraft, identified multiple lines of inquiry, and has been investigated as an incident associated with the loss of the aircraft accident. Witness 1

736 Survival Equipment Section

1.4.173. 736 Survival Equipment Section (SES) was a small three-person satellite section who operated under the command of CO 736 NAS. The structure of the section allowed for training, supervision, and reporting. Staffed by an Able Rate, a Leading Hand, and a Chief Petty Officer, all from the RN's Survival Equipment Technician (SET) trade. The section worked out of the 736 NAS operations building, situated away from the main stn Survival Equipment (SE) bay, conducting routine and unscheduled maintenance on all AEA including helmets and oxygen masks, g-pants, Immersion Protection Garments (IPG), emergency beacons and LSJs (Figure 1.4.35). Exhibit 166

1.4.174. Phase 2 trade training for SETs was conducted at the Defence School of Aeronautical Engineering, Gosport, separate from the RAF Trade Group (TG) 13[56] personnel. However, the training followed a similar syllabus with a similar output standard at the end of the course. Exhibit 113

1.4.175. The SES personnel were all suitably qualified and held the appropriate authorisations for their rank and position, they had all received competence checks as required. They also confirmed that they understood the Digital Air Publications (DAPs) detailing the tasks required of them at the time of the incident. Exhibit 100 Exhibit 101 Exhibit 102 Witness 5 Witness 11 Witness 16

1.4.176. The AEA worn by the Pilot and Passenger had all been serviced using the relevant DAP and was in date for servicing and maintenance at the time of the incident. The Pilot and Passenger wore individually issued equipment and apart from the Pilot's IPG which was from the temporary loan pool.

[56] TG13 personnel make up the RAF's Survival Equipment trade.

Figure 1.4.35 - 736 SES Office and maintenance area – View 1.

The lifesaving jacket

1.4.177. The Mk42M LSJ was made up of a waistcoat which contains the flotation assembly; comprising a stole restrainer and stole. The waistcoat outer was manufactured from aramid[57] fabric twill weave. The stole restrainer was manufactured from yellow polyurethane coated nylon fabric. The stole was manufactured from white polyurethane coated nylon fabric, welded around the edge, forming an inflatable chamber with the necessary water / airtight properties. The two layers of fabric used to make the stole were assembled with the two PU coated faces together then radio frequency welded to form a seam.

1.4.178. The failed stole was manufactured in Apr 2016 and passed all the manufacturers testing requirements. The failed stole was first fitted on 14 Dec 2020. Exhibit 103

1.4.179. Following the incident, the lower half of the LSJ on the left hand (LH) side was cut by paramedics attending the scene to remove it from the Pilot. The LSJ remained at the accident site overnight and then was sent for inspection by RAFCAM where the tear to the neck area was noted. Exhibit 103

[57] Aramid fibre is a synthetic fibre in which the fibre-forming substance is a long-chain synthetic polyamide.

Analysis

1.4.180. The LSJ worn by the Pilot (Figure 1.4.36) should undergo a 30-week cycle of maintenance. However, the Mk42M had recently[58] undergone a conversion from dual stole to single stole; the 30-week maintenance was claimed as part of that modification. The modification enabled pilots a greater degree of movement due to the reduced amount of material around the neck. This also increased comfort. It also allowed the integration of the Emergency Personal Locator Beacon (EPLB)[59]. The floatation and freeboard on the Mk42M (single stole) was like that of the Mk42M (dual stole). Witness 5

Figure 1.4.36 - MK42M LSJ fitted on a mannequin. The restrainer and stole cannot be seen in this image.

1.4.181. Table 1.4.3 assesses the possible factors that may have caused the LSJ (Figure 1.4.37) to deflate.

[58] Beginning in Dec 2020 and all LSJs complete by Mar 2021.

[59] SI – DSA/SI/03/12/ZD743 ZD812, Rec 1.5.20 – 2013.

Cause	Lines of Inquiry	Panel Assessment
Modification to Single Stole	• Pressure to complete task • Difficulty of task • Quality of DAP • Size of task	Not a factor
Damage during ejection sequence	• MDC spatter or shards of canopy	Not a factor
Material Failure	• 1710 NAS analysis of material	Not a factor
Over inflation	• Gas bottle • Gas bottle pressure	Not a factor
EPLB Antenna	• Damage to antenna • Marks on stole	Factor
Incorrect Maintenance	• Training • Unfamiliarity with procedure • Oversight • Complacency • Quality of DAP • Maintenance Area • Maintenance equipment	Factor
Incorrect Packing	• Stole was likely incorrectly seated within the restrainer • Stole restrainer was likely misfolded within protective cover • EPLB antenna likely trapped the stole • Incorrectly routed Mic / Tel lead • Quality of DAP	Factor
Incorrect Stowage	• LSJs should be stowed on metal hangers, as per the DAP, but were found on 's hooks'	Possible Factor
Incorrect Wear	• Waist straps pulled tight but not uniform on left and right • Incorrect sizing	Not a factor

Witness 5
Exhibit 103
Exhibit 103
Exhibit 104
Exhibit 103
Witness 5
Exhibit 105
Exhibit 125
Exhibit 107
Exhibit 103

Table 1.4.3 - Analysis of factors leading to LSJ failure.

Modification to single stole

1.4.182. The modification to single stole was introduced via the re-issue of the DAP. The procedure to remove the dual stoles and replace with a single stole was similar to that of a routine 30-week maintenance inspection. 736 NAS had a total of twelve Mk42M LSJs to convert. Whilst there was no direct Exhibit 75
pressure to complete the task, the aircrew relied on having the approved modifications to fly. The Panel believed that the perceived pressure was likely to have led to an increased possibility of a HF error when conducting a routine and repetitive task.

1.4.183. The DAP, full of pictures and detailed explanations, was initially deemed by the SETs and the Panel to be simple enough to follow and fit for purpose. Stage checks were required to allow supervision of some tasks. The equipment required to complete the tasks was detailed within the DAP. Witness 5 Witness 11 Witness 16

1.4.184. The main SE section was available to assist with the conversion, however, this option was not explored. The Supervisor, during interview, discussed section pride and the attitude that they would get the work done, no matter what. Witness 5

1.4.185. The issues associated with the failure of the LSJ (Table 1.4.3) worn by the Pilot were likely to have been introduced during the conversion to single stole, when the LSJ was repacked. The Panel determined that the conversion itself was highly unlikely to be the reason behind the incident. The issues associated to the LSJ failure would have occurred whether the conversion existed or not. The Panel finds that the conversion from double to single stole was **not a factor**.

Assessment of damage to the LSJ

1.4.186. The waistcoat was visually examined by RAFCAM, and the cut made by the paramedics on the LH side of the waistcoat and restrainer is shown at Figure 1.4.37. The front and rear internal and external surfaces were visually examined for evidence that might explain the failure. A minor amount of soiling was visible on the front face of the pouch on both left hand (LH) and right hand (RH) sides (as worn) (Figure 1.4.38). The soiling was subsequently confirmed as Miniature Detonating Cord (MDC) spatter resulting from the ejection. Exhibit 103

1.4.187. The restrainer was received as two sections. Visual examination indicated all the associated survival equipment remained attached. A minor amount of soiling was visible on the LH and RH side front surfaces. The external surfaces of the restrainer were examined for evidence of fraying or puncture marks and none were visible. The visual examination (aside from the paramedic cut) revealed no other evidence likely to be causal to the failure. Exhibit 103

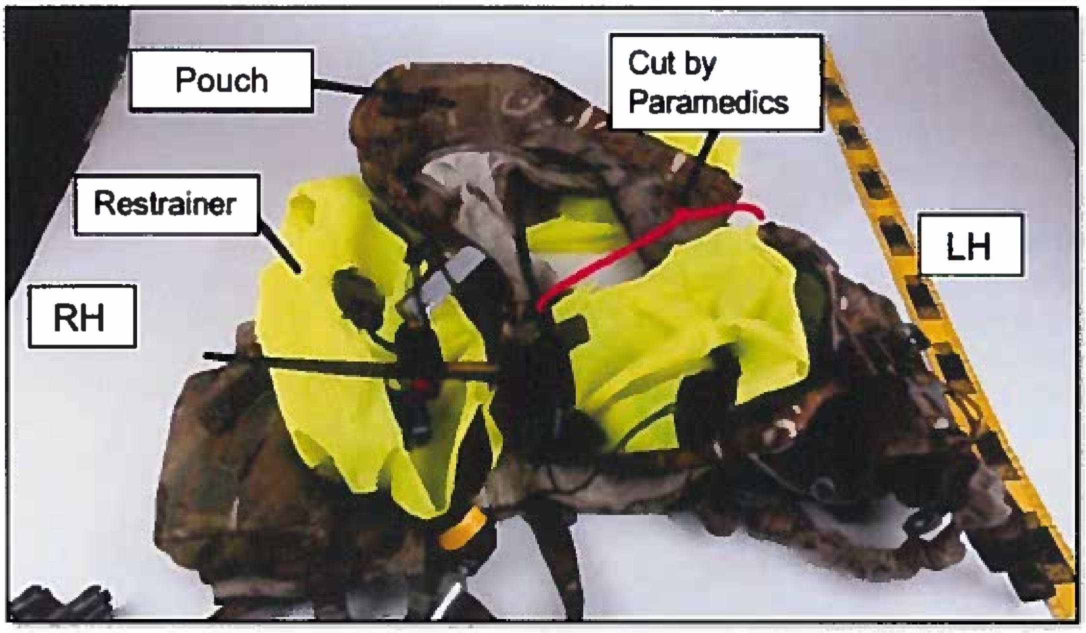

Figure 1.4.37 - Showing as-received (by 1710 NAS) waistcoat and restrainer (in-service failure).

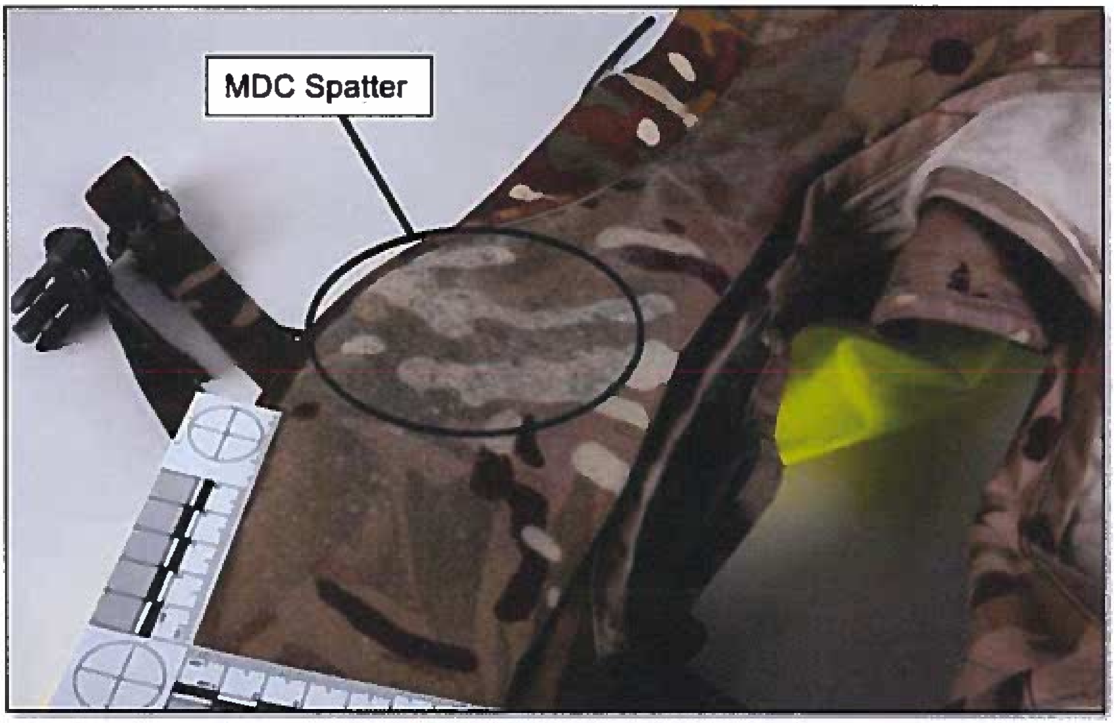

Figure 1.4.38 - Showing MDC spatter on the front face of the waistcoat pouch (in-service failure).

1.4.188. The Panel determined that it was highly unlikely that the LSJ was damaged during the ejection sequence. The Panel finds that damage during the ejection sequence was **not a factor**.

Material failure

1.4.189. Detailed analysis of the LSJ was conducted by 1710 NAS using visual, and stereo microscopy examination techniques. The LH lobe had a horizontal cut about halfway down the length, this was made by the paramedics who cut the LSJ from the Pilot. The oral inflation tube was firmly attached, and the internal foam separator was also intact. The external welded seam was examined for evidence of fraying and puncture wounds and neither were observed. However, both front and rear surfaces of the stole exhibited creasing (rear surface to a lesser degree). A tear to the LH lobe around the inner welded seam by the neck was observed (Figure 1.4.39 and Figure 1.4.40). Exhibit 103

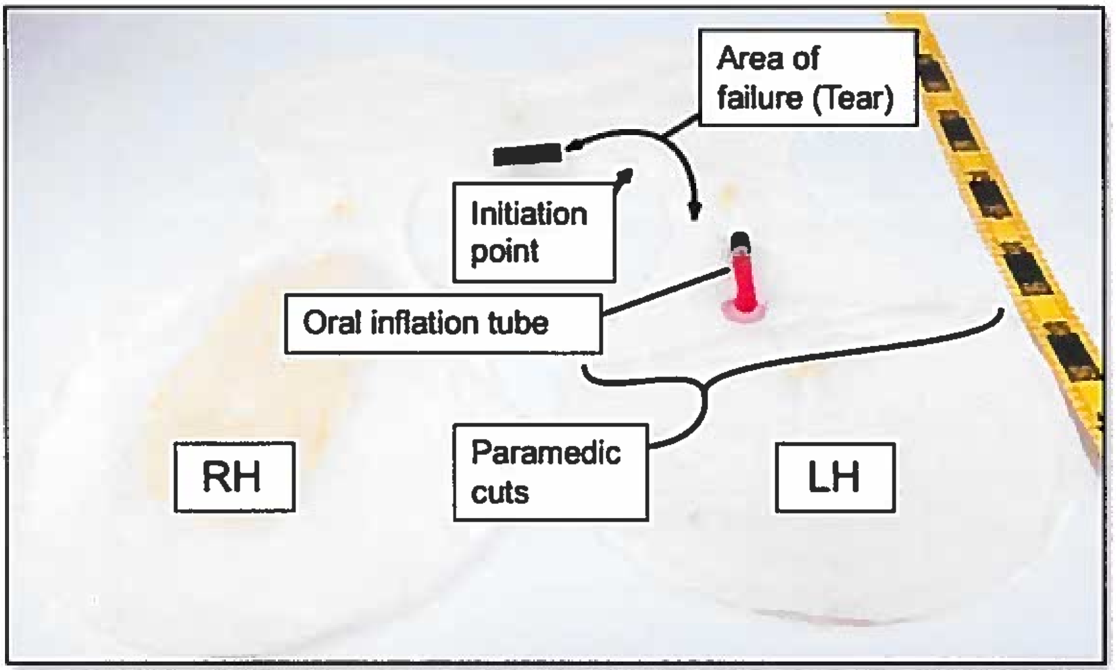

Figure 1.4.39 - Mk42M single stole (front view) highlighting findings from 1710 NAS.

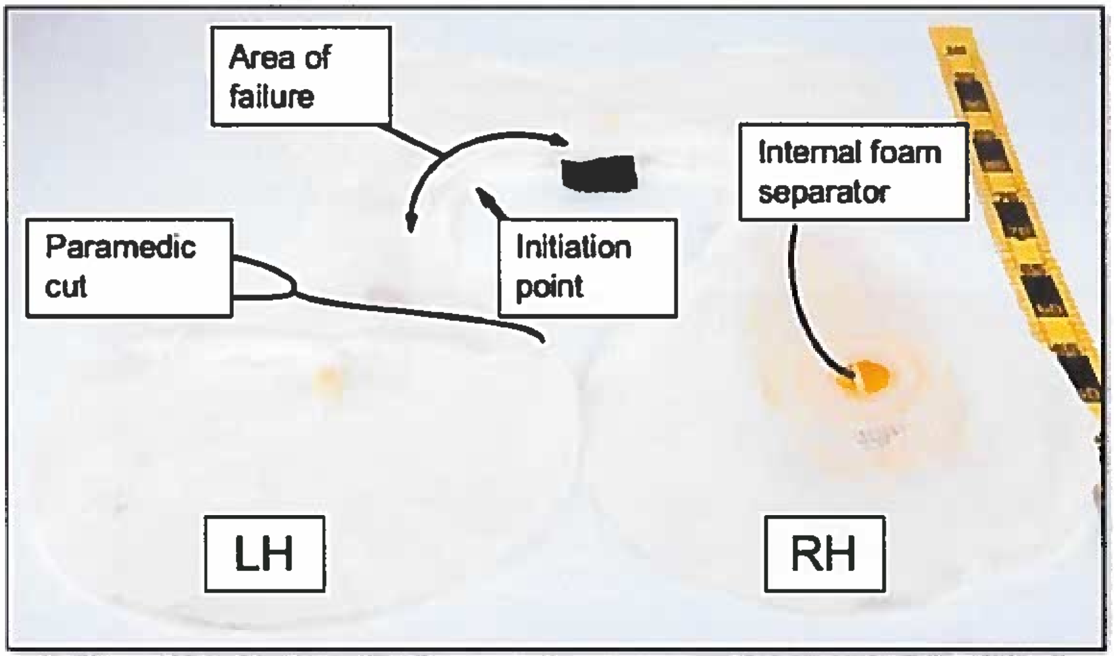

Figure 1.4.40 - Mk42M single stole (rear view) highlighting findings from 1710 NAS.

1.4.190. The tear measured 16cm in length. Approximately 2cm from the RH end of the tear there was a change in direction of the tear where it ran approximately 1cm vertically, before it then continued in the original direction. 1710 NAS assessed the vertical tear was secondary to the main tear. Exhibit 103

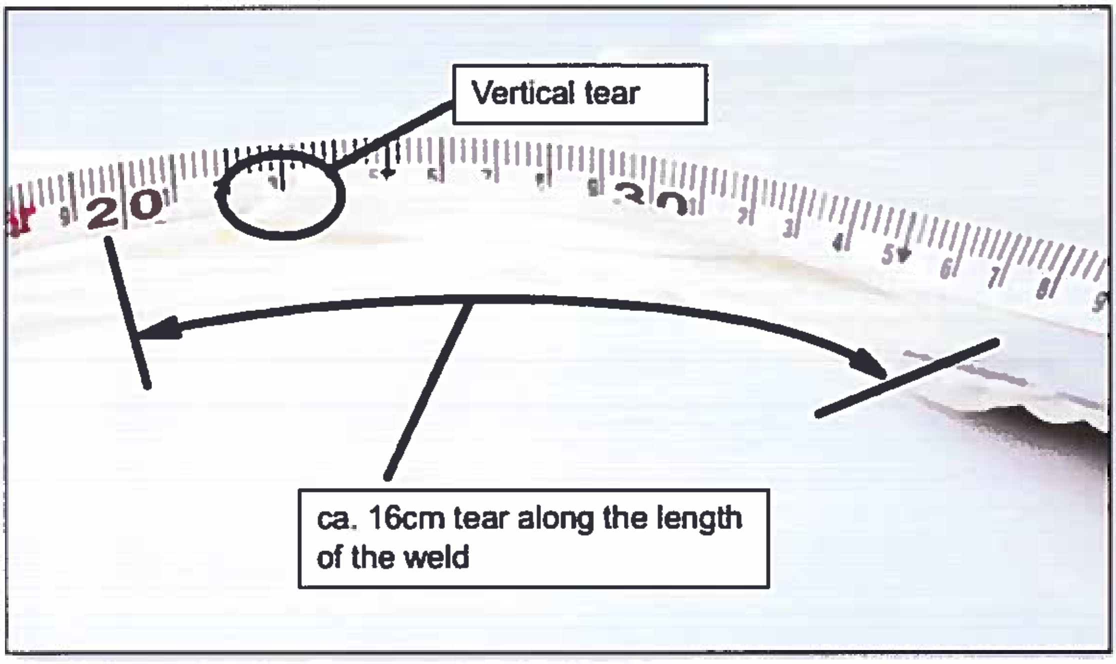

Figure 1.4.41 - Approximate length of the tear to the failed stole.

1.4.191. The area of the failure (Figure 1.4.41 and Figure 1.4.42) was sectioned to enable examination using stereo microscopy. This technique revealed the amount of material mechanically damaged during the failure event changed along the length of the tear (degree and depth of fibre pull out). There was no evidence to indicate the welded seam had failed and it remained intact. The tear occurred at the pressure loaded edge of the welded seam. Exhibit 103

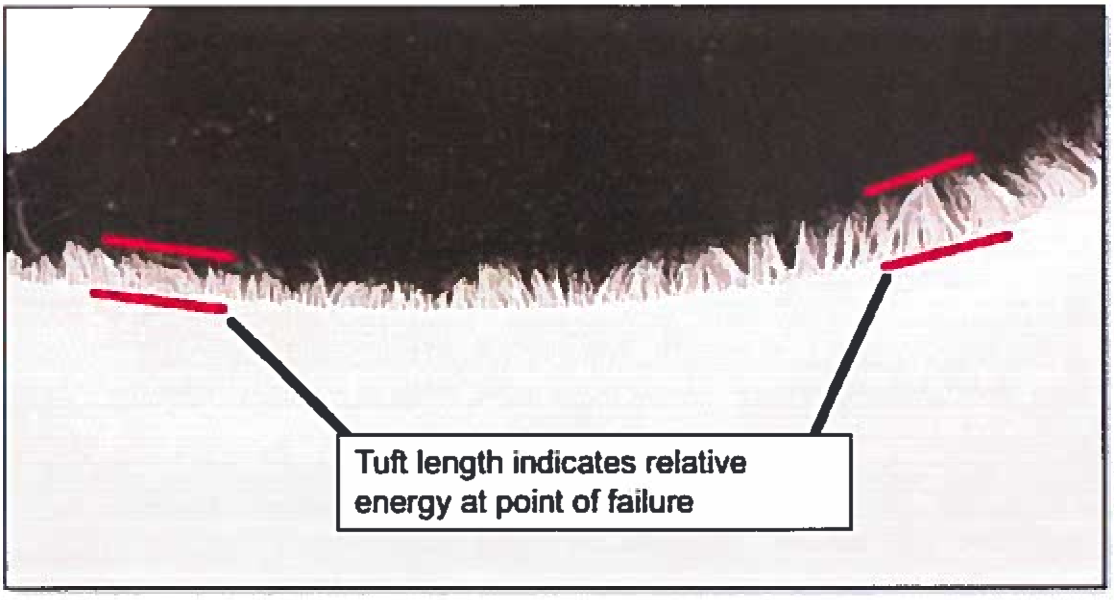

Figure 1.4.42 - Change in degree and depth of the fibre pull on the failed stole.

1.4.192. From the degree, depth and direction of the fibre pull it was possible to identify the area of the initiation for the tear. The initiation location was at approximately 45 degrees around the inner welded seam by the neck. Exhibit 103

The evidence indicated the tear occurred as a single over-pressurisation event. Strength testing of the material indicated that the material met the minimum requirements specified.

1.4.193. The Panel concluded that the material performed within design specification. However, the material experienced loads beyond its design specification. In isolation, a failure of the material was highly unlikely to be the cause of the stole failure. The Panel finds that a failure of the material **was not a factor**.

Over pressurisation

1.4.194. The failure of the LSJ could have been caused by a sudden over-pressurisation of the stole. However, the CO2 cylinders were confirmed as the correct size (40 grams of CO2) for the Mk42M. The CO2 cylinder and inflation unit functioned correctly to initially inflate the LSJ. The possibility of the CO2 cylinder being over charged was assessed as highly unlikely as the cylinders were single use and pre-charged in batches by the manufacturer. The Panel determined that an over pressurisation caused by an overcharged cylinder was highly unlikely. The Panel finds that an over pressurisation was **not a factor**. Exhibit 104

Emergency Personal Locator Beacon antenna

1.4.195. An incorrectly folded restrainer or an incorrectly stowed Emergency Personal Locator Beacon (EPLB) antenna could affect the inflation of the LSJ by causing constrictions as the LSJ inflated. Concern about the effect of the EPLB antenna tip on the fabric was highlighted in the Air Commodities Delivery Team (ACDT) report, but in all examined cases the theory was discounted as there were no marks noted on any of the examined LSJs. However, as detailed in Figure 1.4.43 and Figure 1.4.44, the location of the EPLB antenna tip corresponded to the area of the tear on the failed stole and constriction around the antenna tip was observed during the subsequent unpacking of reference LSJs conducted by 1710 NAS. Exhibit 103 Exhibit 105 Exhibit 125

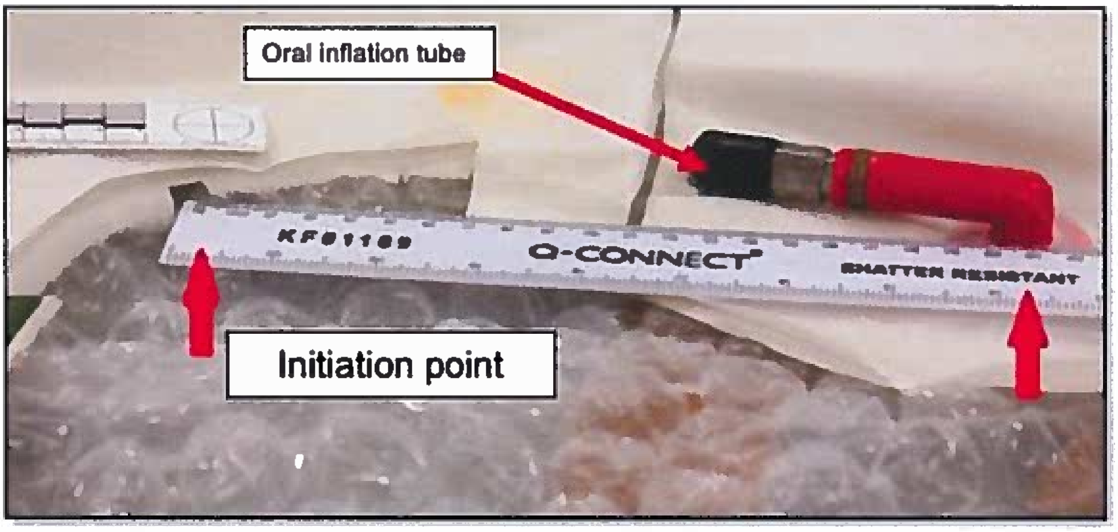

Figure 1.4.43 - Corresponding position measurements for the EPLB antenna on the in-service failed stole.

Figure 1.4.44 - Position measurements for the EPLB antenna on a reference LSJ.

1.4.196. There had been no previously reported failures relating to the position of the EPLB antenna alone, however, the Panel determined that when combined with other factors (below) the positioning was highly likely to be an issue. The Panel concluded that the positioning of the EPLB antenna was a factor in the incident. The Panel finds that the positioning of the EPLB antenna was a **Causal Factor** in the failure of the LSJ.

1.4.197. **Recommendation. Head of Air Commodities Delivery Team should examine the design of the Emergency Personal Locator Beacon antenna to determine if the in-service antenna is the most appropriate design for use with the Mk42M lifesaving jacket in order to prevent similar interaction with the restrainer during inflation in the future.**

Incorrect maintenance

1.4.198. **Inflation.** The Inflator / Deflator used by 736 NAS SES to conduct inflation tests of the LSJ during routine maintenance was found to be the incorrect Inflator / Deflator. The correct Inflator / Deflator was detailed, including NATO Stock Number in the DAP and was available to demand. The Inflator / Deflator found on 736 NAS (Figure 1.4.45) only provided 0.5 pounds per square inch (psi) of pressure rather than the 1psi of pressure prescribed.

Exhibit 105
Exhibit 108
Exhibit 140

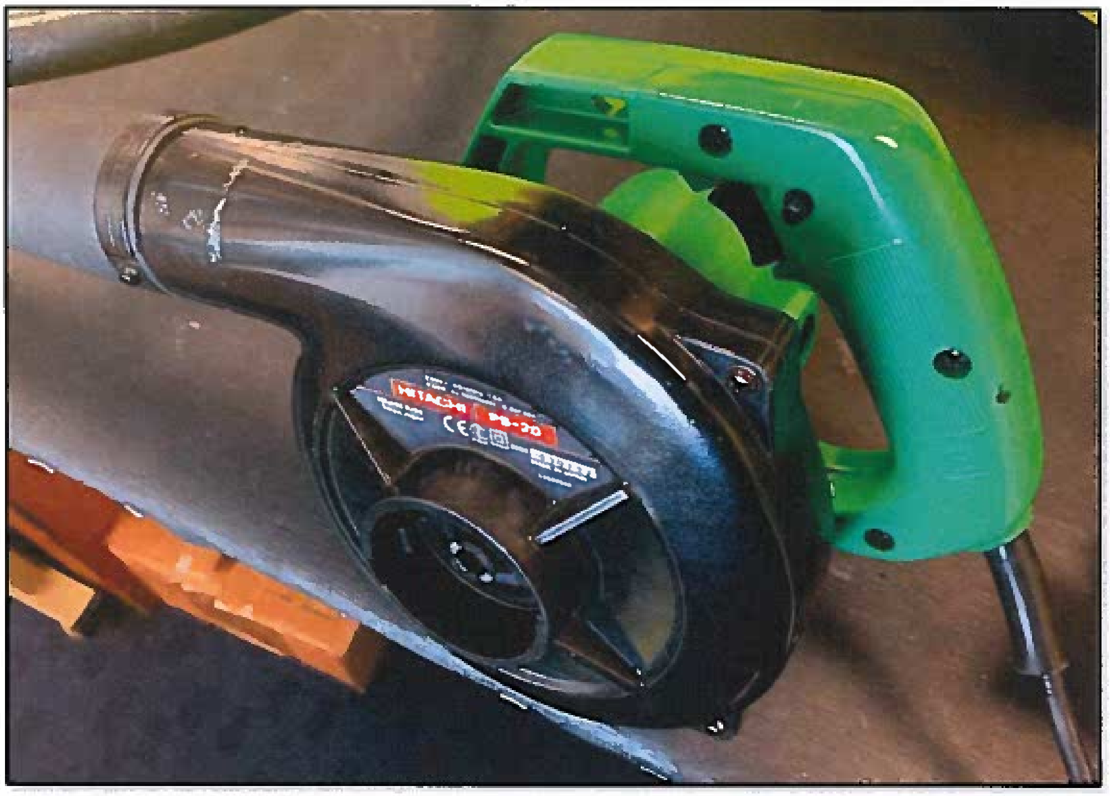

Figure 1.4.45 - Incorrect Inflator / Deflator used by 736 NAS for LSJ inflation tests.

1.4.199. This was assessed by RAFCAM to be sufficient to conduct a leak check. A pressure of more than 1psi was determined to have potential to cause some overstretch of the material. However, during manufacture all LSJs were tested to 2psi by the manufacturer giving some margin for error. The Panel finds that the use of an incorrect Inflator / Deflator during maintenance **was not a factor**. Exhibit 105 Exhibit 140

1.4.200. During the investigation the Panel conducted visits to 736 Sqn, 100 Sqn and RAFAT SE departments. The Panel **observed** that out of the three Hawk T Mk1 operating locations, only one was using the correct Inflator / Deflator for LSJ inflation tests.

1.4.201. **Maintenance area.** As highlighted in Figure 1.4.46, the SES office / maintenance area was small, full of equipment and only contained one work desk where routine maintenance, unscheduled repairs and modifications could be carried out. Exhibit 167

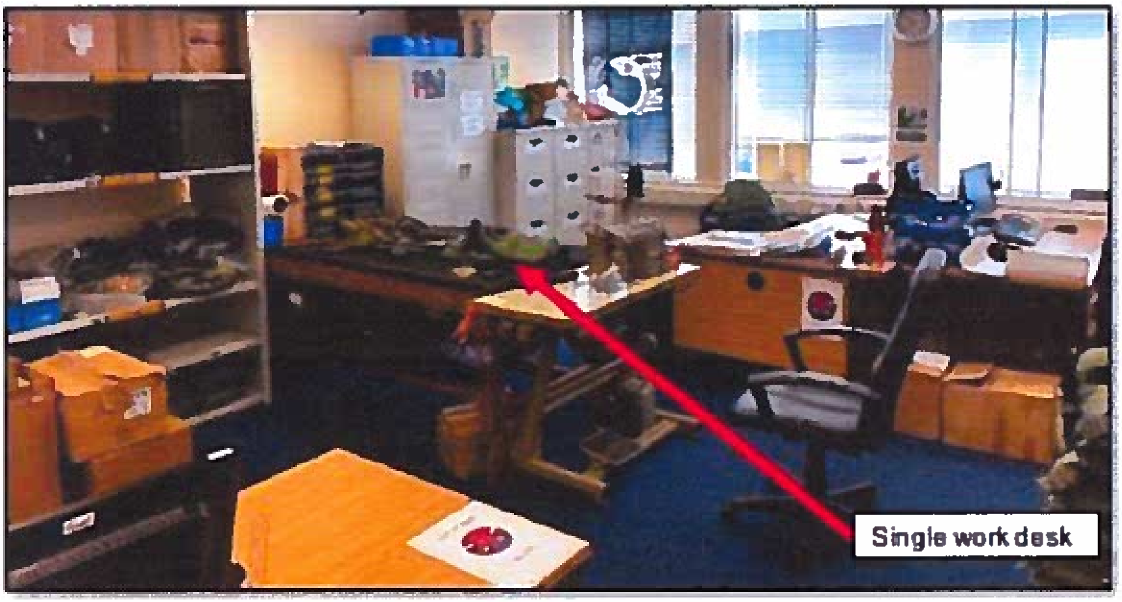

Figure 1.4.46 - 736 SES Office and maintenance area – View 2.

1.4.202. The limited space was barely big enough to place a fully inflated LSJ and did not provide room for other personnel to work concurrently.

1.4.203. Requirements for SES work areas were laid down in DAP 108A-0007-1. The SES on 736 NAS fell short of the requirement when referencing the guide detailing the planning, organisation, and maintenance of the section. Had this DAP been complied with during the move to Bravo site, the SES would have likely been provided with adequate facilities in which they could conduct routine business with sufficient space and storage. The Panel concluded that the area allocated was inadequate. The Panel finds that the inadequate area allocated to conduct safety critical functions was an **Other Factor**. Exhibit 126

1.4.204. **Recommendation. The RNAS Culdrose Delivery Duty Holder should review the working environment within the 736 Naval Air Squadron Survival Equipment Section against the requirements of Digital Air Publication 108A-0007-1 in order to ensure compliance.**

1.4.205. **DAP procedure.** During initial interview, one of the personnel described the procedure used during routine maintenance of the Mk42M LSJ as clear, concise, and easy to follow. However, when questioned further, they stated that they were not as familiar with the procedure as they should be; did not always refer to the DAP when conducting the procedure and often found the procedure difficult to follow. The difficulty came as the DAP contained hyperlinks to lead the technician to additional procedures without a hyperlink to return them to where the procedure left off. These comments were then echoed by other witnesses during interview. The Panel determined that in order for supervision to be effective, to ensure adequate supervision, a clear DAP that could be easily followed by all involved in the process, was essential. Exhibit 108 Witness 5 Witness 11 Witness 16

1.4.206. The DAP, while appearing simple to follow in paper form, did leave room for interpretation. It described the procedures to follow but did not do so in enough detail. From the evidence seen during the unpacking of the quarantined LSJs[60] from 736 NAS it was clear that the procedure was either too difficult to follow, did not detail the steps in enough detail, or was ignored / not used when conducting maintenance on the LSJs. Witness statements discussed stage checks, and work orders seen by the Panel highlighted the stages that required checking. However, stage checks relating to the folding and packing of the stole inside the restrainer were omitted. This was a critical part of the procedure that must be correct to ensure correct function in an emergency.

Exhibit 108
Exhibit 109
Witness 5
Witness 11
Witness 16
Exhibit 139

1.4.207. During the SI, as a response to Urgent Safety Advice and other subsequent issues, a Process Verification Audit (PVA) was conducted by the ACDT[61] at 736 NAS, specifically examining the LSJ maintenance procedure. This resulted in the ACDT submitting a comprehensive MOD F765[62] which contained many and significant changes. These included the addition of clearer explanations, additional photographs, and additional stage checks to improve the clarity of the procedure. Due to the length of time for issuing the amendments being protracted, the ACDT intended to issue an Advance Information Leaflet[63] but at the time of writing the report, this had not happened. Prior to the PVA no MOD F765s or DASORs had been raised in relation to the quality of the DAP. The Panel concluded that the quality of the DAP was not assured. In addition, once introduced into service, there was no process to ensure understanding by the users. These were highly likely to have adversely impact the provision of critical lifesaving equipment. The Panel finds that the quality of the DAP and the method of introduction into service was an **Other Factor**.

Witness 5
Exhibit 172

1.4.208. **Recommendation. Head of Air Commodities Delivery Team should improve the introduction and amendments process for Digital Air Publications in order to ensure that users can understand and comply with the Digital Air Publications.**

Incorrect packing

1.4.209. RAFCAM received the failed stole and requested further samples from 736 NAS for examination. A further four LSJs were sent to RAFCAM and were examined by specialists. Of the four additional LSJs only one was found to be packed correctly. The other three, when unpacked, were found to be incorrectly folded and packed around the neck area of the LSJ. The EPLB antenna position was not assessed during the unpacking of these jackets.

Exhibit 103
Exhibit 105
Exhibit 114
Exhibit 125
Exhibit 109

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[60] RAFCAM randomly selected four LSJs to examine for reference.

[61] Conducted on 16 Jun 2021.

[62] A MOD F765 is an Unsatisfactory Feature Report.

[63] An Advance Information Leaflet is an expedited amendment process.

Figure 1.4.47 highlights the folding of the lobes rather than the lobes being concertinaed in accordance with the DAP.

1.4.210. A further LSJ from 736 NAS was obtained and unpacked, and the packing around the neck area was also noted to be incorrect. This time the EPLB position was noted and found to be correctly retained under the oral inflation tube but the EPLB antenna was not positioned correctly. The antenna was stowed within the stole folds (Figure 1.4.48) contrary to the instructions in the DAP. Exhibit 103 Exhibit 109 Exhibit 114 Exhibit 140

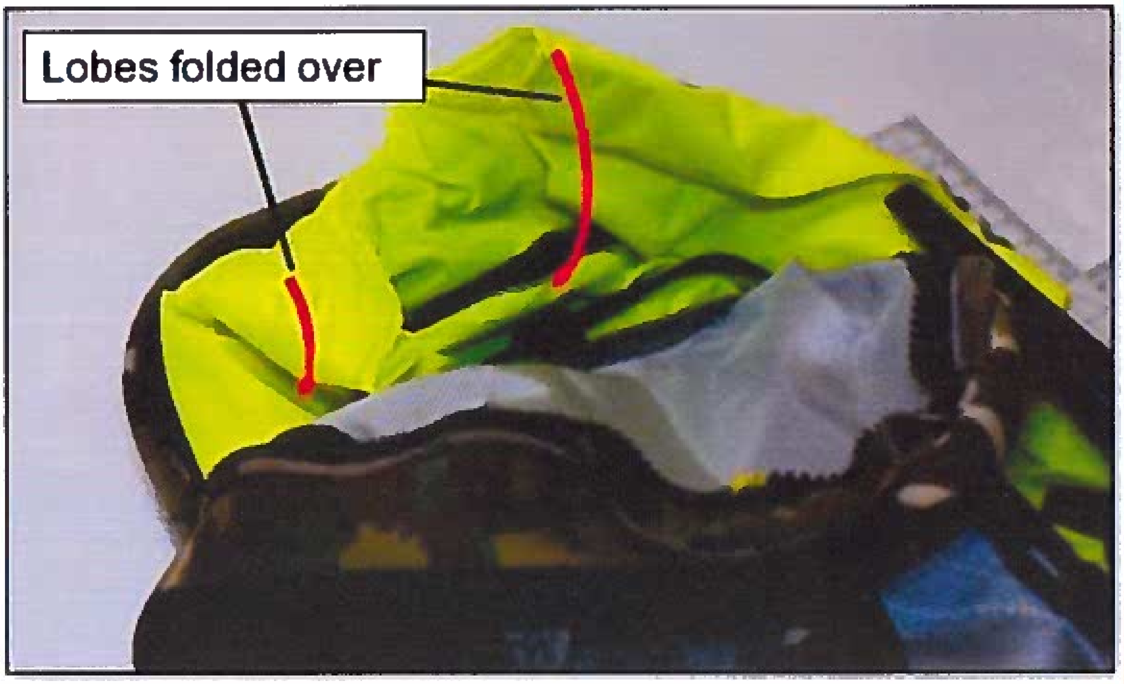

Figure 1.4.47 - Incorrect folding of the lobes on a quarantined 736 NAS LSJ.

Figure 1.4.48 - Incorrect EPLB antenna positioning on a quarantined 736 NAS LSJ.

1.4.211. As the unpacking continued to visually examine the restrainer, it was noted that the cable from the EPLB antenna had formed a loop and had not been straightened out in accordance with the DAP. A low angle light was also used to highlight that the LH and RH lobes of the stole were bunched inside the restrainer and not sitting tightly along the restrainer seam (Figure 1.4.49). Exhibit 103 Exhibit 109 Exhibit 114 Exhibit 140

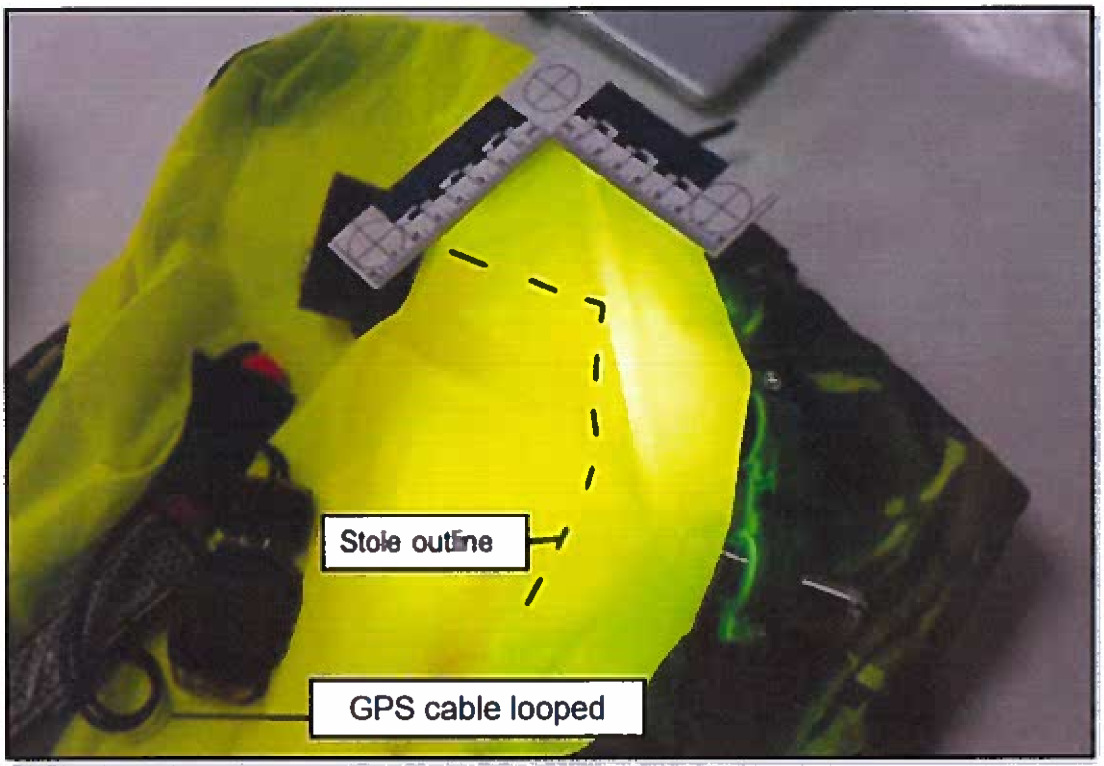

Figure 1.4.49 - Lack of stole extension within the restrainer on a quarantined 736 NAS LSJ.

1.4.212. The DAP required a four hour inflation test following the installation of a stole inside the restrainer. This test should inflate the stole to the maximum extent possible and should have therefore, pushed out any packing inconsistencies. Considering the inconsistencies observed, as in Figure 1.4.49, the Panel determined it to be unlikely that the inflation test was conducted in accordance with the DAP. The Panel were unable to determine whether this was the case on the failed LSJ, but that it was likely to have been the case on other stoles. Exhibit 108

1.4.213. **Comparison of failed and reference stoles.** 1710 NAS was provided with two further stoles for examination and comparison with the failed stole. One stole had been previously installed in a LSJ in Dec 2020 and the other had never been installed. Exhibit 103 Exhibit 140

1.4.214. The visual examination of the failed stole had revealed differences in the creasing of the material between the front and rear fabric surfaces. The reference stoles were examined to determine the level of the creasing observed. This 'baseline' of creasing was used as the datum to assess the failed stole (Figure 1.4.50 and Figure 1.4.51). Exhibit 103 Exhibit 140

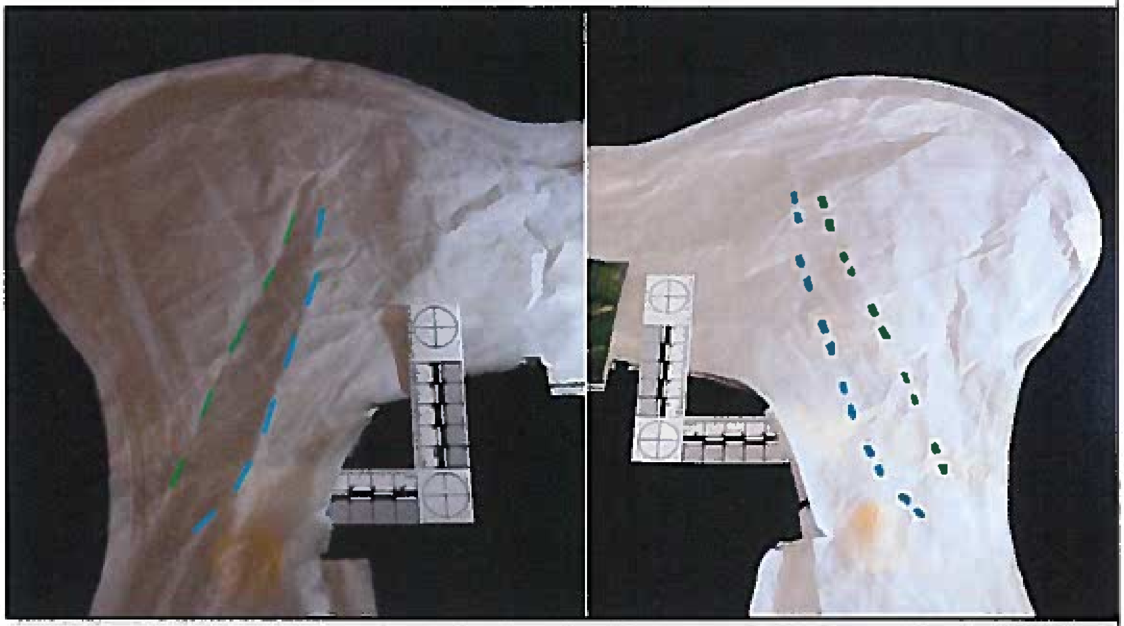

Figure 1.4.50 - Creases on the in-service failed stole; rear surface (left image) transposed to front surface (right image).

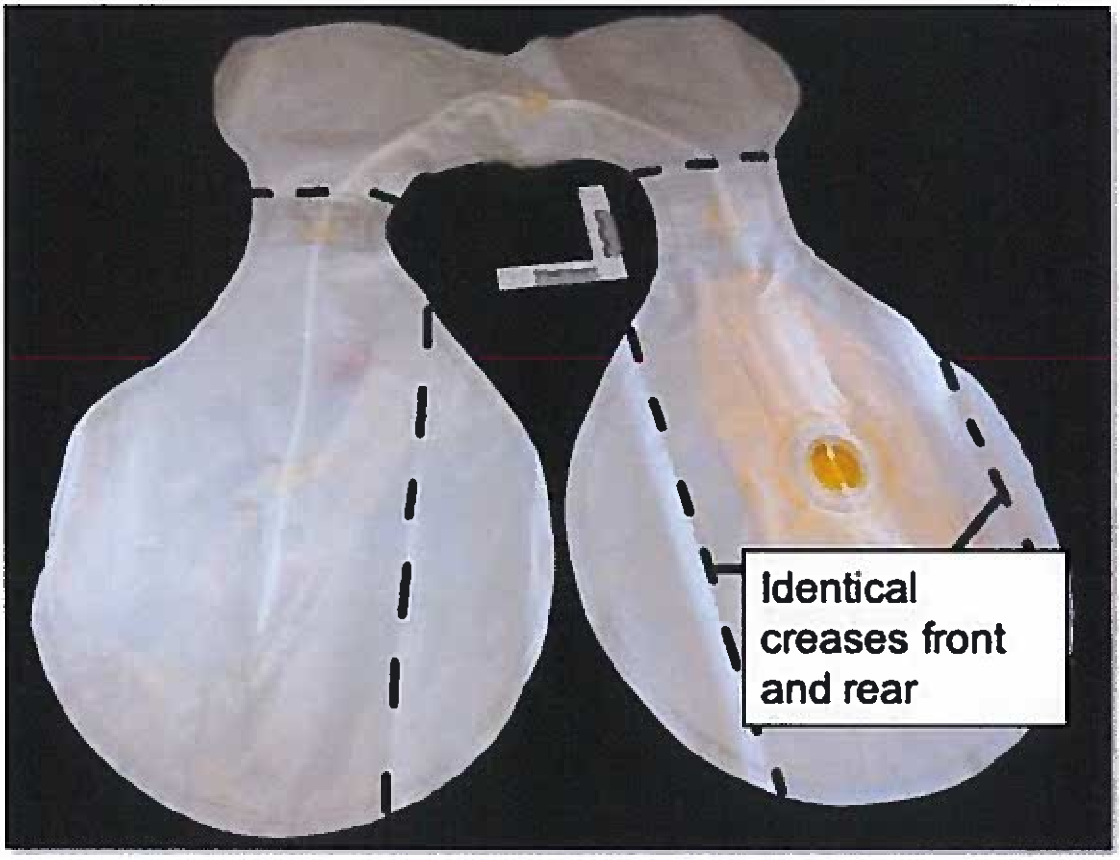

Figure 1.4.51 - Creases on the never installed stole.

1.4.215. Similar differential creasing to that found on the failed stole was observed on the front and rear surfaces on the installed stoles. The never Exhibit 103 Exhibit 140 installed stole exhibited significantly less creasing with identical crease patterns present on the front and rear material surfaces (Figure 1.4.51).

1.4.216. **Failed stole.** The stole worn by the Pilot could not be fully examined or analysed as per the reference stoles as it had been inflated. However, the creasing found across the surface of the stole was consistent with that found on the other incorrectly packed stoles. The Panel assess that it was highly likely that it was also packed incorrectly. However, the supporting evidence was inconclusive. The positioning of the EPLB and EPLB antenna could not be assessed, however, considering the stole failed, it was judged by the Panel to be highly likely that the multiple factors found on the reference LSJs from 736 NAS, could be causal in the failure of the failed stole as stated in para 1.4.195. Exhibit 103 Exhibit 140

1.4.217. **Stole testing.** Of the stoles quarantined from 736 NAS, the original four were carefully repacked using the creases (as found) as a guide and tested using an anthropometrically similar sized individual (to the Pilot) in a parachute harness. The results are per Table 1.4.4. Exhibit 110 Exhibit 114 Exhibit 140

LSJ No	Results	Evidence
1 - SNo:1604575	• Packed correctly • Inflated under parachute suspension with no issues	
2 - SNo:1603883	• Packed incorrectly; the upper stole area of the neck cushion was tucked under the zipped portion. • Inflated without incident	
3 - SNo:1606149	• Packed incorrectly; the stole was not folded in a concertina fashion, the neck cushion was crumpled down on itself; particularly on the left side (as worn) • Inflated but the right-hand horn of the neck cushion became partially snagged on the blast proof pouch	

4 - SNo:1605374	• Packed incorrectly; the stole folded over on itself rather than concertinaed • Additionally, the left-hand lower portion was packed incorrectly with the area surrounding the base of the EPLB antenna crumpled together • Inflated without incident	

Table 1.4.4 - Details of the first four quarantined LSJs from 736 NAS.

Summary of stole testing

1.4.218. 1710 NAS analysis of the failed stole in conjunction with the evidence discussed above confirmed that the mode of failure was a burst resulting from a localised single over-pressure event caused by multiple factors. Exhibit 103

1.4.219. The stoles which had been installed in an LSJ (failed and installed stole) exhibited a high degree of differential creasing compared with a never installed stole. The creasing in the stoles was indicative of the stole not being correctly seated within the restrainer. The stoles exhibited creases independent of the restrainer and outside of the correct packing method contained within the DAP. The creases also indicated that the inflation check required in the DAP was not carried out. The Panel concluded that a trapped fold was more likely to result in a higher degree of material damage. The Panel finds that the incorrect folding of the stole within the restrainer was a **Contributory Factor** in the failure of the LSJ. The Panel finds that the incorrect packing of the restrainer was a **Causal Factor** of the failure of the LSJ. Exhibit 103

1.4.220. **Recommendation. Head of Air Commodities Delivery Team should conduct a Process Verification Audit on existing Aircrew Equipment Assembly Digital Air Publications in order to ensure that they are all as clear and as simple as possible for use by Survival Equipment technicians of all experience levels.**

1.4.221. **Post-event evidence.** During the SI, as part of the investigative process, the Panel were made aware of two in-flight inflations of LSJs during a transit flight as 736 NAS deployed to Exercise JOINT WARRIOR. The partial inflations occurred due to air being left inside the stole post maintenance. As the altitude increased and the ambient pressure decreased, the air within the stoles expanded causing the stoles to partially inflate. These occurrences underpin the concerns highlighted by the Panel regarding the standards and practices of 736 NAS SES and the quality of the DAP in use. The original issue, now compounded by a second LSJ issue subsequently led to a PVA by ACDT. Exhibit 22 Exhibit 68

~~OFFICIAL - SENSITIVE~~

Incorrect stowage

1.4.222. Stowage of the LSJs was directed in the DAP. A coat hanger was required to support the weight of the LSJ via the yoke of the jacket across the shoulders. Hangers were seen in some of the lockers on 736 NAS but should have been found in all lockers. The SES technicians were responsible for issuing the AEA and for conducting pre-initial issue inspections and checks, but they did not conduct routine daily pre and post wear inspections. The personnel on 736 NAS, in this instance, strictly followed the DAP and the requirement to conduct daily checks and ensure all equipment was stowed correctly was left to the aircrew. The aircrew would not normally have access to the DAP, and arguably would not be Suitably Qualified and Experienced Personnel (SQEP) to follow it. They were more than likely to use the in-locker stowage devices as found when a locker was assigned rather than understanding the requirement to use a hanger. Exhibit 126 Witness 5

1.4.223. Some of the lockers contained 's hooks' (Figure 1.4.52 and Figure 1.4.53). Although these held the weight of the LSJ, they were likely to put undue localised pressure on the area where contact was made with the hook. This could cause additional wear and tear to the restrainer or the stole inside the restrainer. Exhibit 107 Exhibit 168

Figure 1.4.52 - LSJ stowed on a non-approved 's hook' as found on 736 NAS.

Figure 1.4.53 - Close up of 's-hook' as used for stowage of LSJs on 736 NAS.

1.4.224. The locker of the Pilot was not examined until approximately six weeks post the accident, so the Panel cannot determine if LSJ stowage was an issue at the time of the incident. The Panel concluded that the use of 's hooks' may have been a factor in the incident, and their use could almost certainly be a factor in future incidents. The Panel finds that the use of 's hooks' was an **Other Factor**.

Incorrect wear

1.4.225. It was noted that the LSJ waist belt adjustment webbing of the failed LSJ from the ejection of XX189 was asymmetrically adjusted. On the LH side (as worn) the waist belt had been pulled through its buckle to leave a 19cm free end (Figure 1.4.54 (left image)). However, on the RH side the webbing had not been pulled through the buckle and the touch and close fastener (Velcro) stitching was abutted directly up against the buckle (Figure 1.4.54 (right image)). Exhibit 103 Exhibit 114 Exhibit 140

Figure 1.4.54 - Rear adjustment straps on the failed LSJ pulled asymmetrically.

1.4.226. Despite the asymmetric adjustment the crotch straps were centrally located and stitched in the correct position. To determine whether this asymmetric fitting could affect the overall fit of the LSJ a representative sized LSJ was configured in this asymmetric manner and re-fitted to a subject with similar anthropometric dimensions as the Pilot from XX189. The asymmetric adjustment did not affect the fit of the LSJ as the design of the waist belt was such that it was freely moveable within its retaining tunnel. The Panel determined that it was unlikely that the way in which the waist belt was adjusted had any link to the failure of the LSJ. The Panel finds that the asymmetric adjustment of the waist belt was **not a factor**. Exhibit 114

LSJ summary

1.4.227. LSJ1, LSJ2 (Table 1.4.4) and the failed LSJ from XX189 were all packed and supervised by the same SETs. The evidence demonstrated that the two SETs concerned were able to pack LSJs correctly according to the DAP, but they were unable to do so consistently, with LSJ1 packed correctly Exhibit 114 and LSJ2 packed incorrectly. However, these inconsistencies do not confirm whether the LSJ from XX189 was packed correctly or not.

1.4.228. The Panel determined that folds caused the need for additional force to open the stole. The incorrect positioning of the EPLB antenna was highly likely to also increase the force required due to the tight fit of the cover around the EPLB antenna tip, which was coincident with the site of the burst initiation. The Panel concluded that it was most likely a combination of factors that were responsible for this incident. The Panel finds that three factors were responsible for this incident: The Panel finds that the incorrect seating of the stole within the restrainer was a **Contributory Factor** in the failure of the LSJ. The Panel finds that the mis-folding of the restrainer within the pouch was a **Causal Factor** in the failure of the LSJ. The Panel finds that a fold on the stole becoming trapped by the EPLB antenna was a **Causal Factor** in the failure of the LSJ.

SES supervision

1.4.229. The incorrect packing observed on the other 736 NAS reference LSJs was due to a deviation from procedure either through mistake or violation. Issues within the DAP, highlighted by 736 SES, had not been addressed through the MOD F765 process. With no approved deviation in place and multiple deviations having occurred, the Panel judges that violations[64] have occurred. Concerns over the SE maintenance location, workshop size, or provision of equipment for maintaining AEA had not been raised through the appropriate chain of command. The can-do attitude of the SES personnel, normally worthy of praise, caused concern to the Panel. Comments made during interview highlighted a supervisor who was unwilling to lead by example. The Panel concluded the SES supervision was a factor in the failures in process as highlighted within the 736 NAS SES. Consequently, this was judged by the Panel to be a fundamental factor in the incident. The Panel finds the SES supervision to be a **Contributory Factor** in the failure of the LSJ. Witness 5

1.4.230. **Recommendation. The RNAS Culdrose Delivery Duty Holder should review the structure and location of the SES department on 736 NAS in order to ensure personnel are led and managed in a way that achieves the output in a safe, effective and policy compliant manner.**

[64] Violation: Deliberate and conscious departures from established rules / procedures, although often with no intent to cause harm.

Survivability

1.4.231. The crew could have afforded themselves greater levels of protection by wearing water resistant gloves. BRd 767[65], NAO 2130 stated that with a sea temperature below 15°C aircrew **should** wear water resistant gloves. The RTS states that the gloves were cleared for use in the Hawk T Mk1 (Gloves, W/R Mk2) but were not worn by either the Pilot or the Passenger. Had the ejection been over water, the sea temperature of 10°C could have affected the use of the hands as hypothermia set in. The Panel finds that the wearing of non-water-resistant gloves was **not a factor**.

Exhibit 115

Exhibit 114

1.4.232. Although the crew were compliant with the requirement to wear an IPG when operating in the maritime environment over water of less than 15°C, they chose to wear the minimum number of layers under the IPG. These were aircrew long johns and aircrew vest and flying coverall. The addition of an aircrew jersey or 'bunny suit' [66], as detailed in Joint Service Publication (JSP) 911[67], would have enhanced the survivability in cold water post an over water ejection. Any rescue taking longer than 2.5 hours would have likely resulted in hypothermia, or worse, without a 'bunny suit' being worn (Figure 1.4.55 and Figure 1.4.56).

Exhibit 115

Exhibit 169

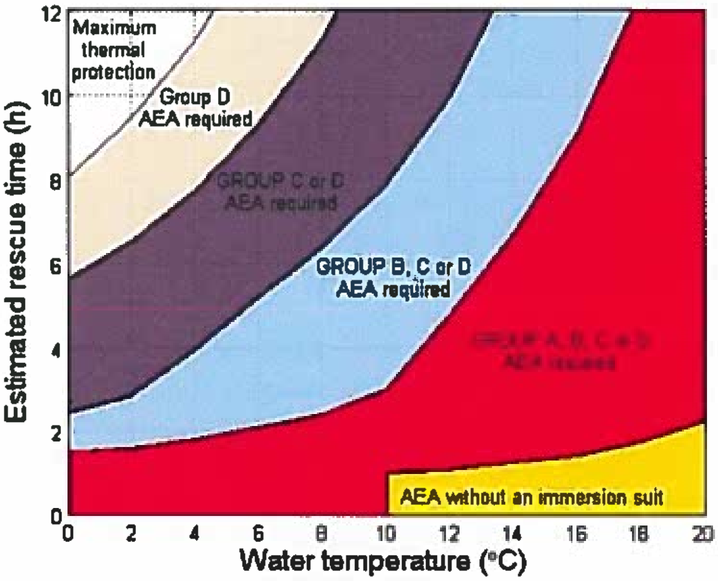

Figure 1.4.55 - Sea Temp vs Estimated rescue time highlighting groups of AEA required.

[65] BRd 767 – Naval Aviation Orders.

[66] A woollen one piece under garment worn by aircrew for insulation.

[67] JSP 911 – Survival, Evasion, Resistance, Extraction.

	All AEA include underwear, long johns, vest, socks, boots, gloves, helmet and life preserver AEA items						Immersed thermal resistance	
	General coverall	Cold weather coveralls	Immersion coverall	Roll neck/shirt	Jersey	Knitted inner	Group	(clo)
Without immersion suit	x1	-	-	x1	-	-		
	-	x1	-	x1	Any combination			
With immersion suit	-	-	x1	x1	-	-	A	0.32
	-	-	x1	x1	x1	-	A	0.39
	-	-	x1	-	-	x1	C	0.67
	-	-	x1	x1	-	x1	C	0.74
	-	-	x1	-	-	x2	D	0.86
	-	-	x1	x1	-	x2	D	0.90

Figure 1.4.56 - AEA groups.

1.4.233. The higher the CLO[68] value, the better the thermal protection. Figure 1.4.56 does not consider having a life raft to climb into but does assume that an IPG was serviceable and watertight. The Passenger in the rear cockpit of XX189 was wearing an unserviceable IPG – but this fact was unknown to them at the time of donning. The serviceability of the IPG is discussed in paragraph 1.4.239. Exhibit 114 Exhibit 115

1.4.234. Inspections of all AEA was carried out by RAFCAM to understand whether the equipment and aircraft escape system had operated as expected and to determine whether it was serviceable at the time of use.

1.4.235. **Mk10R Helmet.** The Pilot of XX189 recalled that their helmet visor had been forced up during the ejection sequence but was certain that it was locked down during flight. RAFCAM observed that the helmet shell had a covering of MDC spatter across its surface (Figure 1.4.57). Both visors[69] were found fully intact with a covering of MDC spatter and light scratches on the outer surfaces (Figure 1.4.58). The velveteen visor cover was found attached correctly and also showed MDC spatter. The LH visor mechanism failed to lock the tinted visor in its down position. The white locking cam had failed and was found to be in two pieces (Figure 1.4.59). Witness 1 Exhibit 115

[68] CLO is Basic measurement for the thermal properties of clothing. One CLO unit is the thermal insulation that is comfortable for a resting man at 21 °C, where relative humidity is less than 50% and the air movement is 6 m/min: it equates to a man wearing a three-piece suit and light underclothes.

[69] The Mk10R helmet includes two visors, a clear inner visor and a tinted outer visor.

Figure 1.4.57 - MDC spatter.

Figure 1.4.58 - MDC visor spatter.

Figure 1.4.59 - Visor locking cam.

1.4.236. Examination of the maintenance record documents indicated that at the last maintenance the visor locking mechanism was functioning correctly. It was likely that the damage to the mechanism occurred during the windblast phase of the ejection when the forces generated were sufficient to overcome the locking mechanism and fracture the locking cam. Exhibit 116

1.4.237. Windblast tests identified that the plastic cams were sufficiently robust to withstand a 450kt windblast. The Panel found it concerning that the failure of the cam on the Pilot's helmet occurred at 180kt. The failure of the tinted visor locking mechanism is subject to ongoing investigation. Exhibit 114

1.4.238. Although the Pilot sustained significant MDC spatter to the eyes, it was unlikely that the failure of the visor locking mechanism contributed to the extent of the injuries. MDC spatter typically occur on immediate detonation of the MDC, a point when the Pilot described that the tinted visor was locked down. The Pilot would have been exposed to the full force of the windblast as the seat travelled up the guide rail above the front canopy's protective screen. This is the earliest opportunity for the visor locking mechanism to fail, and at which point the MDC spatter would have already landed on the Pilot. The Panel determined that only the tinted visor was down during flight. The presence of MDC spatter on the clear visor proves that it was in the up position during flight (Figure 1.4.58). The Panel concluded that the injuries could have only occurred by MDC spatter travelling through the gap left open by the absence of the velveteen cover between the visors and the helmet shell. The Panel **observed** that advice was given to FJ aircrew to use the protective velveteen visor cover to reduce the gap between the visor[70] and the helmet shell to reduce the likelihood of MDC spatter entering the eyes. This advice, in addition to closing eyes prior to ejection, should be followed to avoid injury during the ejection sequence. Exhibit 114 Witness 1

1.4.239. **Immersion Protective Garment.** RAFCAM noted an issue with the IPG worn by the Passenger. The IPG was from the loan items held on 736 Exhibit 114

[70] This requires both visors to be down, so was not entirely effective if only one visor was in use.

NAS but had been temporarily issued and routinely used by the Passenger during previous flights.

1.4.240. IPGs undergo a post maintenance inflation check which puts pressure inside the suit and a liquid across the various seams to check for bubbles caused by air leaking. Air leakage would indicate that water could enter the suit while worn reducing the efficacy and survivability. Exhibit 135

1.4.241. The seam tapes around the neck, both wrist seals and the RH sock attachment, together with the lower arms, where the exposure glove storage pockets had been removed, allowed air to leak out during the bench test. However, visual inspection showed no areas of obvious damage or loss of integrity. The sock, neck and wrist seals were sealed with 20mm wide seam sealing tape (heat pressed, 180°C) that should create a watertight joint (Figure 1.4.60). Exhibit 114 Exhibit 115 Exhibit 135 Exhibit 144

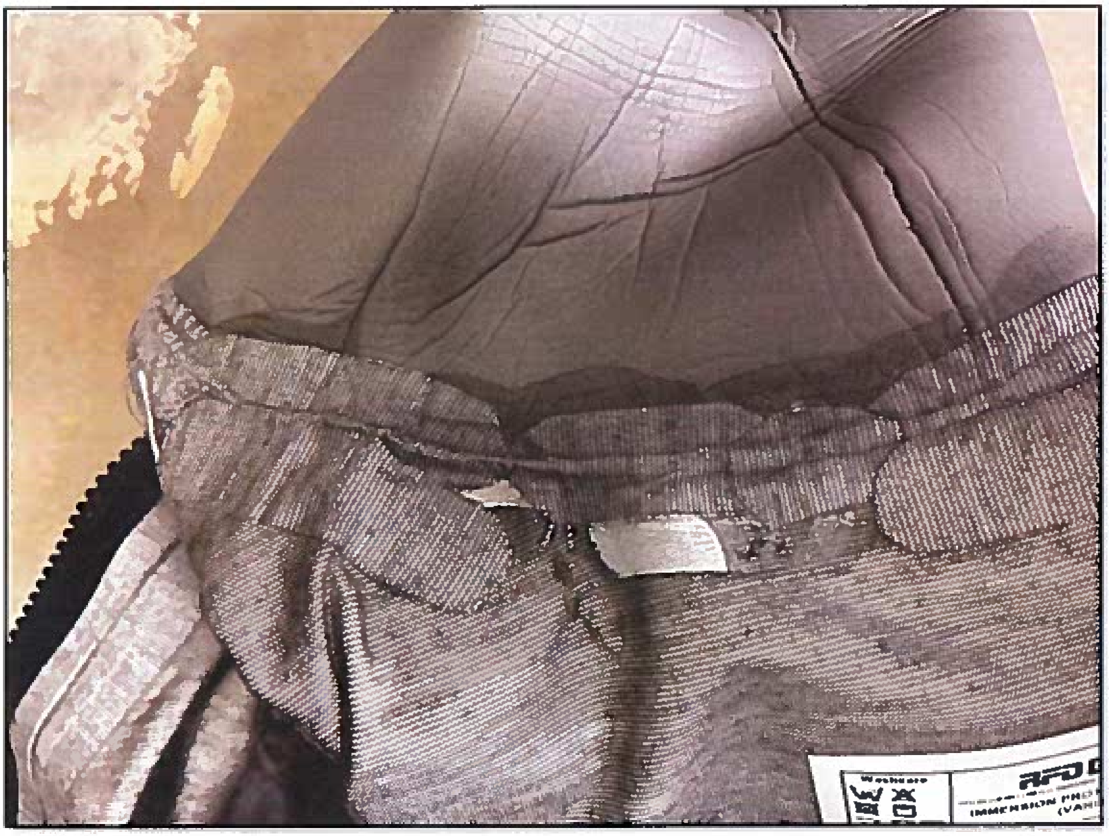

Figure 1.4.60 – Neck seal of the IPG worn by the Passenger.

1.4.242. As the potential loss of seam integrity could have allowed water to enter the IPG had the aircrew ejected over water, a further in-pool assessment was conducted. The aim of this test was to determine the extent of any water leakage. A suitably sized individual donned the Passenger's IPG together with undergarments (Future Aircrew Clothing System (FACS) base layer), socks, Mk42M single stole LSJ and anti-g trousers. The subject was pre-weighed wearing just the aircrew undergarments and socks. The fully clothed subject inflated the LSJ then entered the water and floated for 10 Exhibit 114 minutes. After 10 minutes the subject climbed out of the pool, removed the outer layers of clothing, and was re-weighed in their undergarments together with any free water that had accumulated in the IPG. A 10 minute soak was chosen as flotation of this length was a realistic estimate of the time aircrew are likely to be in the water. After approximately 10 minutes it would be expected that aircrew would have entered their life raft thereby limiting further water ingress.

1.4.243. The pre and post floatation weights demonstrated that 1 litre of water had leaked into the IPG over the 10 minute soak period. As a control a RAFCAM trials IPG was selected at random and subjected to a 10 minute in-water flotation soak. In this control case there was no ingress of water and the FACS undergarment remained dry throughout. Exhibit 114

1.4.244. Previous work published in the scientific literature indicated that leakage of 1 litre of water into an IPG was associated with a reduction of thermal insulation protection by approximately 40%[71]. Based on this and the survival curves used at in the reference material at footnote 71 it was estimated that the in-water survival time at a sea temperature of 10°C would have reduced from approximately 7.5 hours to 2.5 hours. Although this was a substantial reduction in in-water survival time it would still be expected that, had the aircrew ejected over water, they would have survived as previous analysis has demonstrated that the rescue times in UK waters was typically less than 1 hour. In this accident, the Coast Guard Search and Rescue helicopters were on station and had located the aircrew well within the limits of the predicted in water survival times. Whilst this did not impact the outcome of this accident, the IPG failure highlighted another issue with a DAP[72] and the 736 NAS SES standards and practices. Exhibit 114

736 SES conclusion

1.4.245. The various issues highlighted throughout the investigation may not be exclusive to 736 NAS SES and could extend beyond RNAS Culdrose to the wider SE community. Without further examination the Panel were unable to draw wider conclusions. The deviation from procedure and inconsistent standard of workmanship and quality of DAPs, as well as the lack of oversight were all of concern to the Panel. It is almost certain that many of these issues originated because the SES operated as a 'stand-alone' section outside of the main bay operating the only FJ type flying from RNAS Culdrose. The set-up of the section was not compliant with the regulations; the spread of AEA across the Sqn building made it harder for personnel to keep on top of basic husbandry tasks, the lack of workspace in the main office reduced the ability for more than one technician to be carrying out maintenance work at once and

Witness 5
Exhibit 103
Exhibit 105
Exhibit 109
Exhibit 110

[71] J. R. Allan, C. Higenbottam, and P. J. Redman, 'The Effect of Leakage on the Insulation Provided by Immersion-Protection Clothing', Aviat Space Environ.Med., vol. 56, pp. 1107–1109, Nov. 1985.

[72] A further PVA was conducted and identified that significant changes and improvements were required.

daily oversight was only possible if the section was visited – something that had become increasingly hard to do with COVID-19 restrictions in place.

1.4.246. The Panel **observed** significant differences between how RAF TG13 personnel and RN SETs deliver their role. The training system was examined by the Panel and several differences were noted. The RAF and RN syllabi differ in both content and course length. However, all personnel are expected to conduct the same role to the same standard, many on joint units where both TG13 and RN SETs are expected to work side-by-side. The Phase 2 training only instructs the generics of SE maintenance, more specific Phase 3 training is delivered on unit using the actual equipment pertinent to the platform supported. The Panel, whilst visiting other units, **observed** good working practices in addition to the requirements of the DAP. The Panel believes incorporation of these within the DAP should be considered at next issue. The Panel concluded that the local training and supervision of RN SETs was inadequate. The Panel finds that the on-the-job training of the RN SETs was an **Other Factor** in the failure of the LSJ. Exhibit 113

1.4.247. **Assurance of the SES.** Assurance was conducted by the RNAS Culdrose Quality System Manager through the SE hierarchy using Main Bay personnel when required. Assurance reports were provided to the Quality System Owner (QSO) via Cdr AE and to CO 736 NAS for any changes required. Competency checks and assurance activities were carried out in accordance with the extant procedures. However, they did not identify the lack of familiarity with some of the procedures or the lack of confidence in the DAP. Witness 5
They also did not identify any of the issues surrounding the set-up and supervision of the 736 NAS SES. The Panel concluded that the assurance of the SES should have highlighted these issues. The Panel finds that the assurance of the 736 NAS SES was an **Other Factor** in the failure of the LSJ.

Other Factors

Safety reporting

1.4.248. The Manual of Air Safety (MAS) defines a healthy reporting culture as one that was fully encompassing of, and actively embraced by all those personnel involved. Exhibit 153

1.4.249. MAA RA 1410, Annex B, provided a guide on occurrences that required mandatory reporting via a DASOR. DASORs or equivalent, provided an invaluable source of data, particularly when they are comprehensively completed with the inclusion of causal factors and recommendations that could be analysed further. Exhibit 158

1.4.250. However, on 736 NAS the Panel judged that mandatory occurrence reporting was reactive in nature and needed to be augmented by reports of an analytical and predictive nature (i.e. Hazardous Observations) if the system was to become truly effective in anticipating hazard and risk.

1.4.251. On review of the previous year's DASORs, 736 NAS had completed 44[73] Occurrence reports on ASIMS. This figure, matched with the Squadron's flying rate, was considered within the expected range.

1.4.252. As part of this investigation, the Panel discovered that there were two previous incidents involving an OIL caption on XX189. Neither had resulted in DASORs and neither had been deemed a Flight Safety Hazard in the MOD F707A - Aircraft Maintenance Log. On further investigation, the Panel determined that the captions did not meet the threshold for reporting as the system did not suffer a 'significant failure or unforeseen degradation of any safety critical system'. The relay that should have prevented the OIL caption from illuminating under negative g had failed and the caption was illuminating immediately rather than with a 10 second delay. The Panel concluded that the previous OIL related captions were unrelated to the OIL issue experienced by XX189 on 25 Mar 2021. Witness 17

1.4.253. Contractor engineering staff were actively encouraged to use both the Maintenance Error Management System[74] (MEMS) and ASIMS to report incidents and observations. They did not always routinely submit concurrent reports, with MEMS being the primary system for engineering safety reporting. This had the potential that incidents were not tracked on both systems. This risks incidents and observations seen at RNAS Culdrose not necessarily being reported to other Hawk users. This also reduces the utility of ASIMS and the effectiveness of the Defence Aviation Error Management System as a whole. The Panel **observed** that anything reported on MEMS, or indeed any other contractor-based error management system, should also be reported via Witness 6 Witness 7 Witness 15

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[73] Yearly ASIMS review conducted between 25 Mar 20 to the 25 Mar 21.

[74] A contractor led Error Management System.

ASIMS to ensure issues are highlighted Defence wide and tracked correctly for analysis and trending.

Suitably qualified and experienced personnel

1.4.254. The MAA glossary of terms does not define SQEP. However, JSP 755[75] defines it as 'a person who has sufficient and specified qualifications and skills in a defined skills area and is able to implement that skill at varying levels.' The phrase SQEP was widely used across Defence after adoption from industry but in the opinion of the Panel, was often misunderstood.

1.4.255. The Office for Nuclear Regulation[76] defined SQEP 'as an individual who has the necessary competence to perform the duties which may affect safety as defined by their job / role as demonstrated by their training / experience'.

1.4.256. Suitably qualified was simple to define. Personnel either hold the correct level of qualification or they don't. Until they do, they cannot be defined as SQEP. Experience was hard to define, but suitable experience was even harder to define. Whether time served, number of hours flown, or Separation Days[77] accumulated define experience, what was important was the suitability of the experience and relevance to the role in which SQEP was required.

1.4.257. MAA RA 1002 rationale discussed a successful airworthiness strategy as 'one requiring personnel who are assessed as competent and are SQEP'. Competency and relevancy are key to the phrase SQEP but are often left out. Experience in general does not mean experienced for the role in question. The Panel assessed that the personnel working within the 736 Engineering Dept were SQEP, according to the simple definition above. However, they were not all competent in their role as discovered when examining the large number of procedural deviations. Exhibit 157

1.4.258. The Panel **observed** the MAA term SQEP should be replaced by a more definitive term which is less subjective and more measurable. The Panel suggest a term such as Qualified, Suitably Experienced and Competent (QSEC) could enable a better definition of what is required of an individual in a specific role.

Quality assurance

1.4.259. Quality assurance (QA) was the process where product and process are examined to determine quality and management of output risk. QA reports are relied upon by managers to understand how organisations under their

[75] JSP 755, Pt1 (V6.2 Jun 21).

[76] https://www.onr.org.uk/operational/tech_insp_guides/ns-insp-gd-012.pdf.

[77] Separation Days are accrued when personnel spend time away from their home base, normally associated with Operational Deployments.

management are performing and where improvements can be made. It was, therefore, imperative that QA activities were thorough enough both in breadth and depth.

1.4.260. QA on 736 NAS was conducted by the Babcock Compliance Manager (CM). The CM was the only appropriately trained, experienced, and authorised person to conduct the role. Compliance activities were conducted in accordance with ISO 9001[78] and PROQUIS[79]. The latter being a BAE risk-based systems that define the requirements. The Maintenance Organisation Exposition (MOE)[80] links all assurance activities to the MAA RA 4800 series, which would be used by military counterparts for QA. Compliance activities are 'live-linked' to PROQUIS which is routinely and remotely kept up to date to reflect relevant changes to the MAA RAs. The scope of the compliance activities, at 736 NAS, was limited by the size of the single person 'team' responsible for them. Witness 18 Exhibit 175

1.4.261. Compliance activities examined all aspects of the Babcock maintenance contract. They did not always directly examine maintenance activities. When a maintenance procedure was the subject of an audit, all aspects of the procedure were scrutinised: authorisations, documentation, adherence to procedure, tool usage, etc. Witness 18

1.4.262. Compliance activities were discussed amongst the Babcock CMs across three sites[81] on a regular basis[82]. The sharing of information from RAF Valley and RAF Leeming often steered the focus of resultant assurance activities at 736 NAS. For example, if a procedure was found to be non-compliant at 100 Sqn, that procedure might become the focus of a subsequent audit at 736 NAS. There was an assumption that all procedures were being conducted in the same manner across all locations. Witness 18

1.4.263. The CM was also more inclined to ensure less experienced personnel were the focus of compliance audits to assure the training they had received. The CM also favoured more in-depth procedures such as engine module changes where there was more to examine, rather than a quick procedure, such as an MCD change. Witness 18

1.4.264. The 736 NAS CM was only able to conduct approximately 12 Compliance Audits per year, of which approximately 3-4 were specifically looking at maintenance procedures. This resulted in multiple procedures rarely being audited. No cycle of maintenance procedures existed to determine which Witness 18

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[78] ISO 9001:2015 specifies international standards and requirements for a quality management system.

[79] PROQUIS - document management system used by BAE Systems.

[80] MRP Part 145 MOE - Annex F RNAS Culdrose BAE Systems (Operations) Ltd – PROQ141178, Issue 27 (May 2020).

[81] RAF Valley (IV and 25 Sqn flying Hawk T Mk2), RAF Leeming (100 Sqn flying Hawk T Mk1 and Mk1A) and RNAS Culdrose (736 NAS)

[82] Weekly dial-in meetings and CM bi-annual site visits.

p]rocedures had been captured and which ones had not. In the seven years the CM had worked at 736 NAS, the MCD change procedure had never been subject to compliance activity.

1.4.265. The MCD procedure conducted at RAF Valley and RAF Leeming were done using an EFDC cell, as per the AMM. It was only 736 NAS that was deviating from the procedure by utilising the expertise at 1710 NAS. Even if the procedure had been audited by RAF Valley or RAF Leeming, as there were no deviations from procedure at those locations, there would have highly likely have been nothing of note to pique the interest of the CM at 736 NAS. Had the procedure been examined, given the depth the CM described the audits, it is highly likely that the deviation would have been noticed and corrected. Witness 18

1.4.266. The MWO co-ordinator, someone who could be involved with a procedure at any stage, is responsible for completing the MWO prior to it being submitted to the Eng Docs Cell. Part of the responsibilities of a fitter and a supervisor[83] of a procedure was to ensure that they had conducted the procedure in accordance with the AMM – this was part of their signatory responsibilities. Deviations from the AMM should have been noticed prior to the involvement of a co-ordinator. However, the Panel determined that pre-printed work orders were often being used without the AMM being present for some maintenance tasks.

1.4.267. The MAM-P states that a co-ordinator should also ensure the personnel conducting the work are trained, authorised, and using the appropriate equipment; the documentation for the task is present and correct; the MWO has been co-ordinated correctly prior to closing the relevant Maintenance Log entry and the relevant electronic information system, where applicable, has been updated. Once content, the MWO was passed to the Eng Docs Cell for processing. The co-ordinator should have noticed any deviation from procedure as they should be checking the MWO against the AMM and the work conducted against the MWO. In the case of XX189 and the A-10 MCD change procedure, the Supervisor was also the Co-ordinator. Exhibit 07

1.4.268. The Engineering Documents Cell at 736 NAS 'process' MWOs. However, they do not conduct QA. The role of the staff within the Eng Docs Cell is to ensure all signatures are in place, the timecards are correct, and the component life is recorded to forecast future maintenance activities. The role of the 736 NAS Eng Docs Cell differs from those on some other units, whereby other Eng Docs Cells are fully authorised and qualified to conduct QA activities in accordance with the 4800 series RAs. Witness 18 Exhibit 70 Exhibit 71

[83] MAM-P Chapter 2.4 Issue 1.3

1.4.269. The 736 NAS Eng Docs Cell had locally produced a form to record the 'mag wipes' and hold the debris for subsequent analysis by 1710 NAS. Any locally produced forms should have still maintained adherence to the AMM. At no point in the AMM procedure did it describe conducting a 'mag wipe'. The procedure called for an MCD change and EFDC analysis. The 'mag wipe' form was outside of the AMM procedure. The deviation could have been detected at the point of production or authorisation of the form. However, this was not the case. Exhibit 95 Exhibit 90

1.4.270. Single Service policy defines how QA activities should be undertaken, and those undertaken on 736 NAS were in line with RN policy which does not mention Aircraft Maintenance Documentation Audits (AMDA). However, the Panel did witness detailed AMDA at another unit[84] and **observed** that this was good practice.

1.4.271. The Panel concluded that the CM was limited by their capacity and that it was not possible to examine all procedures alone, in the depth described, in a reasonable space of time. The lack of audit cycle meant that some procedures were passed over. The sharing of information between Babcock sites was informative and indicative of a good compliance culture while also aiding the identification of potential underlying issues. However, this did steer the focus of the CM and meant that many of the compliance activities at 736 NAS mirrored those at RAF Leeming and RAF Valley. Routine assurance of maintenance activities was undertaken, at the most basic level, by the supervisor and co-ordinator of that procedure. The Panel finds that the capacity of the Compliance Manager limited the ability to conduct compliance activities at 736 NAS and was an **Other Factor**.

1.4.272. **Recommendation. BAE Systems Head of Maintenance Assurance should increase the capacity of the 736 Naval Air Squadron Compliance Cell in order to ensure that more procedures can be exposed to audits more frequently.**

1.4.273. **Recommendation. BAE Systems Head of Maintenance Assurance should adopt a cyclical approach to audits in order to ensure all procedures are examined routinely.**

1.4.274. **Recommendation. Director Military Aviation Authority should produce a pan-Defence policy for carrying out Aircraft Maintenance Documentation Audits in order to ensure that all military operated aircraft are audited and assured to the same level.**

[84] 659 Sqn, 1 Regt AAC, RNAS Yeovilton – in accordance with Army Policy (AP7400, Section 4815, page 366 and 1 Regt AAC Wksp AESOs, Book 2, Part 1, Chapter 1, Order 1, Annex B).

Engine ground runs

1.4.275. Prior to 2012, Engine Ground Runs (EGR) were conducted on the Hawk T Mk1 post MCD change; this confirmed the integrity of the oil system. This requirement was removed after evidence was presented and agreed upon by the TAA and R-R that MCD o-seal rings would be staged checked by a supervisor. The numerous cases of o-seal ring fitment omissions had caused several oil leaks affecting several aircraft types. O-seal rings not being fitted correctly would allow oil to leak from the engine causing indications of low oil level and pressure leading to possible bearing overheat and subsequent loss of thrust and engine seizure. Exhibit 19 Exhibit 20 Exhibit 21 Exhibit 36

1.4.276. An EGR was one method of ensuring MCDs were fitted correctly, as an incorrectly fitted MCD would be forced out of the housing under the operating pressure of the system during the ground run, as demonstrated by the R-R testing. The removal of the EGR procedure reduced the opportunity to identify human errors or component serviceability issues during the MCD change procedure. The detached MCD would have been found during the post EGR inspection. If the self-sealing valve were to also fail during an EGR, then oil from the engine would be identified in the post EGR inspection and the fault could have been remedied prior to flight. By removing the requirement to conduct an EGR the Panel determined that the MCD change procedure carries additional risk compared to the procedure that was extant prior to 2012. The Panel concluded that an EGR was a more reliable and consistent barrier. The Panel finds the removal of the EGR, as a safety barrier, post MCD maintenance to be a **Contributory Factor**. Exhibit 78 Exhibit 77

1.4.277. **Recommendation. The Hawk Type Airworthiness Authority should identify a method of confirming the correct fitment of Magnetic Chip Detectors while the system is under operating pressure in order to ensure the Magnetic Chip Detectors are locked in place, without leaks, prior to flight.**

Post-crash management

1.4.278. The Stn crash cover was reduced when the crash vehicles responded to the accident, requiring the remaining 736 NAS airborne aircraft [redacted] to divert to the nominated diversion, Newquay. Witness 3 Witness 4

1.4.279. The general PCM response from the Stn was cited as an exemplar response. The crash site was close to the base and PCM and emergency personnel were on site quickly. The local connection to the base almost certainly assisted in the rapid response and public's willingness to be forthcoming with information. Exhibit 57

1.4.280. The Panel did, however, **observe** that the harvesting of evidence fell below the standard expected as defined in the Manual of Post-Crash Management. Many items were photocopied rather than the originals gathered and quarantined, and many items were missed altogether. These included any original Operations room documents from 736 NAS, all the Survival Equipment maintenance records, aircrew logbooks and engineering personnel competency logs. Exhibit 155

1.4.281. The reduced oversight of evidence during the handover of the site resulted in some items of AEA being stolen. This unfortunately meant that the post-accident analysis by RAFCAM was not possible for those items.

KINFORMING

1.4.282. Nominated individuals and Next of Kin (NoK) are informed of injury, missing, or killed in action status through the process of KINFORMING. This rigid process ensures that the correct casualty thresholds have been met and the required information was gathered prior to making first contact with families. The process also allows for support staff / agencies to be in place after the initial information is delivered.

1.4.283. After the crash of XX189, both crew members contacted their NoK using the mobile phone carried by the Passenger. Given their status after the ejection, no formal KINFORMING was required. However, a well-intentioned individual at RNAS Culdrose commenced formal KINFORMING without being authorised, instructed, or having the correct information. Witness 1 Witness 2 Exhibit 121

1.4.284. This deviation from approved procedure, caused [redacted] This would have been avoided by following the approved procedure. The Panel **observed** that the KINFORMING procedures at RNAS Culdrose require re-briefing across the unit to prevent unnecessary upset in the future. Witness 2

1.4.285. Trauma Risk Management (TRiM) was offered to some of the service personnel involved in the accident and was seen by Station Management as an effective way of dealing with the effects of what had occurred. The Panel noted that some civilian witnesses could be equally traumatised by what they had seen, but TRiM and Pastoral Support was limited to service personnel only.

1.4.286. Babcock highlighted that they had a process similar to TRiM, provided via an external agency, to deal with incidents such as this. However, formal TRiM from the Stn was also offered to Babcock staff when it became apparent their own process was limited. Exhibit 171

1.4.287. The Panel **observed** extending the TRiM support to families, close relatives and civilian witnesses in an official capacity would be highly beneficial when dealing with such traumatic events.

1.4.288. The Panel recognise that discussing injury or worse with partners and / or NoK would be a difficult subject. However, providing them with an understanding of the processes in place can protect personnel and sensitive information post an accident or incident.

Summary of Findings

1.4.289. **Causal factors.** The following were found to be causal factors:

a. The Panel finds that the incorrect fitting of the Yellow MCD was a **Causal Factor**. 1.4.90

b. The Panel finds that the failure within the self-sealing valve was a **Causal Factor**. 1.4.97

c. The Panel finds that the positioning of the EPLB antenna was a **Causal Factor** in the failure of the LSJ. 1.4.196

d. The Panel finds that the incorrect packing of the restrainer was a **Causal Factor** of the failure of the LSJ. 1.4.219

1.4.290. **Contributory factors.** The following were found to be contributory factors:

a. The Panel finds that the rapid loss of oil from the system was a **Contributory Factor**. 1.4.78

b. The Panel finds that the failure of the HP Compressor Location Bearing was a **Contributory Factor**. 1.4.78

c. The Panel finds that the incorrect folding of the stole within the restrainer was a **Contributory Factor** in the failure of the LSJ. 1.4.219

d. The Panel finds the SES supervision to be a **Contributory Factor** in the failure of the LSJ. 1.4.229

e. The Panel finds the removal of the EGR, as a safety barrier, post MCD maintenance to be a **Contributory Factor**. 1.4.276

1.4.291. **Aggravating factors.** The following were found to be aggravating factors:

a. The Panel finds that the wording used across the ADS was an **Aggravating Factor**. 1.4.111

b. The Panel finds that safe recovery of [redacted] was affected by the absence of effective communication and this was an **Aggravating Factor**. 1.4.131

c. The Panel finds that the restricted capacity in the radar control room was an **Aggravating Factor**. 1.4.135

d. The Panel finds the unserviceable GPS and the interaction with ATC regarding D005A caused a delay in landing and were an **Aggravating Factor.** 1.4.138

e. The Panel finds that the extended track flown by the Pilot and the additional airborne time was an **Aggravating Factor**. 1.4.139

1.4.292. **Other factors.** The following were found to be other factors:

a. The Panel finds that engineering training and authorisation was an **Other Factor.** 1.4.60

b. The Panel finds that the lack of an inspection regime on the MCD housing was an **Other Factor**. 1.4.98

c. The Panel finds that differing quality and clarity of the MCD maintenance procedure across the engine types was an **Other Factor**. 1.4.151

d. The Panel finds that the wording of the Hawk T Mk1 ADS was an **Other Factor**. 1.4.155

e. The Panel finds that the deviation while conducting the MCD change on XX189 was an **Other Factor**. 1.4.164

f. The Panel finds that the inadequate area allocated to conduct safety critical functions was an **Other Factor** in the failure of the LSJ. 1.4.203

g. The Panel finds that the quality of the DAP and the method of introduction into service was an **Other Factor** in the failure of the LSJ. 1.4.207

h. The Panel finds that the use of 's hooks' was an **Other Factor** in the failure of the LSJ. 1.4.224

i. The Panel finds that the on-the-job training of the RN SETs was an **Other Factor** in the failure of the LSJ. 1.4.246

j. The Panel finds that the assurance of the 736 NAS SES was an **Other Factor** in the failure of the LSJ. 1.4.247

k. The Panel finds that the capacity of the Compliance Manager limited the ability to conduct compliance activities at 736 NAS and was an **Other Factor**. 1.4.271

1.4.293. **Observations.** The following observations were made:

a. The Panel **observed** that a recommendation from a previous Hawk SI (XX179) recommending the fitting of a CVR was still open at the time of writing. 1.4.4

b. The Panel **observed** that a procedure to confirm the correct timing of the MCVR clock on a regular basis would prevent timing errors from reoccurring. 1.4.22

c. The Panel **observed** that a review of the RA could further define flying with a passenger with experience or who is qualified aircrew but unable to meet the definition of supernumerary crew. 1.4.40

d. The Panel **observed** that the potential for discomfort during the fitting of the MCDs could be linked to the incorrect fitting and supervisory checks of the MCD on XX189. 1.4.89

e. The Panel **observed** that the inclusion of the two different bands in the ADS likely resulted from directly quoting R-R's documentation, even though R-R cater for a wide range of customers, some of whom use the Hawk operationally. 1.4.106

f. The Panel **observed** that there was a consensus that the documentation was not as good as it could be. 1.4.108

g. The Panel **observed** that the requirement to maintain 1g in the circumstances of this accident was an almost impossible requirement. 1.4.110

h. When the limitation was so important to the continued running of the engine, the Panel **observed** that the limit in question should be clearly defined. 1.4.111

i. The Panel **observed** that the Hawk T Mk1 RTS contained a large amount of aircrew advice, which would be better placed in the Aircrew Manual and not in the limitations document. 1.4.113

j. The Panel **observed** that the inconsistencies of the 'Land ASAP' definition across fleets introduces the potential for misinterpretation and increased risk. 1.4.118

k. The Panel **observed** that the practise of switching between rotary wing and fixed wing types has the potential to introduce HF hazards which may not be fully evident or understood. 1.4.118

l. The Panel **observed** that the incorrect references to 'Tommy Bars' should have been noted and corrected by R-R and Hawk T Mk1 users. 1.4.148

m. The Panel **observed** that at no point had rectification activity taken place to incorporate the improvements made in the T Mk2 ADS into the T Mk1 ADS leaving multiple issues remaining in the T Mk1 ADS that had been addressed elsewhere. 1.4.155

n. The Panel **observed** that a fleet operated under multiple ADHs led to a complex in-service operating model which did not allow for standardised delivery. 1.4.169

o. The Panel **observed** that out of the three Hawk T Mk1 operating locations, only one was using the correct Inflator / Deflator for LSJ inflation tests. 1.4.200

p. The Panel **observed** that advice was given to FJ aircrew to use the protective velveteen visor cover to reduce the gap between the visor and the helmet shell to reduce the likelihood of MDC spatter entering the eyes. This advice, in addition to closing eyes prior to ejection, should be followed to avoid injury during the ejection sequence. 1.4.238

q. The Panel **observed** significant differences between how RAF TG13 personnel and RN SETs deliver their role. 1.4.246

r. The Panel, whilst visiting other units, **observed** good working practices in addition to the requirements of the DAP. 1.4.246

s. The Panel **observed** that anything reported on MEMS, or indeed any other contractor-based error management system, should also be reported via ASIMS to ensure issues are highlighted Defence wide and tracked correctly for analysis and trending. 1.4.253

t. The Panel **observed** the MAA term SQEP should be replaced by a more definitive term which is less subjective and more measurable. 1.4.258

u. The Panel did witness detailed AMDA at another unit and **observed** that this was good practice. 1.4.270

v. The Panel did, however, **observe** that the harvesting of evidence fell below the standard expected as defined in the Manual of Post-Crash Management. 1.4.280

w. The Panel **observed** that the KINFORMING procedures at RNAS Culdrose require re-briefing across the unit to prevent unnecessary upset in the future.	1.4.284
x. The Panel **observed** extending the TRiM support to families, close relatives and civilian witnesses in an official capacity would be highly beneficial when dealing with such traumatic events.	1.4.287

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PART 1.5

Recommendations

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PART 1.5 – RECOMMENDATIONS

1.5.1. **Introduction.** The following recommendations are made to enhance pan Defence Safety:

1.5.2. **Deputy Chief of the General Staff should:**

a. Conduct promotional messaging for an Army audience to highlight the importance of conducting visual checks correctly.	1.4.93

1.5.3. **Director Military Aviation Authority should:**

a. Produce a pan-Defence policy for carrying out Aircraft Maintenance Documentation Audits in order to ensure that all military operated aircraft are audited and assured to the same level.	1.4.274

1.5.4. **Head Defence Equipment and Support Airworthiness Team should:**

a. Ensure that other Type Airworthiness Authorities consider the read across of technical recommendations from this Service Inquiry in order to prevent similar occurrence on other platforms.	1.4.171

1.5.5. **Head Air Commodities Delivery Team should:**

a. Conduct a Process Verification Audit on existing Aircrew Equipment Assembly Digital Air Publications in order to ensure that they are all as clear and as simple as possible for use by Survival Equipment technicians of all experience levels.	1.4.220
b. Improve the introduction and amendments process for Digital Air Publications in order to ensure that users can understand and comply with the Digital Air Publications.	1.4.208
c. Examine the design of the Emergency Personal Locator Beacon antenna to determine if the in-service antenna is the most appropriate design for use with the Mk42M Life Saving Jacket in order to prevent similar interaction with the restrainer during inflation in the future.	1.4.197

1.5.6. **Director Royal Navy Safety should:**

a. Conduct promotional messaging for a Royal Navy audience to highlight the importance of conducting visual checks correctly.	1.4.91

1.5.7. **Inspector of Flight Safety (Royal Air Force) should:**	
a. Conduct promotional messaging for a Royal Air Force audience to highlight the importance of conducting visual checks correctly.	1.4.92
1.5.8. **RNAS Culdrose Delivery Duty Holder should:**	
a. Instigate a process whereby the Multi-channel Voice Recorder clocks are regularly checked in order to ensure that it remains synchronised.	1.4.23
b. Review the use of D005A in order to ensure that all risks, especially those associated with emergency procedures, are As Low As Reasonably Practicable and Tolerable.	1.4.132
c. Ensure the co-ordination of Air Traffic Control staffing levels with the planned flying activity in order to ensure that adequate capacity is available to respond to aviation emergencies.	1.4.136
d. Re-iterate the importance of adhering to procedure in order to ensure a reduction in deviation from authorised process.	1.4.165
e. Ensure that the correct mechanism for challenging or changing engineering related processes is understood in order to prevent future unauthorised deviations.	1.4.166
f. Review the conduct of all Hawk maintenance procedures in order to ensure compliance with the Aircraft Maintenance Manual.	1.4.167
g. Review the working environment within the 736 Naval Air Squadron Survival Equipment Section against the requirements of Digital Air Publication 108A-0007-1 in order to ensure compliance.	1.4.204
h. Review the structure and location of the SES department on 736 NAS in order to ensure personnel are led and managed in a way that achieves the output in a safe and effective and policy compliant manner.	1.4.230
1.5.9. **RNAS Culdrose Quality System Owner should:**	
a. Review the effectiveness of aviation related audit processes to ensure that latent problems are detected and eliminated in order to improve Air Safety.	1.4.168

1.5.10. **Hawk Type Airworthiness Authority should:**	
a. Implement a robust process to ensure Magnetic Chip Detector housings are serviceable in order to prevent unserviceable housings from being used.	1.4.100
b. Review the Air System Document Set in order to ensure they correctly reflect the configuration of the aircraft.	1.4.149
c. Determine whether the risk associated with the use of Magnetic Chip Detectors is fully understood in order to ensure their use remains As Low As Reasonably Practicable and Tolerable.	1.4.150
d. Standardise Magnetic Chip Detector maintenance procedures across all Adour marks in order to ensure commonality of standards across the fleet.	1.4.152
e. Compare the Hawk T Mk1 and Hawk T Mk2 Flight Reference Cards and Aircrew Manuals to identify good practice and generate amendments in order to ensure all documents contain standardised, concise, and accurate advice.	1.4.156
f. Review the Hawk T Mk1 Air System Document Set in order to remove ambiguity and ensure that the most up-to-date advice is available to aircrew in all documents, and that the vital information contained is standardised.	1.4.157
g. Identify a method of confirming the correct fitment of Magnetic Chip Detectors while the system is under operating pressure in order to ensure the Magnetic Chip Detectors are locked in place, without leaks, prior to flight.	1.4.277
1.5.11. **Delegated Release to Service Authority (Royal Air Force) should:**	
a. Should review the use of the word nominal and include a definition in the glossary in order to ensure aircrew have clear and specific guidance.	1.4.112
1.5.12. **BAE Systems Head of Maintenance Assurance should:**	
a. Increase the capacity of the 736 Naval Air Squadron Compliance Cell in order to ensure that more procedures can be exposed to audits more frequently.	1.4.272
b. Adopt a cyclical approach to audits in order to ensure all procedures are examined routinely.	1.4.273

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PART 1.6

Convening Authority Comments

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PART 1.6 – CONVENING AUTHORITY COMMENTS

Introduction

1.6.1. This Service Inquiry (SI) was convened on 7 April 2021 to investigate the circumstances surrounding the loss of Hawk T MK1 XX189 of 736 Naval Air Squadron (NAS), Royal Naval Air Station (RNAS) Culdrose on 25 March 2021.

1.6.2. After take-off for a routine training sortie, the pilot was alerted to an engine oil fault light on the aircraft's warning panel, with the aircrew electing to recover to RNAS Culdrose. Subsequent engine failure during recovery led to the pilot and passenger ejecting and the aircraft crashing into nearby uninhabited woodland.

1.6.3. The SI panel has submitted its report to me after 10 months of detailed evidence gathering, interviews and analysis. The findings identify the accident factors that directly relate to this occurrence, however, there are broader themes that are applicable to wider Defence.

Causal Factors

1.6.4. The cause of the accident was engine failure due to a loss of engine oil after an incorrectly fitted Magnetic Chip Detection (MCD) plug was ejected from its housing on engine start by the oil system working pressure. Furthermore, there was a failure of the self-sealing valve situated within the missing MCD housing, the purpose of which is to prevent oil from leaking when the MCD is not present.

1.6.5. The panel determined that the requirement for an engine ground run following MCD maintenance had been removed circa 2012. This had previously served as both a component fault identification process and as a screen for human errors. Furthermore, there was no prescribed inspection and servicing regime for the self-sealing valve and thus, there was no way of identifying wear and tear on this critical component. The absence of these checks meant there was no reliable and consistent method of ensuring system integrity. I note, since the identification of the cause, post-maintenance engine ground runs have recommenced at RNAS Culdrose.

Actions of the pilot

1.6.6. The SI Report references a number of aggravating factors including the route flown and the communication flow between aircrew and Air Traffic Control that affected the final outcome of the occurrence. These should be considered in context whilst acknowledging the professionalism of the aircrew in what was an undoubtedly stressful and dynamic situation. These aggravating factors provide excellent learning tools with which to hone working practices and further mitigate the inherent risks of operating in the air.

Aircraft Post Crash Management

1.6.7. The immediate actions of the post-crash management team and emergency personnel were commendable. Rapid mobilisation, inter-agency liaison, and strong connections with the local community played a role in ensuring the wreckage site was quickly identified, secured and all support elements promptly deployed.

1.6.8. During evidence gathering, some items were missed, and many important items were photocopied instead of the originals being impounded. Personnel must be reminded of the importance of securing all available evidence in support of the investigation and analysis phase to assist in the prevention of reoccurrence. Theft from the scene of some items of aircrew equipment also meant that post-accident analysis was inhibited.

Urgent Safety Advice

1.6.9. The Pilot's Life Saving Jacket (LSJ) deflated immediately after activation post-ejection, following a burst to the stole. The LSJ is a vital piece of survival equipment that would have been critical for flotation had the crew ejected over water. Due to the potential further risk-to-life to other users posed by this failure, the SI panel issued an Urgent Safety Advice notice and carried out an in-depth analysis of the failure mechanism. The panel concluded that the cause of the LSJ bursting was due to a combination of factors including: the incorrect packing of the stole within the restrainer; the incorrect packing of the restrainer within the protective cover; and the misplacement of the Emergency Personal Locator Beacon (EPLB) antenna. Each of these factors caused constriction of the inflating gas flow that, in turn, created an area of over pressure resulting in a burst to the stole and deflation of the LSJ.

Digital Air Publications

1.6.10. The panel opined that the lack of clarity within the Aircrew Equipment Assemblies Digital Air Publications led to inconsistencies in the packing of the EPLB within the LSJ which were not raised through MOD Form765 or another appropriate engineering safety forum. With a greater reliance on digital publications and reference material, it is imperative that all electronic publications are clear, concise, and easy to use, with the necessary remedial action instigated to address any identified shortfalls, ambiguity or improvements to procedures.

Assurance

1.6.11. Assurance measures should be designed to ensure consistency of approach across all users of a piece of equipment, regardless of Service and / or location. Best practice should be identified and followed by all asset users. In this instance, the users were spread across 2 Services and 4 sites. It is disappointing that there was no consistent assurance regime in place across the user community.

In the case of the LSJ, isolation of the 736 NAS Safety Equipment Section from the Services' other users, and indeed from the RNAS 'Main Bay', may go some way to explaining how this manifested. However, with a single 'type airworthiness authority,' standardised operating, maintenance and engineering procedures should be well integrated on an aircraft that has been in service with the UK military for over 40 years.

Conclusion

1.6.12. The Hawk T Mk1 was retired from general service in March 2022, though is due to remain in operation with the Royal Air Force Aerobatic Team until 2030. This SI identifies lessons that are pertinent to both Hawk T Mk2 and future Qatari Hawk thus particular attention should be paid to the recommendations and observations that come from this report to ensure that the ageing fleet is appropriately monitored.

1.6.13. There are valuable lessons from this occurrence that are transferrable across all emergency occurrences. From post-crash management and kinforming procedures to aviation specifics across all air systems including, effective and timely communication flow between aircrew and Air Traffic Control, clarity of digital engineering publications and the difficulties of duty holder constructs across platforms operating in the joint environment.

1.6.14. Having read this report, I am content that this occurrence has been investigated, analysed, and reported thoroughly, accurately, and rigorously. I am assured that the recommendations contained within this report have or will be actioned to reduce the likelihood of a future reoccurrence in the Hawk and other fleets.

S J Shell CB OBE MA
Air Marshal
Director General Defence Safety Authority