Defence
Safety
Authority

Service Inquiry

HAWK T Mk1A XX204
RAF Valley

20 March 2018

Defence Safety Authority

Intentionally Blank

PART 1.1

Covering Note & Glossary

Intentionally Blank

PART 1.1 – COVERING NOTE

DSA/SI/02/18

24 Apr 19

DG DSA

SERVICE INQUIRY INVESTIGATION INTO ACCIDENT INVOLVING HAWK T MK1A XX204 AT RAF VALLEY ON 20 MAR 18

1. The Service Inquiry Panel assembled at the Ministry of Defence Main Building, on the 29 Mar 18 by order of the DG DSA for the purpose of investigating the accident involving Hawk T Mk1A XX204 on 20 Mar 18 and to make recommendations in order to prevent recurrence. The Panel has concluded its inquiries and submits the provisional report for the Convening Authority's consideration.

2. The following inquiry papers are enclosed:

Part 1 REPORT	Part 2 RECORD OF PROCEEDINGS
Part 1.1 Covering Note and Glossary	Part 2.1 Diary of Events
Part 1.2 Convening Orders & TORs	Part 2.2 List of Witnesses
Part 1.3 Narrative of Events	Part 2.3 Witnesses Statements
Part 1.4 Findings	Part 2.4 List of Attendees
Part 1.5 Recommendations	Part 2.5 List of Exhibits
Part 1.6 Convening Authority Comments	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

[redacted]
President
XX204 SI

MEMBERS

[redacted]
Aircrew Member
XX204 SI

[redacted]
Engineering Member
XX204 SI

Intentionally Blank

GLOSSARY

ADH	Aviation Duty Holder
ADR	Accident Data Recorder
ADS	Aircraft Document Set
AGL	Above Ground Level
AIHF	Accident Investigation and Human Factors
AOB	Angle of Bank
AOC	Air Officer Commanding
AOT	Air Officer Training
APO	Aircrew Planning Officer
ARM	Accident Route Matrix
AS	Air Safety
ASM	Air Safety Management
ASMP	Air Safety Management Plan
ASMS	Air Safety Management System
ASMT	Air Safety Management Team
ASSG	Air Safety Steering Group
ATC	Air Traffic Control
ATEC	Air Test and Evaluation Centre
AUW	All Up Weight
BHC	Barometric Height Coarse
BHF	Barometric Height Fine
BTR	Basic Training Requirement
CAMO	Continuing Airworthiness Management Organisation
CFS	Central Flying School
CoC	Chain of Command
CofG	Centre of Gravity
Comdt	Commandant
CT	Continuation Training
CVR	Cockpit Voice Recorder
DAIB	Defence Accident Investigation Branch
DASOR	Defence Air Safety Occurrence Report
DD	Display Directive
DDH	Delivery Duty Holder
DFT	Director Flying Training
DHAN	Duty Holder Advice Note
DWR	Deployment Warning Role
ECC	Emergency Coordination Centre
EFATO	Engine Failure After Take-off
FAT	Flying Ability Test
FOB	Flying Order Book
FPA	Flight Path Angle
FSV	Formal Staff Visit
ft	Feet
FTRS	Full Time Reserve Service
g	G force

GDAS	Graphical Data Analysis System
GH	General Handling
Gp	Group
GPS	Global Positioning System
HAMPA	Hawk Advanced Mission Planning Aid
HF	Human Factors
HFACS	Human Factors Analysis Classification System
HIOS	Hawk Integrated Operational Support
HQ	Headquarters
hrs	Hours
HSTF	Hawk Synthetic Training Facility
IAP	Initial Aiming Point
IF	Instrument Flying
IRT	Instrument Rating Test
JARTS	Joint Aircraft Recovery and Transportation Squadron
JPA	Joint Personnel Administration
kts	Knots
MAA	Military Aviation Authority
MF	MOD Form
min	Minutes
MOD	Ministry of Defence
MPFR	Multi Purpose Flight Recorder
MSD	Minimum Separation Distance
NAS	Naval Air Squadron
NVQ	National Vocation Qualification
OC	Officer Commanding
ODH	Operating Duty Holders
OIC	Officer in Charge
OOA	Out Of Area
PAPI	Precision Approach Path Indicator
Para	Paragraph
PCM	Post Crash Management
PCMIO	Post Crash Management Incident Officer
PEFATO	Practice Engine Failure After Take-off
PFL	Practice Forced Landing
PMTF	Post Maintenance Test Flight
PSP	Personal Survival Pack
QA	Quality Assurance
QFI	Qualified Flying Instructor
RA (sortie)	Red Arrows
RAF	Royal Air Force
RAFAT	The RAF Aerobatic Team
RAFCAM	RAF Centre of Aviation Medicine

RBC	Risk Balance case
RHAG	Rotary Hydraulic Arrestor Gear
ROD	Rate of Descent
RPM	Revolutions per Minute
RtL	Risk to Life
RTS	Release to Service
SA	Situational Awareness
SAC	Senior Aircraftman
SC	Supernumerary Crew
sec	Seconds
SI	Service Inquiry
SNCO	Senior Non-commissioned Officer
SOP	Standard Operating Procedure
Sqn	Squadron
SSR	Standard Stall recovery
STANEVAL	Standards Evaluation
STARS	Sqn Training Achievement Recording System
TAA	Type Airworthiness Authority
TOR	Terms of Reference
TQA	Trade Qualification Annotation
VAS	Visiting Aircraft Section
VMC	Visual Meteorological Conditions
W&M	Weight and Moment
1PA	First Party assurance

Intentionally Blank

PART 1.2

Convening Order & TORs

OFFICIAL SENSITIVE

Intentionally Blank

Defence Safety Authority

Service Inquiry Convening Order

29 Mar 18

SI President
SI Members

Hd Defence AIB
DSA Legad

Copy to:

PS/SofS
PS/Min(AF)
PS/Min(DPV)
PS/Min(DP)
PS/Perm Sec

DPSO/CDS
MA/VCDS
Sec/1SLCNS
MA/CGS
PSO/CAS

PSO/Comd JFC
PSO/DComOps
MA/DMAA
MA/AOC 22Gp
DDC Director

DSA DG/SI/02/18 – CONVENING ORDER FOR THE SERVICE INQUIRY INTO THE HAWK T1 XX204 CRASH AND FATALITY THAT OCCURRED NEAR RAF VALLEY ON 20 MARCH 2018.

1. In accordance with Section 343 of Armed Forces Act 2006 and in accordance with 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 recurrence.

3. The SI Panel will formally convene at Ministry of Defence Main Building, Whitehall, London at 1300L on Thursday 29 March 2018.

4. The SI Panel comprises:

President: [redacted] **RN**
Members: [redacted] **RAF**
[redacted] **REME**

5. The legal advisor to the SI is [redacted] (DSA-MAA LEGAD) and technical investigation/inquiry support is to be provided by the Defence Accident Investigation Branch (Defence AIB).

6. The SI is to investigate and report on the facts relating to the matters specified in its Terms of Reference (TOR) and otherwise to comply with those TOR (at Annex). It is to record all evidence and express opinions as directed in the TOR.

7. Attendance at the SI by advisors/observers is limited to the following:

Head Defence AIB – Unrestricted Attendance.
Defence AIB investigators in their capacity as advisors to the SI Panel – Unrestricted Attendance.

8. The SI Panel will work initially from the DAIB facilities at Farnborough. Permanent working accommodation, equipment and assistance suitable for the nature and duration of the SI will be requested by the SI President in due course.

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

Original Signed

R F P Felton CBE
Lt Gen
DG DSA – Convening Authority

Annex:

A. Terms of Reference for the Service Inquiry into the Hawk T1 XX204 crash and fatality that occurred at RAF VALLEY on 20 Mar 2018.

Annex A To
DSA DG/SI/02/18 Convening Order
Dated 29 Mar 18

TERMS OF REFERENCE FOR THE SERVICE INQUIRY INTO THE HAWK T1 XX204 CRASH AND FATALITY THAT OCCURRED AT RAF VALLEY ON 20 MARCH 2018.

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. Ascertain whether Service personnel involved were acting in the course of their duties.

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

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

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

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

g. Identify if the levels of planning and preparation were commensurate with the activities' objectives.

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

i. Ascertain if aircrew escape and survival facilities and equipment assemblies were fully utilized and functioned correctly.

j. Determine any relevant equipment deficiencies.

k. Determine whether the Aircraft 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.

l. Assess any Health and Safety at Work and Environmental Protection implications in line with JSP 375 and JSP 418.

m. Determine and comment on any broader contributory organisational and/or resource factors.

n. Ascertain value of loss/damage to the Service.

o. Report and make appropriate recommendations to DG DSA.

2. The Terms of Reference above have been designed to be wide ranging in order to ensure that you have the freedom to investigate wherever the evidence leads. During the course of your

investigations, should you identify a potential conflict of interest between the CA and the Inquiry, you are to pause work and take advice from your DSA Legal Advisor and DG DSA.

3. If at any stage the Panel discover 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; in order to initiate remedial actions immediately. Consideration should also be given to raising an Urgent Safety Advice note.

4. You are to ensure that any material provided to the Inquiry by the United States, or any other foreign state, is properly identified as such, and is marked and handled in accordance with MOD security guidance. This material continues to belong to those nations throughout the SI process. Before the SI is released to a third party, authorisation should be sought from the relevant authorities in those nations to release, whether in full or redacted form, any of their material included in the SI report, or amongst the documents supporting it. You are not to make a judgement on the origin of the classified material. In addition, the relevant PDR directive should be informed early when dealing with the US or other foreign state material, and should be engaged in the process when doubt exists.

PART 1.3

Narrative of Events

Intentionally Blank

PART 1.3 – NARRATIVE OF EVENTS

All times local (Zulu).

Synopsis

1.3.1. At 1325 hours (hrs) on 20 Mar 18, a Royal Air Force (RAF) Hawk T Mk1A, tail number XX204, crashed on the airfield at RAF Valley whilst conducting a routine training sortie. The aircraft had departed RAF Valley with the intention of conducting a Practice Engine Failure After Take-off (PEFATO) before transiting to RAF Scampton; the aircraft had 2 persons on board, the pilot in the front cockpit and an engineer in the rear cockpit. The pilot successfully ejected sustaining a major injury[1]; the engineer, Corporal Jonathan Bayliss, did not eject and was declared dead at the accident scene; the aircraft sustained significant damage.

Exhibit 01, Exhibit 02, Exhibit 03, Exhibit 04, Exhibit 05, Exhibit 06

Narrative

1.3.2. On 20 Mar 18 a Red Arrows pilot, callsign RED 3 (R3), was one of 5 Royal Air Force Aerobatic Team (RAFAT) pilots scheduled to independently fly from RAF Scampton to RAF Valley to conduct emergency training in the Hawk Synthetic Training Facility (HSTF), before returning to RAF Scampton. The transit sorties were Continuation Training[2] (CT) serials planned to allow R3 to achieve mandated flying currencies whilst concurrently familiarising the engineer[3] with flight in the Hawk. The engineer was a member of the Circus[4] and deemed to be Supernumerary Crew (SC).

Exhibit 04, Witness 1A, Exhibit 07

1.3.3. R3 departed RAF Scampton at 0924 hrs and conducted a medium level transit utilising the Lichfield Radar Visual Corridor at Flight Level 140[5] before descending low level[6] in North Wales and landed at RAF Valley at 1003 hrs. R3 completed a malfunction training sortie in the HSTF between 1115 hrs and 1200 hrs[7]. During this period the engineer carried out a Turn Round servicing and refuel of the aircraft.

Exhibit 08, Exhibit 09, Witness 1A, Exhibit 01, Exhibit 10, Exhibit 11, Exhibit 12

1.3.4. R3 warned out[8] by telephone with RAF Valley Station Operations at 1250 hrs stating his intention of conducting a PEFATO, before transiting at 5000 ft to the Lake District, and returning to RAF Scampton. R3 and the engineer completed a walk round of the aircraft assisted by 2 members of the Visiting Aircraft Section[9].

Exhibit 03, Witness 1B, Witness 1A, Exhibit 13, Exhibit 14

1.3.5. At 1314 hrs R3 requested start on the Air Traffic Control (ATC) Ground frequency and subsequently requested to taxi 3 minutes (min) later. Taxi clearance, including the

Exhibit 15

---

[1] 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.
[2] All pilots were required to possess a current instrument rating and maintain flying currency in core aircraft handling skills.
[3] Two other engineers were also conducting similar sorties that day.
[4] The Circus were RAFAT engineers who flew in the aircraft to provide ground support during the display season.
[5] The Lichfield Radar Corridor is one of 7 Radar Corridors used by Military Aircraft to transit crowded Civilian Airspace; they are mainly to facilitate crossing from one side of the country to the other. XX204 transited at an altitude of 14,000 ft. (VATSIM UK – Military Regional Training Scheme – Radar Corridors – Controllers Guide to Radar Corridors Revision 8 20 Jan 2012. Section 1 Introduction https://vatsim.uk/download/fetch/?downloadID=00197).
[6] Low-flying is categorised as flight below 2000 ft above ground level.
[7] R3 signed into the HSTF building between 1030 hrs and 1215 hrs but the sortie report had no start or end time. He sent/received text messages at 1106 hrs and 1205 hrs and therefore it is estimated that he was in the simulator module between those times.
[8] Warning out entailed the pilot providing airfield departure details and requirements to Air Traffic Control.
[9] The Visiting Aircraft Section personnel were contract engineers working on No 4 Squadron RAF.

airfield pressure setting[10], was passed and read back by R3. During the taxi to the holding point, R3 was given departure clearances and then switched to the ATC Tower frequency.

1.3.6. Having taxied to Runway 31, the duty runway, the pilot transmitted '*RED 3 ready for departure, PEFATO on request*'. Although he had warned out with a request for a PEFATO, the Tower controller had not been made aware of that intention and cleared the aircraft to *'line up and wait'*. After discussions in the ATC tower to clarify any restrictions, XX204 was offered a PEFATO to Runway 01/19 for a high approach[11], or to the reciprocal, Runway 13[12]. R3 proposed an approach back to the duty runway, which was agreed, and take-off clearance was given at 1322 hrs; XX204 was the only aircraft in the circuit. Exhibit 02 Witness 2 Exhibit 16

1.3.7. After take-off, and on passing approximately 255 feet (ft) and at 257 knots (kts)[13], the aircraft commenced a right turn. Having turned through 36°, and at circa 450 ft and 278 kts, R3 initiated a PEFATO. He transmitted to ATC that he had a simulated engine failure and was positioning for Low Key[14] Runway 31; although he initially requested a high approach ATC offered a low approach[15]. XX204 achieved a maximum height on the downwind leg of approximately 1400 ft[16] above ground level (AGL) and a speed of 183 kts. R3 reported Low Key when downwind and parallel to a position approximately halfway down the runway and 7 seconds (sec) later commenced a gradual right final turn towards the runway from circa 1030 ft and 183 kts. XX204's ground track is shown in Figure 1.3.1. Exhibit 17 Exhibit 02 Exhibit 18

---

[10] 1032 hPa. hPa: hectopascal is the unit of atmospheric pressure used to derive height or altitude.
[11] High Approach: The RAF Valley Flying Order Book stated that if a PFL is not planned to touch-and-go, a high approach should be initiated by 300 ft QFE. QFE is the pressure setting for aerodrome operations giving height above the airfield.
[12] Maintenance work at the threshold of Runway 19 restricted clearances to the cross runway (01/19).
[13] Height and speed are taken from the Accident Data Recorder; variations in data will be considered in the Part 1.4.
[14] Low Key is a virtual position within the ATC visual circuit abeam the intended landing point.
[15] Low Approach: The approach can be continued but the aircraft is not cleared to use the runway. If the runway in use is occupied by aircraft or vehicles, an approaching aircraft may be cleared to carry out a low approach which includes a descent not below a specified height or altitude. The minimum height or altitude is defined in regulatory documentation and/or local instructions as appropriate.
[16] ADR height indicated between 1321 and 1424 ft.

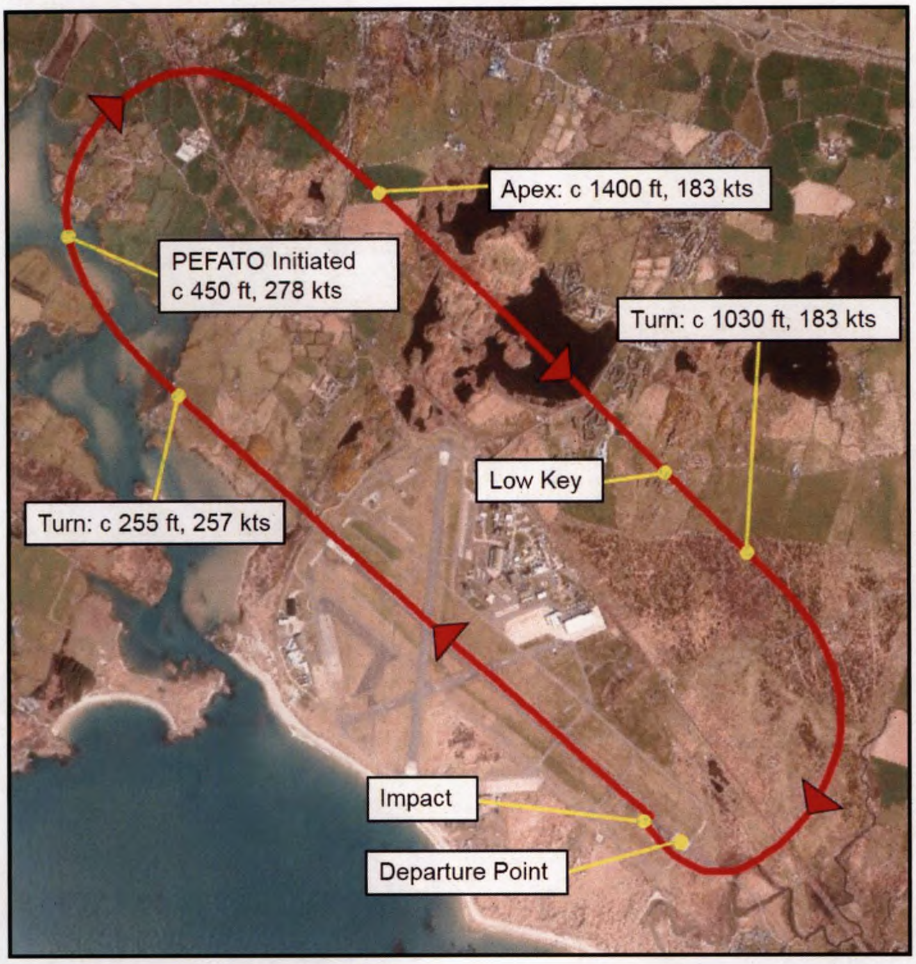


Figure 1.3.1 – XX204's ground track

1.3.8. Angle of Bank (AOB) was progressively applied, to about 45°, for the first 90° of the turn. After approximately 30° of turn the undercarriage was selected down and full flap was selected circa 5 sec later as the undercarriage travelled. About halfway around the final turn, just as the undercarriage locked down, ATC prompted R3 for confirmation that his landing gear was down, to which he immediately replied '*RED 3 gear down*'. ATC then issued clearance for a low approach, which R3 read back; there were no further radio transmissions between the aircraft and ATC. Exhibit 02 Exhibit 19 Exhibit 20

1.3.9. As R3 read back the ATC clearance and the flap reached the fully down position the aircraft was descending through 565 ft, with a high AOB, which momentarily peaked at 70°, had a pitch attitude of 10° nose down and 150 kts airspeed. At around 345 ft, with an increasing rate of descent (ROD), and having crossed through the runway centreline, the throttle was advanced to maximum and roll inputs applied to level the wings, indicating an intent to go-around[17]. Coincident with the application of full power the aircraft experienced a roll reversal and distinct right wing drop, the aircraft's speed was 146.7 kts. During the subsequent 3 secs, applications of full left aileron and full aft control column were made Exhibit 17 Witness 2 Witness 3 Exhibit 02 Witness 4 Exhibit 19

[17]A go-around is a manoeuvre conducted by an aircraft to terminate an approach and continue in flight.

and a further wing drop experienced. Approximately 4.7 sec after the initiation of the go-around and with 15° right AOB, an essentially level pitch attitude and at 151 kts, the aircraft impacted the ground immediately prior to which the pilot ejected; the engineer did not eject from the aircraft. The time of impact was 1325 hrs. XX204's ground track in the final turn is shown in Figure 1.3.2.

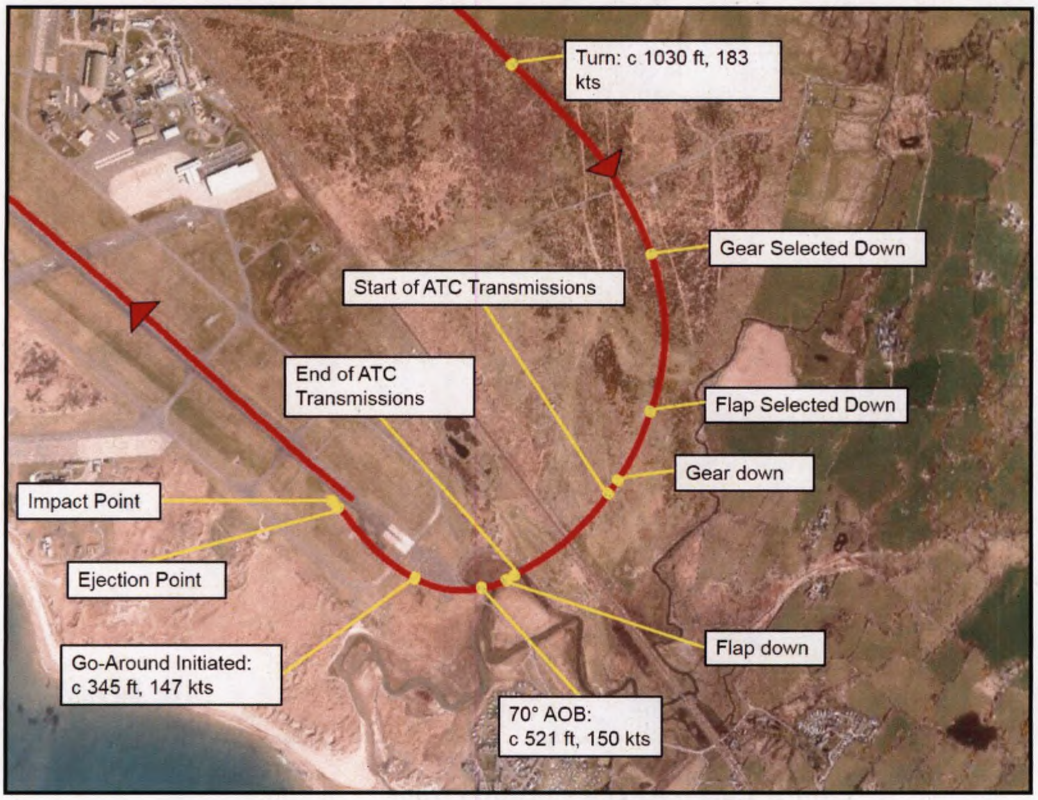


Figure 1.3.2 – XX204's ground track in the final turn

1.3.10. The initial point of impact, as shown in Figure 1.3.3, was approximately 247 m from the runway threshold and 40 m to the left of the runway centreline. During the impact sequence, the aircraft caught fire and the fuselage and wing separated; the fuselage rolled onto its left side before coming to rest in an upright position orientated in the reciprocal direction to the approach path 187 m from the initial impact. There was substantial structural damage to the forward part of the fuselage and a severe fire around the cockpit area. The aircraft wreckage was spread over an area approximately 50 m wide by 200 m long. The fuselage and wing were located within 15 m of each other with scattered wreckage filling the rest of the area. Exhibit 21 Exhibit 22 Exhibit 23

Figure 1.3.3 - XX204 Initial impact point

1.3.11. The RAF Valley actual meteorological conditions at the time of the accident were good: surface wind 310°/7 kts, few cumulus above 3000 ft, visibility 50 km, temperature +7°C, nil warnings. The 2000 ft wind was estimated as 360°/15 kts. Exhibit 24

1.3.12. Immediate crash response was activated by ATC with the on-site Fire and Rescue Services arriving at the aircraft within 2 min and medical personnel shortly after; the fire was extinguished by 1331 hrs. Exhibit 25 Exhibit 26 Exhibit 27

1.3.13. Post-ejection R3 landed within 70 m of the aircraft and was reached within a minute by a member of the Bird Control Unit before receiving medical care from RAF Valley medical personnel. An air ambulance landed at approximately 1350 hrs; a civilian road ambulance and civil fire services also attended the airfield. R3 sustained major injuries and was transported to hospital in Birmingham via the air ambulance, departing at 1459 hrs. The engineer was declared dead at the scene at 1401 hrs by an RAF Valley Medical Officer. Exhibit 22 Witness 4 Witness 5 Exhibit 02 Exhibit 28 Exhibit 26 Exhibit 01 Exhibit 06 Exhibit 05

Post-Crash Management

1.3.14. The RAF Valley Emergency Coordination Centre was activated shortly after notification of the accident and coordinated the Post-Crash Management (PCM) activity in accordance with the Station Crash Support and Major Incident Plan. On completion of the initial fire and rescue response a Post-Crash Management Incident Officer (PCMIO) took control of the accident site from the Fire Crew Commander; a cordon was established with Mountain Rescue Team personnel. Due to the fatal nature of the accident a North Wales Police Officer retained overall primacy of the incident until 21 Mar 18. Exhibit 26

1.3.15. Following notification of the accident, RAFAT and RAF Scampton initiated PCM activities including impounding relevant documentation and activation of command structures. Exhibit 29 Exhibit 30

Salvage Operations

1.3.16. Personnel from the Defence Accident Investigation Branch (DAIB), assisted by the Joint Aircraft Recovery and Transport Squadron (JARTS) and the Royal Air Force Centre of Aviation Medicine (RAFCAM) Accident Investigation and Human Factors Team (AIHF), took Exhibit 26 control of the site at 0600 hrs on 21 Mar 18.

1.3.17. Following the cockpit area being made safe, site surveys[18] and Health and Safety assessments were carried out. Site clearance commenced on 22 Mar 18 culminating with the aircraft wreckage being removed the following afternoon. The aircraft was relocated to Ministry of Defence (MOD) Boscombe Down on 24 Mar 18 for detailed investigation. Exhibit 23 Exhibit 05

Aircraft and Infrastructure damage

1.3.18. The aircraft impacted the ground in a right-wing low, virtually nose level attitude. During the crash sequence the undercarriage detached, the fuselage and wing separated as did the horizontal plane; the tail fin remained loosely attached to the airframe. There was severe structural disruption to the forward fuselage during and following the impact, spreading nose cone and canopy debris in the immediate area. The cockpit area sustained significant fire damage once the aircraft came to rest. Exhibit 21

1.3.19. Having separated from the fuselage, the wing became entangled in the Rotary Hydraulic Arrestor Gear (RHAG) cable and came to rest on the runway margin where a minor fire occurred; in addition, a Precision Approach Path Indicator (PAPI) light was severely damaged. The grass surface of the airfield suffered gouge and fire damage with any fluids (including firefighting foam) being collected in the airfield drainage system. Exhibit 21 Exhibit 26

---

[18] JARTS utilised the Land Survey System to plot almost 1300 points of interest within the impact area.

PART 1.4

Analysis and Findings

Intentionally Blank

TABLE OF CONTENTS – PART 1.4

Introduction 1

Methodology 2

Accident factors 2
Human factors modelling 2
Probabilistic language 3
Available evidence 4
Services 5

Background 6

Pilot currency 6
Practice Forced Landings 11
Stalling 13
Aircraft overview 14
Quality assurance 14
Weight and Moment and Centre of Gravity 15

Pre-flight 16

Planning 16
Authorization process 16
Annotation of signatures 17
Absence of Authorizer 18
Authorization detail 18

Circus 20

Role 20
Crew status 21
Supernumerary Crew training 21
Simulator training 22
Shakedown sortie 23
RAFAT Supernumerary Crew status endorsement 24
Circus flight profiles 25

Pre-accident 27

Accident Sortie 29

Instrument pressure settings 30
Accident Data Recorder height analysis 32
Departure Clearance 33

Accident Flight Profile 33

Introduction 33
Practice Forced Landing context 35
Sortie overview 39
Accident sequence 41
FTP3225H amendment to PEFATO height guidance 45
Finals turn 46

Accident flight profile summary 52

Stall Critical Analysis 53

Stall speed calculation 53
Development of g prior to stall 54
Stall flight testing 57
Stall critical analysis conclusion 58
Stall warning and stall characteristics 59
Stall recognition and recovery 59
Artificial stall warning 60
XX204 - last possible stall recovery height 60
Rate of Descent, Flight Path Angle, and Angle of Bank 61
Pre-contract Angle of Bank 62
Assessment of impact of increased AOB at contract height 63
Consideration of go-around technique 65
Comparison of PFL go-around with other high risk, low height activities 66
Conclusion – go-around 67

Human Factors 68

Work routine 68
Fatigue 70
Awareness 71
Distraction 74
Emergency lowering of undercarriage and flap 75
Cockpit Voice Recorder 78
Human Factors summary 79

Ejection and Aircraft Impact 79

Command Eject 80
Command Ejection simulations 81
Aircraft impact 82

Post-accident 84

Pilot 85
Engineer 86
Examination of Survival Equipment and Aircrew Equipment Assemblies 86
Aircraft Assisted Escape Systems 86
Post-Crash Management 87
Impounding of documentation 87
ADR calibration data collection 88
Aircraft Recovery 88

Organisational Matters 89

Royal Air Force Aerobatic Team 89
Royal Air Force Aerobatic Team reputation 89
Induced pressure 90
Resource 91
Aircrew Planning Officer 92
Engineering 92
Engineering conclusion 95

Air Safety Management System 95
Safety risk management 95
Supernumerary Crew risk assessments 97
Safety occurrence reporting 97
Air Safety resource 98
FTP3225H 98
Aircrew Manual 100

Summary of Factors 102

Analysis conclusion 102
Accident findings 103

Intentionally Blank

PART 1.4 – ANALYSIS AND FINDINGS

All times local (Zulu time).

Introduction

1.4.1. On 20 Mar 18 at 1325 hours (hrs), a Royal Air Force Aerobatic Team (RAFAT) Hawk T Mk1A[1], tail number XX204, crashed on the airfield at Royal Air Force (RAF) Valley whilst conducting a Practice Engine Failure After Take-Off (PEFATO). The sortie had dual purposes: to provide the pilot with Continuation Training (CT) and a familiarisation flight for a RAFAT engineer. Of the 2 aircraft occupants, the pilot ejected but the engineer, Corporal Jonathan Bayliss, in the rear cockpit did not and died at the accident scene.

1.4.2. This accident occurred during good weather and with no other aircraft in the immediate vicinity. The pilot was an experienced Hawk pilot who had been on RAFAT for 7 months and was familiar with the exercise he was conducting.

1.4.3. The investigation identified the cause of the accident as well as a sequence of events that directly contributed to the tragic outcome. Consequently, the report considers the background to the sortie before analysing the accident sequence. There were a number of broader organisational matters that were considered by the Panel and these are discussed after the accident analysis.

1.4.4. XX204 was fitted with an Accident Data Recorder (ADR) but not an active Cockpit Voice Recorder (CVR)[2] capability. Therefore, whilst the Panel were able to establish the aircraft's flight profile there was no recording of in-cockpit discussions between the 2 occupants. The pilot had good recollection of events leading up to the accident but his recall of the last 20-30 seconds (sec) of the sortie was sporadic and therefore it was impossible to determine his thoughts and considerations in the critical moments of the flight. The Panel consciously avoided assessing the pilot's actions with the benefit of hindsight and therefore were reliant on Human Factors (HF) specialist advice to understand what factors may have influenced him.

1.4.5. Although the circumstances of the accident were comparatively straightforward, many of the HF aspects are enduring in nature and are emphasised in order to enhance Defence Air Safety and prevent a reoccurrence.

---

[1] For the purpose of this report the difference between the Hawk T Mk1 and Mk1A are irrelevant and the aircraft will be referred to as a T Mk1 throughout.

[2] The ADR comprised a Data Acquisition Unit and a Multi Purpose Flight Recorder (MPFR). The MPFR had an additional recording capability that was not a recognised or supported part of the MPFR capability on the Hawk T Mk1. Nevertheless, it recorded frequencies related to engine speed as well as electrical anomalies through its power supply but not the crew's voices.

Methodology

Accident factors

1.4.6. 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 final 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.

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.

1.4.7. Throughout the report a range of factors may combine such that they can be addressed by a single recommendation. As a result, recommendations will not always directly follow an identified accident factor.

Human factors modelling

1.4.8. The Defence Accident Investigation Branch (DAIB) Safety Investigation Report ruled out technical failure or system fault as an accident factor. Therefore, the focus of this Service Inquiry (SI) report is on HF rather than technical matters. Specialist advice was provided by the Royal Air Force Centre of Aviation Medicine (RAFCAM) to ensure that HF aspects were suitably analysed. 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. In analysing the accident, evidence was assessed across the following categories:

a. **Unsafe acts.** Fact-based non-judgemental statements aimed purely at categorising potentially unsafe acts of an individual (or team), whether intentional or unintentional; the aim being to identify clearly specific error types so that a correct assessment can be made of human performance issues relating to cited accident factors. They are grouped as:

(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. **Error promoting condition.** The psychological, physical/mental limitations and physiological factors that can influence human performance, i.e. capacity, fatigue, etc.

c. **Organisational influences.** The broader (often indirect and latent) influences that a higher organisation brings to bear on those involved in an occurrence, and which are beyond those individuals' control in terms of resources, climate, etc.

d. **Breached (or failed) defences.** Those rules, orders, practices and procedures designed to assure the safe operation of aircraft, which failed or were breached by those involved.

Probabilistic language

1.4.9. The probabilistic terminology detailed in Figure 1.4.1 below, clarifies the terms used to communicate levels of uncertainty within the report. It is based on terms published by the Intergovernmental Panel on Climate Change in their Guidance Note for Consistent Treatment of Uncertainties[3] as well as the Australian Transport Safety Bureau in their paper on Analysis, Causality and Proof in Safety Investigations[4].

[3] https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf.
[4] https://www.atsb.gov.au/media/27767/ar2007053.pdf.

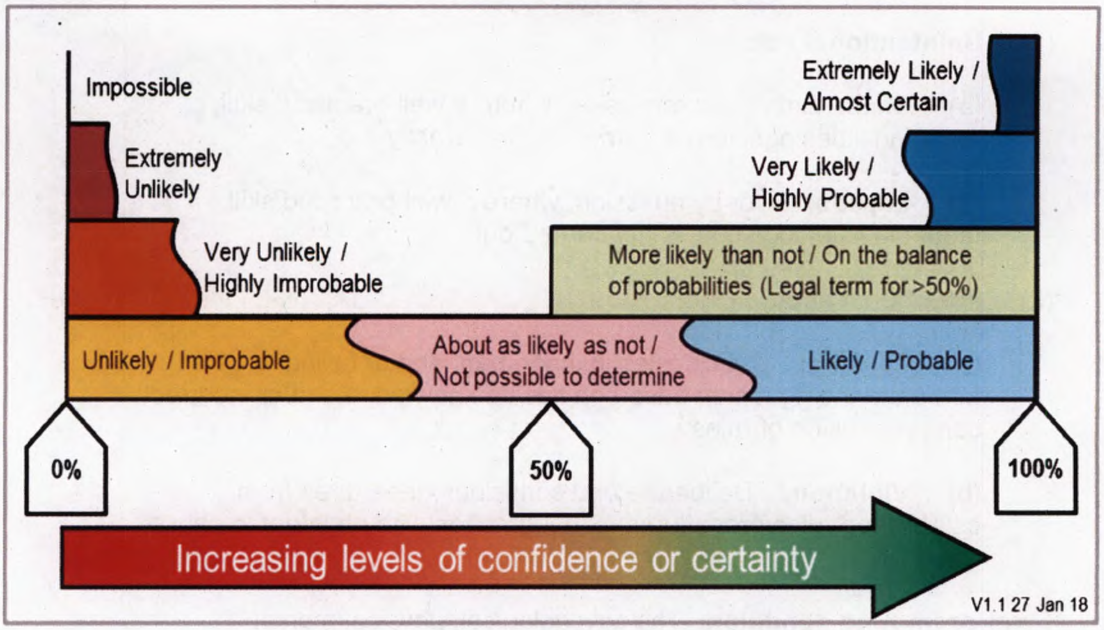


Figure 1.4.1 - Probabilistic terminology

Available evidence

1.4.10. The Panel had access to the following evidence:

a. Interviews with XX204's pilot, RAFAT aircrew and engineering personnel, accident witnesses and other personnel involved in a non-direct capacity.

b. Formal witness statements.

c. XX204's ADR data.

d. Electronic frequency signatures from XX204's Multi-Purpose Flight Recorder (MPFR).

e. Various images from still photography and Hawk T Mk2 head-up displays.

f. Relevant Orders.

g. A range of publications including: the pilot's flying logbook, the Hawk T Mk1 Handling Manual, aircraft documentation, briefing materials, authorization sheets, electronic aircrew currency data.

h. Physical examination of XX204.

i. DAIB Safety Investigation Report.

j. 1710 Naval Air Squadron (NAS) Technical Report.

k. Air Test and Evaluation Centre[5] (ATEC) Technical Report.

l. Rolls-Royce Technical Report.

m. BAE Systems technical data[6]. Exhibit 219

n. RAFCAM HF Report.

o. RAFCAM Accident Investigation Report.

p. RAF Valley Air Traffic Control (ATC) radio transcripts.

q. Hawk Synthetic Training Facility (HSTF) (flight simulator).

r. All flight safety related material, including previous accident reports.

1.4.11. **Timing tolerance.** In considering the electronic evidence, most prevalently the ADR data, ATC radio transcripts and still images, the Panel and DAIB Investigators established a common time datum to ensure consistency throughout the report. However, due to individual system recording constraints there remains a variable of circa +/- one second.

1.4.12. **Accuracy of heights.** In analysing XX204's height profile it was discovered that there were anomalies with recorded ADR heights which will be described during the report. Additionally, the aircraft achieved very high rates of descent (ROD) during the last 6 sec of flight. Therefore, reporting of height is related to brief moments in time and rounded up/down to the nearest 5 feet (ft).

1.4.13. **Flight control inputs.** The ADR did not record pilot control inputs but did record control surface position. Throughout the report the Panel have assumed that any control surface movement was directly related to a pilot control input.

Services

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

a. DAIB.

b. RAFCAM.

c. 1710 NAS.

d. Rolls-Royce plc.

e. BAE Systems plc.

f. Joint Aircraft Recovery and Transportation Squadron (JARTS).

[5] ATEC is the Air Test and Evaluation delivery partnership between the Air Warfare Centre (AWC) and Qinetiq Ltd.
[6] BAE Systems provided technical data that supported analysis of the ADR. This data complimented ATEC findings.

g. ATEC.

h. HSTF.

i. RAF 1 Group (Gp) Hawk T Mk1 Standards Evaluation (STANEVAL).

Background

1.4.15. **Sortie purpose.** XX204 was one of 5 RAFAT aircraft scheduled to independently transit from RAF Scampton to RAF Valley for the pilots to carryout emergency training in the HSTF, before returning to RAF Scampton. XX204's specific sorties served 2 other purposes: the conduct of CT for the pilot and a 'shakedown' flight for the engineer. It was the first time the 2 individuals had flown together and the first time the engineer had flown in a RAFAT Hawk. Exhibit 04 Exhibit 04 Witness 1A

1.4.16. **Pilot experience**. The pilot, RED 3 (R3), qualified as a Fast Jet pilot in 2007 and had over 2200 hr of flying experience including 1350 hr on the Hawk T Mk1 and 655 hr on the Tornado in the Ground Attack/Reconnaissance role. Immediately after flying training he was selected for instructional duties and subsequently assessed as an A2 (above average) Qualified Flying Instructor (QFI); he had RAF Central Flying School (CFS) accreditation to teach newly qualified instructors on the Hawk. He joined RAFAT in Aug 17 direct from flying the Hawk in another role. R3 was one of 2 new pilots to join the Team in 2017; a third pilot with previous RAFAT experience also joined at the same time. Exhibit 31 Exhibit 32 Exhibit 31 Exhibit 33

1.4.17. **Engineer background.** The engineer joined RAFAT in Jan 16. His primary role was as an aircraft mechanical technician undertaking maintenance, servicing and flight line tasks. During the 2017 Display Season (Jun to Oct), he undertook the more specialised role of Dye Team Leader[7]. He was selected for Circus[8] in Dec 17. Exhibit 34 Witness 6A Exhibit 35

Pilot currency

1.4.18. Hawk T Mk1 pilots were required to maintain currency in a series of core General Handling (GH) skills[9]. Known as Basic Training Requirements (BTRs), these differed in content and frequency between the 3 x Hawk T Mk1 squadrons[10] (sqn) (RAFAT, 100 Sqn RAF and 736 NAS), as shown in Table 1.4.1. Exhibit 36 Exhibit 37 Exhibit 38

1.4.19. A comparison of the minimum training requirements across the 3 sqns indicated a difference in core exercises. For example, a RAFAT pilot was only required to fly 1 x Practice Forced Landing (PFL) in a 90 day period. In comparison, and ignoring Radar PFLs[11], a pilot on 100 Sqn was required to 'statistically' fly 6 PFLs and a pilot on 736 NAS 2.6 PFLs in the same period (Visual PFLs & PEFATOs). In the Panel's opinion this variance was despite there being no evidence of differing risk or role specific Exhibit 36

---

[7] As Dye Team Leader he was responsible for the replenishment of each aircraft's smoke pod with dye and diesel after each display.
[8] Circus is the name given to RAFAT engineers that fly with the Team as Supernumerary Crew during the summer season.
[9] In addition, pilots were required to maintain an instrument rating (with associated instrument flying and instrument approaches requirements) and complete annual QFI checks.
[10] MOD Boscombe Down Empire Test Pilot School and RAFCAM Hawk T Mk1 had bespoke handling BTR requirements and are not considered in this report.
[11] Radar PFL exercises were not visual PFLs per se; they were used to get the aircraft back to the vicinity of an airfield to then complete a visual PFL.

requirements between the units.

Basic Training Requirement (BTR)	RAFAT	100 Sqn	736 NAS
Visual Practice Forced Landing (PFL)	Not Mandated	30 Day	60 Day
Radar PFL	Not Mandated	30 Day	60 Day
Practice Engine Failure After Take-off (PEFATO)	Not Mandated	30 Day	60 Day
PFL, non-specific	90 Day	RAFAT only	RAFAT only
Normal circuit	90 Day	Not Mandated	Not Mandated
Low level circuit	90 Day	30 Day	60 Day
RAFAT VRIAB	90 Day	N/A	N/A
Flapless circuit	90 Day	30 Day	60 Day
Spin	90 Day †	12 Month	6 Month
Simulator	90 Day	90 Day	60 Day
Stall on finals turn	90 Day	Not Mandated	60 Day
Stall	Not Mandated	6 Month	Not Mandated
Low level flying	6 Month	Not Mandated	Not Mandated
Low level abort	6 Month	Not Mandated	Not Mandated

Notes:
As a minimum, 1 x BTR of the profile stated was to be flown within the appropriate period.
A visual PFL or RAFAT non-specific PFL, could include a range of profiles commencing at varying heights.
Unique to RAFAT was a 500 ft PFL which was practised in the event of a malfunction on display/formation sorties.
†: RAFAT spinning exercise was carried out in the Flight Simulator due to the Smoke Generating Pod not being cleared for intentional spinning.

Table 1.4.1 - Comparison of Hawk operator general handling requirements

1.4.20. Whilst a unit's role shaped the non-core training requirements, and together with currencies were an Aviation Duty Holder (ADH)[12] function, the Panel **observed** that there were differences in the frequency requirement for core handling exercises, most specifically and in relation to XX204's accident, PFLs and stalling. In the Panel's opinion, Hawk T Mk1 Operating Duty Holders (ODH) should consider reviewing the cross-platform standardisation of currency requirements for core handling exercises.

1.4.21. **RAFAT training requirements.** Specific RAFAT BTRs, as shown in Table 1.4.1 were as follows:

a. 90-day currency for all circuits (normal, low level[13] and flapless), PFLs, stall in the finals turn[14], and RAFAT breaks.

b. 180-day currency for low level flying and the low level abort procedure.

---

[12] ADH are nominated individuals responsible for risk to life associated with operations on a specific aircraft fleet. They include, from lowest to highest level, the Delivery Duty Holder (DDH), the Operating Duty Holder (ODH) and the Senior Duty Holder (SDH). Specific risks are normally owned at the DDH and ODH level.
[13] Low level circuits were flown at 500 ft Above Ground Level (AGL).
[14] Stall in the finals turn was conducted at height with a simulated ground level.

1.4.22. **CT currency**. The CFS Flying Order Book (FOB) and RAFAT Display Directive (DD) required dedicated CT sorties to be flown on average once per month to achieve the GH BTRs and maintain instrument flying (IF) currency, and the currencies to be logged on the Squadron Training Achievement Recording System (STARS)[15]. The Delivery Duty Holder (DDH) recognised that published BTR periodicities were the minimal requirement but expected every opportunity to be taken to practise the associated skills. R3 was current for all BTRs.

Exhibit 39
Exhibit 40
Witness 7
Exhibit 41

1.4.23. The direction to fly dedicated CT sorties did not specify whether they were to be GH and/or IF. As XX204's accident occurred during the conduct of a GH exercise the Panel's analysis focused on GH.

Exhibit 39

1.4.24. **R3's RAFAT flying hours**. Prior to 19 Mar 18, R3 had flown 108 hr 55 minutes (min) on RAFAT; a breakdown of his flying hours is shown in Table 1.4.2. Most CT sorties that the Panel considered as GH were flown during the first 3 months on the Team, prior to R3 commencing display flying; many of those sorties were flown dual with another new RAFAT pilot. Both R3 and the other ab-initio RAFAT pilot achieved very similar flying hours with a comparable breakdown of sortie types.

Exhibit 31
Exhibit 42

[15] STARS was an electronic database that recorded amongst other things, all aircrew currencies.

Flying Activity	Sorties	Hours (hr:min)	Date
6 Aug 17 – 30 Oct 17 (Pre-Display Flying work-up)			
Other	11	6:35	-
Red Arrows (RA) Syllabus	4	3:30	-
Air-test	2	2:00	-
CT (General Handling)	8*	7:10	-
Flying as an instructor (QFI)	1	0:55	-
TOTAL	**26**	**20:10**	-
31 Oct 17 – 19 Mar 18 (Display Flying work-up)			
CT (Instrument Flying)	1**	0:45	7 Dec 17
CT (General Handling)	3	2:10	16 Nov 17† 4 Jan 18 17 Jan 18
Flying Ability Test (FAT) (General Handling)	1	1:05	23 Jan 18
IRE	6	5:10	-
Transit (Valley-Scampton)	1	0:30	-
TOTAL non-display flying	**11**	**9:40**	-
TOTAL display flying	**144**	**79:05**	-

Notes:
Other - RAFAT Display/Flypast – flying as rear-seat observer (non-handling pilot).
Air test - Flying as rear-seat second crew-member during Air-test flight (non-handling pilot).
IRE - Flying as Instrument Rating Examiner (IRE) in rear-seat (non-handling pilot).
* 5 of the 8 CT sorties were flown dual – 3 in rear seat; 2 in front seat.
** Flown dual; front seat. Exhibit 43
† Display work-up cancelled – flown as CT. Exhibit 31

Table 1.4.2 - R3's RAFAT flying hours

1.4.25. **General handling competency.** Once display flying work-up commenced on 31 Oct 17 there was an understandable focus on Primary Role flying. In the following 4½ months, until 19 Mar 18, R3 flew a total of 155 sorties, of which 11 were unrelated to display flying; those 11 sorties included 4 x GH (1 in Nov 17 and 3 in Jan 18). Figure 1.4.2 pictorially shows the span of R3's flying activity up to 19 Mar 18 and demonstrates the predominance of role training. Exhibit 31

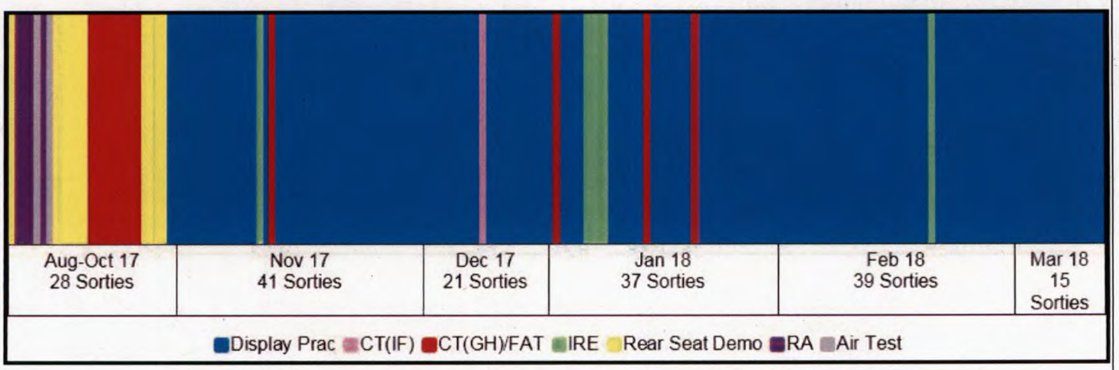


Figure 1.4.2 - R3's sortie distribution by activity

1.4.26. The Panel noted that after commencing role training, except for one sortie in Nov 17, the majority of R3's CT(GH) was focused in Jan 18, and therefore did not meet the intent of achieving CT monthly. All the CT sorties (one was a flying ability test (FAT); non-primary role) had a combination of GH and IF. A breakdown of those sorties is shown in Table 1.4.3. Exhibit 31

Date	Sortie length (hr:min)	Actual instrument flying (IF) (hr:min)	Instrument approaches	Remainder (GH) (hr:min)
16 Nov	0:35	0:10	1	0:25
4 Jan	0:45	0:25	2	0:20
17 Jan	0:50	0:10	1	0:40
23 Jan	1:05	0:30	4	0:35
Total	**3:15**	**1:15**	**8**	**2:00**

Table 1.4.3 - R3's CT (GH) sorties 31 Oct 17 – 19 Mar 18

1.4.27. From the CT total of 3 hr 15 min flown over 4 months and 19 days, the maximum that could have been interpreted as GH was 2 hr. R3 did not fly any further GH until 20 Mar 18. In the Panel's experience, even the most accomplished and capable pilots suffer skill fade and therefore the balanced achievement of CT was a fundamental requirement. Appropriate levels of practice assist in improving a pilot's judgement and associated handling of required flight profiles. Exhibit 44

1.4.28. **Dual pilot sorties.** A significant proportion of the pre-work-up CT sorties flown by the 2 ab-initio RAFAT pilots was flown dual; 6 of R3's 12 CT sorties and 5 of the other ab-initio pilot's 8 sorties. In the Panel's experience this would necessarily have reduced the actual handling benefit that either pilot could have attained and masked the level of CT that each was actually flying[16]. Several pilots expressed the view that they would have preferred more CT opportunities. The Panel recognised that factors such as the pressure to achieve primary role training, poor weather and aircraft availability would have constrained CT flying opportunities. Exhibit 45 Exhibit 46 Exhibit 47 Witness 1C Witness 8 Witness 9A

1.4.29. The accident occurred during a CT sortie. In the Panel's experience, and having considered the focus on primary role training and the minimal attainment of CT, there was potential for skill fade, though there was no evidence to indicate that a lack of CT in general contributed to the accident; the direct effect of PFL currency will be considered in paragraph (para) 1.4.34. In the Panel's opinion, the RAFAT currency requirements could contribute to skill fade, which in turn could make another accident more likely and therefore concluded currency an **Other Factor**. Exhibit 39

Recommendation

1.4.30. The RAFAT DDH should review CT currency requirements both for general handling and instrument flying to ensure that the risk of skill fade for core handling skills is minimised.

[16] R3 conducted a 45 min dual CT sortie on 7 Dec 17. Although flown for IF currency (not GH) R3 was the handling pilot for a max of 15 min.

Practice Forced Landings

1.4.31. In a single engine jet aircraft, a pilot generally has 2 options in the event of an engine failure: either to abandon the aircraft or land at the nearest suitable airfield. Hawk pilots practised Engine Failures After Take-off (EFATO) and PFLs to enable them to be current and competent in the techniques required in the event of an actual engine failure in flight. Exhibit 48 Exhibit 49

1.4.32. PFLs were conducted from various phases of flight and in differing weather conditions. In good weather and with sufficient height, a pilot could practise an academic PFL profile aiming to arrive overhead an airfield with more than 4500 ft of height available[17]. Should the cloud base be lower, and once visual with the airfield, they could practise other PFL profiles commencing at 1200 ft or 800 ft. Uniquely, RAFAT pilots practised PFLs from 500 ft, simulating an engine failure during a display sequence. PEFATOs culminated in the same technique as a PFL and were specifically included in 2 of the 3 Hawk sqns currency requirements. Exhibit 50 Exhibit 51 Exhibit 52

1.4.33. The RAFAT ADH chain acknowledged that PFL competence was a perishable skill. It was deemed important to maintain currency and competence in flying PFL profiles in the simulator and in the air in order to enhance the likelihood that a successful profile would be flown in the event of a real emergency. Exhibit 53

1.4.34. **PFL Currency.** Although there was a RAFAT requirement to conduct PFLs, there was no specific direction as to what profiles should be flown; pilots were advised that PFLs were to be practised from situations representative of those that might be encountered during displays. Consequently, there was no specific requirement to conduct PEFATOs; in contrast, the other 2 Hawk T Mk1 sqns had currency requirements for specific PFLs, including PEFATOs. Theoretically, a RAFAT pilot only had to fly 4 x PFLs of any kind in a year; nevertheless, the Panel acknowledged that pilots maximised opportunities to practise a range of profiles. However, the Panel could find no evidence of pilots recording what type of profiles had been flown during CT sorties and therefore it was possible that a profile could remain unpractised; greater detail was recorded for Red Arrows (RA) and FAT sorties. In the Panel's opinion, non-recording of individual profiles could result in them remaining unpractised, and therefore was an **Other Factor**. Exhibit 39 Witness 1C Witness 10B Witness 11C Witness 9A Exhibit 36 Exhibit 38

1.4.35. **RAFAT Conversion Sorties.** On joining RAFAT pilots completed a formal RA flying syllabus[18] prior to commencing formation training. This consisted of 5 sorties, one of which was an arrival assessment and another a solo flight. Due to his Hawk T Mk1 recent experience R3 did not fly the solo sortie (RA 14); he conducted the remaining 4 sorties over a 24 day period (7-31 Aug 17) when the RAFAT QFI and the Team Leader were available. During the RA sorties R3 had the opportunity to practise PFL and PEFATO profiles and was introduced to and practised 500 ft PFL profiles; he flew PFLs on all 4 RA sorties and PEFATOs on 3 RA sorties. Exhibit 51 Witness 11C Witness 9B Exhibit 31 Exhibit 31 Exhibit 54

1.4.36. **R3's RAFAT PFL currency.** Following RAFAT conversion and during the 2-month period prior to commencing Display Training (1 Sep – 30 Oct 17), R3 flew PFLs on 3 occasions and no PEFATOs. Between 31 Oct 17[19] and the day of the accident, R3

[17] An academic PFL is initiated from a height of 4500 ft.

[18] Syllabus was 5 sorties; RA11-15. For pilots joining RAFAT not directly from a Hawk sqn, Hawk Conversion was conducted on 100 Sqn RAF (RA sorties 1-10).

[19] R3 commenced Display Flying work-up at this point.

flew 4 sorties that included PFLs, one in Nov 17 and 3 in Jan 18; a single PEFATO was flown during his annual FAT[20] on 23 Jan 18; R3 had last practised a PEFATO on 23 Aug 17. The Panel could find no evidence of R3 flying any PFLs or PEFATOs after 23 Jan 18. Exhibit 55 Exhibit 54

1.4.37. **R3's previous PFL currency.** During his previous tour R3 had flown PFLs and PEFATOs on a regular and routine basis. However, since joining RAFAT there had been a marked reduction in opportunities to practise those exercises. Whilst R3 could not specifically recall when he had last conducted a PEFATO at a similar All Up Weight (AUW) to XX204 on the day of the accident[21], (AUW will be discussed in detail at para 1.4.133) he assessed that it was before Jul 17 whilst on his previous unit. During his time on RAFAT R3 conducted 2 simulator sorties during which engine failures were practised. Due to the paucity of detail within the associated reports it was possible that one exercise was representative of a PEFATO, but this could not be confirmed. R3's PFL history between Aug 16 and 19 Mar 18 is shown in Table 1.4.4 (no simulator serials are included). Witness 1C Exhibit 56 Witness 1A Exhibit 54

Period	Unit	PFL Academic/ Low Level	PEFATO	PFL RAFAT	TOTAL PFL/PEFATO
Aug 16 – Jan 17	100 Sqn	16	9	N/A	25
Feb 17 – 1 Aug 17	100 Sqn	20	14	N/A	34
6 Aug 17 – Jan 18	RAFAT	-	4*	11**	15
Feb 18 – Mar 18	RAFAT	-	0	0	0

* Only recorded in Training folder (not recorded on STARS)
** 8 recorded on STARS; 3 included in Training Folder reports (not recorded on STARS)

Table 1.4.4 - R3's PFL history

1.4.38. Specialist HF advice suggested that irrespective of a pilot's experience all skills will fade without frequency and quality of practice. Reduced competency through a lack of practice increases the risk of skill-based error during sorties, especially in an emergency. The frequency of PFL/PEFATO that R3 had conducted reduced markedly after joining RAFAT and, as shown in Table 1.4.4 he lacked recency in those BTRs. As a result, and in the Panel's opinion, R3 may have experienced a degree of skill fade. Exhibit 44

1.4.39. When considering that there was no direction to RAFAT pilots as to the type of PFLs to be practised, the limited currency requirement, and in comparison to R3's previous experience, there was the opportunity for skill fade in the execution of PFLs and PEFATOs. Consequently, the Panel concluded that the RAFAT PFL currency requirements were a **Contributory Factor**.

Recommendation

1.4.40. The RAFAT DDH should review the CT currency requirements and recording process for PFLs and PEFATOs to ensure the maintenance of skill in these core

[20] The PEFATO was not flown after the initial take-off but later in the sortie when the aircraft would have had a reduced amount of fuel remaining (AUW <5000 kg).
[21] XX204's weight on start-up was 5611 kg, 89 kg below the Release to Service (RTS) maximum of 5700 kg.

competencies.

Stalling

1.4.41. In considering the context of XX204's accident, similar currency differences to those identified for PFLs existed for practice stalling, as shown in Table 1.4.1. Of the 3 Hawk T Mk1 sqns, 2 had a BTR currency for 'stall on finals turn', yet the 3rd only had a requirement for a 'stall'; the latter did not specify what type of stall should be practised (eg clean stall, landing configuration stall, stall on finals turn). Furthermore, all 3 sqns had differing currency periodicities. In the Panel's opinion, the ability to recover from a stall was a core handling skill common to all pilots. Exhibit 36

1.4.42. **Stalling on final approach.** The Hawk T Mk1 Aircrew Manual stated that *'during the final turn or on final approach, particularly with MID or FULL flap selected, there is limited natural warning of the onset of the stall. At the first onset of buffet carry out the standard stall recovery'*. It also warned: *'continuing beyond the initial onset of buffet may rapidly result in a stall, the consequences of which will result in significant, and possible irrecoverable, height loss'*. Additional warnings were contained in the RAFAT DD. Exhibit 57 Exhibit 51

1.4.43. Noting the warnings relating to the potential for stall in the finals turn, the Panel formed the opinion that a common currency requirement should exist for such a critical phase of flight.

1.4.44. The finals turn stalling practice was normally flown with the throttle set at a representative revolutions per minute (RPM) (approximately 80%) to simulate a normal powered approach; none of the Hawk T Mk1 sqns practised Stalling in the Finals Turn with the throttle set to idle, as it is during a PFL, where RODs are greater than for powered approaches. With power applied, as would be expected in a normal final turn, a RAFAT Hawk engine would respond to an increased power demand from 70% of engine speed to 95% of maximum thrust in a maximum of 4 sec. However, from idle, as in a glide situation, the response time was 6.5 sec[22]. Following a stall, the delay in engine response from the idle setting, as compared to a powered approach, could further increase the recovery time and consequently contribute to a future accident especially if pilots had not been exposed to the scenario. In the context of XX204's accident the Panel concluded that engine response time was normal and therefore **Not a Factor** as there was insufficient time for the engine to have had an effect. The Panel concluded the lack of a training requirement for a stall recovery from a glide configuration to be an **Other Factor**. Exhibit 58 Exhibit 59

Recommendation

1.4.45. Hawk T Mk1 Operating Duty Holders should consider introducing a currency requirement for a stall recovery during a PFL profile in the landing configuration, into the Hawk T Mk1 BTRs.

[22] For a non-RAFAT engine the response times were 5 sec from 70% to 95% of maximum power and 8 sec from idle.

Aircraft overview

1.4.46. **Recent history.** XX204 entered service with the RAF in May 78, and was transferred to RAFAT in Dec 16. Its Military Airworthiness Review Certificate[23] was awarded by 22 Gp Hawk Continuing Airworthiness Management Organisation (CAMO) in Apr 17. Between Nov 17 and Feb 18, the aircraft underwent a Flight Navigation System modification at RAF Valley. On 2 Mar 18 both the left and right ailerons were replaced; the replacement right aileron failed a Non-Destructive Testing check for an area of disbond[24] being out of limits. After consultation with BAE Systems, the aileron was assessed as serviceable. At the time of the accident the aircraft had a total of 8232 hr 25 min, having flown 174 hr 05 min on RAFAT. Exhibit 60 Exhibit 61 Exhibit 60 Exhibit 62 Exhibit 63 Exhibit 64 Exhibit 65

1.4.47. **Documentation review.** An independent review[25] of XX204's aircraft documentation assessed that the aircraft had been maintained according to the Aircraft Document Set (ADS) and that Modification, Special Instructions (Technical) and airworthiness directives had been completed as required. It was also assessed that the aircraft's configuration complied with the extant Release to Service (RTS). However, irregularities were highlighted relating to: Quality Assurance (QA), Weight and Moment (W&M), and Centre of Gravity (CofG). Exhibit 66

Quality assurance

1.4.48. Examination of XX204's aircraft documentation demonstrated that the depth of assurance check/audit and the authority levels for carrying out the Quality Checks and Aircraft Husbandry Surveys contravened those stated within the higher-level order. Consequently, the required standards for oversight of documentation and maintenance recording were not being met. Thus, previously conducted Ministry of Defence (MOD) Form (MF) 700[26] QA checks may have been limited in their ability to identify and correct documentation deficiencies. The Panel considered that it was possible that the intent of RAF Engineering Policy[27] was not being complied with due to differing instructions in Hawk T Mk1/1A, General Orders and Special Instructions[28]. Whilst not considered to be related to the accident, the Panel concluded that a lack of appropriate QA could compromise Air Safety and therefore considered it an **Other Factor**. Exhibit 66

Recommendation

1.4.49. The 22 Group Hawk T Mk1 Chief Air Engineer (ODH) should review AP101B-4401-2(R)1, Part 1 Leaflet 021 to ensure conformity with AP100B-01 and the management of QA.

---

[23] A Military Airworthiness Review Certificate is issued following a Military Airworthiness Review (Mil AR) which is a physical inspection of the aircraft together with its continuing airworthiness records. The Mil AR is conducted periodically by Mil AR surveyors.
[24] Disbond is the loss of adhesive bonding between the outer skin and the honeycomb core.
[25] Independent review conducted by Royal Naval Air Station (RNAS) Culdrose, Air Engineering Department, Quality Support Team.
[26] The MOD Form 700 is an omnibus title given to a collection of MOD Forms in the 700-numerical series. When assembled and allocated to a specific aircraft these forms provide the means of compiling a complete technical history of the in-service use of that aircraft/equipment and provide a current statement of its condition. Military Air Publication (MAP)-01, Chapter 7.2.1.
[27] AP100B-01 (Part 2 Order 2.1.17 – MOD Form 700 Quality Check).
[28] AP101B-4401-2(R)1, Part 1 Leaflet 021 - Hawk TMk1/1A MOD Form 700 Control and Management, Quality Checks and Aircraft Husbandry Surveys.

Weight and Moment and Centre of Gravity

1.4.50. It was noted that RAFAT were not using the mandated forms and methodology for recording, calculating and informing the basic W&M and the Current Operating Weight. Although alternate methods were believed to have been authorized, there was no evidence to verify the authority to do so. Consequently, it was unclear how Current Operating W&M was being recorded and presented to aircrew. The provision of inaccurate information could contribute to a safety occurrence and was therefore considered an **Other Factor**. Exhibit 66

1.4.51. XX204's basic weight, 3813.9 kg, was assessed to be correctly calculated but not properly recorded on the mandated forms[29]. The Current Operating Weight for the accident flight, 5611 kg, was below the Maximum Take-off Weight of 5700 kg[30]. Exhibit 21

1.4.52. The Smoke Generating Pod had been fitted/removed on at least 4 occasions without the W&M record being updated. The overall W&M, following addition of the Smoke Generating Pod, was not presented to aircrew within the MF700C[31]. At the time of the accident XX204 was fitted with a full Smoke Generating Pod for which there was a reduced CofG clearance[32]. The CofG was calculated to be 2.614 mm inside the aft limit for the role fit and therefore considered to be acceptable and **Not a Factor** in the accident. However, due to differences between individual airframes and documentary irregularities, there was a risk that other Hawk T MK1 aircraft that were not utilising the mandated forms may have been operating outside the CofG limits. Exhibit 21, Exhibit 66, Exhibit 67, Exhibit 68, Exhibit 66

1.4.53. There was a general consensus amongst RAFAT aircrew that for all aircraft configurations and weights, the CofG remained within limits. However, when the ADS and unit orders were reviewed, that assumption could not be assured. CofG limitations were listed in the Hawk T Mk1/1A RTS[33] and the Hawk T Mk1/1A Aircraft Maintenance Manual[34]; both documents presented the limitations in a differing manner, which could result in ambiguity. Witness 9B, Witness 11C, Witness 12, Witness 13, Exhibit 21

1.4.54. Although it was determined that W&M and CofG calculations were **Not Factors** in the accident, the Panel concluded that inaccurate calculation and presentation of the associated data could compromise Air Safety and therefore was an **Other Factor**.

Recommendations

1.4.55. Hawk T Mk1 Type Airworthiness Authority (TAA) should conduct a review of associated documentation to ensure that information appertaining to W&M and CofG is standardised across all relevant publications in order to remove ambiguity.

1.4.56. Officer Commanding (OC) RAFAT should articulate standard W&M and CofG data for RAFAT aircraft role fits to ensure common understanding of the associated limitations.

---

[29] Basic Weight was recorded on the MF701 where as it should be recorded on the MF702.
[30] AP101B-4401-1B Para 1.4 and RTS Para B4.1.1
[31] MF700C is a working document containing current maintenance records and forms.
[32] CofG: RAFAT clean aircraft 6511-6594 mm (range = 83 mm), RAFAT aircraft with Smoke Generating Pod fit 6540-6575 mm (range = 35 mm).
[33] Sections B4 (Mass and Centre of Gravity) and D1 (RAFAT Aircraft).
[34] AP101B-4401-1B Chap 10 (Weight and CG Data).

Pre-flight

Planning

1.4.57. Planning for the serials on 20 Mar 18 was conducted the previous day by 2 of the other pilots scheduled to fly to/from RAF Valley; due to the similarity of the sortie profiles a collective plan was generated and R3 took a copy of the draft plan home to study. The next morning R3 completed his own flight planning and amended his return sortie to take advantage of good weather in the Lake District. He planned to transit to RAF Valley initially at medium level before spending a short time in the low flying system. For the return his intention was for a further period of low level flying before climbing to medium level and conducting CT; he also planned a practice diversion to Liverpool.

Witness 1B
Witness 1A
Witness 8
Witness 1A
Witness 1A

1.4.58. **Aircrew briefing.** R3's plan was comparable to one of the other pilots who was also flying an engineer on a 'shakedown' sortie. Thus, he asked the other pilot to confirm with the authorizing officer if he would authorize his sorties. The other pilot briefed the authorizer who was content but directed that both aircraft should spend no longer than was absolutely necessary at low level so as to mitigate the risk of bird strike.

Witness 1A
Witness 8
Witness 11A
Witness 11B
Witness 11C
Witness 8

1.4.59. R3 subsequently spoke to the authorizing officer who confirmed that he would authorize the sortie, but they did not discuss the intended flight profiles as R3 understood that the other pilot had already done so. In addition to briefing the authorizing officer, both pilots 'out-briefed'[35] with the Duty Senior Supervisor[36].

Witness 1A
Witness 1C
Witness 11B
Exhibit 69
Exhibit 70
Witness 8
Witness 1B
Witness 1A

1.4.60. **Engineer briefing.** On the morning of 20 Mar 18 the 3 engineers who were scheduled to fly received briefs from the RAFAT pilot responsible for passenger briefing before spending time with their respective pilots for specific sortie briefs. R3 briefed his engineer on the content of their sortie, reassured him about flying in a fast-jet and gave him the opportunity to ask any questions. The engineer accompanied the pilot to the out-brief.

Witness 1B
Witness 1A
Witness 14
Witness 15
Witness 1A
Witness 14
Witness 1A

Authorization process

1.4.61. Authorization was the authority given to an Aircraft Commander to fly a particular aircraft on a specified mission or duty. It was normally given in writing and the Aircraft Commander signified that he understood the mission or duty by initialling the appropriate authorization record.

Exhibit 71
Exhibit 72
Exhibit 72

[35] An out-brief covered key items of information to ensure that a crew had conducted appropriate planning and been authorized correctly.
[36] The Duty Senior Supervisor was responsible for the supervision of daily flying at RAF Scampton.

1.4.62. **Independent authorization.** RAFAT had a policy of independent authorization[37], with self-authorization being utilised only in extremis; XX204's sorties on 20 Mar 18 were independently authorized. Exhibit 4 Exhibit 73

1.4.63. **Electronic authorization.** RAFAT utilised electronic authorization to approve all sorties. Electronic authorization was permitted where its use was at least as robust as written authorization; in particular it was to be capable of immediate audit and hard copy reproduction. Due to the prescriptive nature of RAFAT's display flying from different airfields and often in foreign countries, electronic authorization enabled the Team to securely complete the authorization process and upload the associated sheet for later access. The electronic authorization sheet replicated the traditional hard copy version – RAF Form 15758. Exhibit 74 Witness 1A Witness 8 Witness 10A Witness 11C Witness 14 Exhibit 72 Exhibit 71 Witness 11B Witness 10A

Annotation of signatures

1.4.64. One of R3's secondary duties was the compilation of the authorization sheets with sortie details and the annotation of the authorizer and pilots' signatures. This ensured that the authorization process was appropriately managed during the display season when the Team were away from RAF Scampton, and maximised efficiency when all crews were flying the same serial as a formation. Signatures were annotated electronically by 'clicking and dragging' pilots' and authorizer's initials into the relevant column of the sheet. All aircrew and operations staff could also access the system and make changes to the authorization sheets. Witness 1A Witness 1C Witness 11B Witness 10A Witness 11B Witness 10A Witness 15

1.4.65. R3 compiled the authorization sheets, including the pilots' signatures, for the 20 Mar 18 sorties on the previous day but did not annotate the authorization signatures as each pilot was conducting an independent serial and would seek their own authorization. Witness 1C

1.4.66. The Panel were unable to clarify who annotated the authorizing officer's signature to the sheet for the sorties as varying accounts were given during interviews. However, in the Panel's opinion such actions should be unambiguous. Witness 1A Witness 1C Witness 8 Witness 11A Witness 11B

1.4.67. The Panel concluded that the completion of authorization sheets by one individual, and pre-annotation of signatures, was pragmatic and appropriate for RAFAT's primary display role where all 9 pilots briefed together and the task was bounded to an approved display, or associated transit. This is especially apposite when considering the repetitive nature of the task.

1.4.68. For non-primary tasks the Panel **observed** that the process was not as robust as manually written authorization. In the Panel's opinion, manually written entries required both pilot and authorizer to be physically present at the sheets (albeit not necessarily at the same time) and append original signatures. This ensured that the authorizer was fully aware of the detail entered in the sheet. OC RAFAT should consider that, for non-primary role sorties, individual aircraft captains and authorizers must append their own signatures to the authorization sheets in order to ensure complete

[37] The sortie was authorized by an individual not in the crew.

awareness of sortie detail.

Absence of Authorizer

1.4.69. The first RAFAT sortie to RAF Valley on 20 Mar 18 departed RAF Scampton at 0830 hrs[38]. Consequently, that pilot was at work early and text messaged the authorizer to confirm that the sortie detail he had briefed him on the previous day was unchanged and clarify that he was content to authorize the sortie. Once the pilot had confirmation he annotated his and the authorizer's signatures to the authorization sheets. Exhibit 4 Exhibit 8 Witness 14

1.4.70. The Regulatory Article covering the authorization of flights, RA 2306(1) stated: *'Exceptionally, if an Authorizing Officer and/or Aircraft Commander is unable to carry out the procedure for written Authorization, verbal Authorization should be given instead. The Authorization record should be annotated to reflect the granting of verbal Authorization as soon as possible'.* Exhibit 71

1.4.71. In the Panel's opinion, and whilst the 'exceptional' nature of the circumstances may be open to interpretation, the pilot showed due diligence in contacting the authorizer and the confirmation by text was in the same spirit as a verbal authorization; however, no associated annotation had been made on the authorization sheet.

1.4.72. **Sortie detail changes.** Prior to departure from RAF Scampton, R3 telephoned a change to his sortie[39] to the operations room where the authorization sheets were kept. Subsequently, when he text messaged from RAF Valley, it became evident that the authorization sheet had not been amended. Although the sortie detail was changed (after the flight was completed) the Panel could find no record of who made the entry. In the Panel's experience, changes made to hard copy authorization sheets should be done immediately they are agreed and initialled by the individual making the change. In 2016, as part of the process to approve electronic authorization, it was agreed that after the out-brief was conducted the authorization sheet would be locked. If changes were required then a copy should be made, amended and linked to the original. The Panel found no evidence that this procedure was in place. Thus, and whilst there was no suggestion of illicit behaviour, the Panel **observed** that it was feasible that authorization sheets could be amended without either the authorizer or pilot's knowledge. Witness 1A Exhibit 75 Exhibit 4 Exhibit 76

1.4.73. **Regulatory guidance.** Out with XX204's accident the Panel **observed** that there was an increased use of electronic documentation, eg MF700 for Typhoon, and there was likely to be an increased use of electronic authorization. The only regulatory comment that the Panel found was as described in para 1.4.70. In the Panel's opinion, and to provide clarity for media such as text messaging, it would be appropriate to review the use of, and update if required, the associated regulations relating to electronic forms of authorization. Exhibit 77

Authorization detail

1.4.74. It was the responsibility of an authorizing officer to ensure that the details of

[38] RAFAT authorization sheet stated 0830 hrs, the RAF Scampton ATC movements log stated 0834 hrs.
[39] A post maintenance check of the brakes was required; this was notified to R3 when he was signing for XX204 from the engineering staff. This occurred in a different location to the operations room.

each sortie were recorded in the authorization sheet prior to flight using a variety of methods that included unambiguous wording or a code. If a code was used, then a decode list was required to be promulgated in local Orders and displayed where authorization took place. The RAFAT Authorization Sheet[40] decode is shown in Table 1.4.5. Exhibit 72 Exhibit 71 Exhibit 72 Exhibit 78

Authorization Sheet Wording	Implicit Events
Close formation, NB xxxx MSD	Close formation, including formation aerobatics, iaw RAFAT SOPs, flown down to a minimum separation distance (MSD) of xxxx feet.
CT	All General Handling and Instrument Flying events for which RAFAT pilots are required to maintain currency (day and night).
PD xxx	Practice Diversion to a nominated alternate airfield (xxx) for a visual or instrument approach.
Aeros NB xxxx MSD	Singleton aerobatics flown to an MSD of xxxx feet.
LL NB xxxx MSD	Flight in the Low Flying System not below xxxx feet MSD. LFS booking number is to be annotated alongside the authorization detail.
Transit	Singleton or formation transit sortie flown iaw RAFAT SOPs (to be conducted at medium or high level unless low level flight authorized iaw the wording above).
Airtest iaw Schedule	Full or partial Airtest flown in accordance with the Hawk TMk1/1A Airtest Schedule.
Pod Handling Check	Smoke Pod handling check flown in accordance with RAFAT SOPs.
PAX *n*	Indicates that passengers are being carried on the sortie. The suffix 'n' relates to the category of PAX as defined in Annex E of the RAFAT Display Directive.
SC	Indicates that the rear seat occupant is being flown with the status of Supernumerary Crew.

Table 1.4.5 - RAFAT authorization sheet decode

1.4.75. R3 was authorized for 2 sorties, the first to RAF Valley and the second the return to RAF Scampton. Both sorties were authorized as CT, including aerobatics not below 2000 ft Minimum Separation Distance (MSD)[41], the transits, and low flying not below 250 ft MSD. The sortie content was detailed as follows and is decoded in Table 1.4.5: Exhibit 4 Exhibit 79

a. To RAF Valley: CT AEROS NB 2000' MSD, EGXP-EGOV[42] LL LFA 7 NB 250' MSD 160253[43], SC, AFRC[44] Brake Check.

b. To RAF Scampton: CT AEROS NB 2000' MSD, EGOV-EGXP LL LFA

[40] This sheet was located in the RAFAT Operations Room with the Authorization Sheets.
[41] When flying at less than 2000 ft above the surface, MSD is the authorized minimum separation, in all directions, between any part of an aircraft in flight and the ground, water or obstacle. MSD does not apply during take-off or landing or to the separation between aircraft in the same formation.
[42] EGXP and EGOV are the international designators for RAF Scampton and RAF Valley respectively.
[43] Low level booking number.
[44] AFRC: Airborne Flying Requirement Check.

7,11,17 NB 250' MSD 160377 SC.

1.4.76. Neither entry designated the sortie as a 'shakedown' for the engineer or gave any specific detail on the exercises or practice emergencies to be flown.

1.4.77. Although CT was classified as 'all events in which RAFAT pilots were required to maintain currency', it did not specify particular exercises. R3 planned to conduct a PEFATO as part of his CT currency requirements as he was cognisant that he had not recently flown one, and whilst not specifically detailed, was implicit in the authorization. The authorizing officer was unaware of R3's intent to conduct a PEFATO within the PFL element of CT. He stated that he would have liked to have known that he was doing so but would probably not have placed any restrictions on him other than those in the DD. Witness 1B Witness 1A Witness 11B

1.4.78. In the Panel's opinion, whilst the intent of the direction to provide sortie detail was met, especially when solo or with current Hawk aircrew, there was insufficient detail to understand the actual content of a sortie when carrying inexperienced passengers/Supernumerary Crew (SC). Consequently, the Panel considered that there was potential for misunderstanding between a pilot and an authorizer as to what could be flown during a sortie and therefore concluded it to be an **Other Factor**.

Recommendation

1.4.79. OC RAFAT should generate a more detailed authorization matrix to enable clear understanding of flight details for non-core role sorties when carrying passengers/SC.

Circus

Role

1.4.80. RAFAT had an establishment of 85 aircraft engineers[45] providing support at RAF Scampton and when detached or delivering the display programme[46]. Exhibit 80

1.4.81. Circus were the team of 10 engineers[47], and one photographer, allocated to conduct flight line engineering duties and photography/filming at display locations. Circus flew in the rear cockpit on transit sorties to be able to conduct flight servicing and prepare aircraft for display at each location. Although aircrew were qualified to do this themselves, the use of Circus ensured that pilots could focus on the flying task, especially when conducting several displays and/or transit flights in one day. In addition, the engineering capability provided by Circus far exceeded that expected of a pilot in both qualification and experience, ensured sustained levels of maintenance, and reduced the Risk to Life (RtL) from maintenance error, particularly at air displays. Witness 10A Witness 6A Witness 7 Exhibit 53 Witness 7 Exhibit 53

1.4.82. Whilst a similar engineering capability could have been provided via teams deploying by road[48], it would have been manpower intensive and time consuming, Exhibit 53

[45] RAFAT WO Eng stated 85 but contrary evidence stated 87 (2016 Manning Review) para 1.4.416 refers. On 20 Mar 18 actual engineering strength was 82.
[46] RAFAT routinely conducted displays based away from RAF Scampton which over a period could include several in one day from a single location or more than one site.
[47] Included 2 x officers who fly as Circus.
[48] 3 teams to provide a similar capability was estimated to require an additional 22 personnel costing circa £1.04m per annum.

especially if the aircraft operated from different locations over a period of days or had an overseas transit. In 2017 RAFAT conducted 59[49] displays, 3 dedicated flypasts and 57 en-route flypasts, in support of which, for example, one Circus member flew 36 hr and 30 min in 48 sorties. Circus enabled the efficient use of engineering personnel and provided support to deployed aircraft while concurrently sustaining engineering activity at RAF Scampton and were a mitigation for the routine use of aircrew flight servicing and the associated distraction. Witness 6A Witness 10A Exhibit 81 Witness 6A Witness 7 Exhibit 53

1.4.83. In the Panel's opinion, and when considering the number of available engineering personnel and tempo of operations, the carriage of engineers in the aircraft to facilitate RAFAT activity was appropriate and an efficient use of a finite resource.

Crew status

1.4.84. The engineer in XX204 was a member of the Circus and deemed not to be a passenger but rather SC, which was defined as: Exhibit 7 Witness 7 Witness 11B

'an individual, military or civilian, who is temporarily attached to an Air System crew for the purpose of carrying out a specific duty not involved with flying/operating the Air System, as authorized by the appropriate Aviation Duty Holder …'. Exhibit 82 Exhibit 83

1.4.85. In addition to the provision of technical support on the ground, Circus provided technical advice whilst airborne and, with experience, contributed to visual lookout and airmanship duties. Witness 7 Witness 10A Witness 6B

Supernumerary Crew training

1.4.86. The RAFAT DD detailed SC training and currency requirements and stipulated that personnel were to be fully briefed on their role and responsibilities for all flights which they undertook. The following personnel were approved to be trained and qualified as RAFAT SC: Exhibit 7

a. Circus Engineers. Those Circus engineers and Circus Reserve personnel specifically endorsed by Commandant (Comdt) CFS.

b. RAFAT Photographers. Members of the RAFAT Photographic Section.

c. Post Maintenance Test Flight (PMTF) Engineers. RAFAT engineers who had been trained and authorized to fly on PMTFs.

1.4.87. The award of SC required an individual to hold a valid Category 1 medical[50] and complete and be current for survival and emergency drills as detailed below: Exhibit 7

a. RAFCAM Training. To have attended an initial Aviation Medicine Training Centre course during which they were to be assessed as anthropometrically suitable to fly in the rear seat of Hawk and receive elementary instruction on

[49] 66 were planned, 5 cancelled due to weather, 2 for operational reasons.
[50] A Category 1 medical was required for flights with cabin altitude exceeding 18,000 ft; and/or rates of ascent/descent greater than 10,000 ft/min; and/or acceleration forces exceeding +4.5 g or -1 g. (RAF Manual, Assessment of Medical Fitness, AP 1269A, Leaflet 3-03 Annex C: Medical L Requirements – Passenger Flying).

hypoxia and the use of oxygen equipment.

b. Survival and Emergency Drills. To have received the full range of mandated synthetic and practical survival and emergency drills[51]. In recognition of the SCs' limited experience of fast jet aviation, their currency and refresher training periodicities were half that required for pilots[52].

c. Sea Survival Drills.

d. Simulator Training. To have been given a cockpit familiarisation in the Hawk simulator, this was to include a simulated ejection and ground egress. This training was to have been completed as soon as practicably possible and, in any event, before the start of the summer display season.

1.4.88. **Recording of qualifications.** A record of some Circus SC training qualifications was retained in a folder in the RAFAT operations room; other competencies were recorded electronically on the Joint Personnel Administration (JPA) system[53]. Dates on which training had been conducted were annotated on a Circus SC Qualification Matrix. However, the Panel could find no evidence of any formal recording of the completion of training and award of Circus SC status.

Exhibit 84
Exhibit 85

Simulator training

1.4.89. Although the Hawk was a 2 seat aircraft, the simulator only replicated the front (pilot) seat and as a result was not wholly representative of what Circus would experience for real. Whilst not formally articulated, and dependant on who delivered the training, the simulator serial incorporated a scenario of a bird strike at low level which allowed a demonstration of the time available following such an emergency and culminated with a no-notice ejection. It was assessed that a bird strike in the low level environment was the most prevalent potential hazard during RAFAT transits. While normal passengers (ie not an active crew member) did not require a simulator sortie prior to conducting low level flight, the provision of Circus simulator training provided an additional level of preparedness.

Witness 7
Witness 10A
Witness 7

1.4.90. The engineer had not completed the directed simulator training. However, in accordance with the DD, and although it should have been accomplished as soon as reasonably possible, it was not required to be completed until the start of the summer display season, which in 2018 was 31 May. Consequently, his first exposure to the Hawk cockpit environment was during the sortie to RAF Valley. Irrespective of the lack of simulator training, Circus did receive briefings including instruction on a drill ejection seat and they watched an associated passenger flight video.

Witness 16
Witness 15
Witness 14
Exhibit 86

1.4.91. The stipulation that simulator training only had to be completed by the start of the display season did not prevent engineers flying as SC prior to that point, which could include transits to/from overseas training[54]. As a result, the Panel considered that as the required training had not occurred engineers could, dependent upon sortie profile, ie low

Witness 7
Exhibit 4
Witness 10A

---

[51] As mandated in MAA RA 2130 Annex A which included dry and pool life raft drills, procedural ejection and aircraft abandonment drills and synthetic parachute training.
[52] If the currency period in a given event is 6 months for a pilot, then SC must re-qualify after a maximum of 3 months.
[53] Circus Folder in the RAFAT Operations Room contained copies of Cat 1 Medical and Flare firing training. Competencies for Swim Test, Pressure Breathing, Hypoxia, Av Med Lectures, SERE A were recorded in JPA.
[54] Transit to pre-season overseas training was conducted at medium level. The simulator covered the low level risk associated with a bird strike.

level, be exposed to an increased level of risk on their initial (shakedown) flight.

1.4.92. For the 2017 display season, and due to the inability to release engineers, no members of Circus completed simulator training. The decision not to conduct the simulator sorties in 2017 was made at Sqn level and not communicated to the DDH. Prior to the accident on 20 Mar 18, Circus simulator training for the 2018 season had been cancelled due to a lack of available engineering manpower and was planned to be replaced by a briefing. Although 3 x Circus flew to RAF Valley on 20 Mar, the simulator was booked for pilot training and therefore not available for the engineers. Circus simulator training was re-scheduled immediately after XX204's accident. Witness 17 Witness 6A Witness 12 Witness 7 Witness 6B Witness 16 Witness 6A Witness 17

1.4.93. In the Panel's opinion, the conduct of simulator training was appropriate to help prepare an engineer for the Circus role. However, to be of maximum benefit it should be planned, structured and completed before the 'shakedown' sortie and categorisation as SC. Until completed, an engineer should be categorised as a passenger with the associated restrictions. There was insufficient evidence for the Panel to assess whether any training would have prepared XX204's engineer to recognise the need to eject during the critical moments of flight before the aircraft impacted the ground.

1.4.94. The Panel considered that the lack of simulator training could place increased risk on a member of Circus and therefore concluded it to be an **Other Factor**.

Recommendation

1.4.95. RAFAT DDH should formalise a syllabus for simulator training and mandate its completion by personnel selected for a role within RAFAT Circus prior to undertaking duties as SC.

Shakedown sortie

1.4.96. The qualification syllabus for engineers to fly on PMTFs detailed the requirement to complete 2 flights: a 'shakedown' sortie and a full PMTF in a serviceable aircraft. The aim of the shakedown sortie was to assess an individual's ability to cope with the aeromedical demands of a PMTF. Exhibit 7

1.4.97. Shakedown sorties were also detailed for RAFAT supervision training for a new ODH (Air Officer Commanding (AOC) 22 Gp) and for non-aircrew passengers flying on a formation training sortie; for the latter a shakedown sortie was defined as: Exhibit 51 Exhibit 7

> *A flight designed to expose the passenger to the manoeuvres likely to be experienced when flying with the main formation, the specific aim being to assess the individual's ability to cope with the demands of flying on a practice display.* Exhibit 7

1.4.98. Witnesses gave varying descriptions of the requirement for the Circus shakedown sortie. These included the need to show the Circus how the Hawk flew, including aerobatics, PFLs, exposure to g forces (g) and preparation for transits including low level flight[55]. The content of the shakedown was decided by the pilot of the aircraft in which the engineer was flying.

Witness 10A
Exhibit 87
Exhibit 88
Witness 1B
Witness 10B
Witness 14
Witness 8
Witness 10A
Witness 7
Witness 12

1.4.99. The RAFAT DDH advised that a shakedown sortie de-risked the transit to RAFAT's overseas spring training as it exposed Circus to the aircraft environment before being in a 9-aircraft formation and away from the UK. However, it was not mandated as it may have generated additional pressure to fly them. The Panel could find no formal evidence of a requirement, defined purpose or syllabus for Circus to complete a flying serial to qualify as SC.

Witness 7

1.4.100. For serials on 20 Mar 18, XX204's engineer was exposed to medium and low level flight with the intention of completing aerobatics on the return to RAF Scampton. Conversely an engineer flying in another aircraft felt unwell and had very limited exposure to low level or the application of g. Consequently, although they had differing experiences, they would have met the shakedown sortie requirement, albeit the objectives of which were not formally articulated.

Witness 1B
Witness 1C
Witness 1B
Witness 1A
Witness 14
Witness 16

1.4.101. In the Panel's opinion, and considering the frequency of flying and the nature of the role, a formal syllabus should exist to ensure commonality of training objectives and clarification of achievement. The lack of a formal syllabus has the potential for safety critical information and core learning points to be missed and therefore the Panel concluded it to be an **Other Factor**.

Recommendation

1.4.102. RAFAT DDH should establish a formal syllabus with clear training objectives for Circus SC shakedown sorties.

RAFAT Supernumerary Crew status endorsement

1.4.103. The RAFAT DD stated that Circus engineers and Circus reserve personnel could be trained and qualified as SC when specifically endorsed by Comdt CFS[56].

Exhibit 7

1.4.104. The 3 pilots that flew Circus engineers[57] on 20 Mar 18, and the authorizing officer, believed that the engineers flew as SC. OC RAFAT and Comdt CFS also believed that the engineers had SC status as they had discussed the matter the previous evening and Comdt CFS verbally endorsed them as SC. This was captured in his DDH Air Safety Decision Register for 19 Mar 18, which stated that he had held 3 telephone

Witness 1A
Witness 8
Witness 14
Witness 11B
Witness 10B
Witness 7

[55] RAFAT would routinely transit at less than 2000 ft above ground level.
[56] Comdt CFS was also the RAFAT DDH.
[57] Although 5 RAFAT aircraft deployed to RAF Valley on 20 Mar 18 only 3 conducted Circus shakedown sorties.

conversations during which he had approved the status. Exhibit 89

1.4.105. On completion of the RAFAT PMTF engineer qualification syllabus, individuals were authorized in writing by OC RAFAT to fly on PMTFs[58]. The Panel could find no documentary evidence to show an official endorsement of the Circus engineers as SC by Comdt CFS. Exhibit 7

1.4.106. Although the DD detailed training requirements for the award of SC, the lack of direction regarding completion of a shakedown flight and the latitude on when simulator training should occur could result in misinterpretation of an individual's status for flying. It could be interpreted that once RAFCAM and survival drills were complete, then for the purposes of flight authorization, an individual was deemed SC. In the Panel's opinion, until the qualification serials were accomplished, an individual was under training and, unless flying as such, should only fly as a passenger.

1.4.107. In the Panel's opinion, the lack of clarity of SC status and auditable endorsement had the potential for misinterpretation of an individual's qualifications which could result in exposure to an undue level of risk and therefore the Panel concluded it to be an **Other Factor**.

Recommendation

1.4.108. RAFAT DDH should clarify the status of personnel undergoing training for employment as SC, give clear direction regarding the capacity and restrictions of their employment, and formalise the SC status in an auditable process so as to ensure that associated risk is managed.

Circus flight profiles

1.4.109. As part of their core role, Circus were approved to fly on CT and transit flights. Within the DD approvals codes it detailed implicit 'potentially hazardous' events for both categories as follows: Exhibit 7 Exhibit 7

a. CT, as a single aircraft: practice emergencies, instrument flying and low level flight[59]. Further DD limitations applied on PFLs. Exhibit 90

b. Transits: Close formation, low level flight and looping arrivals.

1.4.110. In addition to Circus as SC, passengers could be carried during those flights. In terms of preparation, Circus training (drills, simulator and flight) was more than that required for passengers, who in addition to anthropometry, a medical and weight checks, only required briefings. Exhibit 7 Witness 7

1.4.111. When conducting CT, RAFAT pilots practised PFLs from situations representative of those that might be encountered during displays; therefore, crews would routinely practise PFLs that were initiated at less than 1000 ft above ground level (AGL). Exhibit 39 Witness 10A Witness 7

[58] Engineers must also be SC qualified to fly on PMTFs.
[59] Low Flying is below 2000 ft above ground level.

1.4.112. The DD prohibited the carriage of personnel other than crew[60] (except for Circus) for PFLs commencing below 1000 ft; this prohibition included current non-RAFAT Hawk pilots if flown as a passenger. Consequently, and as with this accident, an individual on his second flight could be exposed to a complex manoeuvre, yet an experienced and qualified on type Hawk pilot, could not. This was based on the premise that generic passengers should not be exposed to unnecessary risk. Exhibit 7 Witness 7 Exhibit 7

1.4.113. Some PFLs that were initiated below 1000 ft could involve the need to manoeuvre dynamically to position for the final approach. As passengers were generally only flown once, the Team had no bench mark as to whether they would be ill or uncomfortable. Consequently, it made sense to generically limit passengers to the PFLs that had smoother profiles. As Circus flew regularly, pilots and authorizers could consider what types of PFLs they were exposed to, taking their experience levels into consideration. Witness 7

1.4.114. XX204 was conducting a PEFATO, which was normally initiated below 1000 ft and concluded in the same technique as a PFL. FTP3225H (Hawk Handling Manual) stated that following the initiation of a PEFATO, and dependant on flight parameters[61], the emergency may no longer be considered a PEFATO, per se, but rather a PFL. Consequently, a PEFATO fell within the broader remit for PFLs and thus, in the Panel's opinion, the carriage of Circus was permitted. Exhibit 91

1.4.115. The Panel were advised that to sustain currency, without sole reliance on dedicated sorties, pilots could conduct CT on the return from display flying transits[62] when Circus were in the rear of the aircraft. The clearance for Circus to be in the aircraft for PFLs below 1000 ft enabled the full CT range to be flown. Witness 7

1.4.116. A Duty Holder Risk Balance Case (RBC) regarding SC flying, which was written after XX204's accident, estimated that SC could be exposed to between 2-4 PFLs during a RAFAT season. The Panel examined all RAFAT authorization sheets for the period 17 Mar 16 -19 Dec 17[63] and recorded sorties where Circus flew as SC with RAFAT pilots. Table 1.4.6 shows the total number of individual sorties that were flown, the number when CT was authorized, and when CT was flown[64]. Whilst these were individual sorties, aircraft could have been part of a formation of up to 9 aircraft. The occasions when CT was authorized resulted from poor weather preventing visual meteorological conditions[65] (VMC) formation transits. Although not shown, the Panel acknowledged that during the Circus 'shakedown' sorties, and on dedicated transits to RAF Valley for pilot simulator training, CT was conducted with SC in the aircraft. Nevertheless, the Panel have focused on core transit sorties as that was the reasoning for Circus being authorized to be in the aircraft for PFLs below 1000 ft. When considering that in 2 years there was one occasion (6 sorties) that CT was conducted during display transit sorties, the Panel determined that there was minimal requirement for the conduct of CT with Circus in the aircraft during transits. Exhibit 53 Exhibit 92 Exhibit 93

[60] Crew were defined as: RAFAT pilots, RAFAT command chain and supervisory pilots, ad hoc examiners and temporarily attached pilots.
[61] If an aircraft had turned significantly as part of a departure, was above 500 ft and less than 250/270 kts, then it was no longer considered an EFATO, per se, but rather an Actual Forced Landing/PFL. The same applied above 300 kts.
[62] Circus, as SC, did not fly during display sequences.
[63] This was the period covered by electronic authorization sheets for the 2016/17 seasons.
[64] Display transit sorties conducted by Red 1-10. Circus also flew with other pilots (OC RAFAT (Red11), Hawk T Mk1 Exam Wing, pilots allocated to recover unserviceable aircraft during the year) carrying out other duties (ie Airtests, Smoke pod checks, photo-chase).
[65] Visual Meteorological Conditions (to remain clear of cloud).

2016	
Display flying transit sorties	1051
Sorties – CT Authorized	18 (3 occasions - poor weather)
Sorties – CT Conducted	6 (1 occasion - poor weather)
2017	
Display flying transit sorties	625
Sorties – CT Authorized	10 (1 occasion - poor weather)
Sorties – CT Conducted	0

Table 1.4.6 - SC sorties with RAFAT pilots

1.4.117. In the Panel's opinion, it was appropriate for Circus to receive familiarisation training on the situations that they may have encountered in support of RAFAT's task. Accordingly, and in the Panel's opinion, associated flight profiles for which they are carried as SC should be related to their primary role, ie transit flying. However, an individual's experience, capacity and confidence should be considered in determining when SC are exposed to the more demanding profiles. SC should not be exposed to hazardous flight profiles unless the additional risk is clearly and appropriately managed to ensure that there is a related benefit and the risk is tolerable and as low as reasonably practicable.

1.4.118. Noting the associated risk of conducting practice emergencies, specifically PFLs initiated below 1000 ft AGL, and when considering that current non-RAFAT Hawk pilots were prohibited during such exercises, there was limited justification for the Circus PFL exemption. The Panel concluded that the carriage of Circus SC in the aircraft during the conduct of PFLs initiated below 1000 ft AGL was a **Contributory Factor**.

Recommendation

1.4.119. RAFAT DDH should ensure that Circus are only employed as Supernumerary Crew on sorties that are directly associated with their primary role and not exposed to potentially hazardous flight profiles, including being in the aircraft for PFLs initiated below 1000 ft AGL.

Pre-accident

1.4.120. On 20 Mar 18, R3 woke at 0500 hrs. Not being able to go back to sleep he checked the weather at local airfields and general weather for the day, including at RAF Valley. Having collected packed lunches, he arrived at work at 0730 hrs where he continued with his secondary duties and completed his pre-flight planning. Witness 1A

1.4.121. He was scheduled to depart RAF Scampton at 0845 hrs but was delayed due to discussions as to whether he would be required to conduct an inverted flight check on another RAFAT aircraft later in the day at RAF Valley. He departed RAF Scampton at 0924 hrs at which time it was still unclear if the flight check was required. XX204 arrived at RAF Valley at 1003 hrs having conducted an un-eventful medium and low level transit. Witness 1A Exhibit 8 Exhibit 1 Witness 1B Witness 1C

1.4.122. **Simulator.** Between approximately 1115 hrs and 1200 hrs[66] R3 completed a malfunction training sortie in the HSTF. The sortie report contained minimal content other than a list of exercises flown; his performance was described as exemplary.	Exhibit 10 Exhibit 11 Exhibit 94 Witness 18
1.4.123. As part of the simulator sortie he flew an exercise that resulted in the engine being shut down and the flying of an 'actual forced landing' from height, including the associated drills such as the emergency lowering of the undercarriage and flap. This will be examined further in para 1.4.333. The sortie report stated that the sortie lasted an hour, but this is contrary to other evidence.	Exhibit 94 Exhibit 94 Exhibit 11 Exhibit 10
1.4.124. In the Panel's opinion, the lack of written comment on the pilot's performance meant that there was no routine feedback to the parent sqn. The view of simulator staff was that any feedback on matters of concern would be verbally reported to the sqn; this was supported by evidence given by RAFAT personnel. The view was also expressed that the HSTF provided a learning environment for the practise of drills, and that it was inappropriate for staff to mark their 'peers' as they may disagree on matters of opinion.	Witness 18 Witness 9A Witness 18
1.4.125. The Panel **observed** that simulator serials provide good training opportunities, and even though conducted regularly, simulator reports should record how an individual has performed, including appropriate advice.	
1.4.126. **Phone text message communications.** At 1106 hrs, immediately prior to commencing the simulator sortie, R3 was advised by phone text message that an update on the potential flight check at RAF Valley was still awaited. Confirmation that the flight check was not required was sent to him during his simulator sortie (1127 hrs) which he acknowledged at 1205 hrs.	Exhibit 11
1.4.127. **Distraction.** The departure to RAF Valley had been delayed whilst clarification over the potential flight check was awaited; this had not been received as the pilot entered the simulator but was resolved shortly after. Whilst not directly a factor in the accident the Panel formed the opinion that it may have contributed to the potential for general distraction, especially when considered cumulatively with other issues such as secondary duties and events during the accident sortie. This will be examined further in para 1.4.326.	Witness 1A Exhibit 11
1.4.128. **Aircraft serviceability.** Whilst R3 was in the HSTF the engineer conducted a Turn Round Service and refuel of XX204; R3 signed for the aircraft in the MF700C at 1250 hrs. The Panel concluded that the aircraft was appropriately prepared for the next flight. Having considered all engineering evidence, including the DAIB Safety Investigation Report, the Panel concluded that the aircraft was serviceable at the commencement of the sortie. There was no indication that the aircraft suffered a subsequent technical failure and in the Panel's opinion, aircraft serviceability was **Not a Factor** in the accident.	Exhibit 12 Exhibit 21

[66] The exact timing of the simulator sortie is unclear. R3 signed into the HSTF building between 1030 hrs and 1215 hrs but the sortie report had no start or end time. He received/sent text messages at 1106 hrs and 1205 hrs and therefore it is estimated that he was in the simulator module between those times.

Accident Sortie

1.4.129. **Meteorological conditions.** The actual meteorological conditions at the time of the accident were: surface wind 310°/7 kts, few cumulus above 3000 ft, visibility 50 km, temperature +07°C, QFE 1032 hPa[67], nil warnings. The 2000 ft wind was estimated as 360°/15 kts. In the Panel's opinion, the weather was good and **Not a Factor** in the accident. Whilst not an accident factor the effect of the wind will be considered in para 1.4.188. Exhibit 24

1.4.130. **Bird activity.** Bird activity at RAF Valley at the time of the accident was very low. There was no evidence that the aircraft suffered a bird strike. Witness 4

1.4.131. **Warning out.** R3 warned out[68] by telephone with RAF Valley Station Operations at 1250 hrs with the intention of conducting a PEFATO, then a transit at 5000 ft to the Lake District to conduct low level flying, before returning to RAF Scampton. Exhibit 3 Exhibit 3 Witness 1A

1.4.132. **Aircraft manning.** R3 and the engineer conducted a walk-round of XX204 assisted by 2 members of the Visiting Aircraft Section[69] (VAS). The VAS engineers were present during aircraft manning, start up and taxi out of dispersal. They confirmed ejection seat pins were correctly stowed, engine start was routine and control surfaces all operated correctly; nothing abnormal was observed. Exhibit 13 Exhibit 14

1.4.133. **Aircraft weight.** XX204's weight on start-up was 5611 kg, 89 kg below the RTS maximum of 5700 kg. A breakdown of the aircraft's weight is at Table 1.4.7. CofG, as discussed in para 1.4.52 was within limits. The calculated AUW at impact was approximately 5558 kg. This was derived by subtracting an estimate of fuel used during start-up, taxi, take-off and the flight from the start-up AUW of 5611.6 kg. Exhibit 21 Exhibit 95

---

[67] hPa: hectopascal; the unit of atmospheric pressure used to derive height or altitude. QFE is the pressure setting for aerodrome operations giving height above the airfield.
[68] Warning out entailed the pilot providing airfield departure details and requirements to ATC.
[69] VAS was part of No 4 Sqn RAF based at RAF Valley.

Item	Weight (kg)	Source	
Basic Aircraft Weight	3813.90	MF700C – MF701(Hawk) Leading Particulars MF751 Aircraft Basic Weight & Moment Record Card – Card 8 of XX204 Aircraft Log Cards Book 1	Exhibit 96 Exhibit 97
Smoke Generating Pod	99.1	*	
Landing Gear Locks	4.0	*	
Fuel	1250.0	MF705(Hawk) Flight Servicing Certificate 03/11	Exhibit 12
Pilot	80.15[70]	RAFCAM Report	Exhibit 5
Engineer	103.15[70]	RAFCAM Report	Exhibit 98
Smoke Generating Pod contents	261.30[71]	*	
All Up Weight (AUW)Total	**5611.60**		Exhibit 99

* Aircraft Maintenance Manual Chap 10 Table 11/12 – AP 101B-4401-1B 3rd Edition August 2014

Table 1.4.7 - Breakdown of XX204's all up weight

1.4.134. **Start and taxi.** At 1314 hrs R3 requested engine start on the ATC Ground frequency and requested to taxi 3 min later. R3 was then given taxi clearance, including the airfield pressure setting of 1032 hPa (QFE); this was acknowledged by R3. Exhibit 15

Instrument pressure settings

1.4.135. Post-accident examination of the aircraft's instruments showed that the front cockpit altimeter sub-scale displayed a pressure setting of 1035 hPa, with 1032 set on the rear-cockpit main altimeter. This 3 x hPa difference would have resulted in a height differential of 90 ft between the 2 instruments[72]. The front cockpit was severely damaged during the impact sequence and the main altimeter was displaced from the airframe. The altimeter was significantly damaged, with the scaled altitude indicator, pointer and sub-scale adjustment knob missing from the instrument. Accordingly, it was not possible to determine if the indicated pressure setting was set by R3 or had changed due to impact damage, specifically that which had resulted in separation of the sub-scale adjustment knob[73]. XX204's front cockpit altimeter as found at the accident site is shown in Figure 1.4.3. Figure 1.4.4 shows a serviceable altimeter and XX204's. Exhibit 100 Exhibit 101 Exhibit 102

70 Mass derived from individual nude weight plus 11.15 kg for Aircrew Equipment.
71 Adjusted to account for a 9 sec burn during previous flight at rate of 10 gal/min.
72 1 hPa equates to approximately 30 ft of height at sea level.
73 On a serviceable instrument rotating the setting knob without power applied moved the hPa scale a few digits.

Figure 1.4.3 - XX204 front cockpit main altimeter as located at crash site

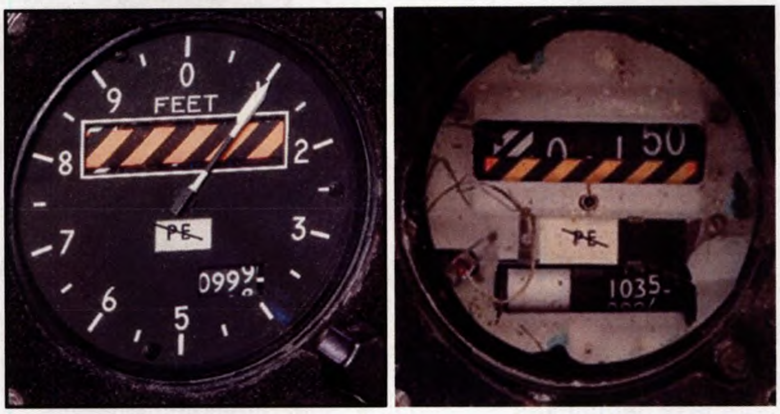


Figure 1.4.4 - Serviceable Hawk T Mk1 main altimeter (power off) and XX204's

1.4.136. Due to XX204's height parameters during the PEFATO sequence, and anomalies identified with the ADR height data, the Panel sought to establish, as far as was reasonably possible, whether R3 had set an incorrect pressure setting. Exhibit 17

1.4.137. R3 recalled that the pressure setting was 1032 hPa; 1032 was written on his flying coverall kneepad. He believed that he asked the engineer to set the pressure setting during start-up, but was not certain. Exhibit 103 Witness 1A The pressure setting in the rear cockpit, as shown in Figure 1.4.5. was accurate and imagery of the previous sortie showed that prior to arrival at RAF Valley the correct pressure for the stage of flight (1028 hPa) had been set, so 1032 hPa had been set subsequently; R3 had instructed the engineer how to set the pressure setting during the transit from RAF Scampton. Exhibit 104 Witness 1A

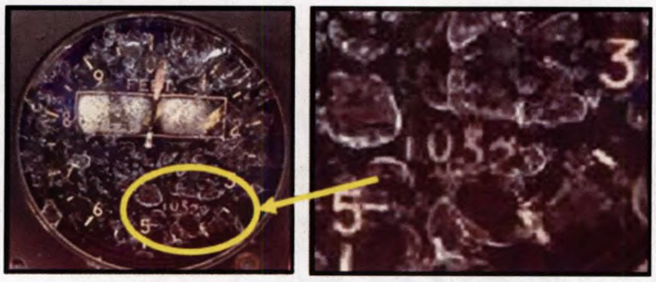


Figure 1.4.5 - XX204's rear cockpit main altimeter

1.4.138. R3 did not recall checking his altimeter prior to take-off but, in the Panel's experience, it is very likely that R3 would have completed runway line-up checks that included checking the altimeter. In the Panel's opinion, based on R3's experience as a QFI and his actions during the transit sortie, it was extremely likely that R3 had directed the engineer to set the appropriate pressure setting during start up, and therefore judged that it was more likely than not that R3 would have set 1032 hPa on his own instruments. Consequently, the Panel concluded that R3 flew the PEFATO profile on the correct pressure setting and therefore was **Not a Factor**.

Accident Data Recorder height analysis

1.4.139. Analysis of XX204's flight profiles identified barometric height anomalies in the ADR data. The ADR recorded two height parameters, Barometric Height Fine (BHF) and Barometric Height Coarse (BHC)[74]. Exhibit 17

1.4.140. The ADR input for these parameters was fed from separate potentiometers within the altitude transducer. The altitude transducer for the ADR had a static pressure source common to that of the cockpit altimeters but was otherwise a separate instrument calculating height independently to the cockpit instruments. Exhibit 17 Erroneous ADR data could have resulted from a fault in the static supply (which would affect both the ADR and cockpit instruments) or in the ADR transducer (which would affect only the ADR). The observed anomalies were more compatible with faults/characteristics in the ADR transducer rather than in the static system and therefore would not have affected the cockpit instruments. Exhibit 17 There was no indication that anomalies were observed in the cockpit during the accident sortie or on previous sorties. However, the ADR information could not be used as proof that there were not issues with the cockpit height indications. Exhibit 17

1.4.141. Post-accident analysis of the front cockpit main altimeter concluded that it was very likely working correctly prior to the accident, however it was not possible to state to what accuracy as internal damage had altered the unit's calibration. It was also assessed that it was very likely that the ADR transducers were functioning to the specified requirements prior to impact. Exhibit 21 The Panel could find no evidence to suggest that XX204's altimeters were unserviceable during previous sorties or the accident sortie.

1.4.142. **Investigation data.** BHF, as the more accurate ADR measure, was used as the height parameter throughout the investigation. The overall BHF parameter trend Exhibit 17

[74] The BHF recorded data between -1616 ft and 5936 ft at a resolution of 7.378 ft/bit, whereas the BHC had a larger recorded height range, between -1100 ft and 63000 ft and a lower resolution of 62.715 ft/bit.

correlated with the expected height profile for the accident sortie, but several anomalies were observed. These included time indicating runway height after take-off, a period at a constant indicated altitude at the apex of the PEFATO profile, and discontinuity in height shortly after the start of the finals turn. Exhibit 17

1.4.143. These discrepancies were assessed as indicative of a slight sticking in the altitude transducer which fed both BHC and BHF parameters. Despite the "sticky" transducer, it appeared that once a rate of change in height was established, the BHF parameters moved at a rate consistent with the expected behaviour of the aircraft. Exhibit 17

1.4.144. The ADR's reference pressure was 1013 hPa, and thus the BHF parameters did not indicate height above ground. Heights quoted in the report for the take-off and climb to downwind are given in terms of BHF height above the runway, where the BHF value was -577 ft; heights during the finals turn have been corrected to provide a height relative to the BHF value at impact which was -474 ft. For downwind heights, it has been stated which BHF datum is being used. Exhibit 17

1.4.145. In the Panel's opinion, and in consultation with flight test experts and having considered other evidence, heights referred to are as accurate as it was possible to determine and sufficiently accurate to enable the Panel to recreate the accident flight profile.

Departure Clearance

1.4.146. During the taxi to the holding point for Runway 31, the duty runway, R3 was given departure clearances and then changed to the ATC Tower frequency. When R3 transmitted '*RED 3 ready for departure, PEFATO on request*', although he had warned out with a request for a PEFATO, the Tower controller had not been made aware of that intention and cleared the aircraft to '*line up and wait'*. After discussions in the ATC Tower to clarify any restrictions, XX204 was offered a PEFATO to Runway 01/19 for a high approach[75], or to the reciprocal, Runway 13[76]. R3 proposed an approach back to the duty runway instead, which was agreed, and take-off clearance was issued at 1322 hrs. XX204 was the only aircraft in the circuit. Exhibit 15 Exhibit 16 Exhibit 2 Witness 2

1.4.147. In the Panel's opinion, as it was R3's suggestion to return to the duty runway he was fully aware of his requirements and intentions. As a result, the Panel concluded that whilst there had been a discussion regarding which runway would be used it was unlikely to have distracted or caused any confusion to R3 and was therefore **Not a Factor** in the accident.

Accident Flight Profile

Introduction

1.4.148. To understand the sequence of events during the accident sortie, and to aid understanding of the aircraft's flight profile, general background information is outlined

[75] High Approach: The RAF Valley Flying Order Book stated that if a PFL was not planned to touch-and-go, a high approach should be initiated by 300 ft QFE.
[76] Maintenance work at the threshold of Runway 19 restricted clearances to non-duty runways.

below regarding Hawk T Mk1 operations.

1.4.149. **Circuit positions.** In the circuit an aircraft would be described as turning upwind, flying downwind and turning finals. Figure 1.4.6 shows the basic visual circuit pattern and labels the areas that will aid understanding of the aircraft's position.

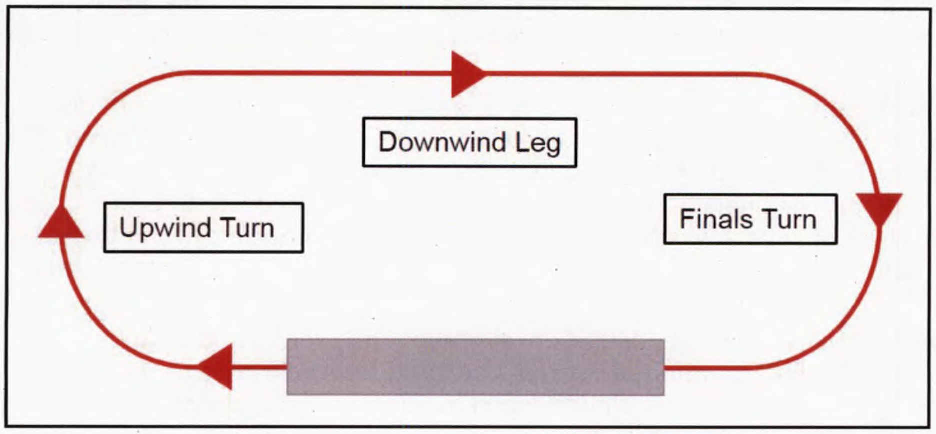


Figure 1.4.6 – Visual circuit pattern

1.4.150. Whilst the pattern that XX204 flew resembled a 'normal' circuit, the requirement for R3's PEFATO was to fly as efficiently as possible to a point where the PFL pattern could be intercepted.

1.4.151. **Academic PFL pattern.** The circuit and approach pattern for a generic forced landing can be built up on two reference points known as High Key (ideally the first checkpoint) and Low Key. An example academic pattern for a forced landing is illustrated in Figure 1.4.7. Exhibit 48 Exhibit 50

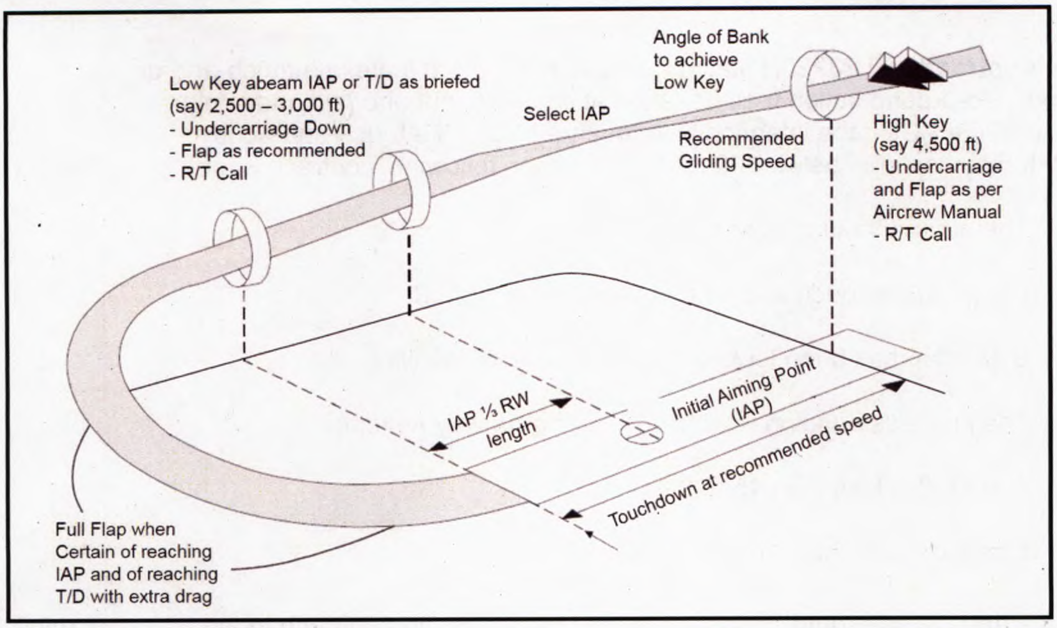


Figure 1.4.7 - AP3456 academic PFL pattern

1.4.152. Academically an aircraft would, height permitting, route via High Key and Low Key; however, if a failure occurred at a height from which High Key could not be achieved, then Low Key would be the first checkpoint. Exhibit 48

1.4.153. To safeguard against landing short of the runway, an initial aiming point (IAP), situated one third into the runway, was considered as the intended touchdown point at the commencement of the procedure. The Low Key position in the Hawk was abeam the IAP. As an aircraft progressed through the manoeuvre, the touchdown point could be re-adjusted towards the runway threshold area by the use of flap when the pilot considered it safe to do so. From Low Key, by maintaining a constant angle between the aircraft and the IAP[77], the pilot could adjust the approach by increasing or decreasing the angle of bank (AOB) to achieve a landing on the runway. Exhibit 48 Exhibit 50 Exhibit 105 Exhibit 48 Exhibit 50

Practice Forced Landing context

1.4.154. Within the context of XX204's manoeuvre the following provides amplification in relation to (P)EFATOs.

1.4.155. As previously discussed in para 1.4.32 a range of PFLs were practised from differing heights and with varying profiles. The low level PFLs (500 ft, 800 ft and 1200 ft) employed subtly different techniques to the academic profile due to a variation in energy states[78]; although the aircraft would be lower in height than on an academic PFL, they were initiated from higher speeds. Whatever low level technique was employed, all were required to intercept at some stage, the academic PFL profile from below, even as late as just prior to the 'contract' point, described below. Exhibit 39 Exhibit 51 Exhibit 51 Exhibit 50

[77] Referred to as a Constant Sight-line Angle.
[78] In this context energy refers to the combination/relationship between an aircraft's height and speed; where speed could be sacrificed for height and vice-versa.

1.4.156. **The 'contract'.** FTP3225H stated a PFL may only terminate in a touch-and-go or a go-around. Go-around action may be taken at any time, but one *(sic)* may only continue below 300 ft AGL if the intention is to touch-and-go. If a touch-and-go is planned, a PFL may continue below 300 ft AGL only if the following 'contract' is met: Exhibit 50

a. The aircraft landing gear is locked down.

b. Clearance to touch and go has been given by ATC.

c. Down flap has been lowered or selected and travelling.

d. The aircraft's heading is within 30° of the runway heading.

e. The AOB is less than 45°.

f. The speed is between 150 kts and 170 kts.

1.4.157. **Go-around.** A go-around[79] was the act of terminating an approach to the runway and the aircraft climbing away from the ground. The decision to go-around could be made by the pilot or directed by ATC. The execution of a go-around was described[80] as: '*Select full power and hold a steady attitude until the power bites, before setting the normal 8° nose up climb attitude*'. In practice, if not flown from a wings-level attitude with low rates of descent, a go-around was 'normally'[81] flown using a blended roll to wings-level and pitch to arrest the descent and achieve a climb away from the ground, as full power was simultaneously applied. This was the technique used by R3. Exhibit 106 Exhibit 50 Exhibit 17

1.4.158. **Low level PFLs.** The guidance for the low level PFL profiles had clearly defined criteria that would aid the pilot in deciding, for example, how to judge downwind spacing and when to commence the final turn as follows:

a. 1200/800 ft PFL. Roll out on a wind corrected downwind leg with the wing tip running down the runway. Minimum speed at Low Key should be 220 kts (1200 ft PFL) or 240 kts (800 ft PFL). The physical point at which to initiate the final turn is specified but caveated with the statement that the absolute minimum final turn speed, to complete the final turn and make the 'contract', is 190 kts. Once 190 kts is reached the pilot must turn finals and, in this case, not all the runway may be available and a new IAP should be selected. The final turn should be flown level until the speed reduces to 180 kts; then a descending glide should be flown at 180 kts until it is assessed as suitable to select the landing gear down and the final stages of the normal PFL can be intercepted. Exhibit 50

b. 500 ft PFL. RAFAT pilots were briefed, once they were clear of the other formation aircraft, to fly downwind at 500 ft (no lateral spacing, or spacing cue was mentioned, but a briefed common error was being too wide) and initiate the final turn when abeam the landing threshold, or when speed reduced to 230 kts. They should maintain a level turn, use buffet if required, lower landing gear and full flap below 200 kts and intercept the final stages of the normal PFL profile, Exhibit 51

---

[79] CAP413 10.45 - the aircraft is to break off the approach and climb to circuit height, or as briefed.
[80] FTP3225H.
[81] ATEC test flights and HSTF go-arounds analysed by DAIB.

ensuring the 'contract' parameters are met. Exhibit 52

1.4.159. The Panel acknowledged that in comparison to PEFATOs, low level PFLs were initiated at higher speeds and whilst only intercepting the 'normal' PFL profile very late, would rapidly place the aircraft on a profile with well established spacings and cues.

1.4.160. **PEFATO.** In addition to the academic and low level PFL profiles, pilots practised PEFATO techniques. An EFATO was described as: Exhibit 50

> *'the most time and energy-critical[82] emergency in the Hawk, requiring skilful handling and continuous situation assessment to ensure a safe outcome. Careful pre-take-off consideration and emergency take-off briefing, of the available courses of action, in the prevailing conditions, is essential in every case. Pilots should not expect to succeed on every EFATO; a timely ejection decision should be made whenever a successful landing is in doubt.'*

1.4.161. Unlike general PFLs there was no guidance for downwind positioning after the initiation of a PEFATO. The Panel noted that since each PEFATO could commence with variable energy states (height and speed), it would be difficult to prescribe exact parameters for conducting these exercises and consequently pilots would be required to use their judgement.

1.4.162. Guidance regarding aircraft speed and associated options following an EFATO was contained in the Aircrew Manual and in 2 sections of FTP3225H, and referred to single and multiple runway situations. Exhibit 91 Exhibit 50 Exhibit 49

1.4.163. **Aircrew Manual guidance.** An EFATO was defined as an engine failure at any point from unstick[83] up to 300 kts. Amongst the possible situations where a failure could occur the Aircrew Manual stated: Exhibit 49

a. *Speed between 250[84]/270[85] and 300 kts. If the speed is between 250/270 and 300 kts commence a turnback to the airfield. However, a turnback to the reciprocal of the runway in use is to be carried out with extreme caution because of the hard manoeuvring which would be required.*

b. *Speed above 300 kts. If the speed is above 300 kts the failure should not be considered an EFATO; the pilot may position for any suitable runway.*

1.4.164. **FTP3225H PFL guidance.** The PFL chapter provided the following guidance: Exhibit 50

a. *If an alternative intersecting runway is available, an actual or simulated EFATO may be followed by a turn to it if the speed at loss of thrust is at or above 250 kts (clean and/ or gun/ or pylons) or 270 kts (with wing stores). The initial turn should be made away from any prevailing wind.*

---

[82] As stated at para 1.4.155, Energy refers to the combination/relationship between an aircraft's height and speed; where speed could be sacrificed for height and vice-versa.
[83] Unstick was the moment that the aircraft's wheels left the ground.
[84] Aircraft was clean (no underwing stores) and/or with a gun, or underwing pylons.
[85] Aircraft with non-jettisonable store.

b. *For single runway operations*[86]*, if the speed is at or above 300 kts, it may be possible to position for a forced landing, from a modified low key, back onto the runway in use. On long runways this may result in landing well in, but with sufficient runway left on which to either stop or engage the barrier.*

c. *For single runway operations, if the aircraft has already turned as part of the departure and the engine fails below 300 kts but above 250 kts, despite the lower speed a modified low key may still be achieved. From the final turn initiation point at 180 kts, the minimum height from which the 300 ft 'contract' might still be met is about 1400 ft, assuming a perfectly flown final turn with the landing gear lowered just after half way round the turn.*

The RAFAT standard aircraft configuration meant that the lower speed limit (250 kts) was applicable as the smoke pod equated to a gun pod. Exhibit 107

1.4.165. **FTP3225H emergency brief guidance.** The Basic Handling chapter gave slightly differing information. In the section on the construction of a Take Off Emergency Brief, and regarding a major loss of thrust at or above certain speeds, it stated: Exhibit 91

a. *250/270 kts (depending on stores fit) with an intersecting runway; consider jettisoning stores, remain VMC, glide at 180 kts, attempt any suitable runway.*

b. *300 kts (all configurations) for single runway operations**; consider jettisoning stores, remain VMC, glide at 180 kts, attempt any suitable runway.*

*** If an aircraft had turned significantly as part of a departure, was above 500 ft and less than 250/270 kts then it is no longer considered an EFATO, per se, but rather an AFL/PFL. Flying to a modified low key may be attempted above 250/270 kts.*

There was no amplification of what 'significantly' meant.

1.4.166. The Panel formed the view that whilst there was clear commonality throughout the guidance documents for speed brackets, there was a lack of clarity regarding their application for selecting a profile to an intersecting or single runway. In the Panel's opinion, the guidance above 300 kts and the option to return to a single runway was clear, however there was ambiguity in the 250/270 to 300 kts speed range - whether an aircraft had turned or not, and by how much, and there was no consideration given to the height at the point of PEFATO initiation/actual engine failure. The Panel acknowledged that pilots would apply airmanship and judgement in real emergencies.

1.4.167. **PEFATO technique.** The technique for flying a PEFATO was to use excess speed to climb and turn, at a moderate rate, towards the chosen runway Low Key and establish a glide at 180 kts, anticipating a late interception of the PFL pattern. Regular decisions to continue or go-around (eject for real) should be made. A go-around was to be initiated by 300 ft AGL if above 5000 kg AUW[87]. Exhibit 50

---

[86] Take-off and subsequent approach to the same runway – no intersecting/alternate runway available.
[87] Current Hawk T Mk1 fleet guidance is not to land/touch-and-go when AUW is =/> 5000 kg.

1.4.168. **Modified Low Key**. When conducting a PEFATO, it is highly unlikely that an aircraft would be able to reach the academic Low Key height due to insufficient energy available at the point of initiation of the exercise; guidance stated the pilot should glide at 180 kts and aim for a 'modified Low Key' position which was abeam the selected IAP. Exhibit 50

1.4.169. **Judgement**. The success of any PEFATO profile, dependant on energy available, was down to the pilot's judgement to select the appropriate lateral spacing and IAP, decide when they were at their 'modified Low Key', establish the correct sightline angle, and time the selection of landing gear and flap. Concurrently, a continual assessment was required to evaluate whether the PFL profile could be intercepted at any stage and the 'contract' be achieved, or whether a go-around (eject for real) should be conducted.

Sortie overview

1.4.170. R3 was practising an EFATO back to a single runway, a similar situation to that he would experience at RAF Scampton. The aircraft had a full fuel load, was carrying 2 crew and had a smoke pod full of dye fuel. The exercise was initiated relatively early after take-off, but deliberately so to use similar parameters to those the pilot might experience when flying a RAFAT take-off. This early initiation resulted in XX204 achieving a maximum height (apex) at the beginning of the downwind leg of approximately 1400 ft; taken in isolation this was not of concern but, as previously mentioned, 1400 ft was the published guidance as the minimum height at which the final turn was to be initiated. This will be further analysed in para 1.4.192. Witness 1B Witness 1C Exhibit 12 Exhibit 17 Exhibit 108 Exhibit 17 Exhibit 50

1.4.171. R3 extended downwind beyond the point at which he called Low Key position in order to give himself more runway available for a potential landing (R3's intention was to go-around no lower than 300 ft). In interview R3 identified a location on the airfield that he had selected as his IAP, this was approximately abeam the position at which the finals turn was commenced. The IAP, Low Key and turn point are shown in Figure 1.4.8. Witness 1B Witness 1C Exhibit 109

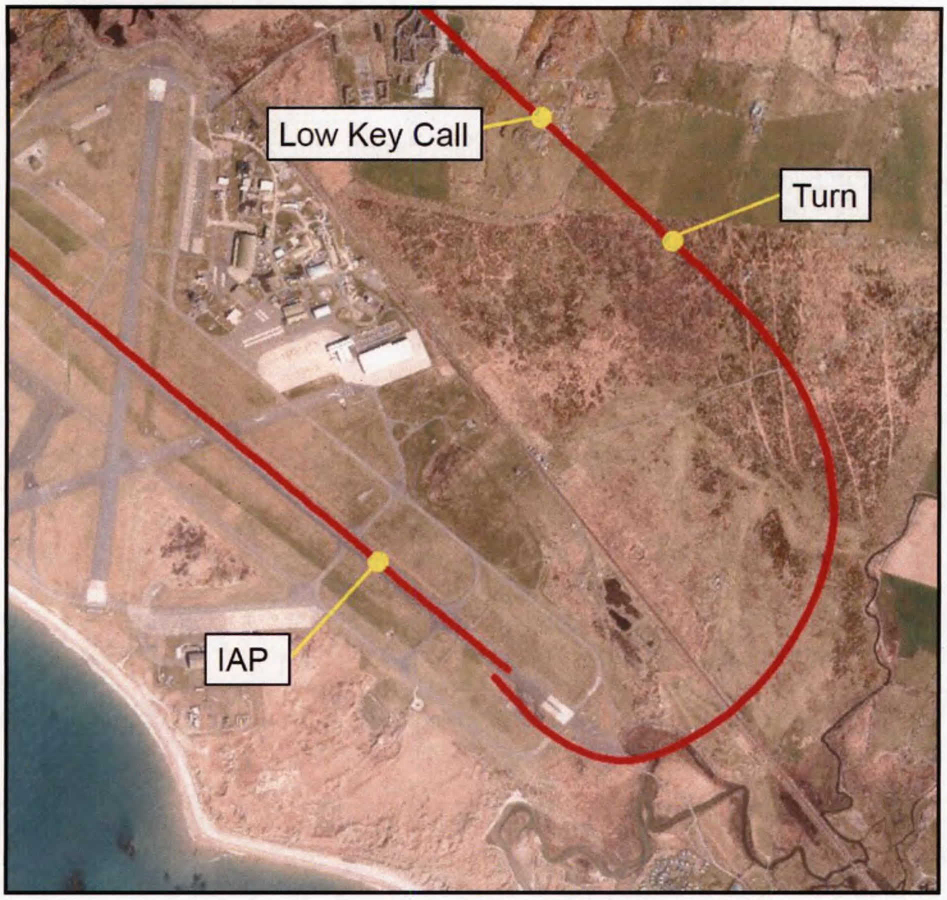


Figure 1.4.8 - Position of Low Key, IAP and turning point

1.4.172. At the point R3 commenced the finals turn XX204 was gliding at approximately 183 kts at circa 1030 ft AGL with a lateral separation of approximately 1268 m from the runway. In the Panel's opinion, the profile flown up to the end of the downwind leg meant that the conditions were set that would make a successful final turn (rolling out on the runway centreline and having met the 'contract' parameters) extremely unlikely. The resultant manoeuvring during the final turn was very likely influenced by the combination of reduced height and lateral separation; once landing gear was lowered 45° AOB was used and speed reduced to approximately 170 kts[88]. The subsequent high AOB was likely to have been used to lower the nose to attempt to maintain the minimum glide speeds and complete the turn in the room available, resulting in an increased ROD and flight path angle (FPA). At around the point of the go-around the aircraft stalled and there was insufficient height available for a successful recovery. Exhibit 17 Exhibit 110

1.4.173. **Flight Path Angle.** As shown in Figure 1.4.9, the Pitch Angle of an aircraft is the angle between the horizon and the longitudinal axis, ie where the aircraft is pointed. This would be displayed to the pilot on the aircraft attitude indicator or artificial horizon instruments. FPA is the angle between the horizon and the aircraft Flight Path, ie where the aircraft is actually going; this is not displayed to the pilot in the Hawk T Mk1.

[88] Published speed for gliding with landing gear down with AUW >5000 kg.

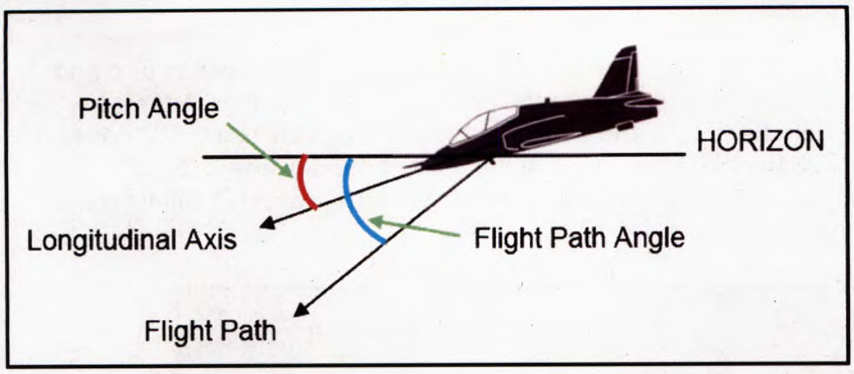


Figure 1.4.9 - Pitch and Flight path angles

Accident sequence

1.4.174. The following section describes, in chronological order, the sequence of events of the accident sortie from take-off to impact.

1.4.175. **Take-off and initial turn.** XX204 took-off using full-power and with an initial nose up attitude of 10°. On passing 255 ft AGL and at 257 kts, a right turn was commenced. Exhibit 17

1.4.176. The height at which R3 started the right turn, although lower than would be seen on other Hawk T Mk1 sqns, who initiated turns no lower than 500 ft[89], was commensurate with a RAFAT departure where turns could be initiated below 500 ft. R3 was knowingly practising a take-off profile similar to that which he would routinely use on RAFAT. Exhibit 111 Exhibit 112 Witness 1A Exhibit 113 Exhibit 114

1.4.177. The Panel concluded that the take-off was normal and although the initial turn was lower than on other units, was 'routine' for RAFAT. This, together with the fact that the stated initiation conditions do not specify a minimum height or in any way guarantee an achievable PFL, led the Panel to conclude the take-off and initial turn profile was **Not a Factor** as R3 could terminate the exercise at any stage.

1.4.178. **PEFATO initiation and upwind turn.** Having turned through approximately 36°, at 278 kts and at 450 ft AGL, R3 initiated the PEFATO by retarding the throttle to idle; he transmitted to ATC that he had a simulated engine failure and was positioning for Low Key Runway 31. Aware that the aircraft was heavy and intending to fly a profile back to the duty runway, R3 had consciously commenced the exercise 30 kts above the minimum speed. Exhibit 17 Exhibit 2 Witness 1B Witness 1A Exhibit 114

1.4.179. In the Panel's opinion, R3's initiation of the exercise at 278 kts was a good airmanship decision; it acknowledged the aircraft's high AUW and increased the energy available to complete the exercise allowing him more flexibility in converting speed to height.

---

[89] RAF Leeming based aircraft turn at or above 500 ft on all departures due to local restrictions and RNAS Culdrose based aircraft turn at 1500 ft if leaving the airfield and not below 500 ft if remaining at the airfield.

1.4.180. At initiation, XX204 was less than a ¼ of the way around the upwind turn and had approximately 144° remaining to achieve the downwind leg heading. After completing a climbing right hand turn and converting speed to height using 18° nose up, 72° AOB and 2.9 g, XX204 achieved an apex at the start of the downwind leg of approximately 1400 ft[90] at a speed of 183 kts[91]. The initial turn, PEFATO initiation and downwind apex are shown in Figure 1.4.10. Exhibit 17

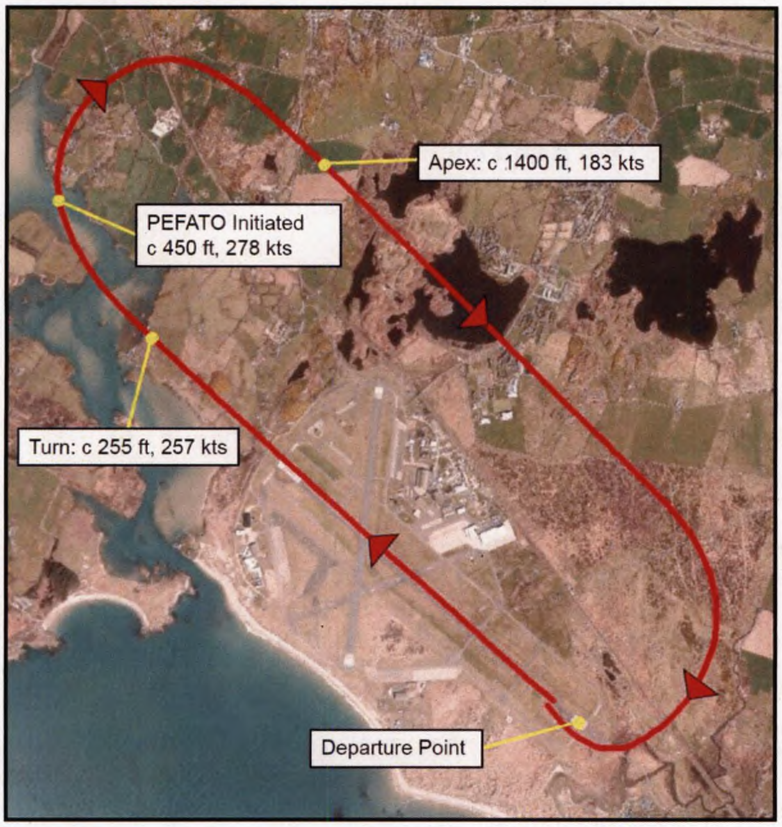


Figure 1.4.10 – Initial turn, PEFATO initiation and apex at start of downwind leg

1.4.181. As described at para 1.4.176, the other 2 main Hawk T Mk1 units commenced the upwind turn no lower than 500 ft after departure and, if planning to carry out a PEFATO, the aircraft had to have commenced the departure turn before initiating the exercise[92]. Exhibit 111 Exhibit 112 Exhibit 50

1.4.182. The point at which XX204's PEFATO was initiated meant the height achieved at the start of the downwind leg was comparatively lower than would be expected had the turn been commenced above 500 ft. The Aircrew Manual advised that the minimum speeds did not guarantee a successful turnback and safe landing; they merely ensured that the pilot was in a position to assess the situation and make a timely ejection decision if necessary. Exhibit 49

[90] Height was somewhere between 1424 ft above take-off datum and 1321 ft above impact.
[91] The optimal glide speed for a Hawk T Mk1 was 180 kts.
[92] IAW FTP3225H PEFATO with single runway operations.

1.4.183. Noting the previously discussed ambiguity in guidance, and whilst speed was but one feature in the overall profile, the fact that XX204 did not successfully complete the manoeuvre may indicate that only considering speed when planning to return to a single runway could result in insufficient energy being available and that returning to the threshold is unlikely to be achievable.

1.4.184. In the Panel's opinion, noting the need for careful handling following an EFATO, the guidance contained in the Aircrew Manual and the FTP3225H lacked clarity and was open to interpretation and was therefore considered an **Other Factor**, as it could contribute to a further safety related occurrence. Recommendations relating to the Aircrew Manual and FTP3225H are made later from para 1.4.451.

1.4.185. The Panel concluded that the timing of the initiation of the PEFATO meant that XX204 was only able to reach 1400 ft[93] at the beginning of the downwind leg. Consequently, and in the Panel's opinion, the timing of the initiation resulted in setting the conditions for the reduced available height at the end of the downwind leg. However, FTP3225H did state that a successful conclusion was not assured and that a timely ejection (for real) or go-around (for practice) decision should be made. Therefore, as R3 could have terminated the exercise at any stage the Panel considered that the initiation parameters were **Not a Factor** in the accident.

1.4.186. **Downwind leg - Height.** Having achieved a height of approximately 1400 ft AGL at the start of the downwind leg, at 183 kts, R3 glided downwind and reported 'Low Key' at around 1200 ft[94] AGL. After the Low Key call R3 continued downwind for approximately 6 sec before commencing the finals turn from a height of circa 1030 ft[95] above impact. R3 recalled extending downwind to have more runway in front of him for the exercise. He recollected being lower than 'normal' downwind but was content as he had flown PFLs from similar heights during previous practices.

Exhibit 17
Exhibit 115
Witness 1B
Witness 1C
Witness 1B
Witness 1A
Witness 1C

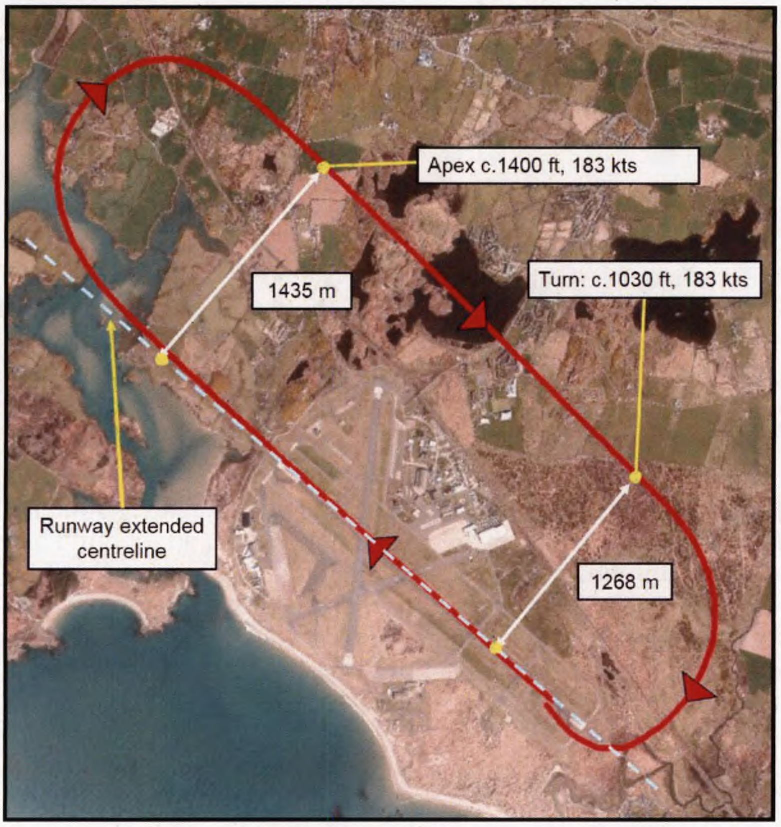
1.4.187. **Downwind leg - lateral displacement.** Interpretation of the ADR data and pilot's Global Positioning System (GPS) enabled a Graphical Data Analysis System (GDAS) replication of XX204's estimated ground track to be generated. At the beginning of the downwind leg, XX204 had a measured lateral displacement of approximately 1435 m. Exhibit 116

1.4.188. It also indicated that XX204's downwind heading meant the aircraft's track was closing marginally towards the runway[96]. The reported surface wind was 310/7 kts and the 2000 ft wind was estimated at 360/15 kts[97]; the Panel assessed that the 1000 ft wind was approximately 340/12 kts which would have had the effect of blowing the aircraft slightly towards the runway[98] during the downwind leg (and during the final turn). R3

Exhibit 19
Exhibit 24
Exhibit 117

[93] Heights from the ADR were: 1321 ft above take-off and 1424 ft above impact point.
[94] Heights from the ADR were: 1292 ft above take-off and 1189 ft above impact point.
[95] Heights from the ADR were: 1201 ft above take-off and 1098 ft above impact point. However, this point occurred just prior to a discontinuity observed in BHF where there appeared to be a correction down by 70 ft (possibly due to a sticky transducer). As such it is possible that the finals turn was commenced up to 70 ft lower, ie 1028 ft above impact. R3 recalled turning from about 1000 ft.
[96] Runway reciprocal track was 133° magnetic - XX204's heading was 135° magnetic; closing the runway by 2°. The generated ground track was based on ADR heading and speed data and adjusted for the estimated wind. It was adjusted to meet the 2 known positions of the aircraft on the runway pre-take-off and the impact point.
[97] Surface wind and estimated 2000 ft wind were contained in the RAF Valley meteorological report. Only the surface wind was passed by radio to the pilot by ATC during the aircraft's departure clearance.
[98] 1000 ft wind would have produced 2° of drift to the right.

was aware of the surface wind and was reasonably happy where he had positioned the aircraft on the downwind leg. XX204's lateral displacement from the runway, at the end of the downwind leg, just prior to turning onto finals, was approximately 1268 m. XX204's ground track and downwind spacing are shown in Figure 1.4.11. Exhibit 2 Witness 1A Exhibit 110



Note: Distances measured from runway centreline, as indicated, rather than from aircraft track.

Figure 1.4.11 - XX204's ground track and downwind spacing

1.4.189. As XX204 achieved approximately 1400 ft at the beginning of the downwind leg, and turned finals from circa 1030 ft, the Panel assessed that XX204 would have been at 1200 ft AGL around the mid-point of the downwind leg. As a comparison, ATEC flight testing indicated that at 1200 ft and approximately 1250 m spacing while gliding at 180 kts the aircraft was, in the Test Pilots' opinion, 'tight' on the downwind leg[99]. Exhibit 118

1.4.190. In the Panel's opinion, since each PEFATO could commence from a different height, speed and position on the upwind turn, and there were no defined points on the profile, pilots had to rely on their judgement to assess the position of the aircraft at any stage of a PEFATO. Following mathematical modelling and analysis conducted in the HSTF (para 1.4.201) where different parameters and techniques were utilised, the Panel concluded that from XX204's downwind lateral displacement it was not possible to accomplish a successful final turn with the attainment of the 'contract' limitations, or without a fly-through of the runway centreline. Exhibit 119

[99] In this context, 'Tight' is the phrase aircrew would use to describe reduced lateral displacement.

1.4.191. **Upwind turn and downwind leg - Conclusion**. The initial turn and the PEFATO were initiated relatively early after take-off and the subsequent upwind turn resulted in a height of approximately 1400 ft AGL being achieved at the beginning of the downwind leg, with the lateral separation from the runway reducing before the final turn. In the Panel's opinion, given XX204's position and flight parameters at the end of the downwind leg, it was extremely unlikely it could successfully achieve the 'contract' and runway centreline. The Panel concluded that the height and lateral spacing at the end of the downwind leg were intrinsically linked and therefore the position from which XX204 commenced the final turn, at 180 kts, was a **Contributory Factor.**

FTP3225H amendment to PEFATO height guidance

1.4.192. FTP3225H Issue 1 (Jan 18) stated that when commencing the final turn of a PEFATO, and gliding at 180 kts, the minimum height at which the 300 ft 'contract' might still be met was about 1400 ft, assuming a perfectly flown final turn with the landing gear lowered just after half way round the turn. The document was published on 1 Feb 18 and had been distributed to all Hawk T Mk1 units; its predecessor[100] made no reference to a minimum height required to commence the final turn to meet the 'contract' parameters. R3 was unaware that the publication had been updated and therefore had no knowledge of the 1400 ft guidance. Exhibit 50 Exhibit 120 Exhibit 121

1.4.193. Although the amended publication was distributed to RAFAT, FTP3225H did not appear on the RAFAT list of documents that required pilot signatures for having read. However, the DD stated in the advanced handling section that the relevant chapters of the FTP3225H should be read in addition to the DD. The Panel were unable to establish if the newly issued document was reviewed by RAFAT staff but noted that even if it had been the list of effective changes in the front of the publication did not indicate that there was a change to the height guidance for a PEFATO. The Panel received mixed evidence as to whether the amended document was briefed to the whole Team. Having considered the evidence the Panel concluded that it was almost certain that RAFAT pilots were not aware of the changes prior to 20 Mar 18. Post the accident, and before returning to flying, RAFAT pilots completed a training package. The training included an emergency focused sortie in the simulator requiring a PFL after take-off with the aircraft returning to the in-use runway, and a flight with an external QFI or STANEVAL that included PFLs. This package was aimed to reinforce GH and PFL procedures. RAFAT pilots interviewed after the accident, and having returned to flying, were aware of the 1400 ft guidance. Exhibit 122 Exhibit 51 Exhibit 123 Exhibit 124 Exhibit 125 Exhibit 126 Exhibit 127 Witness 8 Witness 9A Witness 14

1.4.194. In the Panel's opinion, if R3 had been aware of the amended guidance for the minimum height of 1400 ft, he may have terminated the exercise at the end of the downwind leg, or possibly have initiated the final turn earlier. Therefore, the Panel concluded that R3's lack of awareness regarding the amended PEFATO guidance in FTP3225H was a **Contributory Factor**. FTP3225H will be further considered in para 1.4.451.

[100] The preceding document, AP3225H, was dated Feb 16.

Finals turn

1.4.195. **Lowering landing gear and flap**. XX204 commenced the final turn from approximately 1030 ft[101], at 183 kts and with a lateral displacement of circa 1268 m. AOB was increased progressively over a 4 sec period to approximately 40°, which was held for the first 30° of the turn, at which point landing gear was selected down and AOB increased to 45°, with down flap selected approximately 5 sec later. AOB of 45° was held until the first 90° of the final turn had been completed[102] and the aircraft covered approximately 2/3 of the available lateral distance in the first half of the turn. XX204's ground track during the final turn is shown in Figure 1.4.12. Exhibit 17 Exhibit 110 Witness 1A Exhibit 17 Exhibit 50

Figure 1.4.12 - Final turn ground track

1.4.196. R3 recalled selecting the landing gear down fairly quickly after commencing the turn. However, he could not recall when he selected flap but did recollect intending to use the associated aerodynamic effect to assist the aircraft with the turn. Selection of flap increases the lift characteristics of the wing and reduces the stall speed; this allows more g to be applied at a given speed which increases turn rate and reduces turn radius. However, flap also increases drag which, with the throttle set at idle during a PFL, necessitates lowering the aircraft's nose to maintain speed. The use of flap to assist the turn was not a PFL technique detailed in the Aircrew Manual or FTP3225H; the fact that flap should help pitch the aircraft around the final turn was referred to in the Basic Handling section of the FTP3225H[103]. Witness 1B Witness 1A Witness 1B Witness 1A Exhibit 128 Exhibit 91

[101] As considered in para 1.4.186 this may have been between 1028 ft and 1098 ft above impact. R3 recalled turning from circa 1000 ft.
[102] Guidance stated that, with landing gear lowered and flap up, the maximum angle of bank should be no greater than 45°.
[103] FTP3225H Chapter 1 – Hawk procedures and basic handling stated in reference to powered circuit flying: The selection of Down Flap should help pitch the aircraft around the final turn.

1.4.197. Guidance stated that when commencing the final turn from approximately 1400 ft, the landing gear should be lowered just after halfway round the turn[104]. Based on that advice and the fact XX204 turned from approximately 1030 ft, XX204 was assessed as already being in a position where a successful PFL was unlikely to be achieved. The Aircrew Manual advised that pilots should select flap down when certain of reaching the desired touchdown point. With XX204 still less than half way round the final turn, it was not possible to determine if R3 considered that he could make the desired touchdown point. Exhibit 17 Exhibit 105

1.4.198. Hawk aircraft operations required landing gear to be selected before flap. XX204's reduced lateral displacement, described in para 1.4.187, meant that, for R3 to fully capitalise on the use of the associated aerodynamic effect to assist the aircraft with the turn, flap would be needed to be taken early to have a chance to complete the final turn in the room available. The early selection of landing gear and flap, with the associated increase in drag, resulted in a further reduced energy state with more than 90° of the final turn remaining. Exhibit 17

1.4.199. In the Panel's opinion, the timings of R3's selections of landing gear and flap were appropriate. Delaying landing gear would have made little difference to the height profile[105], and delaying flap would have only exacerbated the fly-through of the runway centreline. The position of R3's selection of landing gear and flap is shown in Figure 1.4.13.

1.4.200. Within the context that R3's intention was always to fly a go-around, and not to perform a touch-and-go, the Panel concluded that the timing of down selection of landing gear did not affect the outcome and, therefore, was **Not a Factor**.

Figure 1.4.13 – Selection of landing gear and flap

[104] FTP3225H.
[105] Lowering landing gear produced an increase in ROD, however, over a small period of time the difference could be considered negligible.

1.4.201. **HSTF analysis.** Analysis of XX204's final turn was conducted in the HSTF[106]. Several techniques were flown and while landings were achieved on a few occasions, at no time were all the 'contract' parameters met. On almost every occasion the HSTF showed indications of stall. The HSTF model replicated the onset of stall, however, if the stall was sustained it continued to replicate the rate of descent and some limited instability but it did not generate random aerodynamic effects that may occur when the aircraft is stalled. Therefore, a stall in the HSTF was generally more stable in heavy buffet than would be experienced in a real aircraft but only to a limited extent. Consequently, whilst the associated analysis enhanced understanding of the final turn it could not be used to assess the aircraft performance at and beyond the stall. The Panel concluded that this analysis reinforced the fact that given XX204's height, speed and reduced lateral spacing at the end of the downwind leg, a successful final turn, achieving the runway centreline and meeting 'contract' parameters without inadvertently stalling, was extremely unlikely. Exhibit 129 Exhibit 130

1.4.202. **ATC radio call**. Approximately 2 sec after selecting flap down, and almost coincident with the landing gear completing its travel, ATC prompted R3 for confirmation that the landing gear was down. R3 immediately checked his landing gear indications and replied, '*gear down*'. ATC then issued a clearance for a low approach, which R3 read back; this sequence of transmissions lasted 5-6 sec. There were no further radio transmissions between the aircraft and ATC. Exhibit 115 Exhibit 2 Exhibit 115 Exhibit 2 Witness 1B Witness 1A Exhibit 115 Exhibit 2

1.4.203. Pilots of aircraft with retractable undercarriage are required[107] to report their landing gear position as part of their request for clearance. If ATC did not receive a landing gear status call from aircrew, their procedures required them to request the status of the landing gear before they could issue a runway clearance[108]. R3 stated he was intending to make a 'final, gear down' call but at this stage it was not his priority; the controller felt such a call was due. At RAF Valley an ATC clearance was normally given when an aircraft reported finals, however, during a PEFATO pilots may delay the gear down call. Exhibit 131 Exhibit 132 Witness 1B Witness 1A Witness 2 Exhibit 133

1.4.204. **AOB and ROD.** During the first 5-6 sec after selecting flap down, coincident with the ATC radio transmissions, XX204's AOB remained fairly steady, only increasing by 4-5° to approximately 51°, and the speed reduced from 172 kts to 153 kts. This AOB was maintained until the last 1 sec of flap travel when AOB rapidly increased, coincident with a reduction in g from 1.67 g to 1.1 g[109], momentarily peaking at 70° AOB as ATC related transmissions ended. During this increased AOB manoeuvre XX204 was approaching the runway centreline 55° off runway heading, descending through 565 ft and with an airspeed of 150 kts. Table 1.4.8 shows XX204's AOB and speed in relation to flap travel and ATC transmissions. Exhibit 19

---

106 Analysis was conducted by 2 x ATEC Test Pilots, DAIB Investigator and the SI Operations Panel Member, all qualified Hawk pilots.
107 CAP 413 10.18.
108 Clearance would have been to: land, touch-and-go or low approach. R3 was cleared for a low approach.
109 This was in line with increasing nose down pitch to maintain airspeed.

Elapsed time (sec)	Event	Radio Transmissions	AOB	Speed (kts)	Pitch (deg)	Degrees to R/W hdg	g	Rate of heading change (deg/ sec)
0	Flap down select		46	172	5	111	1.32	6
1			44	170	5	105	1.38	5
2			45	169	5	100	1.48	6
2.5	Gear locked down		46	166	5	96	1.52	6
3		ATC: R3 check gear	47	167	6	93	1.59	6
3.5			47	167	6	90	1.63	6
4		R3: Gear down R3	48	165	5	88	1.59	5
4.5			50	163	4	85	1.56	5
5		ATC: "R3 Clear low approach"	51	161	5	82	1.57	7
5.5			50	159	6	78	1.63	8
6			50	157	6	74	1.67	8
6.5			50	154	5	71	1.61	6
7			53	153	-1	71	1.32	1
7.5	Flap fully down	R3: Clear low approach R3	58	153	-6	69	1.07	4
8			64	152	-9	64	1.12	10
8.5		Transmission complete	68	150	-10	57	1.26	13
9			70	150	-11	50	1.42	14
9.5			67	150	-11	42	1.50	16
10			63	150	-11	34	1.55	16
10.5			59	150	-12	27	1.55	14
11			56	149	-13	20	1.63	14
11.5			54	148	-12	14	1.67	13
12	Stall		51	146	-12	9	1.63	9

Table 1.4.8 - XX204's flight parameters in relation to flap travel and ATC transmissions

1.4.205. R3 recalled the speed reducing and lowering the nose of the aircraft to capture the minimum speed of 150 kts, but he did not recall the AOB or nose down pitch he used during the manoeuvre. The act of increasing AOB while relaxing back pressure on the control column would have the effect of reducing g and allowing the nose of the aircraft to 'slice' down (effectively lowering the aircraft nose position while maintaining AOB). Witness 1A

1.4.206. Around the point when 70° AOB was achieved there was a significant increase in the ROD, from approximately 1440 ft/min (24 ft/sec) to 4380 ft/min[110] (73 ft/sec), as shown in Figure 1.4.14. The latter ROD remained relatively constant through the final seconds of flight until impact, and at 150 kts equates to approximately -18° FPA. In the Panel's experience, during the final turn of a PFL, pilots would not routinely scan the Exhibit 134 Exhibit 135

[110] A wings level gear down/full flap glide descent should result in a nominal ROD of approximately 3250 ft/min (54 ft/sec) and a FPA of -12.3°.

vertical speed indicator, indicating ROD. The Panel could not determine whether, in the 2.7 sec after the peak AOB and the initiation of the go-around, the difference between a ROD of 3250 ft/min or 4380 ft/min could be perceived by R3. ROD considerations are covered in more detail at para 1.4.257.

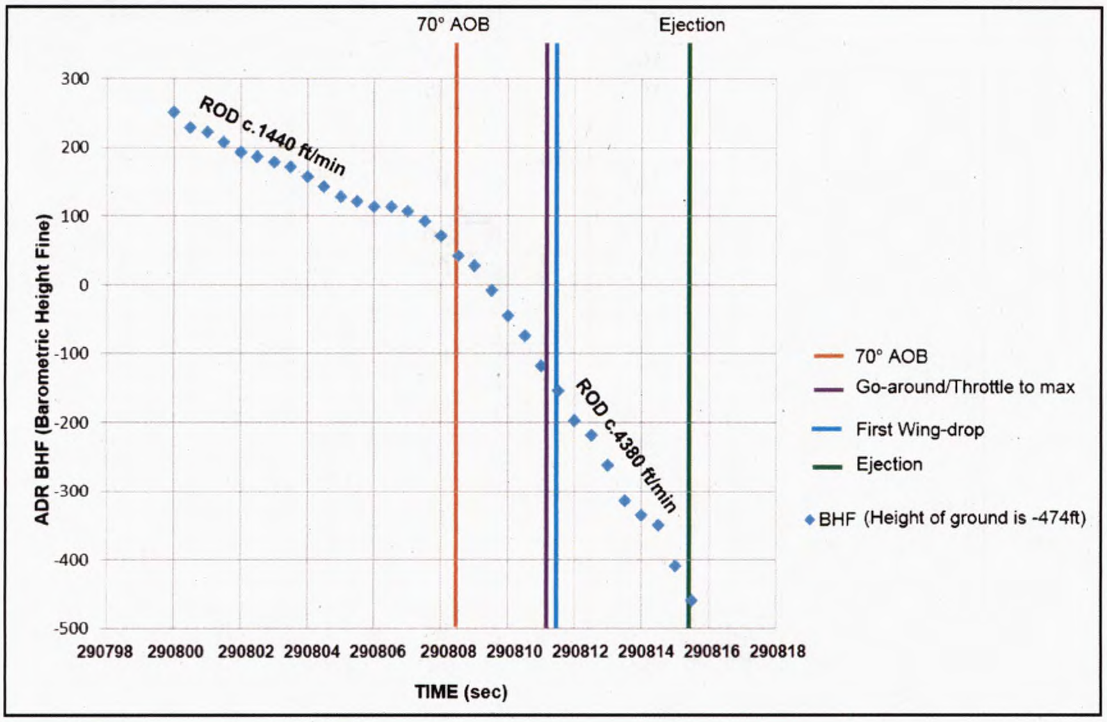


Figure 1.4.14 - Increase in ROD post 70° AOB

1.4.207. The Aircrew Manual stated that after the selection of full flap during a PFL, when the nose of the aircraft was lowered the speed increase was slight. R3 commenced the nose lowering manoeuvre at approximately 153 kts and post the manoeuvre XX204's speed reduced slightly to circa 150 kts. This slight reduction in speed may have been due to the nose down attitude that R3 selected not being quite enough, or due to the applied g in the turn. The Panel considered that had R3 flown the same manoeuvre earlier, during the first few seconds of flap travel while the speed was approximately 165 kts, it is possible some of this higher speed could have been maintained post the manoeuvre and the stall margin may have been greater during the final moments prior to the go-around[111]. This may have resulted in a situation where the aircraft was less likely to stall. However, the Panel could not determine if R3 intended to increase the AOB earlier to lower the nose and capture the higher speed but delayed the manoeuvre as a result of the ATC call. Exhibit 105

1.4.208. **Pilot distraction.** When challenged to 'check gear' R3 recalled changing where he was looking from outside the cockpit to looking in to check the landing gear indications. R3 felt that the ATC calls distracted him during the turn. In the Panel's opinion, R3's application of the increased AOB to lower the nose, as described in para Witness 1B Witness 1A

[111] Modelling showed that where additional speed was used to increase the turn rate it did not make the aircraft more likely to achieve the contract.

1.4.205, may have been delayed resulting in a speed loss of 17 kts during the 5-6 sec of transmissions, and it is possible this could have led to the use of an increased AOB. The Panel concluded that the ATC calls coinciding with the flap travelling and the application of increased bank, whilst appropriate and required by regulations had the potential to distract R3. Distraction will be analysed in greater detail as a Human Factors consideration in para 1.4.327. Witness 1B Witness 1A

1.4.209. **Go-around.** At the initiation of the go-around, marked by the advancement of the throttle to maximum, XX204 was at approximately 345 ft AGL, had 54° right AOB and with an airspeed of 147 kts, a FPA of around -18° and a ROD of approximately 4610 ft/min. Prior to this point speed had been steady at 150 kts for 2.5 sec before reducing below 150 kts just prior to selection of full power. The ADR data indicated that the pitch attitude was maintained as full power was applied and coincident with control inputs to roll to the left; the go-around was initiated approximately 4.7 sec before impact. Exhibit 17

1.4.210. Coincident with R3 initiating the go-around the aircraft flight parameters indicated that although XX204's attitude may still have been controllable, it had actually reached or was beyond the point of the stall; at that point XX204 experienced a roll reversal/wing drop. Exhibit 17

1.4.211. **Stall.** Full throttle was selected and almost instantly[112] XX204 experienced a roll reversal and a distinct drop of the right wing; the wing drop was the first incontrovertible indication of a stall. Speed was approximately 146 kts, having reduced from 150 kts in the preceding second. Due to limitations of the ADR design the equipment would likely not be able to resolve small motion and accelerations such as buffet, and in the Panel's opinion, it was not possible to determine whether R3 had indications of pre-stall buffet; furthermore, flight test data indicated that it was unlikely that there was any significant warning of the impending stall and the roll reversal was in fact the first obvious indication. Exhibit 17 In the 3 sec following the wing drop there was a rapid sequence of several control inputs: full left aileron control input was applied, followed by a momentary centralising of the control column, then half left roll input conjoined with full aft control column was applied and a further stall (wing drop) occurred. Exhibit 17 Whilst application of full aileron below 200 kts is prohibited with gear or flap deployed, the Panel concluded that this application of full aileron occurred after the stall, in particular the wing drop, and was likely an instinctive reaction to a lower than expected roll rate. Exhibit 136

1.4.212. Key activities during XX204's final turn are illustrated in Figure 1.4.15. As has been articulated, the overlap of flap travel and ATC transmissions culminated with the application of 70° AOB.

[112] ADR indicated wing drop was 0.3 sec after full throttle selection.

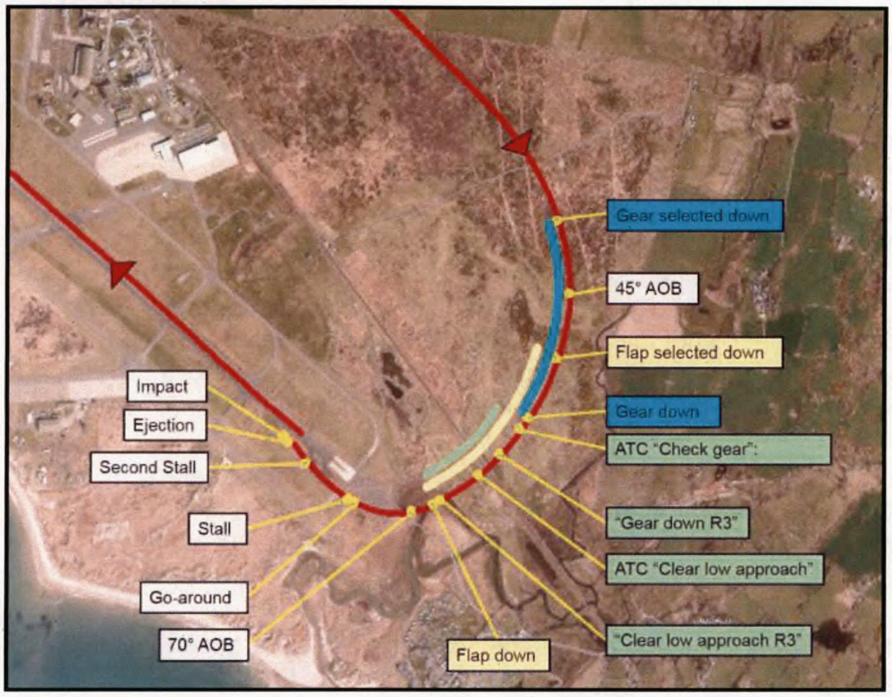


Figure 1.4.15 - XX204 key activities during final turn

1.4.213. **Final turn summary**. Various flight and HSTF trials were flown and final turn modelling was carried out. All results indicated that even if R3 had used a high AOB earlier or taken landing gear and flap at different points during the turn, from XX204's position at the end of the downwind leg, it was extremely unlikely that XX204 could successfully fly a final turn and achieve the 'contract' and runway centreline. The timing of the ATC radio transmissions may have delayed R3's application of bank or resulted in the use of a higher AOB than intended. From the point at which 70° AOB was achieved the ROD increased to 4380 ft/min. The combination of ROD/FPA, AOB and associated g all culminated with the aircraft stalling coincident with the go-round initiation.

Accident flight profile summary

1.4.214. The Panel concluded that XX204's take-off was normal and although the initial turn was lower than on other units, was 'routine' for RAFAT. The point at which the PEFATO was initiated meant the height achieved at the start of the downwind leg was comparatively low. Whilst guidance was provided on aircraft speeds, in the Panel's opinion, and noting the need for careful handling following an EFATO, the guidance contained in the Aircrew Manual and the FTP3225H lacked clarity and was open to interpretation and was therefore considered an Other Factor.

1.4.215. Once parallel to the runway and through to the final turn, XX204's lateral displacement was less than that required to achieve alignment with the runway without the use of increased AOB. XX204 commenced the final turn from 1030 ft; the aircraft's height and lateral displacement at that point were considered a Contributory Factor. In the Panel's opinion, R3's lack of awareness of the amended guidance for the height from which to commence the final turn was also a Contributory Factor. During the final turn the Panel concluded that the coincidence of ATC radio calls with the landing gear locking down, the travel of flap and the increase in AOB had the potential to distract R3.

1.4.216. The status of an aircraft at any stage during a PEFATO or PFL was continually subject to the pilot's decision to continue with the manoeuvre or, when in doubt whether the manoeuvre could be completed, to go-around (or eject for real). Irrespective of XX204's flight parameters, R3 could at any stage, if in doubt whether the manoeuvre could be completed, have initiated a go-around. Therefore, and in the Panel's opinion, as R3 opted to continue with the exercise versus terminating and flying a go-around, his comprehension of the situation and his projected outcomes up until the point chosen to go-around would suggest that he was content with his ability to successfully achieve a safe go-around and he therefore continued up until that point.

Stall Critical Analysis

1.4.217. In considering the final stages of XX204's flight, and the conditions that resulted in the stall, it is essential to recognise that the time between the aircraft's speed reducing below 150 kts and impact with the ground was around 5.5 sec. Consequently, during the following analysis, whilst fine margins are discussed, many events occurred almost coincidently. Exhibit 17

1.4.218. XX204's ADR data and flight characteristics were analysed by ATEC Test Pilots and Flight Test Engineers; in doing so flight testing was conducted and profiles flown in the HSTF.

Stall speed calculation

1.4.219. The Panel examined the flight data and attempted to determine if the aircraft had stalled at any point prior to the go-around. To do this the g and speed data were used to mathematically calculate[113] the 'accelerated stall speed' during the final turn to determine the stall margin. The term 'accelerated stall' refers to a stall when the aircraft is at greater than 1g; therefore, an accelerated stall can, for example, be encountered in a turn when g is increased or during a wings-level pull. For an aircraft to stall in straight and level flight at 1 g the aircraft would had to have flown at the stall speed. XX204's calculated 1 g stall speed was 111.5 kts. However, flight testing on Hawk XX154, ATEC trials aircraft, demonstrated that the calculated results were typically optimistic, and the actual accelerated stall speed was slightly higher than the projection. On average, the accelerated stall speeds on XX154 with a baggage pod fitted[114] were 1.6 kts higher than the prediction, so the predicted accelerated stall speeds considered in the analysis were increased accordingly. Exhibit 17

1.4.220. Wings level stall speeds with the baggage pod fitted closely matched the Aircrew Manual prediction and provided confidence in the Aircrew Manual data. However, any inaccuracies in the measurement of airspeed or normal acceleration, or within the Aircrew Manual chart from which the 1 g stall was derived, could potentially alter the predicted stall speed by several knots; the ATEC report estimated +1 to -3 kts tolerance in the ADR airspeed data. Exhibit 17

[113] Calculation was achieved by taking the predicted 1g stall speed and multiplying by the square root of normal acceleration (g being applied).
[114] A baggage pod was fitted vice a RAFAT smoke pod.

1.4.221. **Stall margin.** The stall margin was the difference between the aircraft's speed and the stall speed and is a measure of the proximity to the stall at any given g. Possible inaccuracies in recorded airspeed and g were not accounted for in the analysis of the accident. Where this report describes a stall margin less than 3 kts, the aircraft could in fact have reached the stall boundary. Exhibit 17

1.4.222. The predicted stall margin at the initiation of the go-around was 1.9 kts. However, with the variable tolerance of ADR air speed data of +1 to -3 kts the stall margin could have been between 2.9 kts to -1.1 kts. Exhibit 17

1.4.223. Figure 1.4.16 shows the recorded airspeed and predicted stall speed of XX204, the difference being the stall margin, and shows the stall/wing drop as both converge. The go-around and the stall are within 0.3 sec of each other and effectively coincident. The time shown is 'ADR time' and is indicated on a 0.5 sec grid. Whilst the stall margin appears to be approximately 10 kts at time 290806, the flap is still travelling down at this point; until the flaps are fully down the predicted stall speeds are unreliable[115]. However, during the high AOB manoeuvre there appears to have been a reasonable stall margin.

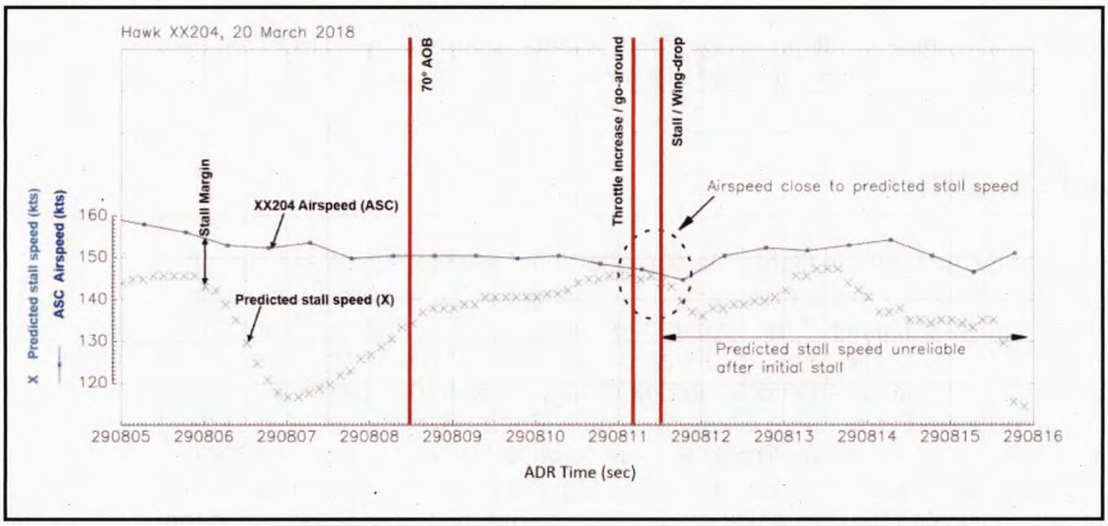


Figure 1.4.16 - Stall margin

Development of g prior to stall

1.4.224. **Speed at 150 kts.** During the 2.5 sec that the speed was at 150 kts the aircraft's pitch angle steepened from -9.8° to -12.7° (nose down) and g increased from 1.18 g to 1.57 g. The increase in normal acceleration resulted in an increase in the theoretical accelerated stall speed from 122.8 (1.18 g) to 141.4 kts (1.57 g). By the time airspeed started reducing below 150 kts the aircraft was approximately 9 kts above the predicted accelerated stall speed and approximately 0.2 g from the theoretical predicted stall g[116]. Exhibit 17

[115] The stall margin was calculated on the assumption that the flaps were down and did not take into account the flap travel time.
[116] Stall g at any specific speed is the square of that speed divided by the square of the unaccelerated stall speed. $150^2/111.5^2=1.8$ g.

1.4.225. **Speed reducing from 150 kts to go-around/throttle advance.** In the one second between the airspeed starting to reduce and the throttle movement, the pitch angle shallowed slightly from -12.7° to -12.4°, normal acceleration increased from 1.57 g to 1.67 g, and airspeed decreased to 147.6 kts. Aileron inputs indicated that up to approximately half left of the control column range of movement was applied at the start of the go-around; this input was applied just before the throttle advanced. Due to the increased g, the predicted stall speed increased further to 145.7 kts, reducing the predicted stall margin to 1.9 kts at the go-around. Exhibit 17

1.4.226. **Go-around/throttle advance to stall/wing drop.** In the fraction of a second (0.3 sec) between the initiation of the go-around and the first positive indication of the stall, airspeed continued to reduce. Modelling suggested this speed reduction was not necessarily consistent with the dynamics of the manoeuvre being flown, and although only happened one sec before the wing drop, may be associated with the aircraft entering the stalled condition. The minimum calculated margin between airspeed (146.7 kts) and the predicted stall speed (145.7 kts) was one knot. In terms of normal acceleration, the recorded value of 1.67 g gave only 0.02 g margin to the predicted stall[117]. Exhibit 137 Exhibit 17

1.4.227. **Stall.** At the point of stall/wing drop, which was 4 seconds from R3 initiating ejection, XX204 was descending through 325 ft at 146.2 kts. Normal acceleration reduced from 1.63 g to 1.46 g coincident with the lowest airspeed during the finals turn of 145 kts, nose down pitch increased, and the pitch angle began to steepen despite an increase in the aft application of the control column. Concurrently, aileron position increased from 7.5° to 14°, indicating the left roll command increasing to full left application of the control column, despite which the aircraft's roll rate reversed and the aircraft rolled right, with AOB increasing from 50° to 57° to the right. The uncommanded right roll was consistent with the characteristics of an accelerated stall. Following the stall, airspeed recovered back above 150 kts. Exhibit 17

1.4.228. **Buffet.** The ADR provided no data to indicate the presence of buffet or any other cue which might have indicated the approaching stall, and it was not apparent what warning, if any, R3 had of proximity to the stall boundary. It was also not clear whether the pilot was able to recognise any signs of the approaching stall; there were no indications of positive stall recovery actions being applied prior to the wing drop. Exhibit 17

1.4.229. **Unload.** The Panel noted that there was a slight 'unload', an easing forward of the control column (reduction in back pressure, resulting in a reduction in g), the timing of which was consistent with it being a reaction to the wing drop (stall). It was associated with a more significant reduction in roll control input and may merely have been a by-product of the pilot's bio-mechanics of the roll input. Alternatively, it may have been an instinctive reaction by R3, although he had no recollection of the stall or his associated actions. In any case, in the Panel's opinion, had it been an attempt to un-stall the aircraft the unload was probably insufficient in scale or duration to recover the aircraft. Exhibit 17

[117] This margin was within the reading error of the Hawk g meter. In the Panel's experience a pilot would not routinely be looking at the g meter during a glide approach.

1.4.230. Following the roll reversal, full left control column continued to be applied for 0.5 sec. The aircraft appeared to respond to the left roll command, and control column input reduced as right bank angle began to decrease. Peak left roll rate during this manoeuvre was 33°/sec. At the same time, an increased aft control column input was applied, the pitch attitude started to shallow from a maximum nose down/pitch angle of -13.6°, and normal acceleration increased again to 1.7 g. Exhibit 17

1.4.231. **Secondary stall.** As XX204 descended through 168 ft at 152.6 kts, it was rolling left through 33° right AOB, and the nose was starting to rise towards the horizon, passing through -10° nose down pitch angle (flight path angle remained significantly steeper, estimated to be -16.4°). Normal acceleration, which had peaked at 1.7 g, rapidly reduced to 1.48 g despite an increasing application of aft stick. This appeared to be a secondary stall, 2.1 sec after the initial stall. Exhibit 17

1.4.232. Within 0.5 sec of the second stall a left aileron input was applied from neutral to 7.8°. However, the roll reversed and roll angle increased from 16° to 23° right wing down. This second instance of uncommanded right roll occurred at a height of 134 ft. Simultaneously there was a large increase in tailplane deflection up to a peak of -13.9°, which would have been consistent with R3 applying almost full aft control column. Exhibit 17

1.4.233. Within one second of the additional roll reversal the application of left aileron rapidly reduced from 7.4° to 1.2°, and the tailplane from -13.1° to 0.2°, indicating a control column movement close to the neutral position. In the Panel's opinion, the decision to actively push the control column towards neutral or release it, indicated that R3 was no longer attempting to pitch the aircraft up and recover the aircraft from its descending flightpath, and was probably reaching for the ejection handle[118]. This action occurred 0.85 sec before impact at a height of 62 ft[119]. Exhibit 17

1.4.234. Although there was no clear evidence that R3 initiated a stall recovery[120], the aircraft showed some indications of returning to an unstalled condition after each of the two stall events. These included increasing airspeed, an apparent improved response to lateral control inputs, and the g reduction. However, it was possible that the aircraft remained in a stalled state from the point of the first stall through to impact with the ground, and that variations in pitch and roll were a combination of post-stall response to control inputs, and undemanded pitch, roll and yaw oscillations which were possibly stall symptoms. Exhibit 17

1.4.235. Approximately one second after the secondary stall, the margin between the airspeed and the predicted stall speed increased to over 15 kts, which appeared to indicate that the aircraft had recovered to a condition well clear of the stall. However, with the increasing aft control column input between the second stall and impact, it was likely at that point the aircraft had exceeded its stall angle of attack and was in a post stall condition. This also had the effect of making theoretical stall speed calculations unreliable, since the underlying assumptions no longer held true beyond the stall. It was possible that a similar post stall situation existed between the initial stall and the secondary stall, but there was less aft stick at that time, and less evidence that the Exhibit 17

---

[118] The Panel did consider that it was possible that the stick being moved forward was an attempt to execute a stall recovery but given the lack of height and the imminent ejection, this was discounted.
[119] This represents the decision to eject rather than the initiation of ejection sequence itself.
[120] R3 had no recollection of the aircraft stalling.

aircraft remained stalled.

1.4.236. The Panel determined that the application of g reduced the stall margin leading to XX204's accelerated stall. The Panel could not establish whether R3 was applying g to arrest the ROD or to assist with the turn to align with the runway but considered that it was probably a combination of both. The Panel concluded that the application of g in the 3 sec prior to the initiation of the go-around was a **Causal Factor**.

Stall flight testing

1.4.237. The Aircrew Manual did not describe or attempt to characterise landing configuration accelerated stalls. Due to the lack of available information on the flight characteristics in this regime, three flight tests were completed on Hawk T Mk1, XX154. The first flight was flown with a clean aircraft, and the subsequent two flights were flown with a baggage pod fitted to the centreline of the aircraft. The baggage pod was considered to be sufficiently representative of the smoke pod fitted to XX204 in terms of weight, CofG and aerodynamics[121]. Testing, with landing gear and full flap down, consisted of: Exhibit 17

a. Wings level unaccelerated stalls (1 g).

b. Accelerated stalls (stalls at greater than 1 g) at constant g and decreasing airspeed.

c. Accelerated stalls at constant airspeed and increasing g.

1.4.238. **Testing results for accelerated stalls at constant g, reducing speed.**

a. **Approach to the stall (stall warning).** A constant light to moderate configuration buffet[122] felt through the seat was noted in the front cockpit in both tested configurations. Buffet intensity remained nearly constant as the aircraft decelerated and there was no consistent or perceptible step increase in buffet until approximately 2-4 kts prior to the stall, at which point there was a step increase in buffet through the front cockpit seat and flight controls. Longitudinal and lateral controls remained effective throughout the deceleration. The light to moderate configuration buffet masked the onset of pre-stall buffet and reduced pilot warning of the impending stall. This was consistent with the Aircrew Manual advice on stalling in the final turn which stated that in the landing pattern with flap MID or FULL there is limited natural warning of the onset of the stall. Exhibit 17 Exhibit 57

b. **Stall characteristics.** In the clean configuration the stall was characterised primarily by a consistent clearly defined wing drop of up to 30° in less than one sec sometimes associated with a less distinct g-break[123]. With the baggage pod fitted, the stall was less clearly defined, with a less distinct and less aggressive wing drop and g-break. On several stalls with the pod fitted, the most obvious cue to the pilot that the stall had occurred was a step increase in buffet combined with a sudden decrease in speed of several knots. During one

[121] The overall weight of the trials aircraft was lighter than XX204 and for safety reasons the stall testing was accomplished at altitudes above 7000 ft AGL.
[122] Configuration buffet results from airflow disturbance due to undercarriage and flap being down.
[123] Uncommanded reduction in normal acceleration.

test with the baggage pod fitted, the handling pilot reached full aft control column before identifying the stall. This is consistent with the Aircrew Manual clean configuration accelerated stall characteristics. Exhibit 17 Exhibit 57

c. **Stall recovery.** Stall recovery was immediately effective when the normal acceleration was reduced toward 1 g. As long as the normal acceleration was reduced to break the stall, the lateral control response permitted the rapid selection of a wings level roll attitude and appropriate pitch attitude. Where the normal acceleration was accidentally maintained following the first indication of stall, any wing drop tended to increase in rate and magnitude thereby significantly delaying recovery. Exhibit 17

1.4.239. **Testing results for accelerated stalls at constant speed, increasing g.**

a. **Approach to the stall (stall warning).** A constant configuration buffet was noted in the front cockpit in both profiles. The buffet intensity remained nearly constant as the aircraft increased normal acceleration, but there was no consistent or perceptible step increase in buffet during the increase in normal acceleration that provided indication of an impending stall. Across the range of speeds tested, the front cockpit pilot reported little to no warning of the impending stall. The maximum buffet margin observed in the cockpit in terms of g was 0.1 g, but frequently the stall occurred coincident with the onset of buffet thereby providing no warning to the crew. While this is not inconsistent with the Aircrew Manual that there was limited natural warning of the stall, the aircraft provided noticeably less warning when the stall was approached with increasing g rather than decreasing speed. Exhibit 17 Exhibit 57

b. **Stall characteristics.** In the clean aircraft, the stall was characterised primarily by a clearly defined wing drop of up to 30 degrees with a less distinct g-break. With the pod fitted, the stall was even less clearly defined, with a less distinct wing drop and g-break. On some stalls with the pod fitted, the most obvious cue to the pilot that the stall had occurred was that there was a sudden wash off in speed of several knots, and this was not always immediately apparent to the pilot. In the Panel's opinion the reduction in XX204's speed within 1 sec of the identified stall point may have been associated with the aircraft entering the stalled condition. The absence of stall warning or buffet exacerbated this characteristic and made it even more difficult to identify the stall. Exhibit 17

c. **Stall recovery.** Stall recovery actions were the same as for stalls conducted at constant g and decreasing speed. Exhibit 17

Stall critical analysis conclusion

1.4.240. In consultation with the Flight Test specialists, the Panel concluded that a pilot conducting a PFL recovery at low altitude and particularly when close to the minimum speed without an indication of stall margin, would have inadequate warning of an approaching stall and could stall the aircraft with insufficient height to recover.

1.4.241. XX204 was flown at the minimum recommended speed, very close to maximum AUW, with landing gear and full flap, and due to the geometry of the manoeuvre the pilot required a high AOB and increased g to achieve runway alignment. These events, combined with a high ROD, resulted in a stall which was confirmed by the distinct wing drop.

1.4.242. Flight testing suggested that with a smoke pod fitted the cue that a stall had occurred was through a sudden wash-off of speed. XX204's speed reduced below 150 kts 0.9 sec before the go-around/throttle advance and whilst there was no evidence to suggest the aircraft had stalled it was assessed the speed reduction may have been associated with the aircraft entering the stalled condition. Consequently, the Panel concluded that XX204 was at the point of stall when R3 initiated the go-around.

1.4.243. In the Panel's opinion, it is very likely that R3 was unaware that he was approaching the stall. It is possible that due to the indistinct stall characteristics with the pod fitted that he had no sensory indication of the stall until the wing dropped and therefore never consciously attempted to execute a stall recovery.

1.4.244. The Panel concluded that the stall, coincident with the initiation of the go-around, with insufficient height to recover was the **Cause** of the accident.

Stall warning and stall characteristics

1.4.245. The Hawk T Mk1 stall characteristics are variable with speed but may take the form of a wing drop, a pitching oscillation, or by the control column reaching the fully aft position. During the final turn or on final approach, particularly with MID or FULL flap selected, there is limited natural warning of the onset of stall; at the first onset of buffet the Standard Stall Recovery (SSR)[124] is to be carried out. The Aircrew Manual provided the following warning: "*Continuing beyond the initial onset of buffet may rapidly result in a stall, the consequences of which will result in significant and possibly irrecoverable height loss.*" To ensure pilots were familiar with Hawk T Mk 1 stall characteristics in the final turn this exercise was practised regularly (see Table 1.4.1) and when taught the exercise conclusions were: buffet is the only reliable symptom of a stall (speed and attitude symptoms are masked), if buffet is experienced on finals carry out SSR immediately and failure to do so would generate a significant ROD denying sufficient height for a stall recovery.

Exhibit 57

Exhibit 138

1.4.246. While the ADR did not provide data on the presence of buffet or other stall warning, flight test results indicated that although speed was less than 150 kts, it was unlikely that R3 had any indications that he was approaching a stall. Exhibit 17

Stall recognition and recovery

1.4.247. From the ADR data, it was possible to observe symptoms of the stall that could have been observed in the cockpit. The most noticeable indication was the aircraft's failure to respond to lateral control inputs (roll commands) and/or the presence of uncommanded roll. Given the aircraft's dynamic situation approaching the point of stall,

[124] SSR from the FTP3225H: Unload to eliminate buffet, Select Full Power, Wings level – use aileron, Climb – as engine power 'bites' select climbing attitude, raise landing gear and flap when positive rate of climb. Aircrew Manual only stated: Recovery at any stage is immediate upon moving the control column forward.

symptoms, other than the distinct wing drop, may not have been clear to the pilot at the time. The indications of stall may have been less distinct due to the configuration of the aircraft per para 1.4.250. Exhibit 17

1.4.248. R3 recalled that having initiated the go-around, the aircraft felt unresponsive, which would be indicative of the stall symptoms. However, in the Panel's opinion, and noting that R3 had limited recall of the accident, and the extremely short time between go-around and ejection, such recollections may have been reflective in the period after the accident. Witness 1B Witness 1A

Artificial stall warning

1.4.249. The risks associated with stalling during the final turn were clearly articulated in the Aircrew Manual and FTP3225H. However, the Hawk T Mk1 did not benefit from artificial stall warning, such as a stick (control column) shaker or a high Angle of Attack alarm. Design features, such as wing leading edge Breakaway Strips did, however, give marginally earlier pre-stall buffet through the tailplane; even so it states the margins from feeling the onset of buffet to the stall could be very small. The first and sometimes only indication to a pilot of an impending stall was the onset of buffet and pilots were reminded that if they experienced buffet on finals they were to carry out a SSR. Exhibit 138

1.4.250. This natural warning could be further complicated by the presence of configuration buffet[125]. During training a pilot is taught to recognise the difference between configuration and pre-stall buffet, which is reinforced with periodic training requirements to practice stalling in the approach configuration. Exhibit 91

1.4.251. Flight test analysis demonstrated that in a low speed/low energy configuration the stall margins were minimal. Furthermore, with a smoke pod fitted the indications of the stall were less clearly defined than in a 'clean' aircraft and may not have been recognisable to the pilot. Exhibit 17

1.4.252. In the Panel's opinion the provision of a stall warner may have allowed R3 to take corrective action prior to the onset of the stall. Consequently, and noting the recognition of the risk of stall during a final turn, the Panel concluded that the lack of stall warning was a **Contributory Factor**.

Recommendation

1.4.253. AOC 22 Group should investigate the incorporation of an artificial stall warning capability in the Hawk T Mk1 to provide sufficient warning to pilots during low speed low altitude manoeuvring.

XX204 - last possible stall recovery height

1.4.254. R3 initiated the go-around at 345 ft AGL, modelling demonstrated that at that height, it was not possible for XX204 to recover from the stall. As a result, the Panel sought to establish the last possible height, with XX204's flight parameters, from which a Exhibit 17

[125] Vibrations felt through the airframe caused by extended landing gear and flap.

stall recovery was possible.

1.4.255. Analysis indicated that due to the relatively low applied g it was very likely that if a SSR was flown and the aircraft was unloaded to clear the stall/buffet[126] a pilot would naturally/instinctively unload to approximately 1 g. Thereafter the pilot would roll at 1 g to a wings level attitude followed immediately by a reapplication of g, flying a careful recovery, remaining clear of the stall boundary. Utilising that technique, whilst accepting minimal ground clearance (0 ft and not allowing for obstacles), it was assessed that the absolute final point at which XX204 was recoverable was at a height of 394 ft, just over 0.5 sec earlier than when the go-around was initiated. Exhibit 17 Exhibit 17

1.4.256. The Panel recognised that such a profile would have been challenging to fly given the proximity to the ground, the aircraft's attitude and ROD. A pilot would have had to recognise the imminent stall and respond before it happened, irrespective of a high likelihood that there was little or no warning. Without any stall warning, the Panel considered it extremely unlikely that a pilot would instinctively choose to unload the aircraft to recover from such a nose low attitude with high AOB and subsequently have the awareness and control to be able to maintain clear of the stall. When mental processing timing required to recognise and react to stall symptoms is considered, this minimum height would increase further.

Rate of Descent, Flight Path Angle, and Angle of Bank

1.4.257. In considering ROD the Panel acknowledged that ROD and FPA were intrinsically linked. At the go-around XX204 had a -18° FPA and a ROD that was significantly steeper than that routinely expected for a glide descent with the gear and flap down. Indicatively a wings level gear down/full flap glide descent should have resulted in a nominal ROD of approximately 3250 ft/min (54 ft/sec) and a FPA of -12.3°. A sustained 1.5 g turn with approximately 50-60° degrees AOB resulted in a ROD of about 4200 ft/min; XX204's ROD at the initiation of the go around was estimated to be 4610 ft/min. Exhibit 17

1.4.258. In the Panel's opinion, the excessive ROD/FPA, was likely the result of the high AOB used during the final turn combined with the increase in nose down pitch angle to maintain speed and was exacerbated by the stall. Consequently, the time available to recover from the stall was reduced whilst the height required was increased. Exhibit 17

1.4.259. After reaching 70° AOB, XX204's AOB slowly reduced and was approximately 54° right wing low at the go-around. It was not possible to determine why the AOB remained high, but in the Panel's opinion, it may have been conducive with R3 attempting to align with the runway as, at this point, XX204 had crossed through the extended centreline. Exhibit 17

1.4.260. Following the peak of 70° AOB, g continued to increase until the point of stall, as shown at Table 1.4.9. The application of g was required to reduce the ROD and maintain AOB; as discussed at 1.4.236, the Panel could not positively identify whether R3 was pulling g to arrest XX204's ROD or to assist with the turn to align with the runway and concluded that it was very likely a combination of both. As XX204's flight profile required the application of g to address both ROD and AOB, the Panel concluded

[126] The Aircrew Manual states that a stall should clear immediately upon moving the control column forward.

that the high AOB and excessive ROD were **Contributory Factors**.

Pre-contract Angle of Bank

1.4.261. To prevent excessive ROD, the Aircrew Manual imposed an airspeed limitation, with flap down, of 170 kts, to *'prevent dangerously steep and steepening approaches.'* The Panel could find no evidence of guidance to prevent the same excessive ROD being generated from a sustained high AOB, where applied g served to increase drag to invalidate the effect of the 170 kts limit. Exhibit 105

1.4.262. FTP3225H stated that *'45°AOB is a realistic maximum for all glide configurations'*, this was derived from an instructional handling exercise, with landing gear down only (no flap) rather than an aircraft limitation. There was no specific AOB limitation with landing gear and flap selected down. The guidance did not explicitly state that the AOB limitation was for minimum glide speed, but the Panel have assumed that to be the case, because for 800/1200 ft PFLs there was direction to use 60°. The increased AOB for those manoeuvres was permissible due to the higher speeds at which they were flown. As a consequence the Panel considered that the 45° AOB guidance required slight amplification to avoid possible misinterpretation. Exhibit 50 Exhibit 50

1.4.263. The FTP3225H also stated that for AOB above 45° *'speed must be increased if a harder turn is required'*. In the Panel's opinion, the 'harder turn' would not be a simple application of bank but also an increase in g, therefore without an increase in speed the stall margin would decrease. However, there was no guidance as to the relationship between speed and AOB. Mathematical analysis calculated that to increase AOB beyond 45°, speed had to be increased by 2 kts for every degree of bank (an increase of 5° AOB would require an increase of 10 kts) to maintain the stall margin present before AOB was increased. Nevertheless, no AOB limit could mitigate for a pilot making harsh control inputs resulting in a stall. Exhibit 50 Exhibit 139

1.4.264. As XX204's AOB increased above 45° speed reduced. However, as AOB passed above 50°, there was a positive pitch nose down and reduction in g before 70° AOB was achieved. As shown in Table 1.4.9 the rate of heading change did not increase until after the aircraft had pitched nose down and g was reapplied. Therefore, although AOB had increased above 45° there was no indication of a harder turn until after the g increased. However, with no increase in speed the stall margin decreased. As the speed stabilised at 150 kts AOB was reducing.

Elapsed time (sec)	Event	Radio Transmissions	AOB	Speed (kts)	Pitch (deg)	g	Rate of heading change (deg/ sec)
0	Flap selected		46	172	5	1.32	6
1			44	170	5	1.38	5
2	AOB > 45°		**45**	169	5	1.48	6
2.5			**46**	166	5	1.52	6
3		ATC: R3 check gear	**47**	167	6	1.59	6
3.5			**47**	167	6	1.63	6
4		R3: Gear down R3	**48**	165	5	1.59	5
4.5			**50**	163	4	1.56	5
5			**51**	161	5	1.57	7
5.5			**50**	159	6	1.63	8
6			**50**	157	6	1.67	8
6.5			**50**	154	5	1.61	6
7	Pitch nose down		**53**	153	**-1**	**1.32**	1
7.5	Flap down	R3: Clear low approach R3	**58**	153	**-6**	**1.07**	4
8	Turn rate increased		**64**	152	**-9**	**1.12**	**10**
8.5		Transmission complete	**68**	150	**-10**	**1.26**	**13**
9	Peak AOB		**70**	150	**-11**	1.42	**14**
9.5			**67**	150	**-11**	1.50	**16**
10			**63**	150	**-11**	1.55	**16**
10.5			**59**	150	**-12**	1.55	**14**
11			**56**	149	**-13**	1.63	**14**
11.5			**54**	148	**-12**	1.67	**13**
12	Go-around/ Stall		**51**	146	**-12**	1.63	9

Table 1.4.9 - XX204's flight parameters in relation to AOB, speed and rate of heading change

1.4.265. The Panel concluded that the lack of guidance for increasing AOB above 45° and the associated relationship with the required increase in speed could lead to mishandling and a safety related occurrence and was therefore considered an **Other Factor**.

Recommendation

1.4.266. AOC 22 Group should commission testing to provide guidance on the relationship between speed and AOB in all glide configurations in order to minimise the risk of stall during low speed manoeuvring.

Assessment of impact of increased AOB at contract height

1.4.267. Other than the 45° AOB mentioned above, the Panel found no guidance relating to AOB limitations prior to the 'contract'. XX204's high ROD was a direct result of maintaining the high AOB in the gear down/flap down configuration for several seconds, in conjunction with relaxing back pressure on the control column reducing the g to approximately 1 g. Arresting high ROD would normally require maintaining back pressure on the control column, keeping positive g on the aircraft, whilst rolling to reduce AOB, with the g applied being such that it would not induce a stall; this is similar to the technique flown for a go-around.

1.4.268. An analytical assessment was conducted regarding the validity of the 300 ft contract when recovery was initiated outside of normal contract parameters, ie greater than 45° AOB. In doing so it was assumed that a go-around would be commenced at 300 ft, speed would be 150 kts, and AOB and g were applied at varying levels. The resulting data was not validated in-flight but checked against other dive recovery planning tools and evaluated in the HSTF at RAF Valley. Exhibit 17

1.4.269. Modelling considered FPAs of -12.3° (throttle at idle with landing gear/flap down) and -16° (a more extreme profile), the findings of which are shown in Table 1.4.10, and Table 1.4.11. Calculations that resulted in ground impact are highlighted in red and those that resulted in a recovery below 100 ft are highlighted in yellow. A -12.3° FPA would be indicative of that experienced on a normal PFL profile. Exhibit 17

g-during roll	1.5	1.3	1
AOB at initiation	Recovery Height (ft AGL) from 300 ft and FPA of -12.3 deg		
50	190	160	100
60	170	130	60
70	140	90	10
80	100	40	-60

Table 1.4.10 - Predicted recovery heights from 300 ft with a -12.3° FPA at initiation

1.4.270. The same recovery analysis was completed with an approach simulating the rate of descent established during a prolonged 150 kts, 1.5 g loaded turn at 60° AOB (similar to XX204's manoeuvre). By starting from a nominal ROD in the accident configuration (-12.3° FPA) and holding 60° AOB and 1.5 g, a -16° FPA is achieved after approximately 3-4 seconds (approximately 40° of turn at 10°/sec turn rate). It should be noted that XX204's estimated FPA was -18° at the go-around. Exhibit 17

1.4.271. The time and altitude required to recover from a dive was significantly increased by the AOB at the point of initiation of recovery; the time taken to decrease AOB resulted in a further depressed FPA, more so at lower rolling g, and a delay in the reduction of the ROD. As shown in Table 1.4.10, recovery heights are minimized by conducting a loaded roll of 1.3 g or 1.5 g during recovery[127].

1.4.272. However, the maintenance of 60° AOB and 1.5 g for more than approximately 3.5 sec increased the FPA to -16° or more[128]. The same manoeuvre at 55° AOB took 7 secs (and approximately 70° of turn) to reach a -16° FPA. Neither of these scenarios would have resulted in an unrecoverable situation developing unless excessive bank angles were present at initiation of the go-around. Predicted recovery heights from -16°

[127] It was observed during simulator analysis that without pre-briefing the type of recovery actions, most pilots recovered by rolling without unloading which improved minimum recovery heights. Analysis showed a significant occurrence of stall during the roll phase.
[128] When starting from a nominal wings level with landing gear and full flap down rate of descent.

FPA are shown in Table 1.4.11.

g-during roll	1.5	1.3	1
AOB at initiation	Recovery Height (ft AGL) from 300 ft and FPA of -16 deg		
50	120	80	10
60	90	50	-40
70	60	0	-110
80	10	-60	-180

Table 1.4.11 - Predicted recovery heights from 300 ft with a -16° FPA

1.4.273. Recovery heights from -18° FPA, estimated to have been the case for XX204, were calculated in a similar manner and the results are shown in Table 1.4.12. In general terms, the additional 2° FPA increased the height required by 50 - 80 ft. The recovery heights achievable increased with the rolling g used but the risk of stall also increased, as holding an exact g is difficult and the 'ground rush' associated with the minimal recovery margins would tend to encourage a harder pull. Note that maintaining any g, down almost to 1 g, during the roll would have made the recovery theoretically achievable, albeit with reducing height margins.

g-during roll	1.5	1.3	1
AOB at initiation	Recovery Height (ft AGL) from 300 ft and FPA of -18 deg		
45	90	50	-15
50	80	40	-40
55	70	20	-70
60	50	0	-100
70	10	-50	-170
80	-50	-120	-260

Table 1.4.12 - Predicted recovery heights from 300 ft with a -18° FPA

1.4.274. The Panel determined that during pre-contract manoeuvring, with landing gear and flap down, a maximum of 60° AOB during PFL approaches kept the height loss during recovery manageable and provided pilots with flexibility to manoeuvre. However, it should be noted that the analysis carried out meant this advice would only be valid subject to any manoeuvres to 60° AOB started from 'normal' FPAs (circa -12.3°), only be held for short periods (circa 3 sec) and should not be present at the go-around. Any breaches of this advice would likely result in very extreme FPAs and RODs building up rapidly.

Consideration of go-around technique

1.4.275. The Aircrew Manual and FTP3225H contained clear warnings regarding the risk of stalling on final approach. However, analysis has shown that an aircraft may have no warning of a stall and therefore at low height and manoeuvring for an approach, the time in which to conduct a stall recovery is extremely limited.

1.4.276. The published go-around technique was: '*Select full power and hold a steady attitude until the power bites, before setting the normal 8° nose up climb attitude*'. In the Panel's opinion, although this published technique made no mention of a requirement to roll wings level, the guidance was built on a pilot's previous training where the go-around techniques are flown and assessed and therefore, assumed that wings were level prior to the initiation of the go-around. As described in para 1.4.157, in practice, if not flown from a wings-level attitude with low ROD, a go-around was 'normally' flown using a blended roll to wings-level and pitch to arrest the descent and achieve a climb away from the ground, as full power was simultaneously applied. Notwithstanding XX204's ROD, this was the technique used by R3.

Exhibit 50
Exhibit 140
Exhibit 19

1.4.277. As has been articulated, the stall margin at low speed whilst applying g can be small and as demonstrated by XX204, manoeuvring (initiation of a go-around) could result in a stall. With limited, if any, warning of a stall the Panel considered that the risk of stalling could be reduced during the roll phase of the go-around by the adoption of a modified go-around technique. As opposed to a full unload to 1 g, which might actually endanger the aircraft, a procedural 'check' forward of the control column as the first action of the go-around would increase the clearance from the stall boundary and provide an additional margin of safety during the roll phase, where any stall, and wing drop in particular, has a severe impact on the height taken to recover. It would also allow an amount of g to be retained during the roll. The Panel recognised that it could be confusing to have 2 go-around techniques and considered that a technique such as outlined above would only be applicable with high AOB and associated g. In the Panel's opinion, the utilisation of the standard go-around technique could, with a fine stall margin, result in an aircraft stalling and therefore concluded it an **Other Factor**.

Comparison of PFL go-around with other high risk, low height activities

1.4.278. Time Safety Margin[129] modelling was used by the test community to ensure adequate safety margins were applied to potentially hazardous manoeuvres. The flight parameters at the point where a recovery was started were used to determine the height taken for recovery, to which a safety height could be applied. The time safety margin required was then applied to add a buffer to cater for pilot reaction time, distraction, delays, slight exceedances of speed/FPA etc at the recovery point; hence a steeper FPA would not only require more height for the recovery itself but would also require additional height for each second of time safety margin added. The ATEC analysis showed that in the relatively extreme case of a -16° FPA, with no safety height on the recovery, the maximum delay available before the aircraft became irrecoverable beyond the 300 ft contract point was:

a. 0° AOB 1.5 sec.

b. 60° AOB (1.3 g roll) 0.5 sec.

c. 70° AOB (1.3 g roll) 0 sec.

[129] TSM was a technique developed and adopted by the USAF test centre which allows a common metric to be used for assessing the level of risk associated with dive recoveries.

1.4.279. **Other Hawk T Mk1 profiles.** Due to being in close proximity to the ground, with relatively high nose down attitudes, normal recovery planning assumptions for Hawk operational dive bombing also utilised Recovery Time Safety Margins. Dive bombing recoveries were subject to strict guidelines on maximum dive angles, maximum speeds, and specific recovery procedures including the amount of g to use, yet there was significantly more recovery time margin available when compared to the time available for a PFL outside of 'routine' parameters. Furthermore, they generally involved flight regimes where stall margin was greater and stall warning was clearer. The Panel found no evidence of similar analysis having been done to support the current PFL manoeuvring guidance or the 'contract' to ensure appropriate safety margins for a go-around and/or landing. Exhibit 141 Exhibit 48

Conclusion – go-around

1.4.280. In the Panel's opinion, for an aircraft arriving at the contract point within the defined AOB and speed parameters[130], the contract was likely to permit a safe go-around as long as FPA was not excessive. However, no analysis was completed to confirm it was sufficient to allow a safe landing, noting that the 30° 'contract' heading limitation could require significant turns to be completed, particularly where an aircraft had flown through the runway centreline. Furthermore, significant excursions outside of these parameters either during immediate pre-contract manoeuvring or at the contract point could result in an irrecoverable flight profile through a combination of high AOB and high ROD/FPA.

1.4.281. As considered in para 1.4.156, the contract was only applicable for an aircraft conducting a touch-and-go and therefore, whilst any PFL should have the contract parameters as a target, they did not have to be met for a go-around. In the Panel's opinion, manoeuvring limitations should be established to ensure that a go-around is achievable down to the contract point irrespective of touch-and-go/go-around intention.

1.4.282. Urgent safety advice was published during the SI by the Panel regarding the use of high AOB when manoeuvring prior to the contract. However, the Panel concluded that, as a minimum, guidance clearly stating a maximum AOB with landing gear down and flap down or travelling should be promulgated and due consideration should be made on how to ensure the requirement for no more than 45° AOB at 300 ft is honoured.

1.4.283. As high AOB and excessive ROD were Contributory Factors in the accident the Panel concluded that amplified guidance was required to mitigate the level of risk associated with manoeuvring at low speed during the final stages of PFLs.

Recommendations

1.4.284. AOC 22 Group, should revise manoeuvring limitations during the final stages of a PFL to ensure that excessive ROD and high AOB are avoided, and that an adequate safety margin for go-arounds is provided, potentially including an alternate go-round technique.

[130] 45° AOB and speed 150-170 kts.

1.4.285. AOC 22 Group, should clarify the requirement to meet the PFL contract irrespective of an aircraft's intention to touch-and-go/go-around.

Human Factors

1.4.286. R3 was an experienced and above average QFI who had flown PEFATOs on multiple occasions, albeit not in the period immediately prior to the accident. In the Panel's opinion, he was suitably qualified and experienced to fly the manoeuvre and was familiar with the associated parameters. However, and irrespective of his ability and the absence of any evidence suggesting technical failure, the Panel placed significant emphasis on HF analysis to understand what led to the accident. HF specialist input proposed several factors that could have affected R3's actions, although none of which could singularly explain what occurred. Exhibit 56

Work routine

1.4.287. **Secondary Duties.** Dedicated secondary duties were allocated to RAFAT pilots to enable the routine running of the Team, and during the winter to prepare for the Display Season when the pilots were detached from RAF Scampton without the assistance of operations staff. The collective input of all Team members ensured that tasks were carried out efficiently, especially when they were 'on the road'. In addition to secondary duties all RAFAT pilots supported corporate and Public Relations visits. Witness 11B Witness 10B Witness 10A Witness 8

1.4.288. R3 had 5 secondary duties: Duty Pilot, Officer in Charge (OIC) of rations, OIC Hawk Advanced Mission Planning Aid (HAMPA), OIC GPS, and Instrument Rating Examiner. Of these roles R3 stated that the Duty Pilot and OIC Rations were time consuming, especially at the beginning and end of the working period; he described his typical day as 'non-stop'. Exhibit 142 Exhibit 143 Exhibit 144 Exhibit 143

1.4.289. **Duty Pilot.** The official Duty Pilot Terms of Reference (TORs) detailed 3 main tasks: Exhibit 144

a. Ensuring that the authorization sheets were completed iaw the DD.

b. Ensuring that the Team Leader was provided with all relevant meteorological, aircraft and diversion details 5 min before briefs (known as the chit).

c. Ensuring that the main briefing room was kept tidy and that IT equipment was serviceable.

1.4.290. R3 described his role as Duty Pilot as being responsible to the Duty Senior Supervisor for ensuring safe flying at RAF Scampton; diversion booking, and calculation of minimum fuel; monitoring the prevailing and forecast weather conditions; ensuring that the authorization sheets were completed correctly; ensuring that the Team Leader was provided with the 'chit'; ringing a bell one min before significant events such as briefs or debriefs to notify other team members that the event was due to start. He also ensured that the main briefing room was kept tidy and that IT equipment was serviceable. In addition, he was to ensure that available aircraft were appropriately allocated on the flying programme, monitor aircrew currencies, and check authorization sheets monthly. Exhibit 143

1.4.291. **OIC Rations.** As OIC Rations R3 was responsible for: ensuring the tea bar was stocked with food and drink; the coordination of on-the-road food arrangements; ensuring that weekly rations returns were dispatched; keeping the kitchen area clean and tidy and ensuring all appliances were in working order, arranging maintenance when required; and ensuring that all appliances and equipment complied with current Health and Safety at Work legislation. Additionally, he collected aircrew packed lunches on a daily basis. Exhibit 143

1.4.292. **Tempo.** R3 felt he lacked the opportunity to apply as much thought as he would have liked pre-and post-sorties to consider what he had done or was going to do next; the only time he sat down was in a brief, debrief or in an aircraft. He remarked that [redacted] and was continuously setting his watch for the next time critical event. He routinely arrived at work around 0730 hrs and departed at about 1730 hrs; the majority of pilots started work at 0800 hrs and finished around 1630 hrs. He perceived that secondary duties were [redacted] Witness 1C Witness 10B Exhibit 44

1.4.293. Due to a perception that previous first year pilots had managed to complete the secondary duties he had not raised any concerns to the Team Leader. Furthermore, he wished to improve on the standard and add value to the development of the Team; he was described as going above and beyond in executing his duties. He acknowledged that [redacted] Throughout his career he demonstrated high levels of professionalism, was highly conscientious and diligent, and even during Initial Officer Training [redacted]. Witness 1C Witness 19 Witness 1C Exhibit 145

1.4.294. RAFAT was busy and all personnel worked hard; there was acknowledgement that flying was intense but that secondary duties should be achievable within the working day. Across the span of secondary duties, R3's duties were traditionally allocated to new joiners. They were described as not difficult but time consuming, allowing little time for relaxation and consolidation. A previous new pilot had felt frustration at being the last to leave at the end of the day but considered it as part of being a Red Arrow. Witness 10B Witness 19

1.4.295. The other 2017 new pilot stated that he was working hard, but felt his workload was manageable, although his secondary duties were different from those of R3. It was observed that R3 was [redacted] busy and putting in a lot of time and effort to his secondary duties. Witness 8

1.4.296. **Flying.** Both new pilots were performing well in the air and probably in advance of their predecessors. RAFAT de-briefs relied on pilots being self-critical and able to identify their own errors. However, R3 was described as [redacted] R3 also expressed a view that he was [redacted] Witness 11B Witness 9A Witness 1A Witness 11B Witness 9A Witness 1A

1.4.297. The Panel recognised that the combination of flying and secondary duties resulted in a busy yet focused working environment. By nature, R3 was [redacted] Consequently, the Panel concluded that [redacted]

1.4.298. Specialist HF advice counselled that a high level of workload reduced the readiness[131] of personnel by acting as a stressor and so reduced the ability to gather information, influencing decision making, and reducing capacity for undertaking other tasks. Over an extended period, high workload can increase fatigue. In the Panel's opinion R3's working routine was [redacted] not allowing him sufficient time for rest or consolidation [redacted] Therefore, the Panel concluded R3's working routine was a **Contributory Factor**.

Exhibit 44

Fatigue

1.4.299. R3 found the tempo of the working routine [redacted] He normally endeavoured to be in bed by circa 2130 hrs, with the aim of trying to be asleep around 2200 hrs; he slept [redacted] with earplugs in. At least one other pilot also reported sleeping [redacted] and another would go to bed at 2130 hrs. Whilst R3 [redacted]. Usually he would set an alarm for 0600 hrs with the aim of leaving for work at about 0730 hrs; he had a 5 to 10 min commute.

Witness 1A
Witness 9A
Witness 8
Witness 1A
Witness 1A

1.4.300. On Monday 19 Mar 18 he woke up around 0600 hrs and that night didn't turn his light off until about 2230 hrs. On the morning of the accident he was awake at 0500 hrs and started reading and checking the weather for the day. He left home between 0715 hrs and 0720 hrs.

Witness 1A

1.4.301. The Sqn Chain of Command (CoC) maintained oversight of personnel fatigue and held the view that as the aircrew worked closely together they could have identified if anyone had appeared to be stressed or tired; crew rest regulations were adhered to. The only time that a senior pilot had seen R3 fatigued was 2 weeks before the accident when R3 [redacted]. On that occasion R3 had removed himself from flying.

Witness 7
Witness 10B
Witness 11B
Witness 8
Witness 7
Witness 10B
Witness 11B

1.4.302. RAFAT flying was described, especially for new pilots, as having an element of fatigue stemming from being in close formation with other aircraft for up to 30 min at a time and needing to use high levels of concentration; the training was acknowledged to be hard work.

Witness 8
Witness 10A

1.4.303. On the day of the accident, and using a 7-point scale, with 1 being completely exhausted and 7 being fully alert and wide awake, R3 selected 4 and 5 – a little tired/less than fresh and okay/somewhat fresh. He described himself as in general good health and having eaten adequately that day.

Exhibit 44

1.4.304. HF specialist analysis advised that fatigue is linked to attention, decision making, and attitudinal changes; all of which could have a negative influence on actions when performing safety critical tasks and reduce personnel's readiness to perform their duties.

Exhibit 44

---

[131] Readiness factors encompassed the tasks undertaken to plan and prepare for a sortie, and the attributes of a pilot.

1.4.305. The Panel found no specific evidence to indicate that fatigue was directly affecting R3's overall performance; as stated in para 1.4.296 he was doing well in the air. However, in the Panel's opinion, R3 may have had an underlying level of fatigue/weariness that when considered collectively with other HF issues could have affected his decision making and reaction times during the critical stages of the accident sortie.

1.4.306. In the Panel's opinion, R3 was working hard in a high tempo environment and as a consequence was experiencing a degree of fatigue. Although there was no evidence that he was outwardly stressed, HF specialist advice conjectured that in relation to his workload he may have been influenced by several recognised stressors: Exhibit 44

a. Demands of the job and ability to meet them.

b. Task and performance demands.

c. Job control: determining own work routine.

d. Job distress: content and workload.

e. Complexity.

1.4.307. Whilst acute stress is sudden and intense, chronic stress arises from factors that are in the background of a person's every day activities including work and organisational requirements, cumulative effects of such stressors can, over time, lead to degraded performance. Chronic stress may reduce a person's ability to respond effectively to an acute stress, such as in an emergency. Exhibit 44

1.4.308. If increased levels of stress continue over a prolonged period, a resultant effect is fatigue. The consequence on flying skills can be tunnel vision when gathering and processing information and pilots may not identify information presented to them. Exhibit 44

1.4.309. Whilst R3 was not visibly stressed the Panel considered that his fatigue levels may have been influenced by underlying work related stress.

1.4.310. Consequently, and when considering R3's working routine, and the potential effect of stress, the Panel concluded that fatigue was a **Contributory Factor**.

Awareness

1.4.311. Although, in the Panel's opinion, R3's working routine had affected him (fatigue), he did feel that in the immediate period leading up to the accident he was meeting the requirements of the role and there had been no reported issues with his performance. On 19 Mar 18 the Team had completed their first full display practice and both he and the other new pilot felt positive, and that there was an end in sight to their training. Witness 8
R3 perceived a change of focus within himself and that [redacted]; the Panel found no evidence to suggest that R3 was regarded as such, but in their opinion his view was reflective of his personal drive. Exhibit 44 Exhibit 44

1.4.312. Between 1 Nov 17 and 19 Mar 18, R3 flew 153 sorties, of which 142 were role training. The remaining sorties were an assortment of Instrument Rating Tests (IRTs), CT, a flying ability test and a transit. GH sorties all included an element of instrument flying. R3's sorties are summarised in Table 1.4.13. Exhibit 31

Sortie Type	No of Sorties	hr:min	Remarks
Role Training	142	77:50	
IRT	5	5:10	R3 in role of examiner, assessing other pilots.
Transit	1	0:30	Flown Dual. Element of IF.
CT (IF)	1	0:45	Flown Dual.
CT (GH)	3	2:10	Solo GH, some IF.
Flying Ability Test	1	1:05	GH sortie, R3 being assessed. Some IF.
TOTAL	**153**	**87:30**	

Table 1.4.13 - Breakdown of R3's sorties 1 Nov 17 – 19 Mar 18

1.4.313. Ninety three percent of R3's sorties (89% of hr) had been display flying which required the focused maintenance of formation positions with high levels of concentration and workload. Conversely, and in the Panel's opinion, the CT sorties on 20 Mar 18 were comparatively routine and less pressurised, and as a single aircraft, did not have the complexity or intensity of flying in close formation. Of note, 2.5% of sorties flown, or 3.7% of flying hrs were GH.

1.4.314. Prior to joining RAFAT R3 routinely conducted PEFATOs, was familiar with the flight profile and on 20 Mar 18 consciously elected to practise the manoeuvre; he was aware that he had not flown one in a heavy aircraft for some time and therefore took the opportunity to do so on departure from RAF Valley. He recognised that he might be 'rusty' but did not consider it something to be overly concerned about. In an HF interview he stated that had intended to use extra focus which he considered his responsibility and described a PEFATO as being "within his comfort zone" and "relatively routine". In the Panel's opinion, and despite his lack of currency the exercise was comparatively routine, especially considering his experience.

Exhibit 44
Witness 1B
Witness 1A
Witness 1C

1.4.315. **Situation Awareness.** Although R3 was more than capable of flying a PEFATO the Panel considered that with the marked change in emphasis of the flying task from which he had been focused and noting the flight profile that he flew and lack of CT recency, it was highly possible that R3 suffered a reduction in Situation Awareness (SA).

1.4.316. **Expectation.** Expectation is an influential factor when building SA. A pilot develops an expectation of what they should see or hear based on factors such as prior instruction or experience of the event, communications and/or their own mental model of the situation. Such expectations allow a pilot to filter out data they may deem as unrequired leaving what they expect to be useful. However, such filtering can lead to a pilot seeing what he expects to see and incorrectly building his SA on reduced or incorrect data. It is possible that although R3 was concentrating on the manoeuvre, he may not have recognised that the situation he was entering did not match his expectations. This is confirmation bias; a person looks for information which supports expectation and fails to look for contradictory evidence even though it would provide a full and accurate picture. R3 was flying a procedure with which he was familiar and in the Panel's opinion would not have expected it to go wrong. Exhibit 44

1.4.317. **SA Errors.** Errors in SA have been categorised as follows: Exhibit 44

a. Failure to correctly perceive the situation. This can be due to information not being presented or not being recognised when presented.

b. Failure to comprehend the situation. Information is correctly identified; however, the significance or meaning is not recognised.

c. Failure to project the situation in to the future. A pilot may be aware of the situation but be unable to project what that means for the future.

1.4.318. R3 acknowledged that the aircraft's height before the finals turn was slightly low but he was happy with the position as he turned towards the airfield. However, in the Panel's opinion, given his lateral separation, speed and height at the point the final turn was initiated, XX204 had insufficient energy for the manoeuvre. Witness 1B Witness 1A

1.4.319. It is possible that R3 incorrectly perceived the aircraft's lateral displacement, especially as the spacing was not dissimilar with that of other (low level / high energy) PFLs that he had practised or a normal circuit, both of which require less displacement than a normal PFL. Equally, it is possible that R3 did not recognise the significance of his relatively low energy state on his turn performance.

1.4.320. With additional speed R3 would have been able to manoeuvre the aircraft using increased AOB. The 3 low level PFL[132] techniques required greater speeds at the initiation of the final turn, before the interception of the PFL pattern. Whilst the Panel could find no evidence to suggest that R3 had experienced a cognitive lapse, and mistakenly used high AOB as required in other PFLs, it could not be discounted as a possibility. Guidance for 800/1200 ft PFLS advised to use up to 60° AOB in the first half of the turn and the Panel could find no guidance for the application of bank during a 500 ft PFL. Consequently, the Panel considered it unlikely that he had conflated techniques. Exhibit 50

1.4.321. R3 recalled feeling that at 500 ft the situation was 'okay' and that there was sufficient room for a go-around. At that stage the aircraft was at 150 kts, had more than 60° AOB, an increasing ROD and was crossing the runway extended centreline with 40° of the turn remaining to align with runway heading. The Panel acknowledged that at 500 ft there was sufficient height for a go-around, however, in the Panel's opinion, XX204's flight parameters were such that at that point the contract was unachievable. Witness 1B Witness 1A

1.4.322. It was not possible to establish if R3 recognised the consequences of the aircraft's position, but if he did there is no evidence to indicate that he took any early (pre go-around initiation) corrective action, therefore there may have been an error in comprehension or future projection.

1.4.323. After initiating the go-around R3 described that he was waiting for the engine and associated aircraft performance; R3 had approximately 2.5 secs from selecting full power to deciding to eject, during which time the engine was accelerating. The engine response time from idle to 95% of maximum power was 6.5 secs. Having initiated the go-around, and with the aircraft descending rapidly, R3 may have been cognisant of the impending impact but unable to project, in the extremely compressed timeframe, the consequences. He described a 'dramatic flip of a switch' and sudden realisation that he was about to crash, which was the point at which he initiated his ejection. Exhibit 19 Witness 1B Witness 1A Exhibit 59 Witness 1A

1.4.324. In the time between initiation of the go-around and ejection the Panel considered that R3 would have been exposed to multiple fast developing inputs: rapid descent towards the ground with changing visual cues, aircraft stall and his associated

[132] 500, 800 and 1200 ft PFLs.

response, combined with his own mental processes to contextualise a situation that was totally unfamiliar to him.

1.4.325. **Disorientation.** HF advice suggested that R3 may have been disorientated during the latter stages of the sortie. Disorientation can be when, for a pilot, everything feels as anticipated until a sudden realisation occurs that the aircraft is not in the position expected ie attitude, height; the change in context can be rapid, particularly at low level. R3's appreciation of his situation changed as the imminence of impact was realised, but by which time he was unable to influence the outcome. Exhibit 44

Distraction

1.4.326. **Additional sortie.** As discussed in para 1.4.127, there was a lack of clarity regarding the possibility for an additional sortie at RAF Valley. Although the requirement for a flight check was removed, the Panel assessed that it was possible that the potential for it would have been in R3's considerations until after the HSTF serial.

1.4.327. **ATC transmission.** During the finals turn R3 recalled the landing gear travelling down and seeing '3 greens'[133]. At about the same time ATC prompted R3 to confirm that the landing gear was down; the start of the call coincided with the ADR data indicating the landing gear completing its travel. The Panel attempted to align the timing of ATC transmissions with ADR timing and as a result the data indicated that the landing gear locked down less than ½ sec after ATC's request. However, due to the potential for errors in harmonising the timings and the lack of a common time datum, it is possible that the landing gear locked down just before ATC's request, which in the Panel's opinion, was timely and appropriate. R3 commented that he felt that the ATC call was a distraction, but instinctively looked into the aircraft to check before replying. R3 remembered looking to the right out of the aircraft towards the runway and having to look into the left side of the cockpit to confirm that he had the correct landing gear indications. In the Panel's opinion, whilst a pilot will continually be moving their head to check external visual cues and monitor flight instruments an added, and unplanned, head movement may cause a distraction. Additionally, as R3 believed that he had already checked the indications, checking it for a second time, which was an instinctive reaction during a busy period in which the aircraft configuration, speed and AOB were changing, may have been distracting. Witness 1B Witness 1A Witness 1B Witness 1A Witness 1A Exhibit 44

1.4.328. R3 recalled feeling frustration at the ATC call and described a clear divide between the radio transmissions and continuing with what he was doing; he had a feeling of being behind and without clarity after the call. Although R3 had checked the landing gear indication, his actions were because of external instigation rather than in his own work sequence; he perceived that he had not forgotten to make the call, he was just not ready to do so, his priority was aircraft handling in the turn. Exhibit 44 Witness 1B

1.4.329. In the Panel's opinion, the fact that ATC prompted a check of the landing gear at the time they did was due to the position of the aircraft on finals, and the fact that R3 felt he was not ready to do so, was possibly a consequence of the flight profile he was flying. Witness 2

1.4.330. The ATC call was the start of approximately 5-6 sec of transmissions that

[133] When landing gear was locked in the down position its status was indicated in the cockpit by 3 green lights.

cleared R3 for a low approach. During that time the aircraft was manoeuvring with increasing AOB, reducing speed and increasing ROD, as shown in Table 1.4.14.

Exhibit 2
Exhibit 19

1.4.331. Immediately after the radio transmissions and the AOB peaking at 70°, there was a significant increase in XX204's ROD. In the Panel's opinion, it is possible that the higher ROD than that experienced on a normal PFL profile, as discussed at para 1.4.206, and associated acceleration towards the ground from approximately 500 ft, contributed to R3's feeling of being behind.

Time to Impact (sec)	Event	Radio Transmissions	Ht (ft)	AOB	Speed kts	ROD ft/min	Degrees to R/W hdg
16	Flap select		734	46	172		111
15			700	44	170	1440	105
14			677	45	169		100
13.5	Gear down		664	46	166		96
13		ATC: "R3 check gear"	657	47	167		93
12.5			650	47	167		90
12		R3: "Gear down R3"	641	48	165		88
11.5			626	50	163		85
11		ATC: "R3 Clear low approach"	612	51	161	1140	82
10.5			599	50	159		78
10			592	50	157		74
9.5			587	50	154		71
9			585	53	153		71
8.5	Flap down	R3: "Clear low approach R3"	576	58	153		69
8			560	64	152	**2580**	64
7.5		Transmissions complete	536	68	150		57
7			521	70	150		50
6.5			491	67	150	**3840**	42
6			455	63	150		34
5.5			420	59	150	**4380**	27

Table 1.4.14 - XX204's flight parameters during ATC transmissions

1.4.332. In the Panel's opinion, the brief sequence of radio transmissions and checking of the landing gear indications may have been sufficient to distract R3 during a critical stage of flight. As R3 had limited recollection of the accident sequence the Panel was unable to establish whether distraction delayed an intended increase in bank to tighten his turn, which subsequently resulted in him applying more than he may have planned, up to a peak of 70° by the end of the radio transmissions. AOB was reduced below 55° in 2 secs. In the Panel's opinion, as XX204 crossed through the runway centreline at 500 ft, R3 was still attempting to align with the runway before initiating the planned go-around. When considering R3's actions, the aircraft's flight profile and R3's acknowledgement that he was distracted, the Panel concluded that distraction was a **Contributory Factor.**

Emergency lowering of undercarriage and flap

1.4.333. XX204's emergency undercarriage and flap selector switches were recovered from the wreckage field; examination suggested that they had been manually activated.

1.4.334. In the event of an actual engine failure, and the resultant loss of hydraulic pressure, the Hawk T Mk1 had an emergency compressed gas system to lower the flap and undercarriage; the system was triggered by 2 independent switches, one for each system. The switches were 'one use only' and had a red 'tell-tale' to visibly indicate that they had been activated[134]. The switches were co-located on the left side of the instrument panel, as shown in Figure 1.4.17. The flap switch featured a square button marked with 'F', and the undercarriage a round button marked with 'U/C'; both had a yellow and black handle. To activate the switches aircrew were required to depress a button on the front of the handle to unlock it and then pull the handle away from the mounting while holding the button in. Exhibit 146

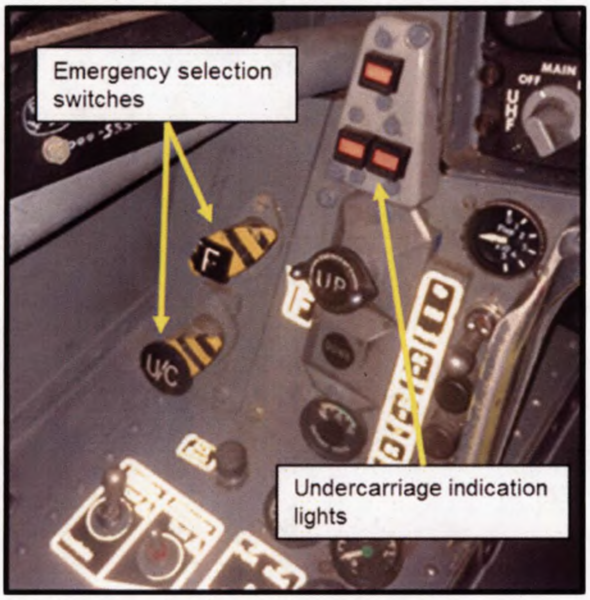


Figure 1.4.17 - Location of undercarriage and flap emergency selectors

1.4.335. Although the flap and landing gear systems were observed in the down configuration, the method of operation was unclear as the standby lowering selectors were recovered[135] with the red tell-tale bands visible, indicating that they had been activated, as shown in Figure 1.4.18. Exhibit 146

[134] Maintenance activity was required to reset them.
[135] The selector switches and panel had separated from the main instrument panel.

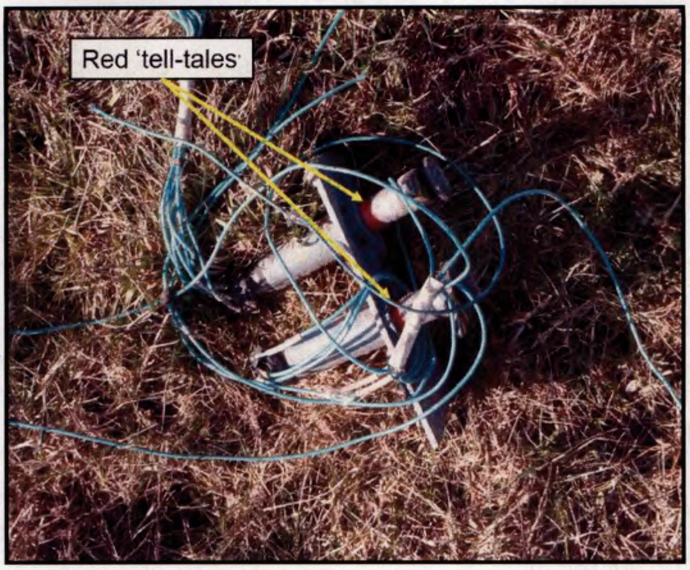


Figure 1.4.18 - XX204's Undercarriage and flap emergency lowering selectors

1.4.336. In-depth technical analysis[136] assessed the level of damage to the switches to be minimal; it was judged that their operation by force would have led to much greater damage both to the switches and the adjacent components. Assessment of the explosive start valves that initiated the standby systems determined that they were free from explosives, but it was not possible to determine if this was due to manual initiation or as part of the accident sequence and subsequent fire. Exhibit 146

1.4.337. Technical analysis concluded that it was very likely that the standby lowering selectors had been activated manually, as opposed to having been displaced during the breakup of the aircraft. Exhibit 146

1.4.338. R3 had no recollection of activating the emergency switches and the Panel could find no evidence of any technical reason for him to have done so; the ADR data indicated that both the flap and undercarriage lowered in the normal manner[137]. The times between selection and completion of travel are shown in Table 1.4.15. Exhibit 19

	Time to impact (sec)		
System	**Selected**	**Down**	**Time**
Undercarriage	21.45	13.85	7.6
Flap	16.35	8.65	7.7

Table 1.4.15 - Undercarriage and flap normal travel times

1.4.339. The undercarriage travel time following emergency selection was similar to routine operation, however, flap would travel from selection to fully down in 1 sec. Due to the similarity in timing the Panel assessed that the undercarriage emergency system could have been activated at any stage following normal selection. As flap took 1 sec to fully lower following emergency selection the Panel assessed that they were very likely operated in a 4-5 sec period between the last second before being indicated as fully Exhibit 147

[136] Assessment included real time radiography, manipulation and disassembly.
[137] There is no data capture facility for the operation of the undercarriage and flap emergency switches on the ADR.

down, which was midway through R3 and ATC's radio transmissions, and approximately 1-2 sec before full throttle was selected, as R3 would have been required to have had his left hand on the throttle[138] at that stage.

1.4.340. **Reason for selection.** In the Panel's opinion, the selection of these systems may have resulted from R3 being distracted, potentially by the ATC radio transmissions. Alternatively, during R3's simulator sortie he conducted an Actual Forced Landing which would have required him to utilise the emergency systems[139]; it is possible that a cognitive failure resulted in his actions. In the Panel's opinion, if the systems were operated as a result of a cognitive failure it is possible that having made the selections, and recognising that he had done so, R3 may have been further distracted whilst he considered what he had done.

1.4.341. Although the Panel assessed that the emergency operation of either system did not affect the aircraft flight characteristics[140], the likelihood that they were operated by the pilot is a significant HF consideration.

1.4.342. HF advice suggested that there was a possibility that the pilot experienced a general error known as 'slip' in which a planned act is not the act carried out. The fact that he had practised the drill in the simulator less than 2 hr previously may have had a lingering effect.

1.4.343. As there was no evidence to support the likelihood that actions conducted in the simulator affected XX204's sortie, the Panel could not conclude if they were factors in the accident. However, in the Panel's opinion, the conduct of a practice malfunction soon after completing complex drills in a simulator could, through cognitive failure, contribute to future accidents and therefore considered it an **Other Factor**.

Recommendation

1.4.344. Military Aviation Authority (MAA) Head of Regulation and Certification should, in order to mitigate against the inadvertent application of real emergency drills during a practice malfunction, regulate that for the first flight, on the same day, immediately following simulator training, single seat pilots should not conduct practice emergencies that have been exercised during the simulator sortie.

Cockpit Voice Recorder

1.4.345. R3 had experience of flying with 'passengers' and during the transit to RAF Valley had communicated with the engineer; he did not recall whether he had talked to him during the accident sortie. The Hawk T Mk1 did not have an enabled CVR capability and therefore the Panel could not ascertain what discussions took place or if they caused a distraction. The lack of a CVR constrained the investigation into XX204's accident, and without it there was a possibility that information that could prevent a future accident was unavailable. As a result, the Panel considered the lack of a CVR was an

Witness 1B
Witness 1A

[138] The throttle, flap and undercarriage, (and emergency selection switches) were operated by the pilot's left hand. In addition, the radio transmit switch was on the throttle.
[139] This would have specifically required the operation of the 'normal' selectors then activation of the emergency selectors.
[140] The landing gear and flap were already fully down.

Other Factor.

1.4.346. The Panel noted that previous Hawk T Mk1 accidents had recommended the incorporation of a CVR into the aircraft, but due to a planned out of service date of 2020, the matter had not been progressed. The Hawk out of service date was subsequently extended until 2030. Exhibit 148

Recommendation

1.4.347. The Hawk T Mk1 TAA should consider, in light of the revised out of service date, the fitment of a CVR to the aircraft to aid accident investigation.

Human Factors summary

1.4.348. In consultation with HF specialists the Panel considered a range of Human Factors that may have affected R3; due to R3's sporadic recall of the final 20 secs of flight it was not possible to gain understanding of his mental processes during that critical stage. In the Panel's opinion, there was no single factor that could explain R3's decisions and actions. The Panel concluded that when considered collectively it was very likely that he was, to a degree, fatigued, distracted during the flight and may have had reduced SA.

1.4.349. The combined factors stemmed from conditions that were present before the accident sortie and could have affected any RAFAT pilot. However, when the flight profile is considered, as well as the emergency lowering of the undercarriage and flap, it is, in the Panel's opinion, very likely that his SA was reduced, and a cognitive failure/slip occurred. When combined with the distracting effect of the ATC radio transmissions, the Panel concluded that at the critical moment of the sortie he may not have recognised the associated hazards as the situation developed. While HF is undoubtedly the key consideration in understanding why the accident occurred it must be evaluated in conjunction with R3's lack of CT and associated skill fade.

Ejection and Aircraft Impact

1.4.350. **Ejection Initiation.** R3 ejected from the aircraft 0.52 sec before impact. The ejection was initiated at approximately 38 ft above ground level with 4.6° pitch nose up, 21° right AOB and at 148 kts; the aircraft was descending at 73 ft/sec. R3 perceived the situation dramatically switching from being 'okay' to not, with a realisation that the aircraft was going to hit the ground. The rear seat ejection mechanism was not activated. Exhibit 17 Witness 1A Exhibit 5

1.4.351. **Pilot's Ejection Sequence.** The RAFCAM conducted computer analysis of the ejection sequence which indicated that the ejection occurred within the survivable envelope for the ejection seat[141], and the forces acting on the pilot during the ejection were well within the limits of human tolerance. R3 impacted the ground approximately 6.7 sec after initiating ejection, landing just after the Personal Survival Pack (PSP)[142] had started to fall from its stowed position under his buttocks; he landed with a ROD of circa

[141] Martin Baker Aircraft Company Ltd Mk 10B ejection seat.
[142] The PSP automatic release system was designed to function 4 secs after the pilot separated from the seat.

21 ft/sec[143]. Exhibit 5

1.4.352. **Verbal Warning.** The command to a passenger to initiate an ejection is "*eject, eject, eject*". The engineer had been briefed that if a hazardous situation occurred from which it was required to abandon the aircraft, he would be given the command to eject. R3 recalled stating a short warning, but not 'eject' x 3, and instinctively pulled the ejection handle; he was uncertain if he said it prior to or as he pulled the handle. The Panel considered that if R3's warning was made during the ejection sequence there was a possibility that the engineer did not hear it as the pilot's intercom may have been separated from the main aircraft. Furthermore, and in the Panel's opinion, even if the engineer had heard the warning there was insufficient time for him to react before the aircraft hit the ground. Having heard it he would have been required to recognise the meaning and act appropriately. Witness 1A Exhibit 44 Exhibit 86 Witness 1B Witness 1A

1.4.353. **Warning time.** The time taken to state "eject" x 3 could not be categorically established, the Panel assessed that, dependant on stress and urgency, it could take circa 0.75 sec, following which individual reaction time would be required. When considering the extremely fine time margin in which R3 instinctively recognised, decided and acted, including his warning, the Panel assessed that if he had given the expected warning of eject x 3, there is a possibility that he may not have successfully ejected.

1.4.354. **Engineer's experience.** The Panel assessed that the engineer lacked the experience to independently recognise the need to eject, especially as the aircraft had not suffered a technical failure and was conducting a practice procedure from which it was reasonably expected to recover. As a result, the Panel concluded that the engineer's lack of experience to independently initiate an ejection was an **Aggravating Factor**.

1.4.355. **Ejection simulation.** A simulation was conducted to hypothetically assess what may have happened if the engineer had initiated an ejection within 0.5 sec of the pilot. It indicated that it is likely that he would have survived and escaped just within the safe ejection envelope. The ejection would have occurred at approximately 5 ft; in relation to the ROD this would have been almost coincident with the aircraft's impact with the ground. The model indicated that the engineer would have landed at about 29 ft/sec and landing related injuries could have been expected. Exhibit 5

1.4.356. In contemplating the simulation results the Panel were cognisant that the point of ejection was established through an assessment of ADR data and not definite. Consequently, the simulation results were purely indicative and potential outcomes could differ by 0.5 sec variations and therefore it is unlikely that the engineer would have been able to eject.

Command Eject

1.4.357. The Hawk T Mk1 was fitted with a command ejection system, as the Hawk was originally a training aircraft, with the flying instructor in the rear cockpit and a student pilot

[143] This was less than the 29.5 ft/sec threshold used to establish if an ejection was within or without the safe ejection envelope.

in the front, the command eject system was designed to be initiated from the rear cockpit; command ejection could not be initiated from the front cockpit. Exhibit 5

1.4.358. The ejection seat firing systems were interconnected through a control valve which was selected to one of two positions, either ON (command) or OFF (independent). In the ON position the rear seat occupant could initiate the ejection; the rear seat would be ejected first followed, after approximately 0.35 sec, by the front seat; initiation by the front seat only ejected the front seat occupant. Exhibit 5

1.4.359. If the aircraft was flown from the front seat with a passenger in the rear seat the control valve was selected to the OFF (independent) position before flight to avoid the pilot being ejected by an inexperienced passenger activating the system in error. In this case initiation of ejection by either the front or rear seat occupant would eject only that specific seat. XX204's control valve was selected to OFF. Exhibit 5

Command Ejection simulations

1.4.360. Additional simulations were conducted to determine the hypothetical outcome if the command ejection system had been selected to ON and the ejections had been initiated from the rear seat. The simulations were also used as a comparison to assess the outcome of theoretical ejections which would have occurred had the aircraft been fitted with a command ejection system which was configured so that the front seat occupant could initiate the ejection. XX204's pilot ejection parameters were used and the time delay between the rear seat and front seat initiation being the nominal 0.35 seconds[144]. The sequence of events would be the same for whichever seat occupant initiated the ejections namely, the rear seat leaving the aircraft first followed by the front seat. Exhibit 5

1.4.361. The simulations predicted that both ejections would have occurred within the safe survivable ejection envelope and both the front and rear seat occupants would have been expected to survive. The rear seat would have left the aircraft 38 ft AGL and the front seat at 12 ft. However, the Panel noted that as extant ejection sequence timing parameters were utilised the modelled outcome for this accident was wholly hypothetical, especially when the short time between R3's ejection and impact are considered. To provide a more categorical assessment would require an understanding of the timing implications associated with any potential re-engineering of the command eject sequencing. Exhibit 5

1.4.362. The change in role of the Hawk T Mk1 from a training aircraft to providing operational support and RAFAT resulted in aircraft commanders routinely sitting in the front cockpit. Consequently, and noting the out-of-service date of the platform, the Panel considered that a front seat command eject capability would reduce the risk to rear-seat non-aircrew occupants in the event of an unalerted ejection.

1.4.363. Although the primary aircraft role had changed, 100 Sqn RAF has recently been tasked to recommence Advanced Flying Training for ab-initio student pilots in 2019 which will result in the instructor sitting in the rear cockpit. As a consequence, any change to the command eject system would have to cater for variations in aircraft role. Exhibit 149

[144] 0.35 sec is the time delay between the ejection seats departing the aircraft.

1.4.364. The provision of a front seat command eject facility may have resulted in both crew surviving, therefore, the Panel concluded that the lack of such a capability was an **Aggravating Factor**.

Recommendation

1.4.365. AOC 22 Gp should assess the feasibility of the incorporation of a command eject capability into the Hawk T Mk1 that would allow aircraft commanders to initiate the ejection sequence for occupants from either cockpit seat.

Aircraft impact

1.4.366. The aircraft impacted the ground approximately 15° right-wing low with an essentially level pitch attitude and at 151 kts; the initial point of impact was 247 m from the runway threshold and 40 m to the left of the runway centreline. The aircraft wreckage was spread over an area approximately 50 m wide by 200 m long. The fuselage and wing were located within 15 m of each other with scattered wreckage filling the rest of the area. An overview of the crash site is shown in Figure 1.4.19.

Exhibit 17

Exhibit 22

Exhibit 23

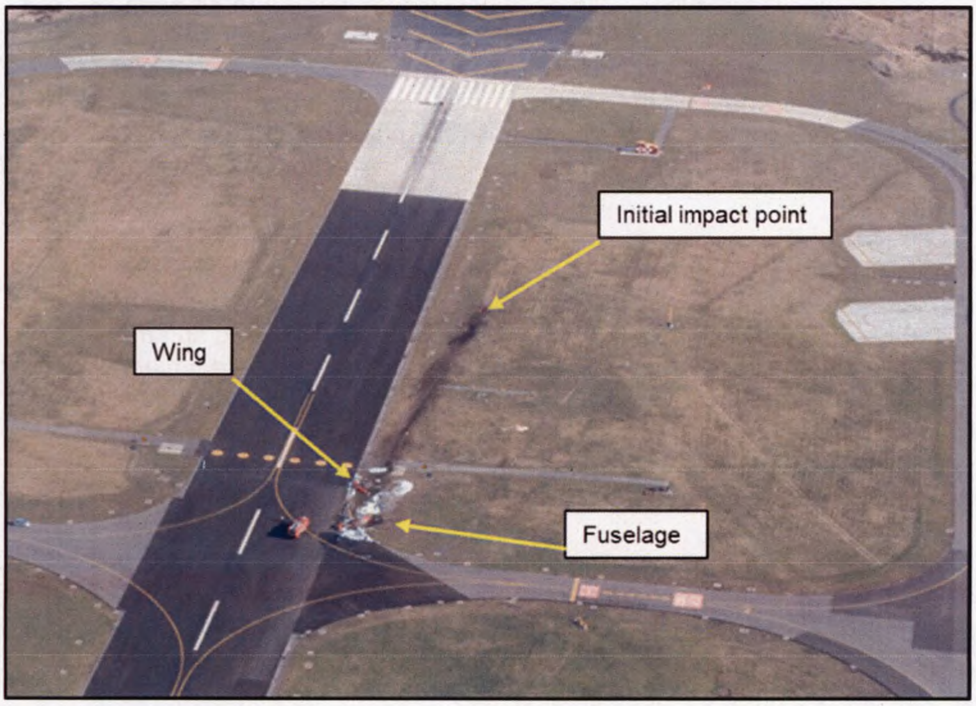


Figure 1.4.19 - Overview of crash site

1.4.367. The initial impact point contained parts of the smoke pod. Fragments of the aircraft canopy transparency and Miniature Detonation Cord were scattered before the impact point, the proximity of which indicated how close to impact the ejection occurred. The initial impact point is shown in Figure 1.4.20.

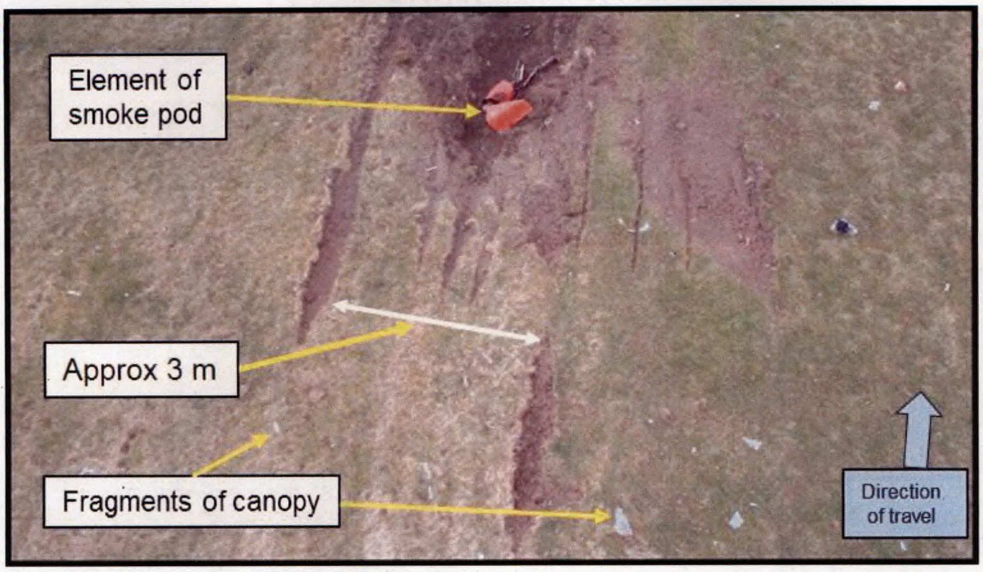


Figure 1.4.20 - Initial impact point

1.4.368. During the crash sequence the undercarriage detached, the fuselage and wing separated as did the horizontal tail plane; the tail fin remained loosely attached to the airframe. The fuselage rolled onto its left side before coming to rest in an upright position orientated in the reciprocal direction to the approach path. There was substantial structural damage to the forward part of the fuselage with nose cone and canopy debris disbursed in the immediate area. In addition to a fire at the point of impact and several smaller fires along the main wreckage path there was a severe fire around the cockpit area once the aircraft came to rest. The aircraft fuselage is shown in Figure 1.4.21.

[redacted]

Figure 1.4.21 - Aircraft fuselage, tail fin and tail plane in final resting position

1.4.369. Having separated from the fuselage the wing became entangled in the Rotary Hydraulic Arrestor Gear (RHAG) cable and came to rest on the runway margin; in addition, a Precision Approach Path Indicator (PAPI) light was severely damaged. The Exhibit 26 wing and RHAG are shown in Figure 1.4.22.

[redacted]

Figure 1.4.22 - Aircraft's wing in final resting position

1.4.370. Other than the aircraft occupants no other personnel were injured, and as the aircraft crashed on to the airfield there was no damage to third party infrastructure.

Post-accident

1.4.371. **Immediate response.** XX204 impacted the ground at 1325 hrs, the immediate Exhibit 150
crash response was initiated via a telephone call[145] to the RAF Valley Fire Station and Exhibit 151
Medical Centre. This was followed-up by activation of the Station crash alarm at 1325 Exhibit 25
hrs and on the ATC ground frequency at 1326 hrs and 10 sec; this was dual transmitted Exhibit 15
on the crash and rescue frequency. The RAF Valley Fire and Rescue fire tenders Exhibit 25
arrived at the aircraft within 2 min[146]; the fire was extinguished by 1331 hrs. Local Exhibit 26
civilian medical and Fire and Rescue services responded to RAF Valley but were Exhibit 27
subsequently stood down as they were not required. Exhibit 152
Exhibit 26

1.4.372. Although ATC initiated the emergency response (the Station crash alarm was activated approximately 1 min after XX204 impacted the ground) not all sections of the airfield heard the alarm[147] and in some non-critical areas, whilst the alarm had sounded, no detail of the incident was heard. The failure to broadcast incident details resulted Exhibit 26
from incorrect operation of the crash alarm and tannoy system. In the Panel's opinion, whilst this did not delay the immediate fire and medical response the fact that the alarm Exhibit 150
sounded should have been sufficient to alert personnel around the airfield that an incident was in progress. However, the lack of detail may have resulted in uncertainty and whilst this did not unduly delay the Station's response it had the potential to cause some confusion. Nevertheless, sufficient information was attained to quickly activate the RAF Valley Emergency Coordination Centre (ECC). Exhibit 26

1.4.373. R3 landed, post ejection, circa 70 m from the fuselage and was attended within Exhibit 22

---

[145] A direct emergency line linked ATC to the Fire Station and Medical Centre.
[146] The operational objective was to achieve response times of 2 minutes, and not exceeding 3 minutes, to any point of each operational runway, as well as to any other part of the operating area. Response time was considered to be the time between the initial call, and the time when the first responding vehicle(s) were in position to apply foam at a rate of at least 50% of the specified discharge rate.
[147] Certain buildings at RAF Valley could not receive the alarm.

a minute by a member of the Bird Control Unit before being joined by RAF Valley medical personnel. An air ambulance landed at the scene at approximately 1350 hrs. R3 was given medical treatment and stabilised where he landed before being airlifted by the air ambulance to hospital in Birmingham departing at 1459 hrs. The engineer was confirmed dead at the scene at 1401 hrs by an RAF Valley Medical Officer.

Witness 4
Witness 5
Exhibit 2
Exhibit 28
Exhibit 1
Exhibit 26
Exhibit 5
Exhibit 6
Exhibit 26

1.4.374. In the Panel's opinion, the Fire and Rescue response and extinguishing of the fire was as expeditious as possible. Nevertheless, the nature of the aircraft impact, severe fire and associated damage meant that their actions were unlikely to have changed the outcome for the engineer. The Panel concluded that the post-crash response was **Not a Factor** in the accident.

Pilot

1.4.375. R3 sustained major injuries during the ejection sequence which necessitated [redacted] The most significant injuries were a [redacted]

Exhibit 5

1.4.376. The ejection simulations predicted that R3's landing velocity was within the design parameters for the Hawk ejection seat parachute[148]. The landing velocity should not have resulted in [redacted] however, it is probable that he landed on his PSP[149]. The simulation and imagery of the parachute descent showed that at the point of landing the PSP had just been released from its retained position, under the pilot's buttocks, and had started to fall; the PSP was designed to auto-deploy during the descent. The fact that the PSP had not deployed was indicative of R3's late and low ejection. Had R3 been on the parachute for a few more seconds the PSP would have fallen to its full extent and the forward drive of the parachute would very likely have resulted in him avoiding contact with the PSP on landing.

Exhibit 5

1.4.377. R3 had sporadic recollection of the final moments of the flight and of the ejection sequence. The amnesia may have resulted from [redacted] There are occasions in an ejection sequence when head injuries can be sustained including during the parachute landing[150]. The damage to R3's helmet was indicative of having contacted a broad impacting surface, such as the ground. R3's helmet had damage and delamination to the shell on the left side of the crown, as shown in Figure 1.4.23.

Exhibit 5

[148] GQ1000 Parachute.
[149] The PSP contained equipment for use in a survival situation.
[150] Head injuries could be sustained through contact with the aircraft canopy, windblast and parachute deployment.

Figure 1.4.23 - R3's aircrew helmet

1.4.378. The Panel were unable to categorically establish how R3 landed but the balance of the evidence[151] indicated that the most likely cause for [redacted], was that his head impacted the ground during the parachute landing. Exhibit 5

Engineer

1.4.379. A post mortem examination carried out on the engineer concluded that his injuries were consistent with the nature of the impact and associated fire. Exhibit 5

Examination of Survival Equipment and Aircrew Equipment Assemblies

1.4.380. Other than the damage to R3's helmet, as described in para 1.4.377, R3's aircrew clothing and survival equipment were serviceable. All the rear seat occupant's clothing and equipment were extensively fire damaged and therefore serviceability could not be established. Exhibit 153

Aircraft Assisted Escape Systems

1.4.381. **Ejection seats.** Examination of both ejection seats indicated that they were serviceable. The rear seat sustained significant fire damage but no structural damage was observed; the front seat sustained major impact damage. Exhibit 154

1.4.382. **Shoulder harness.** The seat shoulder harnesses were attached to a retraction assembly[152] and ratchet mechanism which was designed to lock and prevent forward movement of the occupant. Movement was controlled by a 'go-forward lever' that could be in one of two positions, either locked back, restraining the occupant, or forward, enabling the occupant to lean forward against a retraction spring pressure to a maximum Exhibit 155

[151] Included imagery of the parachute descent and examination of aircraft wreckage.
[152] Shoulder Harness Power Retraction Unit.

of 30 cm.

1.4.383. If, with the lever forward, the retraction assembly extended at an excessive rate (eg during a rapid deceleration of the aircraft), the system was designed to automatically engage and prevent further forward movement. If there was insufficient deceleration, the seat occupant may have been thrown forward and/or downward resulting in the head
striking the cockpit coaming or the top of the control column. In the event of an ejection Exhibit 156
the retraction assembly was designed to pull the occupant's shoulders back into the Exhibit 155
seat. In accordance with the Flight Reference Cards the go-forward lever was to be Exhibit 154
selected aft (locked) and the harnesses tight for take-off and landing. Both of XX204's Exhibit 157
seats' 'go-forward' levers were found in the forward position. Exhibit 158

1.4.384. Evidence suggested that the engineer's harness inertia reel locked appropriately. However, even with it locking, the harness would permit some forward slumping of the upper torso and head, particularly with rapid deceleration. Furthermore, if the engineer had been sitting bent slightly forward prior to impact the inertia reel would lock in that position and he would not have been held as tightly against the seat back as he would have had he been sitting with the harness fully back and the go-forward lever locked. Operation of the inertia reel would not retract the upper torso and shoulders; shoulder retraction would only have occurred on ejection initiation when the retraction
assembly unit activated. Exhibit 5

1.4.385. R3 recalled completing the before take-off checks and ensured that his harness was tight and locked for take-off (go-forward lever in the aft position); he had verbal confirmation from the engineer that his harness was also tight and locked. After take-off, and with landing gear and flap up, R3 moved his go-forward lever to the forward (unlocked) position. As his intention was not to land he did not subsequently change the lever back to the locked position. He was unaware as to the position of the engineer's
go-forward lever during the flight. The Panel could not establish if the engineer moved Exhibit 159
the go-forward lever after take-off, alternatively it was conceivable that it may have been moved during the recovery of the engineer from the rear ejection seat, as a result the Panel could not positively determine its position prior to impact. It is conceivable that if the go-forward lever had been in the locked position the impact injuries sustained by the
engineer may have been lessened. In the Panel's opinion, considering the immediate Exhibit 5
and significant fire, if it had been locked it is unlikely that it would have changed the final outcome. Nevertheless, the Panel **observed** that if a seat harness was not locked during critical stages of flight it could result in an increased risk of injury.

Post-Crash Management

1.4.386. Post-Crash Management (PCM) activity was conducted in accordance with the Station Crash Support and Major Incident Plan. On completion of the initial fire and rescue response a Post-Crash Management Incident Officer took control of the accident site from the Fire Crew Commander; a cordon was established with Mountain Rescue Team personnel. Due to the fatal nature of the accident a North Wales Police officer
retained overall primacy of the incident until 21 Mar 18. Exhibit 26

Impounding of documentation

1.4.387. Following notification of the accident RAFAT and RAF Scampton initiated PCM activities including the impounding of relevant documentation and activation of
Command structures. However, the subsequent collation of data relating to XX204 was Exhibit 29
problematic with documents still being provided 6 months after the accident. Difficulties Exhibit 30

essentially resulted from the number of differing organisations holding relevant documentation and the lack of focused coordination. Interested parties included: Exhibit 160

a. RAFAT.

b. RAF Scampton.

c. RAF Valley (CAMO – maintenance paperwork).

d. RAF Cranwell (Survival Equipment paperwork and Early Failure Detection cell).

e. Hawk T Mk1 TAA (engineering documentation).

1.4.388. These stakeholders were organisationally and geographically displaced, whilst the units directly affected by the accident carried out PCM actions within their immediate environment, the Panel could find no evidence of a coordinated response across key stakeholders.

1.4.389. Whilst DAIB investigators and SI Panel members sought to gain the broader relevant data, they had insufficient knowledge of platform organisations to rapidly collate the range of required evidence. The Panel considered it would be appropriate that in the event of a significant occurrence the affected organisation should determine the location of, and ensure that, all pertinent records are impounded, catalogued and mustered via a single point of contact for presentation to the investigators. This should include any evidence that may be held at different locations due to deployed operations or support activities being undertaken away from the operating base, such as TAA, CAMO, centralised maintenance facilities etc.

1.4.390. MAA regulations provided guidance on general actions to be taken but did not encapsulate the requirement to capture broader evidential requirements. Exhibit 161

1.4.391. The Panel **observed** that delays in the provision of key documentation has the potential to significantly delay SI progress. In the Panel's opinion, the responsibility to coordinate initial documentary collation should be the unit/station of the affected platform and incorporated in PCM plans.

ADR calibration data collection

1.4.392. All ADR calibration data was required to be retained by a Unit's Engineering Records Section as well as the Unit's ADR Bay. ADR data archive storage media was also to be held for each aircraft operated by the unit. However, it took the Panel and investigators several weeks to attain XX204's calibration data from RAFAT, delaying SI progress in a critical area. The Panel **observed** that a delay in making ADR calibration data readily available to an investigation hinders progress with assessing essential evidence and generating an early understanding of the incident flight. Exhibit 162

Aircraft Recovery

1.4.393. Personnel from the DAIB took control of the site at 0600 hrs on 21 Mar 18, in liaison with the Joint Aircraft Recovery and Transport Squadron and the RAFCAM Exhibit 21

Accident Investigation and Human Factors Team (AIHF). Exhibit 26

1.4.394. Once the cockpit area was made safe, site surveys[153] and Health and Safety assessments were carried out. Site clearance was conducted on 22 - 23 Mar 18 with the aircraft wreckage being removed on the afternoon of 23 Mar 18. The aircraft was relocated to MOD Boscombe Down on 24 Mar 18 for detailed investigation. Exhibit 23

1.4.395. **Site Recovery.** A small amount of remediation was carried out immediately after the accident, but a subsequent assessment by a Defence Infrastructure Organisation Environmental specialist, with the approval of Natural Resources Wales, advised that it would not be necessary to remove and replace any further ground. Other than small scorch marks no physical damage occurred to the runway surfaces. One PAPI unit was destroyed along with a Rotary Hydraulic Arrester Gear illuminated marker board; a small length of Air Ground Lighting cabling was replaced. Exhibit 163

Organisational Matters

Royal Air Force Aerobatic Team

1.4.396. **RAFAT roles.** RAFAT's core roles and rationale are summarised as follows: Exhibit 164

a. Representing and showcasing the skills and values of the RAF.

b. Supporting British industry. Renowned both at home and overseas, RAFAT and the excellence it invokes reinforces the reputation of the UK and the country's people and equipment.

c. Assisting defence diplomacy. RAFAT displays are one of the ways the UK strengthens its relationships abroad, benefitting defence and prosperity. The team provides the UK, as the RAF does, with a great ability and option to promote and support the country's interests – diplomatically, industrially and militarily. Displaying in 57 countries worldwide, the 2016 Asia-Pacific and Middle East nine-week Tour visited 17 countries, including China and drew a global audience of a billion.

d. Aiding Armed Forces recruitment.

1.4.397. When considering the strategic effect to which RAFAT contributed and the associated reputational focus, the Panel sought to establish if the associated pressure had an influence on RAFAT personnel.

Royal Air Force Aerobatic Team reputation

1.4.398. The Team has both a UK and international reputation for excellence on the ground and in the air, across all ranks and trades and is recognised as one of the world's premier aerobatic display teams. The Team is renowned for the trademark Diamond Nine formation which is the Team's badge, and the motto *Éclat*, a French word meaning Exhibit 164

[153] JARTS utilised the Land Survey System to plot almost 1300 points of interest within the impact area.

"brilliance" or "excellence". Exhibit 165

1.4.399. The foreword to the RAFAT DD provided a future vision as: *'…that RAFAT directly help to secure the UK national interests, promote 'Great British Excellence' and contribute to the engine of UK GDP and by association raise awareness, understanding and support for the RAF, Defence and National Security…'.* This was to be achieved by harnessing RAFAT values including the persistent pursuit of excellence, humility, courage, exquisite attention to detail, dynamism and ruthless determination. The reputation for Great British Excellence had key relevance to the UK and its drive for prosperity, as was borne out by the 2016 Asia-Pacific tour[154]. Exhibit 166

1.4.400. Conducting a range of displays from flypast through to extremely high profile State occasions and international sporting fixtures, RAFAT have a prominent place in British popular culture, with their aerobatic displays a fixture of British summer events. Exhibit 165

1.4.401. Related literature highlighted the achievement of excellence and the Team was routinely in the media, not only for completion of successful displays but also when appearances were cancelled. In the Panel's opinion not only does RAFAT represent the RAF and Defence but due to its strategic profile was effectively a 'national brand'. As a result, the Panel concluded that with such a reputation there would undoubtably be a level of induced pressure on RAFAT personnel. Exhibit 167

Induced pressure

1.4.402. Although there was unequivocal direction from the CoC to all personnel that there was no higher-level pressure to deliver 9 aircraft or meet all events, the Panel assessed that due to the conspicuous nature of RAFAT's task, there was an imperceptible system induced pressure on the Team. Witness 20, Witness 7, Witness 6A

1.4.403. Accordingly, both aircrew and engineers perceived a degree of self-induced pressure to meet the requirement of their roles. This germinated through professional pride, a desire to achieve and deliver, and in terms of aircraft availability a view that the Red Arrows were 9 aircraft with an associated public expectation. Witness 7, Witness 10B, Witness 6A, Witness 6C, Exhibit 168, Exhibit 169

1.4.404. There was a degree of personal pride and fear of perceived failure if 9 aircraft did not display on time, every time. Comments on social media could have an adverse effect on morale when the public remarked negatively on a display that was either late, cancelled or not 9 aircraft. Excellence was what was always strived for, what the Team stood for, and what the world expected. Reputational pressure resonated through the Team that could affect behaviours and decision making. It manifested as self-induced pressure regardless of how often personnel were reminded to take their time and ensure that tasks were completed safely. Exhibit 169

1.4.405. The ODH recognised that during the display season and tours, additional management challenges could be introduced around the subject of fatigue and pride,

[154] RAFAT conducted a 2 month tour, 28 Sep 16 – 1 Dec 16.

and ensured that additional oversight was applied. Exhibit 170

1.4.406. The Panel acknowledged that a degree of pressure was appropriate to deliver the Team's output throughout the year. However, in the Panel's opinion, the resultant self-induced pressures had the potential to develop into safety related occurrences. This was especially pertinent when exacerbating factors were considered.

Resource

1.4.407. In addition to the 9 display pilots, OC RAFAT and the Team Supervisor (Red 10) were qualified and current on the aircraft; Red 10 flew the tenth aircraft when away from RAF Scampton.

1.4.408. RAFAT had no reserve display pilots, to do so would have required an individual to be proficient in each formation position; each pilot always flew the same formation position during a season. There was a contingency for a missing team member which would result in an 8-aircraft display; there was no contingency for a large (traditional Red Arrows) formation for 2 or more absent pilots. However, the Team were able to provide limited displays commensurate with the number of available pilots of up to 5 aircraft. Witness 10B Exhibit 171

1.4.409. Consequently, for RAFAT to deliver their primary high-profile output, 100% pilot availability was required for each display. The Panel were unaware of any other sqn where 100% availability was routinely required to meet their tasks.

1.4.410. **RAFAT Qualified Flying Instructor.** The pilot training serials that formed part of the new arrivals' checks, comprised 3 dual sorties, 1 solo and a 'check ride' with the Team Leader. The sorties were flown under the authority and supervision of CFS Exam Wing, and until Jan 17 the dual sorties had been instructed by the Hawk T Mk1 CFS examiner. However, following the closure of the last Hawk T Mk1 training sqn and the dis-establishment of the associated CFS examiner's post, the RA sorties in Aug 2017 were conducted by the RAFAT QFI. As discussed in para 1.4.35, R3's 4 x RA sorties took 19 working days to complete, during which time the RAFAT QFI also had to train 2 other new pilots and complete his own duties. The QFI did not conduct any other instructional sorties, such as annual QFI checks or FATs, those sorties being flown by CFS agents (via Hawk T Mk1 STANEVAL). Although suitably qualified and experienced to teach the sorties the Panel could find no evidence that any training/work-up/approval for the QFI to conduct those flights had been provided by CFS Exam Wing. In the Panel's opinion, as the sorties were conducted under the remit of CFS, the RAFAT QFI, (if required to conduct them) should be formally empowered to act on their behalf. The Panel determined that the requirement to conduct RA training resulted from circumstances beyond the Team's control but placed an additional workload on the QFI beyond his normal task and could create undue induced pressure. The Panel concluded that the generation of additional pressure on the RAFAT QFI was an **Other Factor**. Exhibit 51 Exhibit 172 Exhibit 173

Recommendation

1.4.411. RAFAT DDH should consider the provision of RAFAT qualification sorties through an external Hawk T Mk1 QFI so as to alleviate additional workload on RAFAT aircrew.

Aircrew Planning Officer

1.4.412. The Aircrew Planning Officer (APO) position was established in 2013 in response to recommendations from previous RAFAT accidents. The post was for a Full-time Reserve Service (FTRS) Squadron Leader providing additional assurance/oversight from a Fast Jet aircrew perspective that was outside the immediate flying task and to reduce the workload on Team pilots; a full time Operations Officer was also introduced at a similar time. Exhibit 168 Exhibit 174 Exhibit 175

1.4.413. The APO at the time of the accident had been in post for several years but resigned prior to the 2018 Display Season due to the pressures of the role and a progressive increase in responsibilities including overseas tour planning/management; risk register transition to BowTie analysis; management of a new Air Safety reporting programme (ASIMS 3[155]); and Survival Officer duties[156]. The criticality of Air Safety Management will be further considered in para 1.4.429, however in the Panel's opinion, it was an area that required focused continuity to deliver safe output. Exhibit 168

1.4.414. By Dec 18 RAFAT had been unable to recruit a replacement; the gapping of the post was mitigated by the temporary employment of a medically downgraded pilot. In the Panel's opinion the APO fulfilled a key supervisory and safety role and prolonged gapping could result in the transfer of responsibilities to the core Team pilots and increase the risk of a safety occurrence. Replacement of personnel employed as FTRS can take time due to the recruitment process and therefore gapping may be protracted. Witness 20 Witness 7 Witness 10B Witness 7

1.4.415. As such a critical position, the Panel **observed** that the importance of the role may not be reflected due to its FTRS status and that gapping of even a single post in a small busy unit could place further undue pressure on the Team and contribute to a safety related occurrence. In the Panel's opinion, there would be merit in considering the transfer of the APO position to a Regular Officer liability to ensure continuity in a critical supervisory and safety area.

Engineering

1.4.416. **Manning requirement.** RAFAT was established for 85[157] engineering personnel. An engineering manning review[158] conducted in 2016 recommended that the establishment for engineering personnel should be increased by an additional 11 personnel. The review considered all RAFAT engineering activities as well as management and support functions[159]. A Formal Staff Visit (FSV) Report in 2018 highlighted that the requirement for an additional 11 posts to match engineering resource to the RAFAT task was ongoing but stated that an establishment increase was unlikely due to the availability of Trade Group 1 personnel; by May 2018 there had been no increase in establishment or manpower. Exhibit 80 Exhibit 176 Exhibit 177 Exhibit 178

1.4.417. **Aircraft uplift.** During 2017 the number of aircraft on RAFAT increased from 14 Witness 6A

---

[155] ASIMS is a web-based application to support the reporting, management and analysis of Air Safety occurrences, investigations and recommendations.
[156] APO volunteered to take on the Survive, Evade, Resist, Extract Instructor duty due to a new Team member who was going to become the unit SERE officer not being released in time to do the Course.
[157] RAFAT WO Eng stated 85 but contrary evidence stated 87 (2016 Manning Review).
[158] Conducted by AIR COS Manning Requirements and RAFAT WO Eng.
[159] The review focussed on Senior Non-Commissioned Officers and below.

to 16, however, there was no additional engineering manpower to manage the associated increased maintenance task. The 2016 manning review was based on a historic fleet of 15 aircraft, therefore an additional manpower review may be required to accommodate this. A lack of manpower resulted in delays of at least 2 weeks to an 8-week scheduled maintenance process. Exhibit 169 Exhibit 179 Exhibit 180

1.4.418. **Shift capacity.** RAFAT was not sufficiently manned to be able to operate a full night shift and so utilised an enhanced late shift with a limited number of personnel. This reduced the volume of fault rectification and scheduled servicing that could be achieved to prepare the aircraft for the following day, activity which could not be conducted during the day due to the intensity of the flying programme. Exhibit 169 Witness 17 Witness 6C

1.4.419. **Engineer trade training.** RAFAT were required to internally deliver Trade Qualification Annotation (TQA) Courses to new personnel. To do this, experienced technicians were taken away from their primary roles to instruct, thus placing an additional burden on the available engineering manpower. Courses were run on an 'as required basis' but that typically meant waiting for a reasonable number of individuals to be available to complete the training. Consequently, a significant period of time could elapse where personnel were not fully trained and therefore not able to carry out their primary role. This aggravated the existing lack of engineering manpower which was exacerbated if the personnel awaiting a course were supervisors. At the 22 Gp Fast Jet Air System Safety Working Group (15 Nov 17), Director Flying Training (DFT) stated that the current ad hoc delivery was not satisfactory and suggested that the issue should be raised further. Furthermore, a 22 Gp FSV Report stated that a permanent training solution for the delivery of the Hawk T Mk1 engineering equipment courses remained a high priority for DFT and Defence Equipment and Support. Exhibit 181 Exhibit 182 Witness 6A Exhibit 180 Witness 6C Exhibit 183 Exhibit 177 Exhibit 184

1.4.420. **Circus flight servicing training.** In addition to the SC training covered in para 1.4.87, Circus personnel were required to complete flight line training to allow them to conduct aircraft flight servicing; in doing so this removed them from their primary role. One member of Circus stated that his own line training was interrupted as he was required to conduct independent inspections on work being conducted elsewhere on the unit. Due to a lack of manpower, he had to be temporarily taken off Circus line training to carry out his primary role before returning to training again. Whilst this did not prevent all of his training being completed, it was perceived to be an interruption and distraction. Witness 16 Witness 6B

1.4.421. **Circus SC simulator training.** As discussed at para 1.4.92, due to manpower constraints and the inability to release engineers, no members of Circus completed the SC simulator training for the 2017 season. At the time of the accident, the planned 2018 SC simulator training had also been cancelled. This was due to a lack of engineering personnel; the release of Circus personnel would have impacted the ability to generate sufficient aircraft for the daily flying programme. Witness 6B Exhibit 185

1.4.422. **Out of Area deployments.** The number of available engineers was reduced through a commitment to provide personnel for Out of Area deployments (OOA). Although there was exemption for some individuals, most engineers were liable for deployment; RAFAT at times had up to 6 personnel away. The impact on the Sqn was not just evident during the deployment but also through pre-deployment training and post-tour leave. Consequently, a 6 month deployment could impact the team for approximately 8 months. RAFAT exercises or deployments did not attract Deployment Warning Role (DWR) credits which affected an individual's liability for OOA deployments. There was a concern that the absence of DWR credits for RAFAT activity (eg overseas tours) had a cumulative detrimental effect on engineering manning levels. This had been Witness 6A Witness 6C Exhibit 180 Witness 20 Witness 6C Exhibit 180 Exhibit 184 raised to the CoC.

1.4.423. **Qualified and experienced personnel.** The average RAFAT tour length for an avionics Senior Aircraftman (SAC) technician was 18 months vice an average Trade Group 1[160] posting of 4-5 years. Some individuals joined with sufficient seniority (3-5 years) to be competitive for promotion and were moved in circa 12-18 months. Junior avionics technicians did not join RAFAT direct from training due to requirements to achieve National Vocational Qualifications (NVQ); the Hawk T Mk1 did not meet the criteria for the completion of NVQ Level 3 and the achievement of an apprenticeship. RAFAT was gapped 3 out of 7 avionic SACs which was reflective of a broader RAF issue. Of Defence's Hawk operating units (3 x T Mk1 and 1 x T Mk2) RAFAT was the only one employing military engineers. Therefore, where gaps existed RAFAT was unable to gain manpower, or experience from other units. Exhibit 180

1.4.424. **Standards evaluation.** Following a noticeable trend in engineering documentary errors concerns were raised over a reduction in engineering standards and practices. This was perceived to have resulted from a lack of manpower causing personnel to rush tasks in trying to generate serviceable aircraft. Accordingly, increased First Party Assurance activity to monitor engineering standards and practices was implemented through the permanent allocation of a Senior Non-commissioned Officer (SNCO) to a STANEVAL position. However, this further reduced the manpower available to conduct daily line and supervisory activity. Witness 6A Witness 6C

1.4.425. **Station support.** RAFAT was the only flying unit at RAF Scampton; the ability of the Station to fully support the Team was constrained by resource.

a. The absence of an Engineering Wing, meant that some activities that would normally be conducted at Station level (eg fleet management) were completed by RAFAT. The personnel required to manage the movement of aircraft into and out of modification programmes and scheduled maintenance, further compounded the lack of manpower resilience. Witness 6A

b. The lack of a Supply Wing to hasten and prioritise spares resulted in RAFAT fulfilling the role that could have been expected to be completed at Station level. Witness 6A

c. Issues with Ministry Provost Guard Service manpower resulted in RAFAT providing circa 3 personnel per month to the station guard force; personnel were predominantly engineers. Exhibit 179

1.4.426. **Mitigation.** To mitigate the shortfall of the 11 posts identified in the manpower review, innovative ways of trying to create further capacity to reduce engineering workload and pressure were introduced. These included the utilisation of some capacity within the Hawk Integrated Operational Support (HIOS) contract with Babcock at RAF Valley to conduct additional scheduled maintenance tasks on RAFAT aircraft. This temporarily released 5 mechanical technicians back to routine line activity. Witness 6A

[160] Trade Group 1 included avionic, mechanical and weapon technicians.

Engineering conclusion

1.4.427. The Panel assessed that the shortfall in engineering personnel required to deliver RAFAT's tasks, compounded by a reduced level of Station support, the requirement to conduct TQA, Circus and SC training as well as individual gapping, placed additional pressure on the engineering team. As detailed in para 1.4.404, engineering personnel perceived induced pressure in the requirement to deliver aircraft. The necessity for additional personnel had been articulated, but with an uplift being unlikely the Panel formed the opinion that the lack of available personnel would result in enduring pressure being placed on the engineering team. Such pressure could have an individual or collective effect to the detriment of working practices and output. The Panel concluded that the combination of induced pressure and lack of engineering personnel formed an aggregated risk that was an **Other Factor**.

Recommendation

1.4.428. AOC 22 Group should review RAFAT's engineering establishment, and resource at an appropriate level to ensure the safe and sustained delivery of directed outputs whilst allowing for other commitments (OOA) and non-core activity.

Air Safety Management System

1.4.429. RAFAT Air Safety Management (ASM) process was incorporated within the Central Flying School's procedures and Air Safety Management System (ASMS)[161]. An MAA audit in 2016 found that the ASMS was operating effectively albeit with taut Air Safety (AS) resource and without the full breadth of Station support more generally expected at a main operating base. It observed that the DDH, as Comdt CFS, had little organic AS resource and relied on the limited AS capabilities of RAF Scampton and within RAFAT. A 22 Gp FSV in Mar 2018 observed that although the CFS ASMS was effective it had limited assurance due to concerns over AS documentation, auditability and the lack of capacity to analyse risk effectively. However, this was identified as being caused by a lack of resource and not the commitment of the personnel.

Exhibit 186
Exhibit 177

1.4.430. RAFAT, through the DDH, had been well represented at the 22 Gp Air Safety Steering Group (ASSG) and regular CFS/RAFAT DDH Review Groups had been conducted with various RAFAT personnel in attendance. In the Panel's opinion the DDH had expended significant time and effort in driving the ASMS forward to ensure compliance with MAA Regulations[162] and promoted a positive AS culture throughout CFS and RAFAT. During the conduct of the SI the Panel noted constructive initiatives to improve AS and concluded that RAFAT had an effective ASMS, albeit constrained by a lack of AS resource.

Exhibit 187
Exhibit 188
Exhibit 189
Exhibit 190
Exhibit 191
Exhibit 192
Exhibit 193
Exhibit 194
Witness 7

Safety risk management

1.4.431. MAA regulations regarding ownership and management of operating risk stated that all operating risks should be indicated in a Risk Register or suitable alternative. Any suitable alternative should enable a record to be kept of risk decisions, activities and

[161] RAFAT DDH was also Commandant CFS.
[162] RA 1210.

periodic risk reviews. Exhibit 195

1.4.432. **Use of BowTie.** All RAFAT DDH Risks to Life (RtL) were recorded on BowTies[163]. Whilst the Panel acknowledged that a significant amount of work had been conducted into the development of the BowTies, they were assessed as being relatively immature in terms of the wealth/depth of underlying supporting evidence. The Panel was made aware that risk sanctioning activity had taken place to assess the colour coded BowTie barrier risk indicators and during the assessment of risks for RAFAT activity, such as for overseas tours. The Air Safety Management Plan (ASMP) required that anything related to an Air Safety decision was to be retained in such a manner that it ensured a traceable and auditable record of Air Safety decisions. However, in the Panel's opinion, the nature of the BowTie system made it harder to easily track the decision-making and recording process. Witness 7 Witness 12 Exhibit 196 Witness 12 Witness 15 Witness 21 Exhibit 197 Exhibit 198

1.4.433. In the Panel's opinion, RtL appeared to be understood and documented within the BowTies. However, due to a lack of supporting evidence and detail within the BowTie, or records of risk sanctioning, the Panel were unable to ascertain how an overall assessment of the RtL was derived. The Panel noted that the lack of supporting evidence was due to a paucity of AS resource to gather and input the required level of data and concluded that it was an **Other Factor,** as a failure to understand the associated implications could contribute to a safety related occurrence.

Recommendation

1.4.434. RAFAT DDH should comprehensively review RAFAT BowTies to confirm that underpinning evidence is included to ensure that RtL are accurately articulated and that all risk assessments or sanctioning work are accurately documented and retained in an auditable manner.

1.4.435. **Decision recording.** For the daily management of AS risks and issues, the DDH recorded AS decisions, including when AS matters were raised to the ODH, in an AS Decision Register. Risks that needed to be elevated to the ODH were either raised during ASSG meetings or through a Duty Holder Advice Note (DHAN). The register also contained hyperlinks to any supporting documents ie correspondence, DHANs etc. Witness 7 Exhibit 89 Witness 7

1.4.436. Whilst the use of an AS decision register was considered by the Panel to be pragmatic and useful, the Panel **observed** that the register appeared to be more of a personal record rather than a formal DDH AS decision register. There was no reference to the use of the AS decision register within the ASMP. The RAFAT DDH may wish to consider formalisation of the use of an AS decision register within the ASMP to ensure accurate and auditable recording of risk decisions.

1.4.437. **RAFAT primary role risk control measures.** Risks associated with RAFAT formation manoeuvres were detailed in the RAFAT DD and in the Panel's opinion were comprehensive and provided appropriate mitigation. There was also significant evidence of senior officer oversight of RAFAT with engagement by the ODH and Director Flying Training. Exhibit 199 Exhibit 200

[163] BowTies are barrier risk models to assist the identification and management of risk – https://www.caa.co.uk/Safety-initiatives-and-resources/Working-with-industry/Bowtie/About-Bowtie/Introduction-to-bowtie/

Supernumerary Crew risk assessments

1.4.438. The justification for Circus to fly as SC, their carriage in the aircraft during CT and most specifically for PFLs initiated below 1000 ft was considered in para 1.4.115. In examining the RAFAT BowTies that were active at the time of the accident, the Panel could find no evidence of where the flying of SC or Circus had been considered, and consequently there was no evidence of the SC training syllabus having been used as a barrier within a threat line. Exhibit 201

1.4.439. There was no evidence of any risk assessments in relation to the failure of Circus to complete simulator training in 2017[164], or for the exemption permitting the carriage of Circus in PFLs initiated below 1000 ft. The Panel noted that post-accident the DDH produced a comprehensive RBC for the flying of SC to inform the ODH of the risks as part of his decision to return to flying. It concluded that authorizers and aircraft captains were to ensure that SC exposure to PFL, CT, low level and emergency training was to be minimised and done only when operationally essential[165]. Exhibit 53

1.4.440. In the Panel's opinion, as the requirement for Circus and SC had been articulated and a syllabus implemented to provide additional training beyond that of a passenger, consideration had, at some stage, been given to the associated risks. The Panel concluded that the failure to formally record these risks was assessed as an **Other Factor** as no clear risk mitigation was articulated. Witness 10A Witness 6A Witness 7 Exhibit 7

Recommendation

1.4.441. RAFAT DDH should review, capture and sentence, the risks associated with the flying of SC/Circus to ensure that there is clear understanding for aircrew, authorizers and supervisors as to the limitations of their employment.

Safety occurrence reporting

1.4.442. During the conduct of the SI the Panel observed that between January and 10 Aug 18, RAFAT generated 119 Defence Air Safety Occurrence Reports (DASORs). As a comparison, during the same period, 100 Sqn RAF raised 93 and 736 NAS raised 52[166]. Of the RAFAT DASORs raised, 51% had been closed by Aug 18 and most of the remainder had only been created in the last 2 months of the period that the Panel considered. Exhibit 202

1.4.443. It was noted that there was a positive move towards 3rd Age Reporting. Third Age Reporting was the phase all organisations should strive to achieve and begins to reflect a more proactive/generative culture capable of predicatively tackling error before it becomes an incident or worse. In this phase personnel will willingly report near miss events. The Panel concluded that RAFAT had a good AS reporting culture. Witness 6C

---

164 As previously discussed the issue had not been raised to the DDH.

165 The Panel recognised that when the RBC was conducted the cause of the accident was not known and the DDH had little information from which to consider associated risks.

166 This data was not normalised against flying rates/hours.

Air Safety resource

1.4.444. The paucity of RAFAT AS manning was well articulated from a Sqn perspective, in external assurance reports and at ODH level. The 22 Gp FSV in Jan 18 reported *"proactive risk management would only be realised when additional dedicated AS resource has been identified and generated."* Exhibit 186 Exhibit 203 Exhibit 204 Exhibit 177 Exhibit 178 Exhibit 177

1.4.445. As partial mitigation the DDH established a full time CFS AS Manager by allocating a CFS flying examiner to assume the role. In Jan 18 the DDH stated the requirement for an ASM Team (ASMT) of 3 in a DHAN which was supported by the ODH. Exhibit 200 Exhibit 205

1.4.446. Following XX204's accident the decision was made to remove the CFS AS Manager so that the individual could replace R3 in the 2018 Display Season. Consequently, and with no established ASMT and a gapped AS Manager post, the DDH directed an internal re-appointment of several CFS personnel to ensure AS compliance at the expense of other CFS activity. Whilst this action could be assessed as being policy compliant, in terms of numbers, it fell short of the position aspired to in the DHAN. Witness 7 Exhibit 191 Exhibit 178

1.4.447. A lack of AS manning resilience was not unique to RAFAT but was also applicable across 22 Gp to the extent that it was agreed it should be considered for inclusion within the ODH's tops risks. Exhibit 206

1.4.448. In the Panel's opinion, a RAFAT AS occurrence could have both an operational and reputational impact beyond that which would be reasonably expected of any other flying unit. The nature and profile of RAFAT's role, most critically when considering the risk to 2nd and 3rd parties, meant that a clear focus on safety was required. The DDH had placed significant importance on AS and assessed that he had far more considerations than other ADHs due to the variety of factors that could affect the Team's operations. Witness 7

1.4.449. When considering the complexity of RAFAT's tasks, the potential for associated pressure, the articulated requirement for additional engineering personnel and the limited support from RAF Scampton, the Panel concluded that an inability to fully manage and mitigate the associated risks could result in an AS occurrence. The Panel considered that for the DDH to effectively manage AS, and fulfil his DH obligations, both for CFS and RAFAT, an appropriately resourced, suitably qualified and experienced AS staff was required. The Panel concluded that the lack of a permanently established AS team was an **Other Factor**.

Recommendation

1.4.450. AOC 22 Group should resource a suitably qualified and experienced CFS ASMT to ensure the provision of proactive RAFAT risk management and deliver the capacity to effectively capture, analyse and manage risk.

FTP3225H

1.4.451. FTP3225H Issue 1, the Hawk T Mk1/1A Handling Manual, was published in Jan Exhibit 123

18, superseding AP3225H, the Advanced Flying Training Student Study Guide, which had last been amended in Feb 16. Exhibit 207

1.4.452. AP3225H had been a Flying Training Publication sponsored by 208 Sqn RAF[167] and produced in association with 22 Gp[168]. It was published to assist Hawk instructors, trainee instructors and student pilots to fly and operate the Hawk as a weapons system. Exhibit 207

1.4.453. Oversight of AP3225H reduced as 208 Sqn progressed towards disbandment in Apr 16, following which, as student pilots were not being trained on the Hawk T Mk1, the document became redundant as an instructional publication; it was no longer deemed fit for purpose by the other Hawk users. The CFS Hawk T Mk1 Examiner took ownership until that post was dis-established, but the Panel could find no evidence of the document being officially withdrawn from circulation. Exhibit 208 Exhibit 209

1.4.454. As the document contained useful corporate knowledge, the shared intent of the various Hawk T Mk1 DDHs was for it to be re-written and issued as a Hawk Handling Guide. STANEVAL 1 Gp[169] was identified as the new sponsor of the document and a re-write was commenced around Sep 17. All 4 operators of the Hawk T Mk1[170] were consulted and requested to provide input. Exhibit 208

1.4.455. FTP3225H Issue 1 was published in Jan 18 to assist Hawk pilots to fly and operate the Hawk T1 (all variants) in their tasked roles[171]. The document was issued to all 4 Hawk T Mk1 operating units as a 'complete re-write' that replaced all previous editions and amendments of AP3225H. Although RAFAT were consulted during the re-write process they considered that the main documents applicable to them were the DD and the Aircrew Manual, and that the FTP3225H was not considered a primary document for RAFAT operations. When consulted on the draft document RAFAT made no recommendations for change. Exhibit 123 Exhibit 120 Exhibit 210 Exhibit 211

1.4.456. The manual was divided into 2 parts: Part A – the Hawk T1 Handling Manual included GH disciplines, IF, formation and low level flying; Part B – the Hawk T1 Tactics Manual, covered the applied aspects of tactics and weapons. The document listed 4 Annexes. Annex A was the Hawk T1 Formation Standard Operating Procedures (SOPs). Annexes B to D were the responsibility of 100 Sqn, RAFAT and 736 Sqn respectively and included their role specific SOPs and operating differences to the broader manual. It is worthy to note that the foreword stated that any mandatory document that contradicted information in the publication was to be taken as the overriding authority. Exhibit 123

1.4.457. On issue, and having been renamed, FTP3225H had a 'list of effective changes' which, in the Panel's opinion, and unless the full document was read, could be misconstrued as the only changes within the publication. Consequently, it was possible that changes from the previous document could be missed. The alteration in guidance for the height during a PEFATO from which to commence the final turn was not within the list of effective changes. The Panel determined that as the change was not immediately apparent it was less likely to be noted when the document was checked especially if the Exhibit 123

---

[167] 208 Sqn provided Advanced Jet Flying Training and Tactical Weapons Training to prepare pilots for Operational conversion to either the Typhoon or Tornado.
[168] 22 Group had oversight of all Flying Training. At the time of AP3225H 22 Gp was called 22 Training Gp.
[169] 1 Group coordinates the RAF's frontline fast-jets.
[170] 100 Sqn, 736 NAS, RAFAT and MOD Boscombe Down.
[171] Roles included: Close Air Support, Weapon delivery, Air Combat Manoeuvring.

reviewer was busy. Exhibit 123

1.4.458. The document was accessible by all Hawk T Mk1 operators along with their other sqn reference documents. Sqns had individual procedures in place to update the crews of any changes to key publications; these included a brief on the changes from the sqn training officer (QFI) or a requirement for individuals to sign as having read the document. FTP3225H was not a mandated RAFAT reference document that required pilots to read and sign for having done so. Whilst the Panel were advised that it was not a 'primary' document and had little applicability to the Team's task, pilots did during interview make reference to it. In the Panel's opinion, as FTP3225H gave guidance on core handling skills and was referred to in the DD it had applicability to RAFAT.

Exhibit 212
Exhibit 213
Exhibit 214
Witness 11C
Witness 9A
Witness 9B
Witness 12
Witness 13

1.4.459. In the Panel's opinion, with the significant changes in the roles of the aircraft, the re-write to provide users with a suitable document capturing extant corporate knowledge and relevant handling guidance was apposite. However, the Panel concluded that within the document there was assumed knowledge and ambiguity, and with regard to PFLs and PEFATOs, a lack of clarity and detail that was open to interpretation. In the Panel's opinion, as a published 'flying guide' the document should have been clear and unambiguous, providing the endorsed handling techniques and procedures and applicable to all Hawk operators. As concluded in para 1.4.184 the fact that FTP3225H lacked clarity and was open to interpretation was an Other Factor.

Recommendation

1.4.460. AOC 22 Group, should conduct a full review of FTP3225H with formal engagement with each of the main Hawk T Mk1 operators to ensure the document is coherent, unambiguous and applicable to all users.

Aircrew Manual

1.4.461. The Aircrew Manual contained 4 parts with part 2 covering aircraft handling[172] which included information regarding the flying of PFLs and EFATOs. The Panel noted that advice related to an EFATO was limited in terms of what speeds to consider when continuing with the exercise and only described the academic PFL. It also outlined a 'Turnback Manoeuvre' – which, following an EFATO, referred to the act of turning the aircraft back towards the airfield to any suitable runway. Exhibit 49

1.4.462. In the EFATO section, with speeds between 250/270 and 300 kts, there was a caution regarding a turnback to the reciprocal of the runway in use. This manoeuvre was, confusingly, referred to by the Hawk T Mk1 community simply as 'a turnback'. A turnback to the reciprocal runway following an EFATO was prohibited having become no longer permitted following several accident/incidents practising the exercise.

Exhibit 49
Exhibit 215
Exhibit 216

1.4.463. In the Turnback Manoeuvre section it stated that following an EFATO, with landing gear down, and flap still up, the aircraft should be flown at 170/175 kts[173]; this

[172] Part 1 system descriptions and management, Part 3 emergencies and malfunctions, Part 4 illustrations.
[173] The higher speed was to be flown when remaining fuel was >1000 kgs.

conflicted with the section on gliding that stated for the same configuration to glide at 165/170 kts. The Panel could find no evidence why the speeds were different. Exhibit 49 Exhibit 105

1.4.464. In 1995, at the direction of the then Air Officer Training (AOT), Headquarter (HQ) Personnel and Training Command, the gliding speed with landing gear down and flap up, was increased by 5 kts from 165/170 kts to 170/175 kts, to *'increase the safety margins'*.[174] The change was reflected in earlier editions of the Aircrew Manual[175]. However, in 2002 at the then AOT and HQ CFS's direction, these published speeds were reduced back to 165/170 kts. The Panel could find no evidence why the speeds were amended. Exhibit 215 Exhibit 216 Exhibit 217 Exhibit 218 Exhibit 216

1.4.465. The Aircrew Manual contained multiple warnings regarding the danger of stalling. When considering that there may be little or no warning of an impending stall, and with relatively small stall margins, the Panel could not ascertain why the speeds to fly these manoeuvres that can be affected by very small applications of g, resulting in an accelerated stall close to the ground, were reduced. Exhibit 57 Exhibit 105

1.4.466. AP3456 stated that advice on stall recovery handling, should be given in the Aircrew Manual. The Panel observed that the Aircrew Manual contained instruction on when to carry out a SSR but there was no description of what those actions were. The Aircrew Manual does state that recovery from a stall is immediate upon moving the control column forward, but in the Panel's opinion all considerations and actions to be taken in the event of a stall should be clearly defined in the Aircrew Manual. Of note, the FTP3225H did articulate the full breakdown of the actions and considerations of a SSR. Exhibit 48 Exhibit 57 Exhibit 138

1.4.467. The Panel determined that the Aircrew Manual contained conflicting gliding speed advice, referred to a prohibited manoeuvre, and did not detail the SSR. Whilst the Panel acknowledged that the appropriate detail was contained in other publications the fact that the Aircrew Manual, as an authoritative document, contained incorrect information could contribute to another safety occurrence and therefore concluded it an **Other Factor**.

Recommendation

1.4.468. Defence Aircrew Publications Squadron should revise the Hawk T Mk1 Aircrew Manual to ensure coherency, accuracy and completeness throughout the publication and with current operating practices.

---

174 This was endorsed by the Design Authority BAE.
175 Edition 0, AL 19 Jul 96.

Summary of Factors

Analysis conclusion

1.4.469. The Panel concluded that the accident was caused by the aircraft stalling coincident with the initiation of the go-around and with insufficient height to recover. However, there were a series of aspects that collectively contributed to XX204's flight profile that culminated in the stall.

1.4.470. The timing of the PEFATO initiation and subsequent positioning led to the aircraft being low and laterally close to the runway. During the final turn the high AOB and nose down pitch to maintain speed led to an excessive ROD/FPA which required increased application of g resulting in a reduced stall margin. The flight profile was such that the stall was coincident with the go-around rather than as a consequence of it; the Panel could not establish if R3 had any perceptible indications of the stall. Flight test analysis corroborated extant warnings regarding stalling related to the Hawk and demonstrated that at low speed/low energy, stall margins were minimal.

1.4.471. The RAFAT focus on Primary Role flying was understandable, especially when the situation was exacerbated by poor weather and other constraints. However, the Panel concluded that the lack of CT, specifically PEFATO/PFL currency, could result in skill fade. Nevertheless, the frequency of CT and the aircraft's flight profile do not solely explain why the accident happened, as at any stage R3 could have terminated the exercise by initiating a go-around.

1.4.472. R3 was an above average QFI who had flown PEFATOs on multiple occasions, albeit not in the immediate period prior to the accident. He was suitably qualified and experienced to fly the manoeuvre however, a series of HF aspects may have influenced R3 and contributed to the accident.

1.4.473. The Panel determined that when considered collectively it was very likely that R3 was, to a degree, fatigued, during the flight distracted and may have had reduced SA. In relation to the aircraft's flight profile the Panel assessed that distraction may have directly influenced his actions in the application of a high AOB, and at the critical moment of the sortie he may not have recognised the associated hazards.

1.4.474. Whilst the Panel was able to determine the cause of the accident, it was not possible to determine the categorical reason why R3 flew the profile he did. In the Panel's opinion, there was no single factor that underpinned his decisions/actions.

1.4.475. As a member of Circus, the engineer had completed the requisite training as mandated at the time. The Panel concluded that the lack of simulator training prior to flying could place increased risk on an individual as the first exposure to the cockpit environment was the shakedown sortie. The requirement for a shakedown sortie was not formally articulated and lacked a defined purpose or syllabus. Consequently, the level of risk, including low flying and emergencies, that the rear seat occupant could be exposed to was not bounded.

1.4.476. Whilst the training provided Circus engineers with an enhanced level of preparation for their role, vice a passenger, there was insufficient evidence for the Panel to assess whether any training would have prepared XX204's engineer to independently recognise the need to eject during the accident sequence.

1.4.477. R3 ejected 0.5 sec before XX204 crashed following the dramatic realisation that the aircraft would impact the ground. The Panel assessed that there was insufficient time for him to issue a complete verbal warning and for the engineer to recognise the command and react appropriately. Simulations indicated that if a front seat-initiated command eject system had been in place then both individuals might have vacated the aircraft before ground impact.

1.4.478. More broadly, and in the Panel's opinion, RAFAT personnel were subject to induced pressures to deliver the required output, a situation that was exacerbated by resource constraints. It was considered that the shortfall in engineering and AS personnel could lead to a future air safety incident. The lack of dedicated AS manning had an influence on both CFS's and RAFAT's ability to administer the management of risk.

Accident findings

1.4.479. **Cause.** The Panel concluded that the cause of the accident was the aircraft stalling with insufficient height to recover. 1.4.244

1.4.480. **Causal factors.** The Panel identified that the application of g in the 3 sec prior to the initiation of the go-around was a Causal Factor (ie led directly to the accident). 1.4.236

1.4.481. **Contributory factors.** The Panel identified 9 Contributory Factors to the accident (ie those which made the accident more likely to happen):

a. RAFAT PFL and PEFATO currency requirements leading to the potential for skill fade. 1.4.39

b. The carriage of Circus Supernumerary Crew in the aircraft during the conduct of PFLs initiated below 1000 ft AGL. 1.4.118

c. The aircraft's height and lateral spacing at the position that it commenced the final turn. 1.4.191

d. The pilot's lack of awareness regarding the amended PEFATO guidance in FTP3225H. 1.4.194

e. The lack of an aircraft stall warning capability. 1.4.252

f. High AOB and excessive ROD on final approach. 1.4.260

g. The pilot's working routine was detrimentally affecting his morale, not allowing him sufficient time for rest, consolidation and affecting his fatigue levels. 1.4.298

h. Pilot fatigue. 1.4.310

i. Distraction during critical stage of flight. 1.4.332

1.4.482. **Aggravating factors.** The Panel identified 2 Aggravating Factors (ie those that made the outcome of the accident worse):

a. The engineer's lack of experience to independently initiate his own ejection. 1.4.354

b. The lack of a front seat-initiated Command Ejection system. 1.4.364

1.4.483. **Other factors.** The Panel identified 21 Other Factors (ie were not factors in the accident but noteworthy in that they may cause or contribute to future accidents):

a. RAFAT general currency requirements resulting in skill fade. 1.4.29

b. Non-recording of individual PFL profiles could result in them remaining unpracticed. 1.4.34

c. The lack of a training requirement for a stall recovery in a glide configuration. 1.4.44

d. The lack of appropriate Quality Assurance. 1.4.48

e. RAFAT were not using the mandated forms and methodology for recording, calculating and informing the basic W&M and the Current Operating Weight. 1.4.50

f. Inaccurate Weight and Moment and Centre of Gravity calculations. 1.4.54

g. Insufficient authorization detail regarding sortie content when carrying inexperienced passengers/Supernumerary Crew. 1.4.78

h. The lack of Circus Supernumerary Crew simulator training. 1.4.94

i. The lack of a formal syllabus for shakedown sorties. 1.4.101

j. The lack of clarity regarding SC status and auditable endorsement, had the potential for misinterpretation of an individual's qualifications which could result in exposure to an undue level of risk. 1.4.107

k. The lack of clarity of handling guidance following an Engine Failure after Take-off. 1.4.184

l. The lack of guidance for increasing AOB above 45° and the associated relationship with the required increase in speed could lead to mishandling and a safety related occurrence. 1.4.265

m. The utilisation of the standard go-around technique could, with a fine stall margin, result in an aircraft stalling. 1.4.277

n. The conduct of practice malfunctions in an aircraft following the completion of complex emergency drills in a simulator. 1.4.343

o. The lack of a CVR constrained the accident investigation. 1.4.345

p. The generation of increased workload and associated pressure on the 1.4.410

RAFAT QFI.

q. The combination of induced pressure and lack of engineering personnel.	1.4.427
r. The lack of BowTie supporting evidence and detail to formulate an overall risk assessment and provide understanding of associated implications.	1.4.433
s. Failure to record risks and articulate associated mitigation relating to the requirement for Circus and Supernumerary Crew.	1.4.440
t. The lack of a permanently established Air Safety team.	1.4.449
u. Incorrect information contained within the Aircrew Manual.	1.4.467

1.4.484. **Observations.** The Panel made 10 Observations (ie issues that were not relevant to the accident but worthy of consideration to promote better working practices):

a. Differences between the 3 Hawk T Mk1 sqns in the frequency requirements for core handling exercises.	1.4.20
b. For non-primary tasks electronic authorization was not as robust as manually written authorization.	1.4.68
c. Electronic authorization sheets could be amended without either the authorizer or pilot's knowledge.	1.4.72
d. Limited regulatory advice regarding the increased use of electronic documentation.	1.4.73
e. Hawk simulator reports should record an individual's performance including appropriate advice.	1.4.125
f. The failure to lock seat harnesses during critical stage of flight.	1.4.385
g. Delays in the provision of key documentation had the potential to significantly delay SI progress.	1.4.391
h. A failure to make ADR calibration data readily available hinders progress with assessing essential evidence and generating an early understanding of the incident flight.	1.4.392
i. The importance of the Aircrew Planning Officer role may not be reflected due to its FTRS status and that gapping of even a single post in a small busy unit could place further undue pressure on the Team.	1.4.415
j. The DDH's Air Safety register appeared to be more of a personal record rather than a formal decision register.	1.4.436

PART 1.5

Recommendations

Intentionally Blank

PART 1.5 – RECOMMENDATIONS

Introduction. The following recommendations are made in order to enhance Defence Air Safety:

1.5.1. **Hawk T Mk1 Operating Duty Holders should:**

a. Consider the introduction of a currency requirement for a stall recovery during a Practice Forced Landing profile in the landing configuration. 1.4.45

1.5.2. **Air Officer Commanding 22 Group should:**

a. Investigate the incorporation of an artificial stall warning capability in the Hawk T Mk1 to provide sufficient warning to pilots during low speed low altitude manoeuvring. 1.4.253

b. Commission testing to provide guidance on the relationship between speed and angle of bank in all glide configurations in order to minimise the risk of stall during low speed manoeuvring. 1.4.266

c. Revise manoeuvring limitations during the final stages of a PFL to ensure that excessive ROD and high AOB are avoided, and that an adequate safety margin for go-arounds is provided, potentially including an alternate go-round technique. 1.4.284

d. Clarify the requirement to meet the Practice Forced Landing 'contract' irrespective of an aircraft's intention to touch-and-go/go-around. 1.4.285

e. Assess the feasibility of the incorporation of a command eject capability into the Hawk T Mk1 that would allow aircraft commanders to initiate the ejection sequence for occupants from either cockpit seat. 1.4.365

f. Review the Royal Air Force Aerobatic Team's engineering establishment, and resource at an appropriate level to ensure the safe and sustained delivery of directed outputs whilst allowing for other commitments (OOA) and non-core activity. 1.4.428

g. Resource a suitably qualified and experienced Central Flying School Air Safety Management Team to ensure the provision of proactive Royal Air Force Aerobatic Team risk management and deliver the capacity to effectively analyse risk. 1.4.450

h. Conduct a full review of Flying Training Publication 3225H with formal engagement with each of the main Hawk T Mk1 operators to ensure the document is coherent, unambiguous and applicable to all users. 1.4.460

1.5.3. **Military Aviation Authority Head of Regulation and Certification should:**

a. In order to mitigate against the inadvertent application of real emergency drills during a practice malfunction, regulate that for the first flight, on the same day, immediately following simulator training, single seat pilots should not conduct 1.4.344

practice emergencies that have been exercised during the simulator sortie.

1.5.4. **The Hawk T Mk1 Type Airworthiness Authority should:**

a. Conduct a review of associated documentation to ensure that information appertaining to Weight & Moment and Centre of Gravity is standardized across all relevant publications in order to remove ambiguity. 1.4.55

b. Consider, in light of the revised out-of-service date, the fitment of a Cockpit Voice Recorder to the aircraft to aid accident investigation. 1.4.347

1.5.5. **The 22 Group Hawk T Mk 1 Chief Air Engineer (Operating Duty Holder) should:**

a. Review AP101B-4401-2(R)1, Part 1 Leaflet 021 to ensure conformity with AP100B-01 and the management of Quality Assurance. 1.4.49

1.5.6. **The Royal Air Force Aerobatic Team Delivery Duty Holder should:**

a. Review Continuation Training currency requirements both for general handling and instrument flying to ensure that the potential for skill fade of core handling skills is minimised. 1.4.30

b. Review the Continuation Training currency requirements and recording process for Practice Forced Landings and Practice Engine Failures After Take-Off to ensure the maintenance of skill in these core competencies. 1.4.40

c. Formalise a syllabus for simulator training and mandate its completion by personnel selected for a role within the Royal Air Force Aerobatic Team Circus prior to undertaking duties as Supernumerary Crew. 1.4.95

d. Establish a formal syllabus with clear training objectives for Circus Supernumerary Crew shakedown sorties. 1.4.102

e. Clarify the status of personnel undergoing training for employment as Supernumerary Crew, give clear direction regarding the capacity and restrictions of their employment, and formalise the Supernumerary Crew status in an auditable process so as to ensure that associated risk is managed. 1.4.108

f. Ensure that Circus are only employed as Supernumerary Crew on sorties that are directly associated with their primary role and not exposed to potentially hazardous flight profiles, including being in the aircraft for Practice Forced Landings initiated below 1000 ft AGL. 1.4.119

g. Consider the provision of the Royal Air Force Aerobatic Team qualification sorties through an external Hawk T Mk1 Qualified Flying Instructor so as to alleviate additional workload on the Royal Air Force Aerobatic Team aircrew. 1.4.411

h. Comprehensively review RAFAT BowTies to confirm that underpinning evidence is included to ensure that RtL are accurately articulated and that all risk assessments or sanctioning work are accurately documented and retained in an 1.4.434

auditable manner.

i. Review, capture and sentence the risks associated with the flying of Supernumerary Crew/Circus to ensure that there is clear understanding for aircrew, authorizers and supervisors as to the limitations of their employment. 1.4.441

1.5.7. **Officer Commanding the Royal Air Force Aerobatic Team should:**

a. Articulate standard Weight & Moment and Centre of Gravity data for RAFAT aircraft role fits to ensure common understanding of the associated limitations. 1.4.56

b. Generate a more detailed authorization matrix to enable clear understanding of flight details for non-core role sorties when carrying passengers/Supernumerary Crew. 1.4.79

1.5.8. **Officer Commanding Defence Aircrew Publications Squadron should:**

a. Revise the Hawk T Mk1 Aircrew Manual to ensure coherency, accuracy and completeness throughout the publication and with current operating practices. 1.4.468

Intentionally Blank

PART 1.6

Convening Authority Comments

Intentionally Blank

PART 1.6 – CONVENING AUTHORITY COMMENTS

1.6.1. This has been a thorough and well conducted Service Inquiry (SI) which has established the cause of this tragic accident and identified the associated Causal, Contributory and Aggravating factors. I am grateful to the SI Panel for their diligent approach and analysis of the significant volume of evidence and am content that they have met their Terms of Reference. They have produced a comprehensive Report and I agree with the findings and recommendations. Whilst the SI has identified the accident factors that directly relate to this occurrence there are broader themes that are applicable across Defence.

1.6.2. The Royal Air Force Aerobatic Team (RAFAT) is a high profile and extremely well-regarded organisation that has sadly over 8 years experienced 4 major accidents, 3 of which had fatalities. Consequently, it was essential that this SI was mindful of the associated pressures that the investigation could generate. I commend all personnel who have been involved for their focus and application to safely deliver RAFAT's output whilst also supporting the inquiry.

1.6.3. There are a series of themes that the Report discusses, but I will focus my main comments to the most significant issues which are why the accident happened and why the engineer was in the aircraft and did not eject.

1.6.4. XX204 was serviceable, the weather good and the pilot very familiar with the exercise that he was conducting. Although the pilot was current in accordance with the RAFAT Display Directive, the frequency of Practice Forced Landings (including Practice Engine Failures After Take-Off) that he had conducted had distinctly decreased and he had completed very little Continuation Training. Irrespective of experience and ability, all aircrew suffer skill fade if core competencies are not practiced on a regular basis and for XX204's pilot this was potentially exacerbated by the understandable focus that had been placed on training for his primary role.

1.6.5. Constraints such as aircraft availability and poor weather will undoubtably place pressure on any flying organisation to achieve training objectives, especially in such a dynamic environment as RAFAT's. Nevertheless, this accident serves as a reminder that to maintain a baseline of capability it is essential to schedule the practice of core competencies. I agree with the Panel that currency requirements should be reviewed across the Hawk T Mk1 fleets and specifically on RAFAT.

1.6.6. XX204's profile resulted in the aircraft being low, with reduced lateral displacement from the runway on the downwind leg. The subsequent manoeuvring, high angle of bank, rate of descent, and application of g at the minimum glide speed resulted in the aircraft stalling, coincident with the initiation of the go-around, and with insufficient height in which to recover.

1.6.7. It has not been possible to categorically determine why this situation occurred but it resulted from a combination of Human Factors and a lack of Continuation Training. The most significant influence during the sortie was the distraction associated with the Air Traffic Control (ATC) radio transmissions, but this was standard operating procedure and should not be seen as a fault by the ATC controller. When distraction is combined with the likelihood of reduced situation awareness it is possible that the pilot did not recognise the associated hazard of the flight profile that had developed; especially as it was during a period of high workload. Contextually, it is also important to remember the compressed time between events: 3.5 seconds from the end of the radio transmissions to initiation of the go-around and a further 4.3 seconds to the pilot's ejection.

1.6.8. Specialist testing identified that with the Smoke Pod fitted to the aircraft the widely recognised symptom of stall onset, buffet, could be masked. The Aircrew Manual and Hawk Handling Manual are very clear that for an aircraft in the landing configuration if buffet is encountered, then a standard stall recovery is to be carried out. Unfortunately, it has not been possible to confirm if buffet was experienced, and the only definitive indication to the pilot that a stall had occurred was the distinct wing drop. Irrespective, the SI concluded that from the height at which the stall occurred it was not possible for the aircraft to have been recovered.

1.6.9. Analysis indicated that with XX204's rate of descent and flight path angle, the absolute minimum recovery height was 50 ft above the height at which the pilot commenced the go-around, equating to about 0.5 seconds earlier in time. Consequently, it could not be proven what would have happened if the pilot had experienced buffet; however, the lack of an artificial stall warning capability was clearly a Contributory Factor.

1.6.10. The Panel has made recommendations regarding aircraft handling and limitations to improve safety in the low speed, low altitude manoeuvring environment. Despite the Hawk T Mk1 being over 40 years old, and with the current out of service date 11 years away, it is essential that a greater understanding of these factors is gained so as to ensure the aircraft's continued safe operation. Furthermore, it is crucial that the investigation of the incorporation of an artificial stall warning capability is progressed with urgency, especially as RAFAT routinely fly with a smoke pod, given the associated risk of buffet as an indicator, potentially being absent.

1.6.11. Cpl Bayliss was in the aircraft as Supernumerary Crew. Whilst he had completed the directed training there are distinct recommendations to improve the preparation of RAFAT engineers for the airborne role. It is evident that no common training objectives existed for the shakedown sortie and that there were no constraints on the content of the flight. All training should have established aims and an associated syllabus; this ensures common understanding of the requirement and sortie conduct, and also ensures that risks are identified and appropriately managed. The rationale for engineers to be Supernumerary Crew and deliver engineering support away from RAF Scampton is clear. Nevertheless, their employment in such a capacity should only be on sorties that are directly related to their primary role.

1.6.12. This accident occurred during the practice of a core handling exercise for which it was reasonable to assume a successful outcome. The time between the initiation of the go-around and the pilot's ejection was extremely short. The Panel assessed that without a full verbal warning to eject, Cpl Bayliss lacked the knowledge or experience to initiate his own ejection. The Hawk command eject capability can only be operated from the rear cockpit, and when carrying passengers is selected to 'off'. With aircraft commanders in all 3 main Hawk T Mk1 squadrons predominately occupying the front cockpit seat, it is appropriate to assess the feasibility of a command eject capability that could also be initiated from that position. Alternatively, Defence may have to asses if the risks associated with carrying passengers in the rear cockpit of the Hawk T Mk1 are tolerable.

1.6.13. Whilst not directly related to this accident, the Report identifies several other themes that affect Flight Safety. The importance of Quality Assurance, authorization and accuracy of publications, cannot be over emphasised, but in a busy environment it is unsurprising that sometimes such matters require renewed focus, especially in relation to a legacy aircraft.

1.6.14. Though there are a number of specialist units throughout Defence, RAFAT is unique in its position as one of the world's finest aerobatic teams with an associated international reputation. Consequently, there will undoubtably be system and self-induced pressures to deliver and sustain the highest of standards, and although that can be beneficial, it also carries accompanying risk. Even though greater oversight provides a level of mitigation, additional pressure has been generated through the lack of personnel both on RAFAT and in supporting organisations. This is primarily reflected in the engineering cadre, but just as critically, in the Air Safety Management area.

1.6.15. There are intrinsic risks associated with formation aerobatic displays, not only to the Team but also to 2nd and 3rd party personnel at display venues. The primary role related risks are comprehensively articulated in the RAFAT Display Directive; however, greater application is required to understand the detail supporting broader risks. Consequently, it is essential that to ensure the sustained safe delivery of RAFAT the Team is resourced appropriately to meet their task. This is especially apposite when the age of the aircraft and projected out of service date are considered; the ability to proactively identify and manage future risk requires suitably resourced Air Safety staff.

1.6.16. This was a straightforward sortie for which the dual requirement to complete Continuation Training and deliver Circus familiarisation led to Cpl Bayliss being exposed to a flight profile that would not be reasonably expected in his primary role as Supernumerary Crew. Consequently, I believe that this was an avoidable accident where a number of influences combined to culminate in a tragic outcome. Furthermore, this accident serves as a reminder that even highly experienced aircrew can be involved in an accident, and that it may occur on what are relatively routine sorties.

1.6.17. Whilst this was an air accident, the broader effects of resource constraints, pressures and tempo are equally applicable across Defence, irrespective of environment.

1.6.18. On behalf of the Defence Safety Authority I offer my condolences to Cpl Bayliss's family, friends and loved ones.

DG DSA