PART 1.4 – ANALYSIS AND FINDINGS

INTRODUCTION

1.4.1. **Background**. This was a fatal accident, during single seat operations in an aircraft which did not have an in-cockpit voice recorder or video. Additionally the shallow approach angle and high energy of the aircraft resulted in a multiple-impact accident sequence covering 46 000m^2 which was further complicated by the submersion of some evidence within the River Stour. The combination of these events complicated certain forensic aspects of the investigation, and in the absence of the pilot's testimony or any in-cockpit voice/video evidence, the Human Factor (HF) and medical investigations were reliant on a diagnosis by exclusion. Use of the 5M model, as detailed in the MAA Regulatory Publications (MRP), ensured a holistic approach was adopted throughout.[1] As relevant evidence emerged, the Panel systematically closed lines of inquiry, or opened others. The investigation highlighted a number of individual actions, local conditions, risk control measures and organisational influences that were factors in the accident. Any *post factum* inquiry may be at risk of hindsight bias. It is recognised that where a particular course of action is scrutinised, the risks identified by the Service Inquiry (SI) may not have been deemed credible at the time and alternative courses of action may not have been apparent. Despite this, many of the lessons from this accident have an enduring quality and it is in this context that they are highlighted in order to enhance Defence Air Safety and prevent recurrence.

1.4.2. **Accident Factors**. Once an accident factor had been determined it was then assigned to one the following categories:

a. **Cause**. An event which led directly to the accident.

b. **Contributory Factor**. A factor which made the accident more likely.

c. **Aggravating Factor**. A factor which made the outcome worse.

d. **Other Factor**. A factor which was none of the above, but was noteworthy in that it may cause or contribute to future accidents.

e. **Observations**. An issue that was not relevant to the accident but worthy of consideration to promote better working practices.

In simplistic terms the factors can be considered as items that collectively resulted in defensive weaknesses, whereas the cause(s) can be considered to be the trigger(s), on that day, for the resultant accident. For the reasons highlighted in para 1.4.1 there were some aspects of this accident that the Panel had to determine upon the balance of probabilities. When a conclusion was based upon precedence from trends or other data sources the Panel have used the term **probable factor**. When the Panel could not positively exclude a factor this is referred to as a **possible factor**.

1.4.3. **Available Evidence**. In conducting the Inquiry the Panel had access to the following evidence:

a. **Witness Statements**. 57 witness statements were taken from a variety of sources including: eye witnesses, RAFAT personnel, Central Flying School

[1] The 5M model facilitates the systematic identification of hazards by accepting that accidents generally arise from a combination of Human Factors, Technical Factors, Environmental Factors and Managerial Factors. The 5M model refers to this as a Mishap occurs from Man, Machine, Media and Management factors.

(CFS), 22 (Training) (Trg) Group (Gp), the Hawk T Mk1 Support Authority (SA), RAF Centre of Aviation Medicine (CAM), previous RAFAT pilots, Military Aviation Authority (MAA) subject matter experts (SMEs), Hawk T Mk1 SMEs and SMEs from other aircraft types. In the addition to this, the Panel received numerous witness statements from members of the public. While it was not possible to personally respond to those who provided evidence, each item was considered during the inquiry process.

b. **Electronic Data**. The following electronic data was available for exploitation: Air Data Recorder (ADR) files from all 9 aircraft; external video of break manoeuvre, crash site video, 2 in-cockpit videos (XX266 and XX308), eye witness photographs, emergency services photographs, and digital audio of ATC transmissions from BIA.

c. **Documentary Evidence and Formal Reports**. The Panel reviewed and considered 52 formal reports and policy/regulatory documents during the Inquiry process. At the time of the accident the transition was being made between the Military Aircraft Regulatory Document Set (MARDS) and the Military Regulatory Publication (MRP). Where MRP regulatory articles are referenced, these have been cross checked with MARDS to ensure consistency.

d. **Qualitative Assessment using Hawk T Mk1 Simulator**. To validate some aspects of aerodynamic modelling the Hawk T Mk1 simulator was used. Pilot's comments and performance were used to assist qualitative judgement.

1.4.4. **Unavailable Evidence**. The following evidence was not available to the Panel:

a. The aircraft's GPS was too badly damaged to exploit the data storage.

b. Owing to the nature of the crash sequence, it was not possible to collect all of the aircraft's structure and some smaller items were assessed to have been buried within the fields or within the River Stour. The largest unrecovered item was the aircraft nose leg which was assessed to be buried in the riverbed.

1.4.5. **Services**. The Panel was assisted by the following personnel and agencies:

a. MilAAIB.

b. RAF Centre of Aviation Medicine (CAM).

c. BAE Systems.

d. Rolls Royce.

e. Honeywell Aerospace Yeovil.

f. QinetiQ.

g. Empire Test Pilot School.

h. 1710 Naval Air Squadron (NAS).

i. Defence Infrastructure Organisation.

STRUCTURE OF THE ANALYSIS AND FINDINGS

1.4.6. The analysis and findings are grouped under the following headings:

a. Pre-break events.

b. Analysis of the break.

c. Human factors and medical considerations.

d. Engineering and technical considerations.

e. G-induced impairment.

f. G protection measures.

g. Left/Right break procedures.

h. Survivability considerations.

i. Risk management.

j. Occurrence and fault reporting.

k. Generic RAFAT operations, processes and structure.

l. Post crash management.

PRE-BREAK EVENTS

1.4.7. **Pilot Background**. The pilot of XX179 had been assessed as high/above average throughout his RAF career. Having been selected for instructional duties immediately after training, he completed a tour as a Hawk T Mk1 Qualified Flying Instructor (QFI) to an Above Average standard, prior to conducting tactical weapons training and being selected to fly the Harrier GR9. A High Average performance on the Harrier Operational Conversion Unit (OCU) was followed by a frontline tour on IV Sqn and then a brief instructional tour on the Harrier OCU. The pilot left the Harrier Force in Aug 10, as an above average front line pilot and QFI. Table 1 summarises the pilot's military flying background. The RAFAT set stringent minimum experience and ability requirements for all applicants to the team and the pilot of XX179 had met these in all respects. He had been subject to a demanding selection procedure and extensive work up training. The Panel **observed** that the formal record of training had ceased after the team arrived in Cyprus for the pre-2011 season work up. Although the pilot had not received an annual report, a draft copy indicated he had made an outstanding start to his RAFAT tour. At the time of the accident the pilot had flown 65 displays since Public Display Authority (PDA) was granted on 19 May 11, and was current for flying duties in all respects. Analysis of the pilot's flying record, the RAFAT selection procedure, the RAFAT work up training and the pilot's currency statistics indicated that the pilot of XX179 had an excellent record of service and had completed appropriate training for the duties he was tasked to undertake. The Panel concluded that:

Exhibit 20
Witness1-2
Exhibit 3
Exhibit 21
Exhibit 24
Exhibit 25
Exhibit 106

a. The RAFAT should have maintained a formal training record, at all times, during the pilot's work up training. However, this was **not a factor** in the accident

b. The pilot was suitably qualified and experienced for RAFAT duties and that this was **not a factor** in this accident.

Table 1 – The Pilot's Military Flying Background

Year (a)	Type (b)	Sqn (c)	Hours (nearest 5) (d)	Qualifications (e)	Assessment (f)
97-99	Bulldog	SUAS	105	Student Pilot	High Average
01-02	Tucano	2 Sqn (Linton)	150	Student Pilot	High Average
02	Hawk T Mk1	208 Sqn	75	Student Pilot	High Average
03-05	Hawk T Mk1	208 Sqn	1040	A2 QFI	Above Average
06	Hawk TMk1	19 Sqn	50	Student Pilot	High Average
06	Hawk TMk1	208 Sqn	55	A2 QFI	N/A waiting for OCU
06-07	Harrier GR9	20(R) Sqn	210	Student	High Average
08-10	Harrier GR9	IV(AC) Sqn	260	Sqn QFI, 4s Leader, ACL	Above Average
10	Harrier GR9	IV(R) Sqn	10	Sqn QFI, 4s Leader, ACL	Above Average
10-11	Hawk TMk1	RAFAT	260	RAFAT Pilot	
Totals	N/A		2220	N/A	

1.4.8. **Aircraft History**. XX179 was a BAE Systems Hawk T Mk1 under the Aircraft Operating Authority (AOA) of 22(Trg) Gp. Post-accident, all engineering documentation, including historical archived documentation, was impounded. The documentation was audited to confirm that: engineering components were within stipulated life limits; the schedule of maintenance completed was correct; and that engineering standards had been adhered to. XX179 had flown 8996.35 airframe hrs and was 265.05 airframe hrs away from its next scheduled 'Major' service. The aircraft had recently undergone a 'Minor Star' servicing which was completed 61.20 flying hrs prior to the launch of the accident sortie. All engineering components were found to be within the stipulated flying hours or calendar life window of serviceability and the schedule of engineering maintenance was correct. Several administrative anomalies were noted with the engineering documentation but these were not related to the accident and will be discussed later in para 1.4.41. No serviceability issues had been reported during or following the previous day's sortie. XX179 had been prepared for solo flight with a before flight (B/F) servicing completed at 1100 on 20 Aug 11. The pilot signed for XX179 at 1200 on 20 Aug 11 and he did not report any serviceability issues at any time during the sortie. XX179's engineering documentation was reviewed for tail number specific failure trends; none was identified. The Panel concluded that: Exhibit 102 Witness 14 Witness 41

a. Pre-flight servicing was **not a factor** in this accident.

b. XX179 specific failure/fault trends were **not a factor** in this accident.

c. The pilot had not indicated any serviceability issues in flight.

1.4.9. **Previous 24 Hours**. The narrative for the previous 24 hours was given at para 1.3.3. The Panel noted that the PR event at Bournemouth Pier had been programmed to commence 70 minutes after a planned take off from Newquay. This would have been a demanding timeline and on inspection of the authorisation sheets, while all the pilots had signed the aircraft in, no one had noted that the take off and landing columns had not been completed. The Panel concluded that while the Bournemouth Pier PR programme was unrealistic, the previous 24 hours of activity conformed to extant crew duty regulations and was **not a factor** in the accident. Physiological factors over the previous 24 hours are covered later in para 1.4.60. Wider aspects of PR will be discussed under workload at para 1.4.85. Exhibit 28 Exhibit 22

1.4.10. **Sortie Planning, Preparation, Brief, Authorisation and Supervision**. The display and fly pasts had been tasked by the RAF Events Team. The sortie briefing, authorisation and supervision was conducted by OC RAFAT, who was acting within his delegated powers of authorisation, and all aspects of the pre-sortie preparation were considered normal by team pilots. The Panel concluded that all RAFAT personnel were acting in accordance with their duties at the time of the accident and that RAFAT immediate pre-flight preparation, authorisation and supervision was **not a factor** in this accident. Exhibit 5 Exhibit 6 Exhibit 4

1.4.11. **Display, Flypasts and Recovery.** The narrative of the display, flypast and recovery is given at para 1.3.5 and 1.3.6. The sortie followed expectations from the pre-flight brief. No unusual occurrences were reported by any member of the RAFAT during flight and no anomalies were reported during subsequent interviews. The Panel concluded that every aspect of the display, flypasts and recovery appeared normal until after the break to land was initiated and sortie events prior to the break were **not a factor** in this accident. Exhibit 1 Witness 1-1 Witness 3 Witness 8

1.4.12. **Weather/Environmental**. The recovery weather conditions were excellent with visibility in excess of 10km, minimal cloud, a light south-easterly wind and a high summer sun.[2] Other RAFAT pilots considered the conditions to be ideal and the Panel concluded that weather/environmental conditions were **not a factor** in this accident. Exhibit 29 Annex C

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[2] Official recorded cloud from aerodrome observation was 1-2 Octas at 1200ft and the exact wind was 150°/4kts.

ANALYSIS OF THE BREAK

1.4.13. **ADR Background**. Prior to determining the cause of the accident, and any associated factors, the Panel had to determine the point that appeared to be the local trigger. In determining this, the Panel relied heavily upon aircraft ADR data. Although XX179's ADR had been calibrated in accordance with extant engineering procedures, the ADR manufacturer considered that a poorly carried out ground calibration would destroy confidence and could prevent the data from being used by a Service Inquiry. Conscious of the ADR's importance, the Panel elected to have independent data validity checks conducted by QinetiQ and BAE Systems. To complete this task a comparative analysis was conducted, during aerobatic formation flying, with the ADR from XX266. This analysis concluded that the magnitudes, rates and directions of the ADR parameters recorded in XX179 were consistent with those recorded by XX266, giving a high confidence level that the XX179 ADR was working correctly and recording parameters were within the limitations of the ADR design. A second independent assessment of control inputs against aircraft responses was completed using the Hawk T Mk1, 6 Degrees of Freedom (6DOF) aerodynamic model as a truth datum. This analysis concluded that the XX179 response to tail plane, aileron and rudder inputs, as defined by the ADR, was at all times consistent with that expected for a Hawk T Mk1. Based upon these independent assessments, the Panel concluded that XX179's ADR was acceptable for detailed analysis during the Inquiry. The XX179 ADR trace was analysed and compared with 3 other 'Left/Right' breaks flown by the accident pilot on previous sorties, and with the ADR traces of the 'Left/Right' break flown by other RAFAT pilots. The words 'normal/abnormal' are used in this report to indicate comparison with previous data of the accident pilot's breaks and 'typical/atypical' when relating to comparisons with breaks flown by other RAFAT pilots.

Annex M
Annex G
Annex I
Exhibit 33

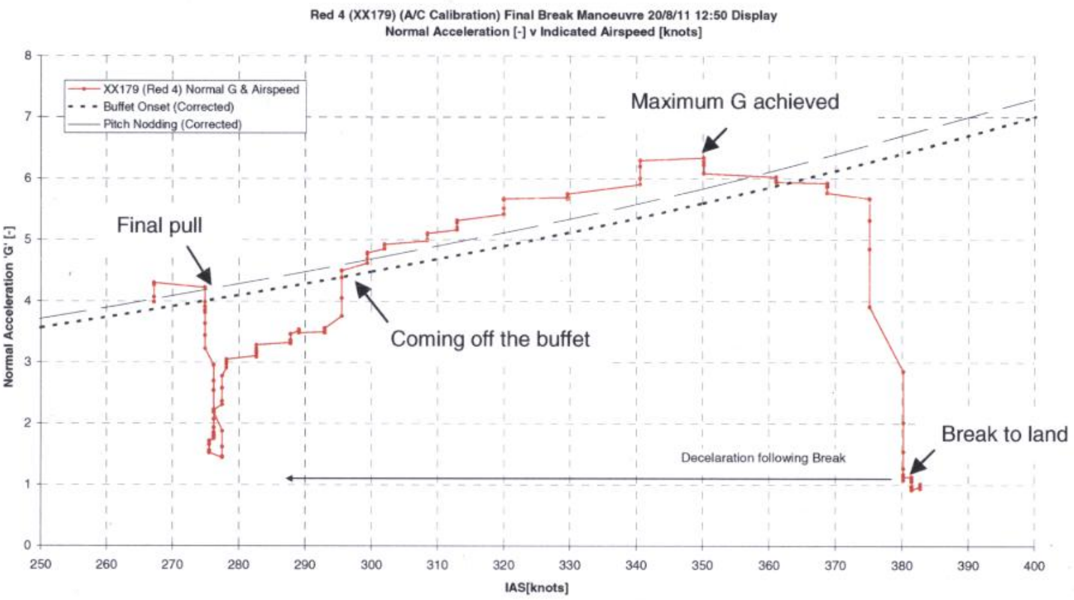
1.4.14. **ADR Trace Analysis**. The pilot's break manoeuvre was commenced with a roll to 75° of right bank and a rapid pull, with a peak G onset rate of 6.9 G/sec, to 6.3G. The throttle was selected to idle and the airbrake extended. For the subsequent 5 seconds the pilot's control inputs, and the resultant flight profile, were normal and typical of previous breaks albeit at the high end of G, G onset rate, pitch attitude and bank angle. At break +5 seconds the pilot's control strategy appeared to become abnormal in that his control inputs and their frequency were reduced. A further anomaly appeared at break +6 seconds when the pitch attitude stabilised unusually low, at 2° nose down, and one second later an abnormal/atypical throttle movement was observed, which would have given a theoretical engine RPM of 77% (±3%). At this point abnormalities continued as nose down pitch attitude increased followed by a gradual but progressive overbank to the right. By break +11.5 seconds, the combination of increasing pitch and bank resulted in an abnormal/atypical aircraft attitude of approximately 16° nose down and 95° right wing low. The aircraft was now at an estimated 250 feet above the ground in what should have appeared, in the opinion of the Panel, to be a very abnormal and uncomfortable position for the pilot. At this point, synchronised video evidence indicated that the pilot of XX266 transmitted a warning of "4 check height". Almost coincident with this warning, at break + 11.5 seconds, a rapid aft and left stick input (half of full deflection) was demanded and the nose down pitch angle and right bank angle started to reduce; however, the aircraft continued to descend. With the airbrake remaining extended and the airspeed at approximately 275 KIAS, the G level peaked at +4.25G which resulted in XX179 being very close to, if not in, the accelerated stall boundary just before the end of trace. From initiation of the pilot's break to the end of the trace was approximately 14.5 seconds.

Annex M
Annex G
Annex F
Exhibit 1
Exhibit 112

1.4.15. **Discussion on ADR Trace Analysis**. ADR data trace analysis indicated there had been a continual, aft, control column demand throughout the break manoeuvre, with modelling suggesting the pull force required was approximately 10daN at the beginning of the manoeuvre, and approximately 4daN immediately prior to the rapid control inputs observed at break +11.5 seconds. Although this suggested the pilot was consciously controlling the aircraft, close comparison with previous breaks indicated abnormalities. For example, the abnormal control strategy and abnormal/atypical flight path. Additionally, the abnormal/atypical throttle input should never be required during this part of a break to land. Annex M Annex G Annex F

1.4.16. **Lift Boundaries**. The Hawk T Mk1 has a very clear lift buffet boundary which provides good warning of the stall. Hawk T Mk1 pilots use this boundary as an easily identifiable method of ensuring that the aircraft is flown to its maximum performance capability, while simultaneously increasing drag to reduce speed. An extended airbrake also increases airframe vibration, but the difference between airbrake buffet and lift buffet is unambiguous. In layman's terms, flying in lift buffet is not dissimilar to driving a car over a cobbled surface; it is obvious when you do so. To assess the pilot's level of situational awareness, the Panel analysed the ADR Gz trace against the Hawk T Mk1 theoretical lift boundaries as shown at Figure 1. Normal and typical breaks see the aircraft remaining in the buffet until the aircraft is downwind. The comparison with theoretical lift boundaries indicated that XX179 was flying in buffet from shortly after the break commenced until the speed reached 296 KIAS (approximately halfway around the turn). This equated to break +5.5 seconds and broadly coincided with the commencement of abnormalities in the control strategy. Exhibit 7 Exhibit 8 Witness 44 Annex M

Figure 1 – Comparison of XX179 G trace with Theoretical Lift Boundaries Normal Acceleration vs Indicated Airspeed [knots]



1.4.17. **ADR Analysis Conclusions**. The Panel concluded that:

a. The likely trigger point in this accident occurred approximately 5 seconds after initiation of the Left/Right break, after which the pilot's control strategy became abnormal and the flight path became abnormal/atypical.

b. Under normal circumstances, the pilot would have been aware that he was no longer flying in buffet approximately 5 seconds after the break commenced.

c. The resultant flight profile was extremely unusual and, under normal circumstances, this would have been obvious to the pilot.

HUMAN FACTORS AND MEDICAL CONSIDERATIONS

1.4.18. **General**. From a human factors (HF) and medical perspective, 4 possibilities were considered when determining why the aircraft deviated from the expected flight path to ground impact. These were pilot disorientation, pilot distraction, a deliberate act or pilot incapacitation.

a. **Pilot Disorientation**. The Left/Right break is a visually flown manoeuvre requiring minimal reference to cockpit instruments. With the exception of an occasional cross check of the altimeter, and possibly speed, the pilot's primary reference for spatial orientation would have been the actual horizon and external ground features. Visibility was greater than 10km with a clearly defined horizon and good discrimination of terrain and obstacles. Indeed the environmental conditions during the recovery were later assessed as ideal by other RAFAT pilots who flew the manoeuvre. The pilot of XX179 was a very experienced, above average pilot who had flown breaks to land, on an almost daily basis, since commencing fast jet pilot training. The procedure was not new to him, it was not unusual to him and he flew the manoeuvre regularly. Furthermore, having operated from BIA since 17 Aug 11, he was familiar with the local area. The Panel concluded that while it could not be conclusively ruled out, it was highly likely that pilot disorientation was **not a factor** in this accident. (Annex C, Exhibit 22, Exhibit 25, Witness 44)

b. **Pilot Distraction**. ADR evidence indicated that no Red central warning panel (CWP) caption had illuminated during flight. The ADR does not record Amber captions and it is possible that an Amber caption may have illuminated during the break. However, such a warning would be relatively minor in nature and, had an Amber caption illuminated, it would not have been likely to distract the pilot from his primary task of flying the aircraft. While the Panel could not discount distraction by a loose article, this would need to have lasted for approximately 6 seconds which was the elapsed time from commencement of an apparently abnormal control strategy until an apparent attempt of recovery. With respect to external distractions, only RAFAT aircraft were in the BIA visual circuit at the time of the accident with normal spacing from each other. There were no major ground events reported in the vicinity; and no other pilot reported any external distractions. When considering the possibility of physiological distractions the Panel noted that the pilot had self-medicated ibuprofen in response to back pain on the morning of the accident. However, medical opinion suggested that the side effects of such a drug would not have affected his ability to undertake the flying task; other effects of a recurrence of pain are discussed in para 1.4.60. With the exception of back pain, the pilot had not reported feeling unwell and the post-mortem examination revealed no evidence of a pre-existing medical condition. In the absence of the pilot's testimony the Panel can never truly ascertain if distraction was a causal factor, however, the Panel considered it unlikely for an experienced and capable pilot to become so distracted, on the break to land, as to result in controlled flight into terrain. The Panel concluded that while it could not be conclusively ruled out, it was highly likely that pilot distraction was **not a factor** in this accident. (Annex L, Witness 1-1, Annex C, Exhibit 1, Annex A)

c. **Deliberate Act**. The pilot of XX179 had been making long-term plans both at home and at work and there were no poor wellbeing factors either in the weeks preceding the accident or on the day. The Panel concluded that deliberate action by the pilot was **not a factor** in this accident. (Annex C)

d. **Pilot Incapacitation**. The pilot held a current medical employment standard which was appropriate for duties as a fast jet pilot and the post-mortem examination revealed no evidence of a pre-existing medical condition. Other causes of sudden incapacitation, including abnormalities of the heart rhythm or electrical abnormalities in the brain would not necessarily leave post-mortem evidence, but there was nothing in his medical history to raise the likelihood of such events. Post-mortem toxicology results also indicated that there was no evidence of drugs present in the body and alcohol levels were consistent with post-mortem production rather than ante-mortem ingestion. Additionally, there was no evidence of exposure to carbon monoxide. The deviation from the aircraft's expected flight path shortly after exposure to high G raised the possibility that the pilot was subject to G-induced impairment. G-induced impairment would not be expected to produce any characteristic or specific pathological findings, but there was nothing in the post-mortem that was inconsistent with it. The Panel concluded that pilot incapacitation resulting from G-induced impairment was a **possible cause** of the accident, and this will be discussed in greater detail later in the report. Annex A

1.4.19. **G-induced Impairment Diagnosis.** After any fatal accident, a diagnosis of G-induced impairment can only be made by exclusion. Hence, all the non-medical, technical, engineering and HF possible causes of the accident need to be eliminated before a diagnosis of G-induced impairment could be made. Annex A

ENGINEERING AND TECHNICAL CONSIDERATIONS

1.4.20. **General**. XX179 had flown twice on 19 Aug 11 with no reported serviceability issues and no faults noted during that day's after flight servicing or the before flight servicing on 20 Aug 11. Additionally, during the accident sortie, no serviceability issues were reported by the pilot. The crash sequence involved multiple impacts, as described in Part 1.3.10, with some wreckage being recovered from the River Stour. Whilst this made forensic evidence analysis more difficult, where at all possible, all items recovered were subjected to detailed assessment and/or testing using a variety of sources including design authorities, engineering authorities and specialist governmental/MOD agencies. When engineering components were sent away for examination the process was observed by MilAAIB engineering investigators. This section will summarise the engineering investigation and cover the following areas: major systems; instruments and communication systems; life support systems, escape systems, aircrew equipment assemblies and documentation. Figure 2, taken after the recovery of XX179 to MOD Boscombe Down, highlights the complexities of the engineering investigation task. Exhibit 102

Figure 2 – XX179 lay out in MOD Boscombe Down as part of the engineering investigation.

MAJOR SYSTEMS

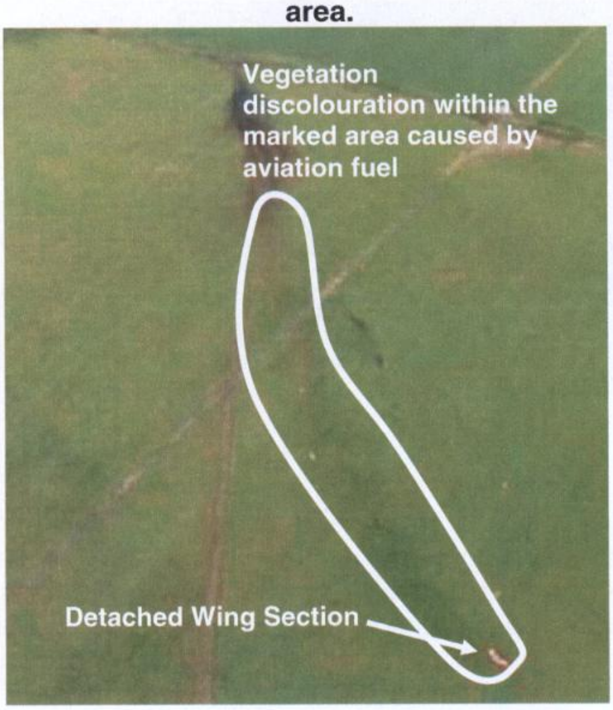
1.4.21. **Engine And Fuel Systems.** With the wreckage *in situ,* examination of the compressor blades indicated relatively minor damage, with the ingestion of mud and foliage being consistent with an engine that had been powered during the crash sequence; see Figure 3. The engine was recovered, still attached to the fuselage, and taken to MOD Boscombe Down where a design authority air safety investigator inspected the engine prior to its removal and transfer for a detailed strip and analysis. The detailed strip and analysis indicated evidence of bird ingestion, although ADR engine data suggested that this had not occurred airborne and the characteristics of the mechanical damage to the LP and HP compressor corroborated this assessment. Furthermore DNA analysis of bird remnants was consistent with a bird carcass found in the vicinity of the river bank. The cabin air supply system was intact, up to the engine to aircraft interface, with further mud ingestion corroborating the initial assessment that the engine was operating during the crash sequence. No evidence of cabin air contamination was found. Engine wear analysis was conducted using magnetic probe samples taken from the internal gearbox, HP and LP turbines, and the high speed and external gearbox. The wear analysis results were found to be normal. Figure 4, shows the extent of fuel contamination at the crash site which indicated that fuel remained in the aircraft at impact. Aviation fuel and engine oil samples were analysed, with each sample being consistent with its reference type. There was no evidence of adulteration of the samples with any other petroleum, oil, lubricant (POL) type

Annex K
Annex E
Annex L
Witness 16
Annex O
Exhibit 19

materials. Additionally, no significant degradation in the overall quality of the fluids was evident. In addition to the detailed engine examination, the ADR trace analysis revealed no engine anomalies. The Panel concluded that the engine and fuel system were **not a factor** in the accident.

Figure 3 – The forward face of the compressor as viewed through the left hand air intake.

Figure 4 – Ground discolouration, caused by aviation fuel, shown within the marked area.



1.4.22 **Flying Controls**. The damage to XX179's control rods, powered flight control units (PFCUs) and control surfaces was inspected by several SMEs, who independently concluded that all failures were consistent with post-impact overload; an example of failure is shown at Figure 5. The PFCUs were also subject to functional testing and the results indicated that these units were all serviceable prior to impact. As part of the investigation it was noted that a servicing error had occurred following the incorrect placing of a washer on a PFCU connection; however, this had not affected functionality. This servicing error will be discussed in further detail at para 1.4.88. The SI Panel concluded that the integrity of the flying control system and control surfaces was **not a factor** in the accident. Annex L Annex H

Figure 5 – Typical example of XX179's damaged control rods post accident.

1.4.23. **Electrical Systems**. Due to significant damage, see Figure 6, it was not possible to conduct functional testing of the electrical systems. However, ADR analysis indicated there were no major unserviceabilities of the electrical systems during flight. Radio transmissions, DAU and ADR functionality, anti-collision lights and the aircraft nose light were observed to be operating correctly, which all indicated that power was being supplied to the essential services busbar up until the point of ground impact. The Panel concluded that, with no contradictory evidence, the aircraft electrical system was serviceable until impact, and was therefore **not a factor** in the accident.

Annex L
Witness 29
Exhibit 1

Figure 6 – Damaged electrical components.

1.4.24. **Hydraulic System**. Like the electrical system, the hydraulic system was severely damaged during the crash sequence. However, the ADR trace indicated that there had not been any major hydraulic failure and this was corroborated by the emergency hydraulic ram air turbine which remained stowed. A visual inspection of the wreckage suggested all damage to the hydraulic system was consistent with a high

Annex L

energy impact. Sufficient hydraulic fluid was collected to enable forensic analysis, which indicated that the sample was consistent with its reference type. The Panel concluded that the hydraulic system was serviceable until ground impact and was therefore **not a factor** in the accident.

1.4.25. **Undercarriage**. XX179 was found with the nose wheel and left hand main wheel detached from the fuselage and wing structure. The right hand main wheel was found in the retracted position, as shown in Figure 7, with the lock engaged. The aircraft ADR indicated that the undercarriage was up and this was corroborated by eye witness accounts. It was concluded that the undercarriage was retracted at impact and was therefore **not a factor** in the accident. Annex L Annex H

Figure 7 – Underside of wing with right hand main wheel in the retracted position.

INSTRUMENTS AND COMMUNICATIONS

1.4.26. **Cockpit Instruments**. The river bank tree impact, discussed in para 1.3.10, resulted in significant damage to the front and rear cockpits, see Figures 8 and 9 below. The impact damage, coupled with the fact that the front cockpit instrument panel was submerged in the River Stour, resulted in an inability to conduct any functional testing for the majority of the instruments. The only instruments assessed as suitable for detailed forensic testing were the airbrake indicator, the standby attitude indicator and the main altimeter. The results of the forensic analysis were inconclusive due to the severe damage that had occurred. The Panel noted, from a review of the Air Safety Information Management System (ASIMS), that a trend of failures within the Attitude and Heading Reference Systems (AHRS) had affected the Hawk fleet. The implication of an insidious failure of the AHRS whilst the aircraft is being flown solo and under Instrument Metrological Conditions (IMC) is potentially significant and could ultimately lead to inadvertent controlled flight into terrain. Considering the experience level of the pilot, the weather conditions and the fact that the break was a visually flown manoeuvre, the Panel concluded that it was unlikely that an AHRS failure would have led to an inadvertent controlled flight into terrain. Due to the nature of the visually flown manoeuvre, the Panel concluded that instrument failure was **not a factor** in this accident. Annex L Exhibit 78 Annex C Witness 8-1

Figure 8 – General view of the front and left hand side of the fuselage structure.

Figure 9 – Front cockpit centre instrument Panel.

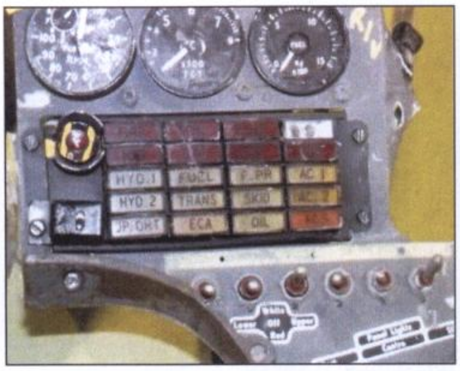
1.4.27. **Communications System**. Due to significant damage and submersion in water, XX179's communications system was assessed as unfit for further testing. The pilot had maintained successful communications throughout the accident sortie, including a transmission approximately 16 seconds prior to impact and an apparent reaction to a warning call 3.5 seconds prior to impact. The Panel concluded that, at least, the main radio system was serviceable at impact and **not a factor** in the accident.

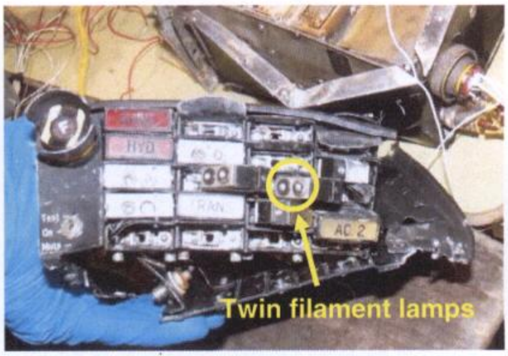
Annex L
Exhibit 1
Witness 2-1

1.4.28. **Central Warning System**. The central warning system (CWS) provides the pilot with automated warning of system failures that require prompt action. The CWS comprises a Central Warning Panel (CWP) and 2 'attention-getter' lights in each cockpit which are powered from the essential services busbar. The CWP distinguishes between major and minor malfunctions using coloured, twin filament, warning lights; the former illuminating a Red caption which is backed by an audio warning and the latter illuminating an Amber caption with no audio. In both cases any CWP illumination will be visually backed by flashing attention-getters. An illumination of any Red captions will be recorded on the ADR. The front and rear cockpit CWPs, shown at Figure 10, were removed from the wreckage together with the only remaining 'attention-getter'. In some situations, filament failure characteristics can provide an indication of whether a lamp was illuminated at the point of impact so XX179's CWP lamps were sent for filament and glass analysis.

Annex L
Annex C

Figure 10 – Front (left picture) and rear (right picture) CWP.





Out of the 64 lamps examined, 16 of the lamps were found to be potentially illuminated at the time of impact. However, due to conflicting evidence between either twin lamps on the same caption or counterpart lamps on the other CWP, the analysis has shown the results to be inconclusive. In addition to the filament and glass analysis, and with the exception of the pre-flight test sequence, the ADR indicated that no Red CWP captions had been illuminated during the sortie. The significance of a possible Amber caption illuminating has been discussed at para 1.4.18.b. The Panel concluded that there was nothing in the CWP bulb analysis that contradicted the results of other engineering forensic investigation.

LIFE SUPPORT SYSTEMS

1.4.29. **Oxygen System**. Evidence suggested that the Personal Equipment Connector (PEC) assemblies had been correctly seated prior to impact and disconnection witness marks were consistent with the crash sequence. During post accident testing, the oxygen regulator did not conform to its design specifications but this was considered to be attributable to impact damage. The oxygen supply charging bottles used on XX179 were tested. The results were found to be within moisture limits and no gaseous contamination was present. The Panel concluded that the aircraft oxygen system was serviceable prior to impact and that the gaseous oxygen supply used to charge the aircraft bottles was within specified limits and free from contamination. XX179's oxygen system was therefore **not a factor** in the accident.

Exhibit 74
Exhibit 75
Annex L

1.4.30. **Cockpit Conditioning**. High pressure engine compressor air passes through an air filter, prior to feeding the cabin conditioning system. This filter was subjected to forensic analysis to ascertain whether any contamination may have entered the cockpit. The results from the analysis indicated that there were no anomalies in the cabin air supply and, as previously stated in para 1.4.21, this corroborates an independent assessment conducted on the engine air supply system. The SI Panel concluded that the air supply to the cockpit was normal prior to impact and **not a factor** in the accident.

Annex K
Annex L

1.4.31. **Anti-G System**. The Hawk T Mk1 anti-G system provides a controlled supply of air to each cockpit, via anti-G valves (AGV), to inflate the pilots' anti-G trousers. Both the forward and rear AGVs were sent for forensic examination and functional testing.

Annex L

1.4.32. **Rear Anti-G Valve**. The rear seat from XX179 had been prepared for solo flight, which requires the AGV to be in the off (rear) position; however the rear AGV lever was found in the on (forward) position. Due to the crash sequence it was not possible to state the position of the lever at impact. However, even if the rear AGV had been in the on position, this would not have affected the performance of the front cockpit anti-G system. There was no significant damage to the rear AGV and the component was assessed as fully serviceable when tested. Annex L Witness 14 Witness 41

1.4.33. **Forward Anti-G Valve**. The front AGV ended up on the outside of the fuselage during the impact sequence and it was only the connecting pipe work that was holding it in the position as shown at Figure 11. The AGV had been subject to significant impact damage with the stop valve lever being ripped off whilst it was assessed to be in the mid-position. As with the rear cockpit, it was not possible to determine the lever's position at impact. However with both levers being found in abnormal positions the Panel concluded it was likely that they had been moved during the crash sequence. Corrosion product was identified within the inlet filter of the front AGV and some trace was also identified within the stop-valve. There was also evidence that the stop-valve and inner AGV had rubbed against each other during the service history of the component; however, there was no evidence to indicate that the rubbing caused the stop-valve to stick. Notwithstanding minor corrosion and indication of internal rubbing, testing of the forward cockpit AGV indicated that it was serviceable. Moreover, given the location of the AGV selection lever in the front cockpit, it was deemed highly unlikely that it could have been disturbed from the on position during flight. It was therefore considered likely that the AGV was fully functional prior to the ground impact and was **not a factor** in this accident. Annex L

Figure 11 – Fuselage wreckage with the front AGV still attached to the pipe work

1.4.34. **Anti-G Valve Serviceability Trends**. Witness evidence identified that RAFAT pilots had experienced AGV unserviceability during a pre-season deployment overseas. The unserviceabilities resulted in anti-G trousers being slow, or failing to inflate or deflate. Subsequent evidence indentified that a total of 19 RAFAT occurrences of AGV unserviceabilities had occurred over a 17 month period. Reviewing fleet wide data, a total of 51 occurrences of AGV unserviceabilities had occurred across the Hawk fleet over a 9 month period. None of these occurrences appeared to have been reported via ASIMS or the engineering fault reporting chain; the wider issue associated with the failure to fault report and/or occurrence report will be discussed in para 1.4.76 to 1.4.82. The Panel concluded that:

Witness 20-1
Exhibit 61
Exhibit 62
Annex L

a. With both AGVs having been tested as serviceable the AGVs were **not a factor** in the accident

b. There was a wider issue of Hawk anti-G system serviceability and this was considered to be an **other factor**.

ESCAPE SYSTEMS

1.4.35. **General**. The escape system pin stowage unit was observed with the escape system pins correctly stowed for flight. The canopy had suffered major damage; however, the miniature detonation cord (MDC) had not fired and the canopy was assessed to have shattered under impact forces.

Annex L
Annex A

1.4.36. **Front Cockpit Ejection Seat**. The front seat pan sustained major impact damage. The seat pan firing handle assembly remained fully stowed, although one side of the flexible handle had sheared from its attachment. The firing handle assembly was connected to the firing sear which was resting in the firing pin housing; the cartridge had not fired. With the seat pan firing handle assembly and housing removed from the wreckage, a pull-off test was conducted and the unit was within the required tolerance limit. The Panel concluded that the front cockpit escape system was serviceable at impact and that no attempt had been made to initiate ejection.

Annex A
Witness 2-1

1.4.37. **Rear Cockpit Ejection Seat**. The aircraft documentation indicated that the rear cockpit had been prepared for solo flight. This was confirmed by 2 RAFAT engineers who had been responsible for the final aircraft checks on XX179 during the see-off procedure. As with the front seat, the rear seat had sustained major impact damage. Although the drogue gun cartridge, remote rocket initiator cartridge, rocket motor and the barostatic time release unit cartridge had fired, this was assessed to be the result of impact forces. The rear seat pan firing handle was still in its housing and still had its safety pin fitted, the seat pan cartridge had not fired. The Panel concluded that the rear cockpit escape system was serviceable at impact.

Annex A
Witness 14
Witness 41

AIRCREW EQUIPMENT ASSEMBLIES (AEA)

1.4.38. **General**. The pilot's AEA was significantly damaged in the accident and only limited forensic testing could be undertaken. An audit of AEA equipment and documentation indicated that all equipment had been serviced in accordance with extant procedures and this servicing was in date. With the exception of the pilot's Anti-G trousers, which will be discussed in detail in para 1.4.39, the Panel considered that AEA was **not a factor** in the accident.

Annex A

1.4.39. **Anti-G Trousers Observations and Analysis**. The accident pilot was wearing Mk4 five bladder anti-G trousers which were last serviced, in accordance with extant air publications, 26 days prior to the accident with the next scheduled maintenance not due until 7 Nov 11. During the sortie, the pilot had not reported any unserviceability with his anti-G system; evidence from other RAFAT pilots indicated that such unserviceabilities were normally relayed to the formation leader by radio. This opinion was supported by video evidence of another RAFAT pilot relaying intercom and radio problems immediately prior to the recovery to BIA. The aircraft portion of the PEC was recovered from the wreckage, but the man portion, together with its anti-G connector and the lower segment of the inflation hose, were not. Reviewing occurrence reporting from Jan 2000 onwards, there had been a single instance of Hawk G trousers failing in flight following the detachment of the inflation hose from the stomach bladder. However, the inflation hose and its connection with the anti-G trousers' bladder and extension connector appeared intact, with the connection seals air-tight. The remainder of the trousers were extensively damaged. Examination of teeth damage to the thigh zips indicated they were not fully done up. Medical opinion suggested that as long as the lacing cords were fitted appropriately it was considered unlikely that the partially opened zips would have had a significant effect on G tolerance. The Panel concluded that the pilot's G trousers had been serviced in accordance with extant air publications and no radio calls were made to highlight any issues with the accident pilot's protective anti-G systems. The Panel noted the medical opinion, but determined that the anti-G trousers were designed to be worn with the zips fully secured. Therefore, the Panel concluded this may have resulted in a partial reduction to the anti-G trousers effectiveness which is considered to be **a possible contributory factor** in the accident.

Annex A
Annex R
Witness 1-1
Exhibit 1
Exhibit 76

DOCUMENTATION

1.4.40. **Engineering Documentation Overview**. Engineering documentation, including historical archived documents, relevant to XX179, its AAES and AEA was impounded as part of the post crash management process. The documentation was audited to confirm that engineering components were within stipulated life limits, the schedule of maintenance completed was correct and that engineering standards had been adhered to. The RAFAT engineering personnel manage a monthly schedule of Internal Quality Audit checks on all aircraft documentation which is designed to identify mistakes and maintain RAFAT standards.

Exhibit 69
Annex Q
Annex R
Exhibit 102

1.4.41. **Engineering Documentation Audit**. The following provides a summary of the engineering documentation audit:

Exhibit 69
Annex Q
Annex R
Exhibit 102
Exhibit 77
Exhibit 105
Exhibit 108

a. **Component Life**. All engineering components were found to be within the stipulated flying hours or calendar life window of serviceability.

b. **Schedule of Engineering Maintenance**. No anomalies were found with XX179's schedule of engineering maintenance. Discrepancies were identified, but these were not specific to XX179. While the MAA had identified that maintenance work had been completed on the Hawk T Mk1 fleet by a non-Maintenance Approved Organization Scheme (MAOS) contractor, this was not relevant to the accident.

c. **General Documentation Standards**. The SI audit of XX179's engineering documentation highlighted procedural errors and areas where attention to detail was lacking (**Observation**). Typical examples included:

(1) An F700 entry had been made for XX179's after flight servicing on 20 Aug 11. Clearly the aircraft did not return from the sortie and

therefore this was indicative of engineering documentation being commenced before work had been undertaken. Although the servicing had not been signed as completed there was no reason, at all, for any detail to have been entered.

(2) A common occurrence of deviations in wording from that specified in the Manual of Maintenance and Airworthiness Processes.

(3) The scoping of multiple independent checks under one all encompassing scoping statement which could lead to incorrectly conducted independent inspections.

1.4.42. **Engineering Documentation Conclusion**. The Panel observed that although no component life or maintenance scheduling discrepancies were identified, documentation anomalies were observed. However, the Panel concluded that the engineering documentation relating to engineering actions and procedures were **not a factor** in this accident.

ENGINEERING SUMMARY

1.4.43. After a comprehensive engineering investigation the Panel concluded that XX179 was serviceable prior to ground impact and that **neither technical failure nor engineering action were factors** in the accident. Partially fastened thigh zips may have resulted in a partial reduction to the accident pilot's anti-G trousers effectiveness which was considered to be a **possible contributory factor** in the accident. Annex L Annex H Annex K Annex A