SECTION 1.4.1 - PRE-EXISTING CONDITIONS

Introduction

1.4.1.1 The purpose of this section is to situate the mind of the reader to the day of the accident with as little hindsight bias as possible. This offers the reader the opportunity to understand the environment within which the crews were operating and making decisions.

1.4.1.2 The Pre-existing Conditions section is divided into the following sub-sections:

a. The "See and Avoid" Principle

b. Weather Conditions

c. Tornado Collision Warning System

d. Secondary Surveillance Radar Maintenance

e. Aircraft Condition

f. Electronic Planning (Deconfliction) Aids

g. Split Squadron Operations

h. Medical care of ASTON 1 WSO

The "See and Avoid" Principle

Introduction

1.4.1.3 This sub-section of the report introduces the "See and Avoid" principle, whereby civil and military aircraft avoid mid air collision. It is divided as follows:

a. Background

b. Regulation, Policy, and Orders

c. Limitations of "See and Avoid"

d. Effectiveness of "See and Avoid"

e. Factors Specific to Tornado GR4

f. Training

g. Summary

Background

1.4.1.4 **"See and Avoid" Principle.** Significant amounts of UK military flying is conducted in open airspace classified as Class G[4] airspace. In Class G airspace there is no

Exhibit 51
Exhibit 52

[4] The International Civil Aviation Organization Airspace Classification System consists of seven classes of airspace, each specifying minimum Air Traffic Service requirements and the services provided. Classes A-E are Controlled Airspace whilst Classes F & G are

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formal requirement for aircraft to use an Air Traffic Service; indeed, they are not always available, particularly at lower altitudes and within the UK Low Flying System (UKLFS)[5]. Military aircraft share this airspace with civilian users, collision avoidance relies fundamentally on seeing conflicting aircraft (lookout) and manoeuvring to remain clear. Colloquially, this method of operation is known as "See and Avoid". Additionally, a number of measures are employed to aid safe separation such as regulation, including the division of airspace and Rules of the Air; and a variety of deconfliction measures, for example one way flow systems within the UKLFS. Exhibit 54 Exhibit 55

1.4.1.5 **Defence Requirement for Class G Airspace.** Defence uses Class G airspace to satisfy a number of requirements which cannot be met in other types of airspace. These requirements are described below: Exhibit 56 Exhibit 55 Witness 19

a. **General Tactical Flying Practice.** The Civil Aviation Authority's (CAA) Future Airspace Strategy[6] states that the military conducts a wide range of operational training missions covering all aspects of aviation and has a requirement for airspace over the whole of the UK Flight Information Region. Examples of these requirements include carriage of military passengers to destinations both within the UK and throughout the world, air-to-air refuelling, general handling for pilot basic and advanced training, and the practise of air to air and air to ground combat skills from singleton aircraft and complex formations of aircraft. The military requires the freedom to operate tactically with as few constraints on its activities as possible. Operational training missions rely on the availability of suitable airspace.

b. **Low Flying.** The RAF has a requirement to train crews in the LL environment to prepare for the roles which could be asked of crews in current (for example shows of Force on Op HERRICK) and contingent operations. AOC 1Gp has stated that *"operational imperative"* drives the need to conduct low flying training; however, low flying is constantly analysed to ensure that the gain in operational capability is balanced against the associated risks.

1.4.1.6 **Risk of Mid Air Collision.** A 1Gp review of airprox[7] over the past 2 ½ years revealed that 53% of airprox occurred at LL (0-3500 ft), with Tornado as the largest 1Gp user of the UKLFS, accounting for 24 of the 45 events. Historically, a significant proportion of airprox and mid air collisions at LL occur in the UKLFS. MoD studies have attempted to mathematically quantify collision rates and predict the risk of mid air collision. There is significant variance in predicted rates. The Tornado CWS Review Note published in Jan 12, supported by research and analysis conducted by QinetiQ and Defence Science Technology Laboratory (DSTL), calculated that the expected rate of random Tornado mid air collision would be 1 in 30 or 1 in 32 years dependent upon the Out of Service (OSD) of the platform and flying hours. This modelling is on current predictions, and does not represent previous risks and conditions. Exhibit 57 Exhibit 58 Exhibit 59 Exhibit 60 Exhibit 413

1.4.1.7 **History of Tornado GR1/4 Mid Air Collision.** There have been 11 mid air collisions involving Tornado GR1/GR4 since 1984, nine of which have occurred at LL. Five mid air collisions involved Tornado vs Tornado, including the 1986 accident which was a Exhibit 61 Exhibit 62 Exhibit 63

Uncontrolled Airspace (the area outside the volumes of controlled airspace created to protect Commercial Air Transport etc). CAA VFR Guide 2011.

[5] The UKLFS comprises Class G Airspace extending vertically from the surface to 2000ft Above Ground Level/Above Mean Sea Level and laterally to the Flight Information Region boundary. It does not include airspace within Air Traffic Zones, Military Air Traffic Zones or Danger Areas.

[6] Class G Airspace for the 21st Century, Part of the CAA's Future Airspace Strategy, 30 Mar 12.

[7] An airprox is a situation in which, in the opinion of a pilot or controller, the distance between aircraft as well as their relative positions and speed was such that the safety of the aircraft involved was or may have been compromised.

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result of a close formation join where the "See and Avoid" principle was not a factor. Prior to this accident, the most recent mid air collision involving a Tornado was 13 years ago. The timeline at Figure 8 shows the history of Tornado GR1/4 mid air collisions.

Exhibit 64
Exhibit 65
Exhibit 66
Exhibit 67
Exhibit 68
Exhibit 69
Exhibit 70
Exhibit 58

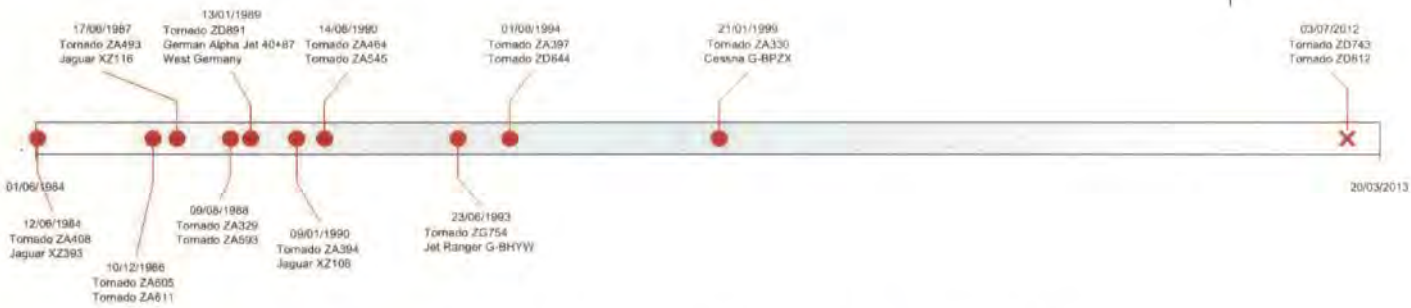

Figure 8. Mid Air Collisions involving Tornado GR1/4.

1.4.1.8 Since the early 1990s the rate of mid air collisions involving Tornado GR1/4 has reduced. The Tornado CWS Review Note attributed this to several factors, *"including improvements in procedures, greater awareness, reducing fleet sizes (and flying hours) and changes to training practices (a greater proportion of medium level training) have contributed to this trend."*

Exhibit 58

Regulation, Policy and Orders.

1.4.1.9 **Rules of the Air.** The Air Navigation Order (ANO) was made law by the Civil Aviation Act 1982. The ANO directs that all aircraft must obey Rules of the Air; military aircraft are exempt from the vast majority of the ANO, including Rules of the Air. However, it is MoD policy that military regulations, in relation to the Rules of the Air and Avoidance of Aerial Collisions, should conform to the civilian rules where possible. Rules of the Air specify some procedural deconfliction and who should give way to whom. While there is no specific use of the term "See and Avoid" in any civil or military regulation, it is an implicit method of avoiding collisions when flying under Visual Meteorological Conditions (VMC). The CAA recognises "See and Avoid" as *"…one important way in which crews seek to minimise the risk of collision when flying in VMC and in particular when operating in Classes D, E, F and G airspace"*[8].

Exhibit 51
Exhibit 52

1.4.1.10 **Visual Flight Rules.** Flights by military pilots are required to be conducted under Instrument Flight Rules (IFR) or Visual Flight Rules (VFR)[9]. VMC and Instrument Meteorological Conditions (IMC) refer to the weather conditions encountered during flight. The terms IMC and VMC refer to actual weather conditions, as distinct from the flight rules under which flight is being conducted. VMC exist when the weather permits flight in accordance with the VFR; IMC exist when the weather conditions are below the minima for VFR flight. The Manual of Military Air Traffic Management states that:

Exhibit 52
Exhibit 71
Exhibit 55

"Within the UK, VFR are as follows:

[8] CAA, Safety Regulation Group Flight Operations Communication Aug 2010: Collision Avoidance – Use and Limitations Associated with the See-And-Avoid Principle

[9] Flight can also be conducted under Special VFR but is not relevant to this report.

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a. *Avoidance of Collision. Pilots **should** maintain safe separation from other traffic.*

b. *Flight Conditions. The aircraft **should** remain in weather conditions which satisfy the VMC minima specified…"*

For ASTON and ABBOT, within the UKLFS the applicable weather minima was: 5 km visibility, 500 ft vertically clear of cloud and 1500 m horizontally clear of cloud. In conjunction with the speed limits published in the Military Low Flying Handbook, this minima sets the environment in which fast jets operate in the UKLFS.

Limitations of "See and Avoid"

1.4.1.11 **General.** The "See and Avoid" principle relies upon a number of important steps and its limitations are well documented. The information processing required for "See and Avoid" takes time; it has been estimated that the time required from detecting an object, recognising it as an aircraft, and avoiding a collision is at least 12.5 secs.[10] Factors affecting lookout can be separated in to four categories: physiological (e.g. vision and eye), physical (e.g. cockpit obscuration), Human Factors (e.g. workload and cockpit familiarity) and environmental (e.g. weather and use of radar service). Figure 9 summarises the possible points of failure in the information process for seeing and avoiding an aircraft.

Exhibit 72
Exhibit 15
Exhibit 580

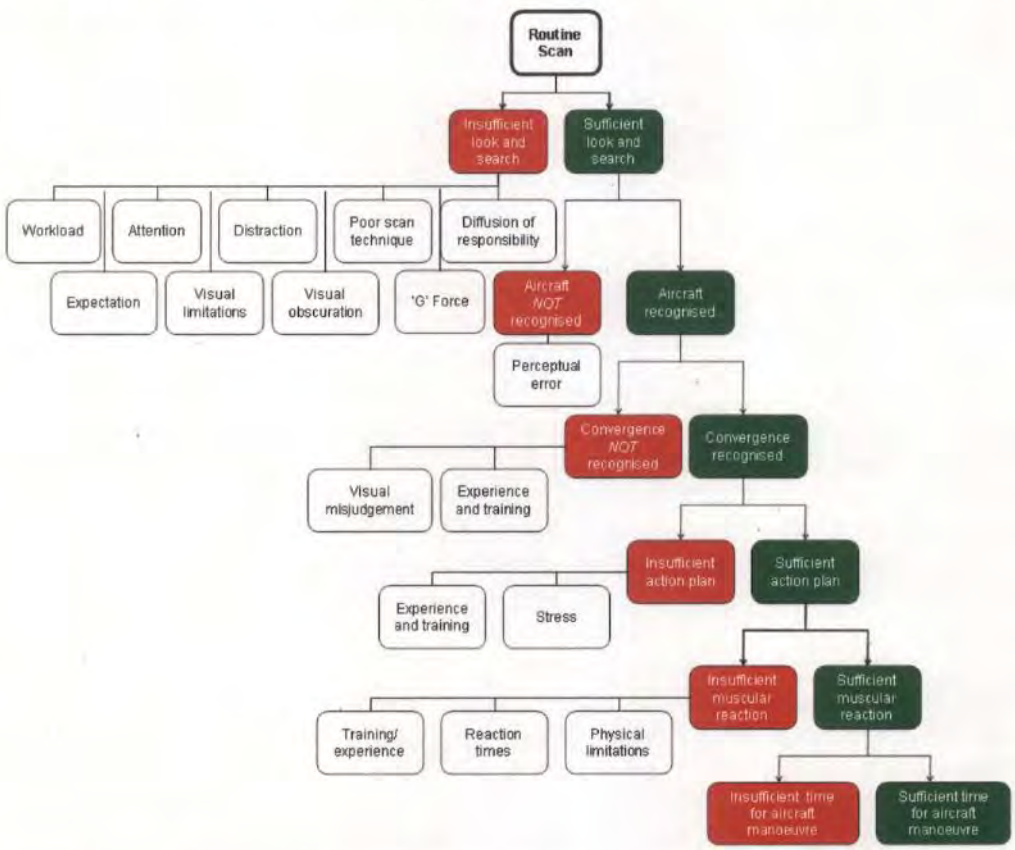

Exhibit 15

Green boxes represent successful processing, red boxes represent unsuccessful processing and white boxes represent potential contributors to unsuccessful processing.

Figure 9. Information Processing Sequence for "See and Avoid".

[10] Federal Aviation Administration. Pilots' role in collision avoidance. Washington, DC: Federal Aviation Administration; 1983 Advisory Circular 90-48C.

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1.4.1.12 **Factors Affecting "See and Avoid".** A number of the factors listed in Figure 9 are considered in more detail below, paraphrased from a 2010 CFS report.

Exhibit 72
Exhibit 73
Exhibit 497

a. **Familiarity with Aircraft.** When converting to a new aircraft a pilot takes time to achieve familiarity with the platform and cockpit layout. As experience increases the task of flying the aircraft becomes less onerous. During conversion to a new aircraft, student pilots' lookout could be less effective than a more experienced pilot. However, conversely some studies[11,12] have suggested that experienced pilots have a "reasonably accurate perception of the rather low probability of a mid air collision, and most likely will not make their outside visual traffic scan a top priority."[13]

b. **Visibility.** During poor visibility the brain expects objects to be further away than they are; a lack of distinctiveness implies distance. Poor visibility can also reduce the time available for an observer to sight an aircraft.

c. **Sun Direction/Intensity**. The effect of sun on visibility can be significant, particularly if an observer is looking into the sun.

d. **Contrast**. Contrast is a significant factor in visual acquisition; various meteorological phenomena provide a variety of light and intensity levels.

e. **Precipitation**. Precipitation can be troublesome. A rain swept windscreen can act like a lens. Image distortion through a rain-swept windscreen occurs more readily at higher air speed[14].

f. **Cloud**. The effect of cloud on lookout is two-fold: obscuration and background. A confliction obscured by cloud is impossible to see. However, the background provided by cloud can improve or reduce the possibility of acquiring an aircraft, dependent on the contrast with that aircraft.

g. **Corrective Flying Spectacles and Contact Lenses.** ABBOT 1 FS Pilot had been issued with Corrective Flying Spectacles and contact lenses. His uncorrected visual acuity was 6/9 in both eyes; Corrective Flying Spectacles or contact lenses corrected this to 6/6 (normal vision). ASTON 1 WSO had also been issued with Corrective Flying Spectacles which corrected his vision from 6/9 in his left eye to 6/4 (better than normal) in both eyes. With any spectacles there is a risk of blind spots where the spectacle frame encroaches on the visual field. Nevertheless, Corrective Flying Spectacles are specifically designed to minimise any encroachment. However, mechanical failure of Corrective Flying Spectacles or lens obscuration due to misting or sweat obscuration have been known to contribute to flight safety incidents.[15] Similarly, appropriately worn contact lenses should provide the required corrective vision and will have the advantage of having no frame to potentially encroach on the visual field. A drawback of contact lenses is if they become dislodged or irritate the eye during flight then they could become a source of distraction.

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[11] Midair Collisions: Limitations of the See-and-avoid Concept in Civil Aviation, C. Craig Morris. Aviation, Space and Environmental Medicine Vol 76, No 4 April 2006.

[12] The Influence of Flight Experience on Midair Collision Risk Perception, Paul Shuch. Accid. Anal. & Prev. Vol 24, No 6, 1992.

[13] Ibid.

[14] Rainford, DJ and Gradwell, DP (eds)(2006) Ensting's aviation Medicine. London: Hodder Education P289.

[15] Rainford, DJ and Gradwell, DP 2006. Ensting's Aviation Medicine. London: Hodder education, pg 699.

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Effectiveness of "See and Avoid"

Exhibit 15

1.4.1.13 **General.** Fast jet aircraft can achieve high speeds and rates of climb/descent, resulting in rapid closure rates with other aircraft. A number of studies have attempted to quantify the effectiveness of "See and Avoid".

1.4.1.14 **Effectiveness Studies.** A report produced by the Australian Transport Safety Bureau (ATSB)[16] on the limitations of "See and Avoid" stated that:

Exhibit 74
Exhibit 75

a. "*although 'See and Avoid' was often effective at low closing speeds, it usually failed to avert collisions at higher speeds. It was estimated that see-and-avoid prevents 97% per cent of possible collisions at closing speeds of between 101 and 199 knots but only 47 per cent when the closing speed is greater than 400 knots.*" [17]

b. The CAA has also reported that "'*See and Avoid is significantly less effective against high-speed traffic, in conditions of poor visibility and/or night. Of the 21 risk-bearing airprox outside controlled airspace (last 5 years), 13 involved conflictions with high-speed military traffic and 9 of these were caused by late or non-sighting.*"

1.4.1.15 **Focused Lookout.** The UK Airprox Board (UKAB) is an independent organisation sponsored jointly by the CAA and the MoD to investigate all airprox reported within UK airspace. Their sole objective is to assess reported airprox in the interests of enhancing flight safety. The UKAB report covering the period Jan to Jun 11 assessed the main two causes of airprox involving military aircraft as a failure to see conflicting traffic and the late sighting of conflicting traffic:

Exhibit 76
Exhibit 74

"Underlying a significant proportion of these causes … is the use of a quiet frequency or the selection of a Basic Service from ATC when a Traffic Service (TS) would be more appropriate to the flight profile…[and] *the reluctance of pilots in receipt of a TS to change course in response to specific traffic information. Rather, pilots tend to stand–on their course in anticipation of seeing the traffic they have been advised about, thereby allowing easily-resolvable encounters to develop into more serious conflicts."*

The ATSB report also highlights alerted search versus unalerted search, for example as a result of a traffic warning from Air Traffic Control. The report states that alerted search was found to increase lookout effectiveness by a factor of eight.[18,19,20,21]

Operator Understanding of Effectiveness. AOC 1Gp stated that "See and Avoid" is just one of a raft of mitigations to avoid mid air collision; physiological limitations, obscuration and effectiveness is well understood, he summarised *"maybe see and hopefully avoid."* The limitations and effectiveness of "See and Avoid" are well documented in academic and military literature. Following mid air collisions in 2009, CFS conducted an in depth review of "See and Avoid" and lookout training in the flying training system, publishing a detailed report supporting common themes. This was the last UK military analysis of "See and Avoid".

Witness 19
Exhibit 72

[16] Limitations of the See-and-Avoid Principe April 1994, Australian Transport Safety Bureau Research Report.

[17] Graham, W and Orr, RH 1970, Separation of Air Traffic by Visual Means: an Estimate of the Effectiveness of the See-and-Avoid Doctrine, in Proceedings of the IEEE, vol. 58, pp337-361.

[18] Andrews, JW 1977, Air to Air Visual Acquisition Performance with PWI, FAA-RD-77-30.

[19] Andrews, JW 1984, Air to Air Visual Acquisition Performance with TCAS, IIDOT/FAA/PM-84 17.

[20] Andrews, JW 1984, Unalerted Air to Air Visual Acquisition, FAA-RD-PM-87/84.

[21] Edwards, GD and Harris, JL 1972, Visual Aspects of Air Collision Avoidance: Computer Studies on Pilot Warning Indicator Specifications, Final Report NASA Grant NGR-05-009-05 Report SIO 72-3.

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Factors Specific to Tornado GR4

1.4.1.16 **Cockpit Obscuration.** The Tornado GR4 has a number of cockpit obstructions that limit the external view. These obstructions limit what can be seen out of the aircraft, thus affecting the likelihood of detecting a target. Exhibit 15

a. **Front Cockpit.** Figure 10 shows a 2D forward view from the front cockpit. Without a 3D panoramic picture the depth and perspective of the cockpit cannot be replicated exactly, but can give an impression of the visibility. The cockpit instrumentation takes up some of the field of view as do the canopy arches, limiting the pilot's view of the external environment in these locations. These obstructions are partially mitigated by stereoscopic vision and by the pilot moving their head as part of look and search.

Exhibit 15
Exhibit 91

Figure 10. Front cockpit View.

b. **Rear Cockpit.** Figure 11 shows a 2D forward view and part of the side view from the rear cockpit. The same caveat as in 1.4.1.16.a. must be applied to a 2D impression of the cockpit. The forward view from the rear cockpit is somewhat more restricted than the front cockpit, because it is obstructed by the instrumentation and the head box of the front ejection seat. The external view from the rear cockpit is also partially obstructed by the engine intakes. Exhibit 15

Exhibit 91

Figure 11. Rear Cockpit View.

1.4.1.17 **ZD812 (ABBOT 2).** The left hand windscreen quarterlight of ZD812 contained a chip measuring 3 mm by 2 mm. Chips, dirt and insect splatter can create focal traps, making it difficult to see distant objects. Exhibit 11
Exhibit 77
Exhibit 74
Exhibit 461

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1.4.1.18 **Aircraft Conspicuity.** A number of factors affect Tornado GR4 conspicuity. Exhibit 79

a. **Colour Scheme.** The Tornado GR4 is dark grey in colour. Consequently, the aircraft is more difficult to detect against backgrounds such as cloud and sea that may be similarly coloured and lit.

b. **Aircraft Lighting.** Tornado GR4 is fitted with dual colour High Intensity Strobe Lighting (HISL), with white lights for day flying and red lights for night flying. It is mandated[22] that the lights achieve 150-250 Candela (red) and 1500-2500 Candela (white). In theory, to be visible at 3 nm on a very dark day, a strobe light must have an effective intensity of around 5000 candelas. In full daylight, the strobe must have an effective intensity greater than 100,000 candelas. The ATSB report quotes several studies on the effectiveness of HISL:

(1) Tests in 1958, 1970 and 1989 found that strobe lights were ineffective in daylight;

(2) A US Army study conducted in 1970 found that HISL were helpful when aircraft were viewed against the ground;

(3) USAF tests in 1976 found that in all cases, aircraft were sighted before their HISL.

c. US Air Force Aeronautical Systems Division trials in 1977 found that in daylight, even a strobe of 36000 candelas was not particularly conspicuous. However, strobes were more visible when the background illumination was less than 30 candelas per square metre, equivalent to a very dark day.

1.4.1.19 **Cockpit Design.** A CAM review of Tornado GR4 aircrew found that they considered the cockpit ergonomics as poor. Aircrew reported that the layout was not intuitive and that a number of modifications had been incorporated over the lifetime of the aircraft. Poor cockpit ergonomics can increase workload, likelihood of distraction, time spent "heads in", and/or likelihood of error. Exhibit 15

Training

1.4.1.20 **General.** Pilots and WSOs are briefed on the limitations of "See and Avoid" during training. Lookout is taught and assessed throughout both pilot and WSO flying training.

1.4.1.21 **Ab-Initio Training.** Pilot lookout training is described below from Elementary Flying Training (EFT) on the Tutor aircraft through to Advanced Fast Jet Training (AFJT) on the Hawk aircraft, taken from a Review of Lookout Training Across 22(Trg) Gp report. Exhibit 80

a. **Elementary Flying Training (EFT).** RAF EFT students receive the following training:

(1) **Aviation Medical Training.** Prior to EFT, all students attend CAM where they are taught about the anatomy and limitations of the human eye.

(2) **Classroom / Airborne Training.** EFT provides most students with their first experience of military aviation, so provides very detailed, technique driven

[22] DAP101B/4104/1HB

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instruction on lookout. Students are taught how, when and where to look based on aircraft position and manoeuvre. Correct scanning procedures are checked and assessed throughout EFT, a practice that is aided by the side-by-side seating arrangement of the Tutor. The Traffic Avoidance System (TAS) is incorporated into lookout training using the mnemonic LAIT (Lookout, Attitude, Instrument, TAS). In addition, students are taught how to obtain and use an ATC Traffic Service (TS) during every sortie where its use is practicable. This provides students with an enhanced understanding of ATC capabilities (and limitations) compared to students trained prior to the introduction of Training Group Orders concerning the use of TS in Tutor.

(3) **Simulator.** There is no Tutor simulator.

(4) **Assessment.** Students' performance is assessed by instructors during every sortie.

b. **Basic Fast Jet Training (BFJT).** BFJT students receive the following training: Exhibit 80

(1) **Aviation Medical Training.** Prior to starting BFJT, students attend CAM for Fast Jet (FJ) specific training. This training also includes refresher training on the physiological aspects of human vision.

(2) **Classroom / Airborne Training.** Lookout instruction on BFJT builds on the LAIT work cycle from EFT. Blind spots due to airframe blanking are emphasised and students are introduced to formation and night flying lookout techniques.

(3) **Simulator.** The Tucano simulator has the capability to introduce other aircraft to the visual environment. Limited visual fidelity means that these images are not wholly realistic; however, they are sufficient to give an indication of students' lookout ability.

(4) **Assessment.** Airborne assessment is hampered by the tandem layout of the Tucano cockpit, therefore QFIs are taught to assess lookout in flight by using cockpit mirrors and monitoring head movement. Performance is assessed subjectively on all sorties.

c. **Advanced Fast Jet Training (AFJT).** Hawk students receive the following training: Exhibit 80

(1) **Aviation Medical Training.** Prior to AFJT, students receive further training from CAM which includes human vision refresher.

(2) **Classroom / Airborne Training.** Lookout on AFJT relies heavily on BFJT teachings. Only elements specific to the Hawk are formally trained; however, emphasis is now on a high standard of lookout, even at the expense of accurate flying. During the FJ Tactics and Weapons phase, pilots conduct evasion training against aggressor aircraft which provides effective assessment of student lookout performance.

(3) **Simulator.** Both the Hawk T1 and Hawk T2 simulators have the ability to inject conflicting traffic into synthetic exercises to test student lookout.

(4) **Assessment.** Performance is assessed subjectively in all sorties and simulators. During the evasion phase, lookout assessment is more objective;

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without sound lookout, students will fail this part of the course.

d. **Ab Initio WSO Training.** The RAF Fast Jet WSO (historically known as Navigator) training pipeline has now closed to new entrants. There are only a handful of ab initios who are still to complete their training and this should be complete by early 2014. Thereafter only refresher WSO training will be undertaken. The summary of the training below is to provide some comparison between WSO and pilot training. Exhibit 81 Exhibit 82

e. **Bulldog Module.** RAF Basic WSO Training students received the following training: Exhibit 15 Exhibit 81 Exhibit 212

(1) **Aviation Medical Training.** Prior to Basic WSO Training, all students attended CAM where they were taught about the anatomy and limitations of the human eye.

(2) **Classroom / Airborne Training.** Like EFT, for many WSOs this was their first experience of flying. The importance of good lookout was focused on during classroom training, including the correct techniques for scanning.

(3) **Simulator.** Nil

(4) **Assessment.** WSOs were briefed prior to every sortie about the importance of lookout and were assessed by their instructors. The taught scan technique was a Vertical Raster Scan: moving the eyes in a sine wave along the horizon from nose to tail, then over the top of the canopy to the nose, a quick check of the relative instruments and then repeat. Side-by-side seating arrangements in the Bulldog made assessment of lookout relatively easy.

f. **Tucano Air Navigator School (TANS) / 76(R) Sqn.** At TANS WSO students received the following training: Exhibit 15 Exhibit 83 Exhibit 214 Exhibit 81 Exhibit 85

(1) **Aviation Medical Training.** Prior to starting TANS, students attended CAM for specific training. This training included refresher training on the physiological aspects of human vision.

(2) **Classroom / Airborne Training.** Lookout instruction at TANS built on the work cycle from the Bulldog Module: lookout, clock, instruments. This included the dangers of task focus at the expense of lookout: *"There is a danger that the student will become will engrossed in the work cycle and what the instructor is saying, and will forget lookout. Great emphasis should therefore be placed on adequate lookout and the need to split checks up"*, and dead-wing checks: *"Specific 'dead-wing' checks are to be carried out after every turn."*

(3) **Simulator.** There are 2 types of simulators at RAF Linton-on-Ouse, one providing a "wide" visual coverage a total of 275°, the other providing a "narrow" visual coverage of 45° either side of the nose (a total of 90°). The "wide" simulator was preferred for the majority of WSO sorties and is capable of providing conflicting traffic to ensure the student WSO is looking out. Lookout was a mandated reporting item on each sortie and was easily assessed as the simulator instructor could observe the student WSO. The Crew Resource Management (CRM) elements of lookout were also introduced.

(4) **Assessment.** Lookout was a mandated reporting item on each sortie. Airborne assessment was hampered by the tandem layout of the Tucano cockpit with the pilot located in the front seat. Therefore QFIs were taught to assess

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lookout in flight by using cockpit mirrors and monitoring the WSO's head movement.

g. **D-Flt 55(R) Sqn – Dominie.** Exhibit 15 Exhibit 86 Exhibit 81 Exhibit 82 Exhibit 83

(1) **Aviation Medical Training.** Prior to 55(R) Sqn WSOs would attend an initial multi-engine aviation medicine course, also known as the multi OCU aviation medicine course. This was similar in content to the course pilots receive prior to BFJT and included refresher training on the physiological aspects of human vision.

(2) **Classroom / Airborne Training.** The primary purpose of this phase of WSO training was teaching initial radar handling procedures. This was the first time the student WSO controlled the sortie from the rear of the Dominie aircraft without a means of looking out. For the majority of these sorties a second student WSO would occupy the right-hand seat in the cockpit alongside the pilot, and would act as the Pilot's Assistant (PA). One of the responsibilities of the PA was lookout and although the visibility from the Dominie's cockpit was restricted, students were briefed to spend approximately 95% of their time on lookout when at LL.

(3) **Simulator.** The "simulator" for the Dominie phase of training was a procedural air-to-ground trainer and as such was not capable of being used to teach lookout.

(4) **Assessment.** There was no funding or syllabus for a WSO operating in the PA role, although there was a Dominie PA Course to train student WSOs to operate in the right-hand seat of the Dominie aircraft. WSOs would only fly as PAs if a dedicated (funded) WSO training sortie was programmed, but each sortie was written up and recorded in the WSOs training folder. The side-by-side seating arrangements in the Dominie made assessment of lookout relatively easy.

h. **WSO Training Unit - 100 Sqn.** Exhibit 15 Exhibit 81 Exhibit 84 Exhibit 213

(1) **Aviation Medical Training.** Prior to AFJT, students receive further training from CAM which includes human vision refresher.

(2) **Classroom / Airborne Training.** Lookout training re-introduced the WSO to the work-cycle: lookout, clock, instruments. Having graduated from the Dominie phase of WSO training, with limited focus on lookout, the Hawk phase re-focused WSOs on the importance of lookout. This included, during the latter phases of the ground-attack phase, specific evasion training against aggressor aircraft, providing an effective assessment of student WSO performance.

(3) **Simulator.** During initial simulator training at RAF Valley the Hawk T1 was used to inject conflicting traffic into the training serials.

(4) **Assessment.** Lookout was a mandated reporting item on each sortie. The CRM aspects of lookout were focused on and were assessed by, without prejudicing flight safety, not calling aircraft spots to assess the student WSO's performance. Like the Tucano, the tandem layout of the Hawk cockpit hampered airborne assessment of lookout. QFIs were taught to assess lookout in flight by using cockpit mirrors and monitoring the WSO's head movement.

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1.4.1.22 **Operational Conversion Unit (OCU).** The XV(R) Sqn Student Study Guide instructs pilots to "*keep your head moving in order to cover the dangerous blind spots behind the canopy arch and front windshield pillars. Look hard below and above the horizon and remember that an ac on a collision course will be stationary in the field of view and so harder to see.*" Students' lookout is scored in each sortie report; students are expected to check the down-going wing and blind spots on rolling out of turns. Exhibit 87

1.4.1.23 **Tornado Ground Reconnaissance 4 Force (TGRF) Simulator Lookout Training.** Following a visit to the RAF Lossiemouth simulator, the Panel **observed** that the TGRF simulator projectors are limited in their ability to display realistic entities (other aircraft) to facilitate lookout training and assessment. Simulator staff can use workarounds to allow visual acquisition of entities and then assess crew's head movement using video cameras, however the busy nature of simulator profiles can mean that opportunities to conduct and assess lookout training are limited. Furthermore, STANEVAL have stated that very little emphasis is placed on lookout training and it is not routinely assessed. Exhibit 669 Exhibit 671

1.4.1.24 **Dead Wing Checks.** Throughout flying training students are taught the importance of Dead Wing checks. Guidance on dead wing checks is provided in: Exhibit 88

a. **EFT Courseware.** *"Lookout remains very important before, during and after a turn to ensure that the area into which the aircraft is turning remains clear…the normal lookout scan needs to be modified slightly because the horizon on the outside of the turn is 'underneath' and blind to you… immediately you roll out of a turn, the blind side (or dead wing) must be cleared"*

b. **XV(R) Sqn Student Study Guide.** *"Turns should normally be flown at 2g. The dead wing must be checked on roll-out, as turns can be prolonged at only 2g."* Exhibit 87

1.4.1.25 **Refresher Training.** 1Gp ASOs require that aircrew undergo aviation medicine refresher training at CAM at five yearly intervals. This refresher training includes a brief on the anatomy of the eye and limitations that affect 'See and Avoid'. Exhibit 89 Exhibit 90

Summary

1.4.1.26 A significant amount of UK military flying is conducted in open airspace classified Class G airspace, including at LL, where collision avoidance relies fundamentally on seeing conflicting aircraft and manoeuvring to remain clear of them.

1.4.1.27 Defence has a requirement for Class G airspace and to operate at all altitudes within that airspace, including at LL. Witness 19 Exhibit 55 Exhibit 56

1.4.1.28 For ASTON and ABBOT, within the UKLFS the applicable weather minima was: 5km visibility, 500 ft vertically clear of cloud and 1500 m horizontally clear of cloud. Exhibit 71

1.4.1.29 The "See and Avoid" principle relies upon a number of important steps and its limitations are well documented. Factors affecting lookout can be separated in to four categories: physiological (e.g. vision and eye), physical (e.g. cockpit obscuration), Human Factors (e.g. workload and cockpit familiarity) and environmental (e.g. weather and use of Air Traffic Service). Exhibit 72

1.4.1.30 Due to limited experience on type, student lookout can be less effective than that of more experienced operators. Conversely, some studies have suggested that more experienced aircrew could have their lookout adversely affected by previous experiences. Exhibit 15 Exhibit 497

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1.4.1.31 A number of studies have attempted to quantify the effectiveness of "See and Avoid". The ATSB report stated that "See and Avoid" is "*47 per cent* [effective] *when the closing speed is greater than 400 knots.*" However, the ATSB report also stated that alerted search, for example through the use of an Air Traffic Service, was found to increase lookout effectiveness by a factor of eight. The CAA has stated that "*'See and Avoid' is significantly less effective against high-speed traffic, in conditions of poor visibility.*" The Panel **observed** that "See and Avoid" has known limitations, which are mitigated by training and education. Exhibit 74 Exhibit 75

1.4.1.32 The view from both the front and rear cockpit of the Tornado GR4 is affected by obscuration; this can be mitigated to an extent by the crew continually moving their heads and modifying their search patterns. Exhibit 87 Exhibit 91

1.4.1.33 A number of factors affect the conspicuity of the Tornado GR4: the grey colour scheme can mean that it is more difficult to detect against similar coloured backgrounds such as cloud and sea; HISL are ineffective against a daylight background but can aid acquisition when aircraft are viewed against terrain. Four other studies concluded that, in daylight in good light conditions, the aircraft would be identified before the HISLs. Exhibit 15 Exhibit 74 Exhibit

1.4.1.34 Notwithstanding the limitations of "See and Avoid", lookout training for RAF Pilots and WSOs is comprehensive and effective. Aircrew are briefed on the limitations of "See and Avoid" during training. Lookout is taught and assessed throughout both pilot and WSO flying training, including on the OCU. Exhibit 81 Exhibit 87

1.4.1.35 The OCU teaches that as turns at 2 g can be prolonged it is necessary to check blind spots on rolling out of the turn. Exhibit 87

1.4.1.36 The limitations of "See and Avoid" and the analysis of their effect on the accident will be discussed further in Section 1.4.4.

Weather Conditions

1.4.1.37 A large number of sources provided the Panel with an idea of the weather in the Moray Firth environs. Overall, a rather complex picture was painted with the weather differing significantly between RAF Lossiemouth, Tain AWR and the vicinity of the accident site. This section is divided as follows: Exhibit 78

a. General Weather Situation

b. RAF Lossiemouth Weather

c. Tain Weather

d. Weather In the Vicinity Of (IVO) the Accident

e. Hindcast

General Weather Situation

1.4.1.38 As explained in Part 1.3 the developing area of low pressure to the SW of Scotland had introduced light winds from an Easterly direction. This allowed the land mass of the Aberdeen coastline to afford some protection for the Moray Firth and RAF Lossiemouth and gave higher cloud bases and some better visibility, although upwind coasts (the Helmsdale coastline) would also be susceptible to fog and low cloud.

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RAF Lossiemouth Weather

1.4.1.39 The 11:50 hrs RAF Lossiemouth weather was reported as scattered cloud at 1900 ft, 30 km visibility, 19°C with a surface wind of 130°/16 kt. ABBOT 1 described the weather at RAF Lossiemouth to have improved from the early morning conditions to be a *"relatively nice day"* and by the time they launched *"it was fairly wide open".* Exhibit 8 Witness 4

Tain AWR Weather

1.4.1.40 A Tain Air Weapons Range Controller (AWRC) believed the weather to be "*fit enough beyond Tarbat Ness for us to conduct laydown profiles*" and "*the horizon was visible….although I would have thought there was a sea haar or maybe sea fog in the distance."* Witness 3

1.4.1.41 At 11:57 hrs [redacted] a USAF F-15E, climbed into an overcast layer above Target 1 at 4180 ft AMSL; they described the "*radar pattern run in to Target 1 was clear*" and that "*visibility was not an issue.*" Exhibit 9

1.4.1.42 Directly to the NE of Tain AWR, [redacted] stated that there was a second overcast layer at approximately 1000 ft AMSL overland which extended a couple of hundred ft offshore. Visibility improved to greater than 10 km between 11:50 hrs and 12:50 hrs, with visibility of 5000 m in mist to the W. Low cloud remained with few at 200 ft and scattered at 900 ft. The weather was as predicted in the 09:53 hrs Range Area Forecast. Exhibit 8

Weather IVO the Accident

1.4.1.43 ABBOT 1 was surprised at how far the mist and fog was off the Helmsdale / Wick coastline. Their expectation was that with a SE flow the poorer weather would be *"hugging the coast."* A review of ABBOT 1 video tape shows the fog and stratus bank to be approximately 6 nm off the coast. Following the accident, ABBOT 1 letdown just to the N of Wick to 750ft but was still in cloud. Wick Airport Meteorological Aerodrome Report (METAR) at 11:50 hrs reported 700 m in fog with overcast cloud at 100 ft. ABBOT 1 also attempted to get visual with the crash site between Helmsdale and the Beatrice oil rigs at an altitude of 1000 ft. They reported layered weather, particularly to the west of the area, with stratus and fog. Outside of the layers the weather was nice with *"reasonable visibility outside of the stratus."* ASTON 2 HUD suggests that the ML cloud structure to the south of the accident site consisted of scattered and broken cloud from 3000 ft to 6000 ft. They also stated that they could see Tain AWR from this position through gaps in the cloud and believed that the weather was fit enough for the FRA they had planned to conduct. Exhibit 10 Witness 4 Witness 2 Witness 6 Witness 5

1.4.1.44 R137, the first RAF Lossiemouth SAR helicopter on task, stated that the weather consisted of a fog bank up to about 1000 ft with 7 oktas cover. To the S they reported visibility of 30 km with no significant weather. R138, the second SAR helicopter on task, stated that the weather IVO of the accident site was patchy fog with cloud tops of about 800 ft and *"blue above."* Slant visibility *"wasn't brilliant"* but through patches they could see R137 in the hover *"brightly lit up in bright sunshine."* Witness 6 Witness 5

Hindcast

1.4.1.45 Met forecasters can utilise all available data to create a "Hindcast" including: actual recorded weather data, modelling, satellite pictures and observations. The Hindcast for the Moray Firth Sea Area covered the period from 11:00 hrs to 15:00 hrs and reported cloud in the SW of the area with few stratus base 500 ft with tops of 1000 ft and cumulus base 1500 to 2000 ft with tops of 8000 ft. The surface visibility was reported as 25 km with 7 km in showers, with widespread areas of 2500 m and occasional fog of 200 m. Exhibit 8

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1.4.1.46 The weather and its contribution to the accident will be analysed further in Section 1.4.4.

Tornado Collision Warning System

1.4.1.47 Collisions between military aircraft were a common occurrence in the early years of FJ aviation, with an average of two collisions per year which continued into the 1980s. A programme of focused improvement in procedures and training dramatically reduced that rate but did not extinguish the risk completely. In 1990 a MoD report from the collision of an RAF Tornado GR1 and an RAF Jaguar GR1A stated, "*purpose built electronic collision warning equipment will be evaluated and developed for the RAF over the next few years.*" Exhibit 62 Exhibit 68

1.4.1.48 Later that same year an accident report from the collision between two RAF Tornado GR1s stated as mitigation, "*MOD is in the early stages of conducting a technology demonstrator programme trial for an electronic CWS.*" It took a collision between an RAF Tornado GR1 and a civilian Bell JetRanger helicopter in 1993 to highlight the limitations of "See and Avoid" as a concept of separation in uncontrolled airspace and devote analysis to methods of deconfliction of military and civilian aircraft. The recommendation by the AAIB that "*the Ministry of Defence should give a high priority to the development and introduction of technology which provides low flying military FJs with an aircraft collision warning system..*" reinforced the work that was already in place to develop a Collision Warning System (CWS) for the GR4, which was regarded as "*most prevalently involved in all mid-air collisions (11 occurrences in 20 years)*". Exhibit 432 Exhibit 61 Exhibit 62

1.4.1.49 The Strategic Defence Review (SDR) in 1998 enshrined the requirement in policy, stating *"The main decisions taken in the Review are.....*[to] *develop a new collision warning system for the Tornado GR4, to enter service early in the next century.".* Over the next 14 years the Tornado CWS programme was *"subject to five deferrals, prioritising cuts in activity and availability over equipment enhancements"* and after nominal deletion in the 2010 Strategic Defence and Security Review (SDSR), subsequent review in the "3 Month Exercise" (3ME) and resurrection in 2012, the current In Service Date (ISD) for a Tornado CWS is 2015. The Tornado platform OSD is currently Mar 2019. Exhibit 92 Exhibit 433

1.4.1.50 Tornado CWS was allocated funding in 1998 with a predicted ISD of 2004, however the most realistic and achievable ISD during its developmental history to date was 2010, which meant it could have been fitted to Tornado aircraft at the time of the accident. Exhibit 431

1.4.1.51 The analysis of a Tornado CWS on the outcome of the accident will be covered in the Section 1.4.4 during the final minutes before the collision, and the requirement, funding and development history will be analysed in Section 1.4.6 of the report.

Secondary Surveillance Radar

1.4.1.52 **Introduction**. At the time of the accident RAF Lossiemouth was operating without Secondary Surveillance Radar (SSR) which was undergoing scheduled maintenance. RAF Lossiemouth receives its SSR feed from the RAF Kinloss Monopulse Secondary Surveillance Radar (MSSR). The impact of which was that RAF Lossiemouth ATC were unable to ascertain the altitude and identity of traffic directly from their radar screens. The task of identifying and handing over traffic to other agencies could be protracted. This sub-section is divided as follows: Witness 20 Witness 21

a. MSSR Maintenance 2-6 Jul 12

b. MSSR OSD

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c. MSSR User Availability

d. Procurement of Replacement SSR

e. Analysis

MSSR Maintenance 2 – 6 Jul 12

1.4.1.53 Defence Equipment & Support (DE&S) Air Defence and Air Traffic Services Delivery Team (ADATS DT) is the Engineering Authority (EA) for MSSR. MSSR is flight checked triennially in accordance with Flight Check Instruction 1, managed by ADATS DT. The MSSR was flight checked in Mar 12 and categorised as *"Restricted: Below 20,000ft the MSSR is not to be used outside of 61nm from the radar head. At 20,000ft and above the MSSR is unrestricted."* Witness 22 Exhibit 93

1.4.1.54 ADATS DT 3rd Line testing of the MSSR Large Vertical Antenna (LVA) had noted a continued deterioration in radar performance since 2007: the LVA will *be "soon suffering from double plotting/punch through*[23]*. A point will soon be reached when the system will be declared unusable."* ADATS DT decided that the LVA would need to be replaced with a refurbished LVA. Exhibit 94 Exhibit 95 Exhibit 101 Exhibit 331

1.4.1.55 In Jan 12, ADATS DT offered RAF Lossiemouth a choice of dates to complete the maintenance: Mon 2 – Fri 6 Jul, Mon 9 – Fri 13 Jul or Mon 16 – Fri 20 Jul. The dates provided to RAF Lossiemouth were as a result of the availability of Raytheon Systems Ltd (RSL) personnel (RSL is the Design Authority for the MSSR and contractor assistance is required to replace the LVA). RAF Lossiemouth preferred the period of Mon 2 – Fri 6 Jul from the list of dates provided, and this was approved by HQ 1Gp Battlespace Management Air Traffic Management Eng Role Office (BM ATM Eng RO). Exhibit 96 Exhibit 94

1.4.1.56 The LVA replacement schedule comprised of a travel day for personnel, a day to change the LVA, 2 days to carry out 3rd Line servicing and a day for a Flight Check (FC) by Cobham Aviation. The LVA was in the process of being changed at RAF Kinloss at the time of the accident. Exhibit 94

MSSR OSD

1.4.1.57 MSSR has been in-service for 26 years and the OSD was originally 2008. The ATC capability sponsor desk officer from 2002 stated that the OSD was as a result of NATO funding cycles, rather than as a result of obsolescence or reliability problems. The Air Operations Support Integrated Project Team (AOS IPT), predecessor to ADATS DT, placed a task on RSL to produce a sustainability report to assess the feasibility of extending MSSR to 2014. The Nov 05 report made a number of recommendations, of which most were accepted. As airfields have closed, the MSSR at these sites have been recovered to be used as system spares. RSL have a 90% confidence level that they can support the MSSR to 2017. Exhibit 97 Witness 23 Witness 22 Exhibit 332

1.4.1.58 ADATS DT stated that the MSSR has obsolescence problems and is starting to have reliability issues, but that it is supportable and that *"at the moment we foresee no significant problems in sustaining the capability."* In order to maintain MSSR capability ADATS DT has a rolling LVA refurbishment and replacement programme. RSL refurbishes LVAs and a combined RSL and ADATS DT team replace them. Six of the 19 LVAs have Witness 22 Exhibit 252

[23] Double plotting occurs when a transponding aircraft is plotted in one or more locations other than its actual location. This can be caused by "punch through" where an incorrect antenna pattern causes a transponder to be interrogated more than once.

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been replaced since 2005.

MSSR Availability

1.4.1.59 BM ATM Eng RO and ADATS DT aim to achieve a 95% serviceability figure for MSSR. The ATM Eng RO has reported RAF Kinloss MSSR availability as 95.16% for Jul 12. This could imply that the MSSR was unavailable for a period of 36 hrs to RAF Lossiemouth ATC. In reality, ATM Eng RO has stated that *"the dates the system may have been released from use may be 2-6 Jul; however, the radar may not have been 'switched off' until late on 2 Jul and been back on 5 Jul; therefore availability figures may be considerably less than that of the ATC staff."*[24] Witness 24 Exhibit 98 Exhibit 99 Exhibit 100

1.4.1.60 RAF Lossiemouth ATC Watch Log records that the SSR was on maintenance from 07:21 hrs 3 Jul, at which point SSR information would have been selected off at controllers' consoles to avoid a confusing air picture. ATC did not reselect the SSR feed until they were informed that all maintenance activity, including a successful FC, had been concluded. Exhibit 100

1.4.1.61 A review of RAF Lossiemouth records reveals that the MSSR was released for maintenance for 79 hrs between 2–6 Jul, during which time it was not in use by ATC. This would translate to a user availability figure of 89% for the month, without reviewing records for dates outside the 2-6 Jul 12 period. By comparison, a modern SSR would be expected to achieve an availability figure of greater than 99%. Furthermore, the Panel **observed** that although Primary Surveillance Radar (PSR) maintenance is scheduled for Sundays, it is often completed during the week due to watch patterns not supporting Sunday maintenance. Exhibit 105 Exhibit 98 Exhibit 103 Exhibit 102 Exhibit 662

Procurement of Replacement SSR

1.4.1.62 Two projects have been tasked with delivering a capability to replace MSSR: Airfield SSR Programme (ASSRP) and Joint Military Air Traffic Services (JMATS) which was renamed Project MARSHALL in 2010. Exhibit 107

ASSRP

1.4.1.63 An enhancement option was raised in 2003 to replace MSSR and "*provide a SSR capability at military airfields by replacement of obsolescent equipment for which supportability problems exist beyond 2006.*" The Impact Statement stated that "*a lapse in capability will impact the management of airspace around MOBs* [Main Operating Bases] *and weapon ranges…even if this Option is taken, there is a high risk of reduced capability while the legacy system is replaced.*" Exhibit 108 Witness 23

1.4.1.64 The Impact Statement also identified that "*Cat A airprox (severe risk of collision) cited lack of SSR data as a major contributing factor (UK airprox Report 184/01)*". The ATC capability desk officer from the time stated that the main driver for the project was the need to have a Mode Select (Mode S) compliant SSR. At the time the CAA mandated date for Mode S compliance in UK airspace was 31 Mar 08, which led to the ASSRP. Exhibit 103 Exhibit 108 Exhibit 414

Air Operations Support Integrated Project Team (AOS IPT)

1.4.1.65 The task of delivering ASSRP was given to a small team whose primary task was to sustain legacy equipment, within the AOS IPT. The team were unable to fill the Witness 25 Exhibit 108

[24] ATM Eng RO availability figures are calculated on the time taken to change the MSSR LVA. The records do not include the period that ATC would consider the MSSR to be on maintenance (time from when informed the MSSR was on maintenance prior to the actual LVA change activity and the time post LVA change until completion of the FC to confirm that the MSSR is serviceable).

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vacancies that came with the project, and therefore the task of delivering the £51.4m project fell to one individual without any previous project management experience. The project plan, based on learning from other projects and a Learn From Experience database estimated an ISD of 2011/12. A contractor was subsequently brought in to effectively plan the project back from an ISD of 2009, to align with the then mandated date for Mode S compliance. Exhibit 499

JMATS and Project MARSHALL

1.4.1.66 In 2005 it was recognised that a number of pieces of ATC equipment were becoming obsolete and therefore a package of equipment requirements was captured in the concept of JMATS. At the JMATS start up brief in Oct 05, it was considered that ASSRP with a forecast ISD of 2009, could be incorporated in to JMATS. Witness 23 Exhibit 109

1.4.1.67 The ATC capability desk officer made enquiries into the date that Mode S would be mandated and, on the information available at the time, ASSRP was aligned with JMATS. The JMATS start up brief envisaged an ISD of circa 2011/12. In Dec 10, the JMATS project changed name to Project MARSHALL. Project MARSHALL is the replacement programme for a wide range of Terminal ATC enablers, including SSR, and seeks to embrace Commercial Off The Shelf (COTS) solutions. Witness 23 Exhibit 109 Exhibit 107 Exhibit 110

1.4.1.68 At Initial Gate approval in Jan 10, the Planning Assumption for ISD was Feb 14, with an anticipated six to seven year transition period until Full Operational Capability (FOC) was achieved. The ISD has subsequently been delayed to circa 2017 due to a number of reasons, including: changes to processes, governance, scrutiny and approvals within DE&S & HM Treasury. The legal and commercial requirements of the competitive dialogue process have meant there is very limited scope for timeline reduction. Contract Award is scheduled for Mar 15 with a transition period to Mar 21. Exhibit 110 Exhibit 111

Analysis

1.4.1.69 Operations without SSR can have a negative impact on airspace management. Lack of SSR has been cited as a major contributing factor in Cat A (severe risk of collision) airprox when under an ATS. Exhibit 108

1.4.1.70 The decision to replace the MSSR LVA during the period 2-6 Jul was driven by the availability of contractor support, rather than minimising the impact upon flying operations. Exhibit 96

1.4.1.71 SSR was unavailable on the day of the accident due to replacement of the MSSR LVA with a refurbished LVA. The Panel considered that the challenges of maintaining MSSR will invariably increase as the system continues to operate beyond its original OSD. When coupled with the current maintenance policy of conducting radar maintenance during normal airfield operating hours, SSR availability to ATC can be significantly below that which would be expected from a modern system. Witness 20 Witness 21 Exhibit 94 Exhibit 97

1.4.1.72 The Panel **observed** that SSR user availability may not be fully understood by HQ 1Gp; BM ATM Eng RO availability figures for Jul 12 do not reflect the extent of SSR availability to ATC. The confusion lay in the definitions between *actual* availability to the end user vs reported serviceability. Witness 24 Exhibit 104 Exhibit 98

1.4.1.73 Analysis of the effect that lack of SSR had on the accident will be covered in Section 1.4.4 and vegetation encroachment of the MSSR and Tactical Air Navigation (TACAN) aid and its management will be covered in Section 1.4.6.

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Aircraft Condition

1.4.1.74 **Introduction.** This subsection details the loadout, existing faults and limitations for each of the aircraft. It is subdivided as follows:

a. ZD743 (ASTON 1)

(1) Loadout

(2) Pre-existing Limitations/Faults

(3) Implications of Aircraft Limitations/Faults

(4) Summary

b. ZD812 (ABBOT 2)

(1) Loadout

(2) Pre-existing Limitations/Faults

(3) Implications of Aircraft Limitations/Faults

(4) Summary

c. Conclusions

ZD743 (ASTON 1) - Loadout

1.4.1.75 ZD743 was fitted with the following role equipment: Exhibit 2 Exhibit 15

a. Left outer pylon (Station 1): Skyshadow ECM pod

b. Left inboard pylon (Station 3): 1500 litre fuel tank

c. Left shoulder pylon (Station 3A): LAU-7A missile launcher

d. Right outer pylon (Station 2): Dummy Boz pod

e. Right inboard pylon (Station 4): 1500 litre fuel tank

f. Right inboard shoulder pylon (Station 4A): RAIDS pod

g. The Mauser gun was empty

Pre-existing Limitations/Faults

1.4.1.76 The Radar Homing Warning Receiver (RHWR) of ZD743 was unserviceable. The RHWR fault was recorded in the aircraft documentation and rectification of the fault had been deferred by an Engineering Officer holding appropriate authority. Exhibit 2

1.4.1.77 The four Auxiliary Air Intake Doors are subject to maintenance at a periodicity of 300 flying hrs. This maintenance was due and had not been carried out. Special Instruction (Technical) (SI(T)) SI/TORNADO/265 raises the maintenance requirement. There is dispensation within the SI(T) for an Engineering Officer to defer the maintenance if the Exhibit 112 Exhibit 626

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aircraft is deployed Out of Area. The dispensation was not applicable in this case.

1.4.1.78 The crew make reference to having to recycle the radar whilst over the W coast of Scotland. Recycling the radar refers to the process of switching it off and switching it back on again to clear a fault. It is not unusual for this to be necessary during a sortie. There was no further discussion of the radar. It is assessed that the radar operated correctly after that point as the Panel believes the crew would have discussed it further had it not been serviceable. Exhibit 7

Implications of Aircraft Limitations/Faults

1.4.1.79 **RHWR.** Had the RHWR of ZD743 been serviceable, it could have provided the Pilot and WSO of ZD743 with visual cues to inform them that another aircraft was present and, potentially, the direction in which it lay. The Tornado Ground Reconnaissance 4 Force (TGRF) Handbook directs that aircraft are to employ their RHWR to aid collision avoidance once airborne and to adjust their own radar to provide the most conspicuous beam pattern for other aircraft with RHWR to detect. The procedures and practices of using an RHWR as an aid to avoiding mid air collision is stated as mitigation within the 1Gp Risk Register. Mitigation is not weighted, and the benefits of the RHWR as a collision avoidance aid are not stated with regard to how effective it is to assist in this task. The 1Gp ALARP statement for mid air collision regarded RHWR fitted under the heading *"Current technical mitigations are based on systems used primarily for alternative purposes other than for bespoke aircraft-aircraft spatial positioning and avoidance."* Exhibit 113 Exhibit 114 Witness 26 Exhibit 583

1.4.1.80 The RHWR, as its name suggests, provides warnings when the aircraft detects radar energy. The RHWR can provide threat dependent visual cues and audio warnings when the aircraft is illuminated by radar. Visual cues indicate the direction and type of received radar emissions. Audio warnings accompany the visual cues if the emission is identified as a threat. The RHWR is capable of detecting radar emissions from Tornado GR4 radars which can be displayed by a T label. Exhibit 114

1.4.1.81 [redacted] It was recommended by the Board of Inquiry into the mid air collision of Tornado GR1 ZA545 and Tornado GR1 ZA464 in Aug 1990, that the RHWR software in peacetime training programmes be amended to include the Tornado Ground Mapping Radar (GMR) and Terrain Following Radar (TFR) emissions as high priority threats. [redacted] Exhibit 68

1.4.1.82 However, it was considered that this recommendation would result in compromises being made in the design function of the RHWR. Furthermore, it was considered that the recommendation could result in crews becoming desensitised when flying in formation with other aircraft or crews ignoring or switching off the equipment to reduce nuisance warnings. Therefore, the recommendation was not implemented. The RHWR remained capable of detecting GR4 radar energy and could display a T or one of the other threats that shared the same frequency. The frequencies of the GR4 radars are not unique to the RHWR, and the equipment may not accurately determine if the radar energy was coming from a GR4 or another threat system, making the warning difficult to label correctly. Exhibit 114

1.4.1.83 **Auxiliary Air Intake Doors.** There is no evidence to indicate that the condition of the Auxiliary Air Intake Doors contributed in any way to this incident. Exhibit 15

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Emergent Faults

1.4.1.84 There is no evidence of emergent faults, prior to the collision, which contributed to the incident. Exhibit 15 Exhibit 7 Exhibit 78

ZD812 (ABBOT 2) – Loadout

1.4.1.85 ZD812 was fitted with the following role equipment: Exhibit 15 Exhibit 624

a. Left outer pylon (Station 1): Dummy Skyshadow ECM pod[25].

b. Left inboard pylon (Station 3): 1500 litre fuel tank

c. Left shoulder pylon (Station 3A): LAU-7A missile launcher

d. Right outer pylon (Station 2): Boz pod

e. Right inboard pylon (Station 4): 1500 litre fuel tank

f. Right inboard shoulder pylon (Station 4A): The aircraft documentation indicated that a RAIDS pod was fitted, however it was known to have been removed as the aircraft was going on a strafe sortie. Carriage of RAIDS pods is not cleared for strafe sorties.

g. The Mauser gun was loaded with 45 27 mm training rounds

Pre-existing Limitations/Faults

1.4.1.86 The Pilot's left hand windscreen quarterlight, location shown in Figure 12, was chipped. The chip was 3 mm in length, 2 mm wide and 0.25 mm deep. A concession had been granted for the aircraft to fly without limitation subject to the chip having been blended/polished out. The Panel **observed** that the chip had not been blended/polished out. Exhibit 11 Exhibit 461

Figure 12. Left Hand Windscreen Quarterlight and Location of Chip.

Implications of Aircraft Limitations/Faults

1.4.1.87 Windscreen chips can obscure or degrade the view out of the aircraft. Obscuration and the possible effect of this chip are covered in more detail in Section 1.4.4.

[25] A Dummy Skyshadow pod provides the representative weight and aerodynamic characteristics, but not the operational capability as a Skyshadow ECM pod.

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Emergent Faults

Exhibit 15
Exhibit 7
Exhibit 78

1.4.1.88 There is no evidence of emergent faults, prior to the collision, which contributed to the incident.

Conclusions

1.4.1.89 The Panel concluded that aircraft maintenance was **not a contributory or aggravating factor** in this accident.

1.4.1.90 Pre-existing/emergent faults prior to collision were **not a contributory or aggravating factor** as a discrete category in the incident. The contribution that the quarterlight chip made to "See and Avoid" is explained in Section 1.4.4.

Electronic Planning (Deconfliction) Aids

Exhibit 318
Exhibit 63

1.4.1.91 Electronic planning (deconfliction) aids can be used to highlight potential conflictions during mission planning, thereby allowing aircrew to take action to avoid or deconflict with other airspace users.

Witness 23
Exhibit 320
Exhibit 318
Exhibit 63

1.4.1.92 Following increased use of the UKLFS throughout the 1980s and mid air collisions in 1987/88, the Automated Low Flying Enquiry Notification System (ALFENS) project was broadened to include night deconfliction. The deconfliction concept was one of a networked mission planning system that would calculate a lozenge around a user's route and highlight conflictions with other users' routes.

Witness 23
Exhibit 320
Exhibit 318

1.4.1.93 The ALFENS project was due to deliver in Apr 94. By Apr 93, it became clear that the complexities associated with the project had not been well understood by the prime contractor until several months into the programme. A progress report a year later noted that the project would not deliver the required functionality.

Witness 23
Exhibit 321

1.4.1.94 In the early 2000s the Military Flying Management Information System (MFMIS) project aimed to deliver a conflict alert function. The MFMIS project suffered similar problems to ALFENS; the networked deconfliction part of the system failed to deliver and it was decided to cancel the project in late 2007.

Exhibit 322
Exhibit 323
Exhibit 324

1.4.1.95 The Army Air Corps (AAC) contracted BAES in 2010 for a year long trial of Centralised Aviation Data Service (CADS) to see if it could be used to reduce the potential for mid air collision during the planning process. Up until then the AAC relied on fax, telephone and email to deconflict. At the time, CADS was not adopted by other Front Line Commands. Another product, the Defence Aircraft Collision Avoidance Service (DACAS) project, was due to deliver an electronic (deconfliction) aid in Aug 12.

Exhibit 325
Exhibit 322

1.4.1.96 It is difficult to accurately quantify the effect of CADS on airproxs although one Duty Holder commented in Mar 12 that since the introduction of CADS there has not been an airprox reported locally. JHC has also commented that *"during its service CADS had identified potential risks and they have been avoided; that said only JHC and elements of Brize* [RAF Brize Norton] *have access, our civil partners do not."*

Exhibit 327
Exhibit 324
Exhibit 400

1.4.1.97 DACAS was approved in Planning Round 12, at a 10 year cost of £2.53m, with an ISD scheduled for Aug 12. No 1 Aeronautical Information Documents Unit (AIDU) were tasked with delivering the project; however *"it soon became apparent that the limited system requirements provided to AIDU were not coherent with those required by the users…JHC and AIR…requirements were actually far in excess of AIDU's ability to deliver."* AIDU did not

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have the necessary project management expertise and, following redundancies, it became clear that they would be unable to deliver a DACAS solution.

1.4.1.98 Electronic planning (deconfliction) aids and their effect on sortie planning will be discussed in Section 1.4.2 and 1.4.6.

Split Squadron Operations

1.4.1.99 The TGRF conduct operations in Afghanistan, contingent operations and foreign and UK training exercises on an annual cycle. This is normal practise for the most prevalent Attack[26] air platform in the RAF inventory, and requires intricate planning to ensure crews are qualified, current and capable of fulfilling their task to the highest standards.

1.4.1.100 Stations (Stn) (and Sqns) can bid, through their respective planning and coordination cells, for exercises that prepare for future operations. North American AWRs offer the ability to practise live High Explosive weapon delivery profiles which are not possible within the UK, and other international exercises offer reliable weather conditions and favourable airspace to conduct specific training objectives.

1.4.1.101 XV(R) Sqn had bid for and been allocated an exercise at RAF Akrotiri, Cyprus, to conduct Air Combat Training (ACT) in July 12, where the Sqn could enjoy favourable weather for flying and fulfil the required training syllabi for students, refresher candidates and continuation training for instructors. Witness 11

1.4.1.102 XV(R) Sqn deployed six aircraft and 99 personnel to RAF Akrotiri on 26 Jun (advance party) until 6 Jul on Ex LONE EGRET. The supervisory personnel that attended the exercise included the Commanding Officer, the Senior Engineering Officer (SEngO), a Flight Commander and a Junior Engineering Officer (JEngO). Exhibit 17

1.4.1.103 At RAF Lossiemouth, there remained 166 personnel (of which 93 were available) and 15 aircraft (of which six were serviceable to support the Flypro). The supervisory personnel at RAF Lossiemouth included OC B Flight (programming) who was Acting OC XV(R) Sqn in the OC's absence in RAF Akrotiri, OC Standards Flight (who was new in post) and a supernumerary Squadron Leader (Sqn Ldr) who had just relinquished the post of OC Standards Flight. The Executive Officer (second in command) was responsible for the Tornado GR4 role demo and was away from the Sqn, on his stand-down day, having flown at the weekend. Exhibit 17

1.4.1.104 The Sqn OC had previously discussed at a Sqn level Command Brief and with the Station Commander (Stn Cdr) at a Stn level command brief who would assume the role of OC XV(R) Sqn during the exercise and agreed that the most suitable person for the role was OC B flight (ASTON 1 WSO). Witness 7

1.4.1.105 There was a heightened awareness of perceived risk in "split Sqn operations" which was briefed to the XV(R) Sqn senior supervisors prior to the exercise. The Sqn OC stated *"my number one concern was supervision"* as "*the Squadron had not done split ops for a long time*[27]*"* and he made sure the right levels of supervision remained at RAF Lossiemouth in his absence. The Panel believes this placed a high tariff on the time available to the senior supervisors as it was directed that a flying Sqn Ldr (Flight Commander (Flt Cdr)) should remain on the ground during flying operations. Witness 7

[26] AP3000 Role 4, Attack.

[27] XV(R) Sqn had deployed in a similar fashion in Aug/Sep 11.

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1.4.1.106 The workload of supervisors will be covered in Section 1.4.2.

Medical Care of ASTON 1 WSO

Background

1.4.1.107 The ASTON 1 WSO presented to the SMO on 25 Apr 12, stating that he had reached *"a crisis point"* and *"could not face going flying"* due to the anxiety he felt when flying at ML. He had already declared his intent to seek medical help to his Sqn OC, who had arranged the appointment with the SMO. The SMO diagnosed a phobic anxiety disorder. The symptoms of vertigo (dizziness), fear of falling, sweaty palms, dry mouth, abdominal discomfort and feeling disabled until the aircraft returns to LL and a history of anxiety had now also become symptomatic whilst on the ground. Having gained permission from the patient, the SMO consulted with the Sqn OC. The Sqn OC then consulted the Station Commander and, on medical advice from the SMO that the WSO remained fit to fly, the Executive agreed that he was fit to continue flying. The WSO was given an absence from duties of 2 days on 25 Apr by annotation of his medical notes. The WSO was referred to the local Department of Community Mental Health (DCMH) for treatment. Exhibit 21 Exhibit 463 Exhibit 464 Witness 7 Witness 11 Witness 27 Exhibit 480

1.4.1.108 The SMO conducted the initial assessment and a physical examination of the WSO and on 14 May he was deployed on an Out of Area posting. Before departure he conducted a "hand over" of his practise to the Civilian Medical Practitioner (CMP) in the Medical Centre, and the Deputy SMO. This included passing on a list of "priority patients" and a verbal description of the diagnosis, prognosis and treatment. The WSO was on the list and a description of the treatment and prognosis was given to the CMP. The description included the facts that the WSO was fit to fly and that the Station Executive were aware of, and happy with, the decision for him to remain flying. The SMO felt that the WSO's presentation was *"a moderate presentation"* rather than being *"at the severe end of the spectrum."* Immediately after the "handover" of patients, the CMP went on two weeks leave and did not see the SMO again until he returned from his OOA posting. The SMO accessed medical records on 3 May and read the Community Psychiatric Nurse's (CPN) assessment of the patient from his first appointment; no further action was taken. After the SMO accessed the documents on 3 May, the Lossiemouth Station Medical Centre took no further part in treating or managing the WSO for anxiety. Exhibit 465 Exhibit 478 Witness 28 Witness 27 Exhibit 21

1.4.1.109 The WSO did not fly for three weeks after his initial presentation to the SMO. His next flight took place on 16 May 12. The WSO had no recorded absences from duties (declared unfit to fly) apart from the initial two day period prescribed by the SMO. The Sqn OC briefed the WSO that he would "*...work out whether or not you're fit to fly with the SMO. As soon as we get the green light from the SMO you can fly again...*". His course of action included directing the WSO to "*...go and do your first treatment at the psychiatrist over at Kinloss prior to...physically flying for the first time...*". The WSO declared at a review with the CPN and a consultant on 24 May 12 that he had had *"a 2 week period of grounding and following this had returned to flying"*. This was not documented in his flying records. At this review, the CPN noted that the WSO should remain in flying duties and recommendations on his Joint Medical Employment Standard (JMES) would be made as appropriate. OC XV(R) did not receive feedback from the CPN or SMO/CMP prior to the WSO resuming flying duties, he received feedback from the WSO. Witness 28 Exhibit 22 Witness 7 Exhibit 464

1.4.1.110 The WSO recommenced flying on 16 May after a plan was formulated by the Flying Executive that he would avoid medium level flight, which he had identified as the trigger mechanism for his anxiety. Additionally, he would only fly with staff instructor pilots, and not students. This was initiated by the WSO as he felt he should not be flying with students. This change in instructional status and control of flight regime was not regarded as a limitation by OC XV(R), but "*...an attempt to keep the sorties to a certain profile...*" Exhibit 22 Exhibit 21 Exhibit 464

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1.4.1.111 The WSO did not attempt to hide his condition; instead he explained it to the instructors on the sqn at a communal meeting (without students present) and discussed it with colleagues on station and elsewhere. On 8 Jun, at an informal function at another station, and under the influence of alcohol, the WSO described to a previous SMO he knew that he had an irrational fear of ejector seats that "*...could either kill me or save me...*" and that "*...he didn't really want to fly again...*" Discussing his condition with another doctor at the same event he informed him "*...that he wasn't comfortable flying, he didn't feel... in control..*" "*...and it hadn't happened to him before, and he couldn't explain why it was happening at that time, but he had decided not to continue flying...*" The two doctors did not raise any concerns as they both thought the WSO was no longer flying. Witness 7 Witness 29 Witness 30 Witness 33 Witness 40 Witness 34 Witness 36 Exhibit 477

1.4.1.112 On 27 Jun, ten weeks after initial presentation and having conducted 15 flights with staff pilots from XV(R) Sqn (22 hrs 40 mins flying, of which none was classified as medium level), the WSO resumed flying with student pilots. There was no medical review associated with this change in role nor any stipulated incremental sortie plan to resumption of instructional duties. He continued to see the CPN and the Consultant Psychiatrist who noted the change in training roles, recommended no requirement for medication and that the patient should not be downgraded. This is normal practise for DCMH recommendations. There was an understanding between the WSO, the CPN and the Consultant that the WSO remained in the early stages of managing the anxiety. He was assessed as "mildly anxious" but it was noted that his anxiety was *"deep rooted"*. Exhibit 22 Witness 7 Exhibit 21

1.4.1.113 During the preceding phase of flying with staff pilots, the WSO had informed them individually of his condition (if they had not been at the communal meeting where he declared his anxiety) and he made sure they were content with him to continue as their WSO. He informed them that his anxiety was brought about by flying at ML, and also described "*...suffering a bit with knife edge*[28]*...*" where he felt he was "*...a bit nervous when at medium level...*" The sorties were then planned to remain at LL. On resumption of instructional duties, the WSO did not inform the students of his condition prior to flying with them; they were generally aware of the situation from *"crew-room rumour."* Witness 16 Witness 13

1.4.1.114 The CPN and Consultant both conducted separate reviews with the WSO on 28 Jun, five days before the accident. The WSO gave conflicting information about his levels of anxiety to them, but both reports noted it was still present, albeit less severe than at his initial presentation. There were no inquiries about ML flight or the WSO's exposure to it. Exhibit 21 Exhibit 464 Exhibit 22

1.4.1.115 On 31 May, just over four weeks before the accident, he informed the pilot he was going to fly with that he felt a '*tunnelling effect when he looked out*' during low workload sections of the sortie and that he was very anxious before flying. On 18 Jun, he requested if the pilot who was conducting the planning for the sortie could "*avoid medium level*" if possible. On 26 Jun he stated to a pilot he was flying with that he preferred "local sorties" that remained at LL. The day before the accident, when speaking to the instructor who was setting the scenario for the flight for the day of the accident, the WSO had asked him to "*try and keep it at a low level*" which he duly planned to do. Interviews and electronic flight records show that the WSO was not exposed to ML flight or flight higher than 2-3000 ft AGL between 25 Apr (initial presentation) and 3 Jul 12 (the day of the accident). Witness 31 Witness 16 Witness 2 Witness 34 Exhibit 233

[28] Usually associated with high altitude flights, and during periods of low stimulation, some pilots have been known to suffer from various "out-of-body" experiences, where they "sense" that they are on the wing looking back in at themselves flying the aircraft. Under similar conditions, some pilots have also reported feeling that the aircraft is precariously balanced on a knife edge and extremely sensitive to small control inputs, or sometimes being "held" or restrained somehow, such that the controls become ineffective.

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Symptoms

1.4.1.116 The symptoms experienced by the ASTON 1 WSO at initial presentation to the SMO were vertigo, dizziness, fear of falling, sweaty palms, dry mouth and abdominal discomfort. These symptoms had begun to get worse and had arisen in an anticipatory fashion before flying (and during mundane flying related tasks such as reviewing the Flypro). He admitted he had chosen to fly the Tornado GR4 rather than the Tornado F3 due to the *"ML issue"* in flying training. The SMO diagnosed these symptoms as mild and recommended he remain fit to fly. Exhibit 21 Exhibit 464 Exhibit 480

1.4.1.117 Symptoms described to the CPN by the ASTON 1 WSO were vertigo, anticipatory anxiety of mid-level flight and anxiety about his ability to fulfil his role should he be unable to control his anxiety at ML. Feelings of panic and disorientation when looking out of the aircraft at ML with significant anxious arousal resulted in him not looking out of the aircraft. Hyperventilation, increased heart rate, paraesthesia, holding onto the sides of the aircraft and feeling disabled until returning to low level. He also experienced disturbed sleep through anxiety with resulting fatigue the next day. The CPN diagnosed these symptoms as *"a straightforward anxiety case"* and recommended he remain fit to fly. Exhibit 21 Exhibit 464 Exhibit 480

1.4.1.118 Symptoms initially described to the Consultant by ASTON 1 WSO were of an anxiety and phobia related to flying at ML. He had been experiencing anxiety since his early training as a WSO. Sweating, palpitations and paraesthesia had reached panic levels with fear of losing control. These symptoms have been present since early flying training. Whilst the symptoms tended to occur at ML they were also now affecting him when flying at LL. The symptoms were worse at periods of low work intensity during flight. He described feelings of anxiety when thinking about flying even when not in work, and on walking out to the aircraft. He began anticipating the symptoms and felt relief when a possible exposure to flying related events were cancelled, such as a recent cancellation of a sea survival drill. He had a worry of acute anxiety/panic attack whilst flying and the possible serious consequences when instructing students. There was also an anxiety of the impact of the illness on his career. The Consultant Psychiatrist diagnosed the patient as moderate and recommended he remain fit to fly. Exhibit 21

Anxiety Disorders

1.4.1.119 Anxiety disorders include generalised anxiety, specific phobias and panic disorder. Problems associated with stressful circumstances may be more appropriately classified as an adjustment disorder, which can be a lesser presentation of anxiety. Symptoms and signs of an adjustment disorder can include palpitations, tremor, shortness of breath, chest pain, dizziness, fatigue, weakness, headaches and paraesthesia (pins and needles). In panic disorder there is a risk of sudden incapacitation. Exhibit 115

1.4.1.120 Both anxiety and adjustment disorders may elicit an appropriate limitation in their working duties. This may be appropriate for individuals with phobic disorders (to avoid the circumstances of the phobia initially) and also in the case of adjustment disorder when minor degrees of anxiety symptomatology arise in association with difficult psychological circumstances. In these cases judgement and cognitive performance might be impaired. Exhibit 115

1.4.1.121 The medical condition of ASTON 1 WSO is analysed in Section 1.4.3 and the medical care of ASTON 1 WSO is analysed in Section 1.4.6.

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