PART 1.4 – FINDINGS

INTRODUCTION

1. The Panel formed an account of events prior to the sortie from witnesses. The R-ADR, Engine Health and Usage Monitoring System (EHUMS) and RAIDS from ZE982 along with the R-ADR, RAIDS and HUD video from BLACKSMITH 2, enabled a comprehensive reconstruction of the sortie to the point of impact. The disbandment of the Sqn during the early stages of the Inquiry made revisiting some issues time consuming. To meet the Panel's TOR the investigation was split into the following areas:

a. Escape System and Survival Aspects.

b. Damage to AC, Public and Civilian Property.

c. Technical Events.

d. Risk Controls.

e. Local Conditions.

f. Individual Actions.

2. The evidence available to the Panel is catalogued at PART 2 of this Report.

SERVICES

3. To assist the Panel in its deliberations the following services were available:

a. The RAF Centre for Aviation Medicine (RAFCAM).

b. QinetiQ.

c. RAF LEUCHARS Senior Medical Officer.

d. Joint Ac Recovery & Transportation Squadron (JARTS).

e. Air Accidents Investigation Branch (AAIB).

f. RAF LEUCHARS Met Office.

g. BAE Systems (BAES).

h. Rolls-Royce.

i. Tornado PT.

j. No 1 Aeronautical Information Documentation Unit (AIDU).

k. Air Staff Service Inquiry Advisors.

[redacted]

ESCAPE SYSTEM AND SURVIVAL ASPECTS

4. The crew were found dead at the scene by the Strathclyde Police Helicopter Observer. — Witness 12

a. **The Pilot.** Investigation into the Pilot's ejection seat shows that the Seat Pan Firing Handle (SPFH) had not been moved and no gas had passed through the command-ejection firing connector[1]. A full autopsy was carried out which concluded that the pilot died from head and chest injuries. These injuries and his location within the wreckage were consistent with him being in his seat, within the ac, at the time of ground impact and being thrown clear during the subsequent break up. — Exhibit 4

b. **The Navigator.** Investigation into the Navigator's ejection seat showed that the SPFH had moved from its housing. The seat pan cartridge, primary gun and secondary gun cartridges had fired with the Harness Power Retraction Unit being activated to withdraw and lock the harness straps. The seat rocket motor had also fired. A full autopsy was carried out which concluded that the navigator died from multiple injuries. These injuries and his location, at the end of the wreckage trail, were consistent with him being in his seat, within the ac, at the time of ground impact and receiving additional momentum from the ejection gun and rocket motor during the ac break up sequence. — Exhibit 4

c. The Command Ejection selector lever was not recovered. The selection of the Command Ejection lever to 'both' was mentioned by the Crew though not in a challenge/response format. The canopy micro switch parameter on the R-ADR can be used to indicate the firing of the canopy during an ejection sequence. No indication of the canopy micro switch was recorded post canopy lowering during crew-in. The Navigator had a high level of concern for the aircraft's flight path in the last 2-2.5 seconds though there was no verbal indication of an attempt to eject. The cockpit 60Hz tone, as a result of penetrating the preset Radar Altimeter minimum height, can be heard during the brief period following the Navigator's comments to EOD. The SPFH could have been displaced by the Navigator though it could also be displaced during ac break up. The Navigator had separated from the cockpit wreckage on a diverging trajectory along the wreckage trail. His Personal Locator Beacon (PLB) was detached from his waistcoat. The PLB pocket was complete with the stitching attaching the pocket to the waistcoat having broken. The pocket and his helmet were recovered in the vicinity of the main cockpit wreckage. — Exhibit 63, 6 — Exhibit 4

d. The Panel concluded:

(1) No ejection command was made prior to main impact.

(2) The Navigator may have been in the process of making an ejection attempt. However, it is likely the force of the main impact caused either fatal or debilitating injuries, preventing any further deliberate egress actions.

[1] Normal initiation of ejection is by own Seat Pan Handle or by gasses from the other occupants ejection sequence passing through the connector.

[redacted]

[redacted]

(3) The lack of an abandonment decision, by either of the Crew, suggests that they were not aware of their situation early enough to process an ejection decision. This was deemed a survival aspect of the accident and did not contribute to the loss of the aircraft. The Panel judged a crew could not reasonably be expected to have assessed and actioned a valid ejection decision in the time available.

5. **Degree of Injury.** The Panel found the following: Exhibit 7

a. **Service Personnel.** Both the Pilot and Navigator were killed.

b. **Civilian Personnel.** There were no injuries to any civilian personnel.

DAMAGE TO AC, PUBLIC AND CIVILIAN PROPERTY

6. **Tornado F3 AC.** ZE982 suffered Category 5 damage. The ac suffered catastrophic damage on impact with the ground.

7. **Public Property.** Damage to Public Property at 'Net Book Value' was:

a. Ac ZE982 – £721,889.

b. Aircrew flying assemblies x 2 - £17,019.

c. ASRAAM Trg Missile – [redacted]

d. RAIDS Pod - [redacted]

The total loss of Public Property calculated by the Panel was £955,550.

8. **Civilian Property.** The accident occurred on civilian owned land. The landowner has commissioned an independent survey of the accident area. Any issues identified in the independent survey will be managed by Defence Estates.

9. **Classified Material.** ZE982 contained 6 classified Line Replaceable Units and 4 classified cryptographic items. 3 of the 4 cryptographic items were recovered from the crash site; none of the remaining items were located intact. The quick arrival of the police at the crash site ensured the site was cordoned off. JARTS conducted a thorough trawl of the crash site and removed all of the associated debris from the mountain side. The Panel concluded that there was minimal risk of any classified material not being recovered. Should any piece of classified material not have been recovered, the risk of subsequent exploitation would be unlikely due to the level of the ac destruction.

TECHNICAL EVENTS

10. **Ac Integrity.** There was no evidence of structural failure, critical system malfunction or damage to the ac prior to the accident. Analysis of quarantined batch samples of liquid oxygen, engine and hydraulic oils following the accident did not reveal any anomalies that could have contributed to the accident. The panel concluded that ZE982's integrity had not been compromised prior to the crash. Exhibit 1,3,6

[redacted]

[redacted]

11. **Ac Maintenance.** A review of all rectification conducted since the last scheduled maintenance (25:10 hours prior to final sortie) did not reveal any disturbance of the primary and secondary flying control systems. There were 8 extant Limitations on the ac. However, none were pertinent to the accident. The ac had 1 pre-flight requirement ("RED SNOW") on the final sortie, requiring a CSAS functional test to be conducted before flight. The test was successfully completed by the Pilot during crew-in.

12. **Ac Air Incident History.** During the ac's penultimate flight, on 1 Jul 09, the pilot incident-reported that the RH engine had suffered a surge resulting in a curtailed sortie. A review of the ac's air incident history over the last year was carried out and the Panel discounted any other incident reports from the Inquiry. Exhibit 15

13. **Engine Serviceability History.** Rolls-Royce Air Safety Investigation attended the accident and recovered the major engine components including both Digital Engine Control Units (DECUs). Both DECUs were fitted with EHUMS, enabling more detailed engine reporting. The ac had received post engine surge checks for a right-hand engine surge on the sortie prior to the accident. EHUMS data revealed that the engine had surged twice. The first, at 20,000 ft and 250 kts, during reheat modulation; the engine recovered within 2 seconds and it is unlikely the pilot noticed the event. The second, at 38,000 ft and 250 kts, again during reheat modulation; this time running down to a sub-idle condition for 27 seconds before recovering. The ac was being operated in a marginal region of the operating envelope with respect to speed and altitude and it is not uncommon for engine surges to occur in these circumstances. 1st Line maintenance conducted the appropriate examination iaw the Mandatory Procedures. No faults were reported but the beta function settings for the right-hand engine were adjusted to improve the reheat running line (standard engineering procedure). There were no other reported engine incidents within the last year and examination of the engine documentation revealed no gaps in maintenance. Exhibit 2

14. **Engine Serviceability and Performance.** During crew-in, the right engine experienced a 'hot start' which was dealt with by the Pilot and subsequently re-started correctly with no further complications. Prior to take-off the Crew of ZE982 carried out the required Minimum Power Checks. The figures were recorded and were within the limits stated in the ac documentation. Assessment of the R-ADR and EHUMS data confirmed that the engines were operational and providing power in response to the throttle input demands throughout the accident flight. Post accident investigation found no evidence of pre-impact damage that could have affected engine performance. The Panel discounted engine serviceability as being a factor in the accident. Exhibit 63 Exhibit 16

15. **Wing Sweep and Manoeuvre Device System Serviceability.** In-depth investigation by BAES under AAIB supervision revealed that: Exhibit 1,3

a. From 130 sec to EOD the wing sweep was at 27.9° and not the expected 25° or 45° position. On the subsequent selection of MVR the flaps were in the UP position and the slats were in the MVR position. The flap position was as a result of the wings not being at 25°.

b. The indication of wing and slat position being transmitted to the cockpit instrumentation was commensurate with the actual position.

[redacted]

The flap angle being sent to the cockpit instrumentation could not be directly ascertained. However, whilst the output to the cockpit could not be established, the fact that the assembly is driven by the same mechanism that provides feedback to the HLWSCU E-Box (which was correctly indicating that the flaps were up) indicates that the signal sent was likely to be correct.

c. The calibration of the cockpit instrumentation had been disrupted by the accident and could not be verified.

d. There was no evidence to indicate a wing sweep control restriction either within the throttle box or the wing sweep control run; however, this could not be ruled out.

16. Following confirmation of the ac configuration at impact, the Panel considered the possibility of a temporary restriction within the wing sweep mechanism or both an unserviceable and/or misread Cockpit Position Indicator (CPI) as factors. Investigation into the CPI found that the graduation movement of the wing sweep indicator from 25° to 27.9° was small. A slight gauge discrepancy could easily be interpreted as the wings being fully forward (25°). With the wings fully forward (25°) the selection of MVR would have provided a flap and slat indication on the CPI as shown in Figure 6. With the wings at 27.9°, only the MVR slats would travel (Figure 7). Additionally, slat deployment could easily be confirmed visually on the leading-edge of the wing (though the flap would not have been visible). At MVR selection, the gauge movement for the flaps on the CPI is less than that of slat. The calibration of ZE982's CPI could not be proven post the accident. The final recorded check of the wing sweep was verbal by the Pilot and was carried out after selection, during a relatively benign phase of flight. The selection of MVR was carried out on entry to the series of valleys at TARBET, coincident with an increase in workload. The Panel could not rule out a combination of gauge error, gauge interpretation and/or temporary restriction as factors effecting the ac configuration at the time of the accident. Nonetheless, considering the weight of evidence, the Panel concluded that the final configuration was more likely to be as a result of mis-selection and subsequent gauge interpretation, rather than a technical event.

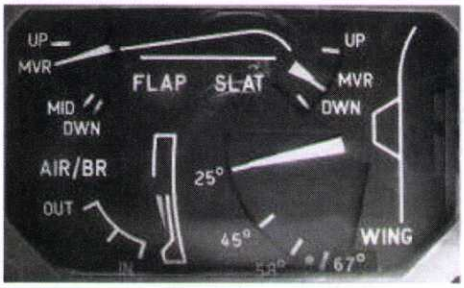

Figure 6

Exemplar 25° MVR Wing

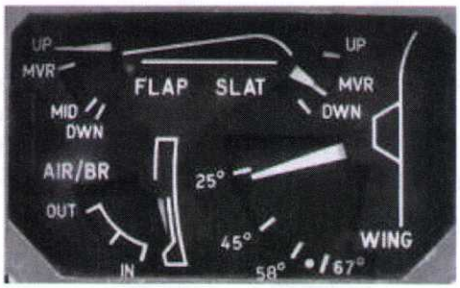

Figure 7

Likely Configuration at Accident

17. **Loose Articles.** ZE982's Loose Article Register (MOD Form 704LA) contained history of 2 suspect loose articles. Having assessed the potential risk that each loose article presented to restricting the wing sweep system, the Panel concluded that they were not germane to the inquiry. However, a review of archived engineering documentation revealed that a record of a loose article had been incorrectly removed from the Loose Article Register (SNOW 5545). Exhibit 17

The item was a Master Armament Safety Switch (MASS) actuator pin and was found missing in the cockpit on 30 Jun 08 (SNOW 5062). Analysis of the work done to mitigate the risk that this item presented to the ac was within extant policy and the Panel concluded that the risk had been suitably reduced. Although unlikely to be a factor, the Panel could not positively rule out that a loose article prevented the wing sweep selection lever from moving fully forward.

18. **R-ADR Normal Acceleration Parameter.** The normal acceleration parameter was not recorded throughout the flight. The most likely cause is the failure of the Normal Accelerometer Unit (NAU). This is a known issue and was also found with BLACKSMITH 2's recorded data. The Panel understands work has begun to address this issue though remedial work has yet to be implemented. It is fortunate that the Panel were able to exploit RAIDS data to replace this important parameter; without which, the Panel would have had multiple variables to contend with to resolve ac flight path and performance characteristics. Exhibit 6

19. **R-ADR Identification.** The R-ADR was not found at the crash scene until day 4. The R-ADR was found within its associated spine panel (Figure 4) and, as there were no associated external marking, the spine panel was frequently overlooked. Exhibit 3

Figure 4

R-ADR spine panel

IAW DEF STAN 00-970, Section 7.4 specifies the requirements for ac markings. Para 7.4.27 stipulates that servicing points should be marked iaw DEF STAN 05-18. DEF STAN 05-18, Table 1, Symbol 16 specifies the external marking for an ac's flight data recorder (Figure 5). Exhibit 18,19

Figure 5
ADR DEF STAN marking

The Panel observed that the R-ADR spine panel of ZE982 was not marked, thereby directly contributing to the delay in recovery of the R-ADR. Additionally, the internal colour of the R-ADR bay was no different to the rest of the ac's internal finish. Also, the organisations in attendance at the crash site were not fully aware of the DEF STAN symbol for a flight data recorder.

20. A comprehensive review of engineering documentation, ac history, cockpit voice recording, ac system parameters during the sortie (from the R-ADR and EHUMS data) and external reports allowed the Panel to conclude that ZE982's flying control systems, engines and structure were serviceable and all critical systems operated correctly during the sortie; there was no evidence to prove that a technical event caused the loss of ZE982. However, the panel could not positively determine why the ac was in 27.9° wing sweep.

RISK CONTROLS

21. **Engine Power Management.** Prior to 2008, all Tornado F3 (Mk 104) engines were Stator Outlet Temperature (SOT) rated. A policy review in 2006 decided that the rating of Tornado F3 engines would be changed from SOT Rating (of 1590K) to Thrust Rating (of 38.8kN), in line with the Tornado GR4 (Mk 103 engine). This change provides a known and consistent thrust output for the Mk 104 fleet, as well as reducing the cost of ownership by reducing the engine cycle temperatures. The Minimum Installed Thrust Level (MITL) on which the Operating Data manual (ODM) is based was not changed. Implementation of this policy was agreed by HQ 1 Gp in Sep 06 and implementation commenced in Feb 08. The Panel concluded that this change in policy was not a contributory factor in the accident. Exhibit 20,21,22,23

22. **Pilot Checks.** The merger of the F3 OCU with the Sqn as the Operational Trg Element (OTE) during Apr 08 under PROJECT WATERFRONT gave rise to a single sqn with 2 distinct outputs. The OTE and FL operated as 2 separate units. The boundary between OTE and FL was only routinely traversed by Sqn execs and QWIs. Regular Authoriser meetings were held, though OTE student progress was covered at a separate meeting for OTE crews only. 1 Gp Air Staff Order (GASO) 360 directs that all pilots arriving on a sqn from an OCU Long/Main Course are to be given both a day and a night arrival check prior to flying as captain by day and night respectively. Day and night arrival checks were not carried out by the Sqn when a pilot finished the OTE Long Cse and joined the FL unless exceeding the 31 day currency period following the Cse. There was no record of waivers being sought from higher authority for this omission. 1GASO 360 states that in exceptional circumstances, extensions may be considered on a case by case basis by the Fce Cdr. If granted, written approval of the extension is to be retained in the individual's Trg Folder until the outstanding periodic check is completed.

a. The Pilot of ZE982 flew a Mid-Course Check on the OTE on 29 Apr 08. He did not complete an arrival check when he moved across to the FL. As a dilutee[2], as described in 1GASO 360, the Panel considered he should complete a day handling check every 6 months. He subsequently flew his next recorded 6 monthly dual handling check on 27 Mar 09 – an 11 month gap. This 11 month period included a deployment to the FALKLAND ISLANDS (FI). The Pilot's last dual Annex A Exhibit 45

[2] A dilutee is a fist tourist pilot in the first 2 years of his tour.

[redacted]

check was curtailed by a flat/slat problem and the check was not completed to the minimum requirements as prescribed by 1GASO 360; however, Duty Carried Out was recorded. Exhibit 49

b. From other records available the Panel made the following observations: Annex B

(1) The Sqn QWI flew out of day currency during the return from EX RED FLAG in Mar 09. The Sqn was aware of his impending currency requirement prior to deployment should the return trail be subject to a delay. The Sqn OC cleared continuance and his first sortie on returning to the UK was an annual day dual check. No retrospective extension was sought.

(2) A dilutee pilot is required to conduct an annual night dual check for the first 2 years of his tour. Another dilutee pilot joined the Sqn on 1 Apr 08 having completed a night dual on 17 Dec 07 on the OTE. He did not complete a night arrival check and flew his next night dual check on 1 Apr 09. He was out of night dual currency from 17 Dec 08 to 1 Apr 09, completing both QRA duties and night flying in the period.

(3) A dilutee and First Tourist Instructor ('*Creamie*') is required to fly 6 monthly dual checks for the first year of a tour. A pilot fulfilling these criteria flew on 1 occasion out of day dual currency before completing a day check the next day.

23. **FI Pre-deployment.** As part of pre-deployment preparation, a Qualification Form was required to be submitted to OC 1435 Flt at least 4 weeks prior to deployment. The Form was used to compile a local Authorisers Matrix and ensure an audit control of aircrew currencies. The Form included supervisory qualifications and a Sqn Cdr's Certificate, which included any waivers granted by HQ 1 Gp. Following a visit by the incoming F3 Fce Cdr to the FI, in Dec 07-Jan 08, and the removal of the FI exec flying, the requirement to duplicate supervisory responsibility was to be removed by placing the responsibility within the F3 Fce HQ. This decision resulted in the Qualification Form being made redundant. However, the Tornado F3 Operational Training Syllabus (OTS) was not updated to reflect this decision and no replacement order was generated. Despite the requirement in the OTS not being removed (F3 Fce Cdr as Custodian but Governed under HQ 1 Gp, AO CAE signature), the Sqn discontinued completion of the Pre-Deployment Qualification Form. The Panel concluded that: Exhibit 24 Exhibit 27

a. The informal removal of the requirement to complete a Pre-Deployment Qualification Form, without putting in place alternate procedural controls, undermined the Fce's ability to ensure all aircrew currency requirements were met for deployment to the FI.

b. The removal of the Form at the Sqn-level may have allowed the Pilot to deploy to the FI without a 6 monthly dual check.

24. **Fast Jet Refresher Trg.** The Pilot of ZE982 should have attracted a refresher cse in accordance with 22 Trg Gp Orders. The dates that attract this refresher are bounded by the graduation and commencement of phases of trg; in this case graduation from the NATO Flying Trg Course (NFTC) and the F3 Exhibit 25 Exhibit 9

[redacted]

[redacted]

OCU. The dates were 14 Aug 07 and 14 Jan 08 respectively, a period of 22 weeks which exceeded the 19 week threshold and should have attracted a refresher of 20 hrs. The aim of such a refresher cse is to refresh the student in FJ handling prior to an OCU. In addition, the Panel was unable to find a record of the decision to exclude the Pilot from Fast Jet Refresher Trg. Although refresher trg was bounded by cse dates, the Pilot flew on 14 Aug 07 on NFTC and flew his next trg event on 07 Apr 08; a period of 29 weeks. The Panel considered that the light-ac flying the Pilot undertook from finishing NFTC may have had a detrimental effect on his fast jet handling. This may have been detected or trained out during a period of refresher trg. The Panel could not discount the lack of Fast Jet refresher trg as a factor in the accident. Exhibit 26

25. **Light-Aircraft Flying.** During trg and periods of consolidation, certain basic flying control skills (including the use of rudder on light-ac) are trained to an automatic level; this results in a pilot not having to use valuable processing capacity during various stages of a sortie. It is possible that during high workload periods, when a pilot approaches task saturation in a discipline that has not been practiced, a pilot may misapply techniques learnt on a different ac type. The Pilot of ZE982 had recorded 36:50 hrs flying in light-ac since Mar 09. Due to the extent of the Pilot's light-ac experience it cannot be ruled out that he had developed distorted handling habits. Additionally, it is possible the Pilot's visual assessment of the turn, the attention afforded to the hillside and the distraction of the valley exit, were influenced by his light-ac experience. Annex A Exhibit 5

26. **Low-level Competency and Currency.** Since the introduction of new weapons on the F3, the operational output has shifted from a low/medium-level emphasis to one of medium/high-level. QRA scenarios endorse the requirement to fly at low-level, in varying terrains and at low speed. The F3 OCU/OTE syllabuses contained serials to qualify students in operating and weaponeering the aircraft at low-level. Post conversion, no currency or check of competency is mandated and it is not a formal requirement as part of the dual check. The Panel could not rule out the lack of low-level currency requirement and competency checks as factors in the accident. Exhibit 50

27. **Pilot CR Status.** The pilot was awarded Limited Combat Ready (LCR) status on 28 Oct 08 and CR on 20 Apr 09. There was no record of the Pilot completing the whole of the Air to Air Refuelling (AAR) phase. The Panel observed that the OTS offers contradictory direction toward awarding LCR at the sqn cdr's discretion whilst mandating the completion of the whole of the AAR phase prior to LCR. Exhibit 48

28. **Aircrew Trg Folders.** A number of inconsistencies were observed in the Sqn Trg Folders. 1GASO 360, 1GASO 401 and the F3 OTS offer contradictory direction. 1GASO 360 and 1GASO 401 state that Trg Folders for each individual are to include full documentation of the qualifications and trg status relevant to an individual's current role/tour. Documents requiring a STAFF privacy marking should be raised as a temporary enclosure in the F5200. Pilot handling and navigator/Weapons System Operator (WSO) role/tactical currencies could not always be referenced as the sortie dates on the Operational Status Certificate (OSC) were missing and no reports were evident. Many of these reports may have been raised into individual F5200s. These include Instrument Rating Tests (IRT) and pilot/WSO Standards checks (STAFF privacy). Annex B

[redacted]

29. **In Year Delivery Plan (IYDP) Confliction - STANEVAL**. The reduction in Fce size was the key driver for the changes to STANEVAL for FY07/08. The extant 2 week STANEVAL of FL sqns every 2 years was not agile enough to fit in with Fce requirements and commitments. As a result, STANEVAL would be conducted on a continuous assessment basis under supervision of the F3 Fce ACOS A7. This rationale was accepted in subsequent IYDP. There is no reference in FY07/08, or subsequent IYDP to the reporting timeline conflict with 1GASO 360.200. The Panel were unable to find any acknowledgement of this conflict from HQ 1 Gp. A STANEVAL (Central Flying School) visit was carried out on the Sqn prior to the implementation of PROJECT WATERFRONT during Jan-Mar 08. A STANEVAL (Tactical Standards) visit was conducted on the Sqn during 3-21 Nov 08. No adverse comments were made in a combined report dated May 09. Exhibit 28 Exhibit 47

30. **Post Crash Management (PCM).** The Stn was well prepared for PCM activity, having undergone a 2 day PCM Ex 6 weeks prior. The Stn had an ECC which was stood up immediately following notification of the accident. The priority for the Stn remained the safe maintenance of QRA whilst PCM activities were carried out. The crew of BLACKSMITH 2 attended the ECC to add some immediate clarity on the accident to the command chain. The Stn was first notified of the deaths informally, via telephone. Subsequently, formal confirmation was received from the MOD Duty Officer. There was an element of confusion regarding which organisation had the lead on Kinforming. It was confirmed that CIVPOL have the lead on confirmation of casualties and authority to Kinform. Kinforming authority, by RAF LEUCHARS, was granted at 1415 by CIVPOL and Kinforming was completed by 1555. The Navigator's NOK were informed iaw his wishes from post incident/accident information held on the Sqn. The Pilot's NOK were informed via his father's military (LAND) chain of command and COS F3 visited his family early that evening. The accident was initially widely reported on both local and national media. Media reported within minutes of the accident with national coverage through television news and radio. The Sqn was in MINIMISE conditions throughout the period of Kinforming. The combination of media reporting and MINIMISE lead to some angst by surviving formation members NOK. The Panel observed that the Sqn informed the next days programme via external e-mail to Sqn recipients and the distribution list had not been amended during a period of multiple postings. This resulted in past Sqn members, and their partners, being able to identify members of the Formation outwith the Sqn Kinforming procedure and in confliction to MINIMISE procedures. RAF LEUCHARS personnel all received TRIM either as groups or individually, depending on degree of exposure. The Panel concluded that PCM at the Stn and Sqn level was well executed and enabled the Stn to maintain the operational output without compromise. The Panel felt that the angst caused by MINIMISE on the Sqn was justified to ensure that Kinforming was not compromised. Exhibit 56,64

31. **Ground Proximity Warning System (GPWS)**. Tornado F3 GPWS is provided to give audio only warnings to the crew that the ac is in danger of impacting the ground or an obstruction. GPWS relies on the use of digital terrain map data contained in the Terrain Profile Matching system and a digital vertical obstruction file. The Predictive Ground Collision Avoidance System element of the GPWS uses ac position and the stored terrain and obstruction Exhibit 52,53

databases to provide a warning where the ac may penetrate a set Minimum Clearance Height (MCH). F3 standard operating procedure is to confirm that the default of 80ft is set. The warning is based on an assumed ability of the ac and pilot to react to the warning, achieve wings level flight and pull to a set g value at a specific g onset rate. The following are the parameters used:

a. 60°/sec Roll Rate.

b. 3g/sec onset rate.

c. Available g calculated using speed and ac configuration data. A value of g is then determined between 1.5g and 3g; enabling the GPWS to provide better protection over a larger proportion of the flight envelop.

d. When the system calculates the current available g is less than 3g, g operates in the range 1.5g to 3g.

e. 2 secs reaction time.

32. The system operating advice is based around the following:

a. The GPWS is advisory only; it does not have safety critical levels of integrity.

b. The GPWS does not change the ac operating philosophy, ie, it is not a replacement for the existing aircrew procedures with regards to ground/obstruction avoidance.

c. The GPWS should never be used to maintain safe separation from the ground and/or obstacles.

33. The audio output level of the GPWS system is fixed at a moderate level. As a result, the audio warning can be swamped by audio outputs from other communications or warning systems.

34. Since GPWS introduction on the F3, in most configurations the ac has excess performance to outperform the GPWS predictions. The introduction of the 4g ac limit during 2008 reduced the margin of excess performance. An ac configuration that has a NO limit of less than 3g will have any performance reduced further. The Panel determined that the GPWS was functioning as prescribed in the technical documentation. The panel felt that the operating direction was correct for the GPWS and the Aircrew Manual was accurate. However, the Panel found that GASO reference presented too many sources of information to the end user and the level of system understanding needed to be increased. Exhibit 52,54,55

35. **Formal Staff Visit (FSV) and Assurance.** No record of a FSV later than 2005 could be found by HQ 1 Gp or F3 Fce Hq. A FSV was carried out in Sep 07 by F3 Fce A7 on another F3 sqn. A report and response was written, though no record of the visit or any subsequent actions could be found. The Panel considered the HQ 1 Gp Assurance Manual and concluded that some of the anomalies in aircrew documentation on the Sqn would have been avoided had the Sqn been subject to external audit using the extant Manual (dated May 09). A review of the HQ 1 Gp Assurance Manual revealed a number of Exhibit 57 Exhibit 66

[redacted]

reservations; however, the Panel were unable to source the necessary documentation to pursue the matter any further, in the time available.

36. **Conclusion.** The Panel drew a number of conclusions when considering Risk Controls. Although there was no evidence to directly link a single risk control with the loss of ZE982, the association and combination of factors within risk controls could not be discounted by the Panel as contributory factors in the accident.

LOCAL CONDITIONS

37. **Brief/Planning Process.** The tasking, planning and preparation at the Sqn level was executed within extant rules and regulations. The alteration of the sortie profile to meet the delayed AWACS was dealt with correctly. The Panel could not find any aspect of this phase of the sortie that contributed to the accident.

38. **Medical Issues**. There were no extant factors affecting the Pilot's medical category. The Navigator had an A2 marker [redacted] — Exhibit 7

39. **Competency and Currency.** The Panel considered the following competency and currency of the Crew:

a. **The Pilot.** The Panel could not rule out the following, individually or collectively, as contributory factors in undermining the Pilot's competency to undertake the tasked sortie: lack of Refresher Trg, paucity of Dual Checks, light-ac flying, lack of low-level currency and lack of competency checks at low-level. These issues have been discussed previously in Risk Controls and will be discussed further in Individual Actions.

b. **The Navigator.** The Panel concluded that the Navigator was competent to undertake the tasked sortie though this was as a result of the likelihood of a lesser degree of skill fade in the low-level environment due to his experience level. — Annex E

40. **Wellbeing.** The Sqn had gone through a significant amount of change in the year preceding the accident. The announcement of Planning Round 2009 (PR09) called for the removal of Tornado F3 Force Elements At Readiness (FE@R), thereby reducing the Fce to supporting QRA only. This measure reduced the flying hrs to 10 hrs per month per crew, for a total of 16 crews, by Oct 09. This measure was backdated to 01 Apr 09. This announcement resulted in the extant run-down profile for the Sqn being brought forward. As a result, the Sqn was to be disbanded with 6 weeks notice. Fce HQ and 1 Gp staff provided mitigation to prevent a cliff-edge effect and smooth the run down profile for personnel. Despite having a posting to remain on the F3 Fce, the Pilot aired his concerns over both his immediate and long-term future in the RAF. As part of the Sqn disbandment activities, the Pilot was tasked with organising the Sqn Open-Day on the weekend of 11 Jul 09. This task had been allocated at short notice following the posting of the original Project Officer. The Panel concluded that the sudden change and insecurity in both immediate and long-term careers influenced the personal wellbeing of the Crew. Whilst the Panel concluded that the wellbeing of the crew was likely affected it was not able to determine whether this contributed to the accident. — Exhibit 5; Witness 1; Witness 10,11; Witness 6; Exhibit 5; Exhibit 7

[redacted]

[redacted]

41. **Fatigue.** Separate witness testimony, bar receipts and a visit by the Panel to the Pilot's private accommodation raised no concerns over the Pilot's on-the-day readiness, as a consequence of fatigue through the consumption of alcohol or lack of rest. Toxicology tests showed that the Pilot had no alcohol in his blood though he had a small quantity of alcohol in his urine. A post-mortem level of alcohol in the urine, without a level of alcohol in the blood, suggests that alcohol was still in the blood the last time the bladder was emptied. There are a number of assumptions that need to be applied to interpret the level of alcohol in the urine to ascertain the level of alcohol consumed. These assumptions include the last time the bladder was emptied and an individual's metabolic processing rate for alcohol through the body. The Panel considered the variations for the Pilot that included when he may have last emptied his bladder and how much alcohol he would have needed to consume to provide the levels reported. The panel could find no explanation for the small level of alcohol in the urine. With the weight of evidence contrary to the urine sample, the Panel could not account for this anomaly and concluded that the pilot was not fatigued through lack of rest or subject to any post-alcohol induced performance limitations.

Part 2.1
Witness 4,5,6,7
Exhibit 7,65

42. **Fuel Load.** At the point of impact the ac had an AUW of 23,500kgs, with a relatively high fuel load of 7,700kgs. The turn was still achievable in Lima fit at 23,500kgs. A heavy AUW limits the manoeuvrability performance of the ac and its ability to maintain speed.

Annex C

a. For an ac with an AUW of 18,000kgs, entering the final turn at 330 kCAS, modelling has shown that the outcome would remain unchanged using the same technique and 2.94g[3]. However, interpolating between sustained and instantaneous g available (accepting a significant airspeed reduction) using 3.5g, the turn would have been achievable.

b. For an ac with an AUW of 18,000kgs, entering the turn at 360 kCAS using 2.99g[4], the turn was unachievable. Additionally, interpolating between sustained and instantaneous g available (accepting a significant airspeed reduction) using 3.5g, the turn was unachievable.

c. For an ac with an AUW of 18,000kgs, entering the turn at 400 kCAS using 4g, the turn was unachievable.

43. The Panel concluded that airspeed in a lighter ac would not have decreased as rapidly and is likely to have remained above 350 kCAS. The previous calculations show that the turn was unachievable at that airspeed. AUW was an aggravating factor in this accident but a reduced AUW would not have prevented the accident. Additionally, the Panel could not determine how a lower AUW may have changed the course of events throughout the latter stages of the sortie. It is possible that a lower AUW could have altered the handling decisions by the Pilot, prior to positioning the ac for the final turn, and therefore changing the final outcome. Nevertheless, this hypothesis does not modify the causal and contributory factors the Panel have identified surrounding the accident.

[3] Sustained g at 330 kCAS and 18,000kgs AUW.
[4] Sustained g at 360 kCAS and 18,000kgs AUW.

[redacted]

[redacted]

44. **Terrain.** Low-level flying is inherently hazardous, as a consequence of flying at speed with a reduced separation distance from terrain. Effective Situational Awareness (SA) is vital mitigation to the hazards that low-level flying presents. The Panel concluded that the terrain selected by the Crew during their route selection was challenging but achievable within the limitations of the ac.

45. **Use of Velocity Vector (VV)**

a. When VV is selected in the HUD, the ac symbol is referenced to the ac velocity vector within the limits of approximately +/- 5° in azimuth and +5° to -15° in elevation with respect to the longitudinal fuselage datum. The VV will inform the pilot of the ac's flight path. When flying at low-level, in addition to other visual cues, it can be an additional source for identifying a hazardous trajectory. However, during manoeuvring, the VV display will drift as the data source is dynamic thus hindering air-to-air weaponeering. It is common practice on the F3 to fly with the ac symbol locked to prevent excessive drift. The VV can be locked either by pilot selection or during excessive drift when the symbology reaches the limits above. As a result the use of the VV as a supplementary visual cue is no longer available. The Panel observed that the Tornado GR Fce used VV at low-level, though it has a larger HUD, a different role and different weapon system HUD displays.

b. As the VV was locked during the accident sequence, the Pilot of ZE982 had no supplementary visual cue to the ac's actual trajectory. Due to the VV drift, it is likely that during the series of turns from TARBET, VV would have been of little use in the dynamic environment. However, it may have indicated to the Pilot that the airspeed was decreasing and his ac ADD was rising as the HUD symbology would have drifted to the bottom of the HUD and became locked. The Panel concluded that the selection of Locked VV in the HUD was unlikely to have affected the sequence of events.

46. **Met.** To the north of a line between Edinburgh and Glasgow the forecast that was valid 020800 to 021700 stated that there was an isolated risk of visibility falling to 3000m in a heavy thundershower. However, outside of these isolated heavy showers and in the vicinity of the accident area, the actual weather conditions were as forecast – 25km visibility, occasional scattered/broken cloud, bases between 3000 and 6000ft AMSL. From witness statements, visibility was good and there was no cloud covering the high ground in the GLEN KINGLAS area. The scattered/broken nature of the medium-level cloud would have created shadows on the ground in the accident area. As the formation transited west, the crew of ZE982 did comment that they may have to deviate from their route in the LOCH EARN area. However, as they progressed the weather improved and this was not necessary. The Panel concluded that the weather was suitable for low-level flying throughout the sortie.

Exhibit 34

Witness 1,2

47. **Conclusions.** The Panel concluded that the ac AUW and the competency and wellbeing of the Crew could not be discounted as factors in the accident.

INDIVIDUAL ACTIONS

[redacted]

[redacted]

48. **The Sortie.** There was no evidence to suggest that the sortie was planned, briefed, authorised, crew constituted and executed out with any extant rules and regulations.

49. **Low-Level Plan.** Prior to taxy, the Crew of ZE982 discussed the low-level routing that would take the Formation west towards TIREE. The Pilot suggested the routing down LOCH LOMOND, west at TARBET and into the A83 valley, past REST AND BE THANKFUL and into GLEN KINGLAS exiting at LOCH FYNE. The use of locations not included on the charts in use by the Crew provides evidence that the Pilot was familiar with the area. The Navigator was content with the routing. The Panel observed that the Pilot's desire to fly the route as discussed may have lead to him being task-focused; persevering with the entry into GLEN KINGLAS. Additionally, the awareness of the NOTAM to the north could not be ruled out as an influence on the Crew to their routing and in decision processes associated with entering the final turn. Exhibit 63

50. **Ejection Brief.** Prior to take-off, the Pilot briefed the Navigator on ejection decisions during the take-off phase and the remainder of the flight. It was agreed that post take-off, the Pilot would call the ejection if required and the Navigator would initiate the ejection sequence. This brief was accepted by the Navigator. It is possible that the brief reinforced the Navigator's perception that the turn was achievable as he did not hear an ejection call from the Pilot. This may have created indecision in the Navigator's mind, incurring a delay in the decision to eject. However, the Panel considered it extremely unlikely that the Navigator would have delayed an ejection decision by waiting for the Pilot's call. Exhibit 63

51. **Distraction/Desensitization.** Throughout the sortie persistent RHWR audio warnings in ZE982's cockpit are present as BLACKSMITH 2 flew in trail. The GPWS audio is fixed at a moderate level and, as a result, can easily be swamped by other audio outputs. Following a trial on another F3 by the Panel, it was found that the RHWR volume recorded on the R-ADR of ZE982 was consistent with that set by the Crew in their respective cockpits. The R-ADR indicated that the volume was set louder in the rear cockpit, [redacted] The higher RHWR volume and possible desensitization may explain why the Navigator spoke over the beginning of the GPWS warning in the final turn. Had the crew been conscious of the RHWR audio as a distraction they could have turned their respective audio volume down or the RHWR off. The Panel concluded that the Crew were not distracted by the RHWR audio but may have been desensitized by its presence. Consequently, the Panel could not rule out the RHWR audio warnings from having an effect in the accident sequence by desensitizing the crew to GPWS audio warnings. Exhibit 5

52. **AC Configuration.** As ZE982 transited south along LOCH LOMOND, wing sweep was moved from 45° to 27.9°. This is a transient wing position and its selection was contrary to the 25° or 45° selection expected by the Panel. With a wing sweep angle of 27.9°, operation of the MVR switch would result in the slats deploying to MVR but the flaps remaining up. If the wings had been at 25°, operation of the MVR switch would result in both the flaps and slats deploying to MVR with a corresponding increase in wing performance. Having reviewed the technical evidence the Panel could not positively rule out a control restriction within the wing sweep mechanism. However, the Panel concluded that the final configuration was more likely to be Exhibit 1

[redacted]

[redacted]

as a result of miss-selection and/or gauge interpretation, than a technical event. As such the implications are discussed in the Final Turn.

53. **Low-Level Height Keeping.** ZE982 was flying at 350 - 400ft above ground level and this height was maintained as the formation approached GLEN KINGLAS. This height bracket is not uncommon for pilots of lesser experience or currency and could indicate a cautionary trait in the Pilot's approach to low-level flying. Exhibit 6 Witness 1

54. **Turn Performance.** The Panel could not exclude that the Pilot was trying to fly cornering speed.[5] This technique was considered unusual by the Panel when flying a low-level navigation exercise in Lima fit. The Panel expected the ac to be holding a higher energy state to allow aggressive 3-dimensional manoeuvring. The Panel also considered further aspects of turn performance:

a. Turn radius is a function of airspeed and g.

b. For any given g, if airspeed increases so does turn radius.

c. If airspeed decreases available g also decreases.

d. NO and NE limits.

e. In a heavy ac at a constant power setting, airspeed will reduce more quickly due to increased lift-induced drag.

55. The table at Annex C shows performance available at different permutations of ac AUW, g and airspeed. Annex C

56. **Penultimate Turn.** ZE982 commenced a right hand turn at 22 secs to EOD, away from the prominent ridge that ran north east, down from the summit of BEINN AN LOCHAIN. Following turn initiation, the GPWS audio warning sounded at 18 secs to EOD, for 6 secs, without acknowledgement from either crew. The warning was satisfied at 12 secs to EOD and as the warning stopped, ZE982 reversed left into the final turn. Turning room into GLEN KINGLAS was now reduced due to the ac position in space, the ridge ahead and the flat nature of the turn. The Panel felt that, given the Crew's earlier GPWS awareness, it is possible that the Crew were reacting to the GPWS warning by flying away from the ridge. Although contradictory to the possibility of the crew being desensitized, to the GPWS by the RHWR, the Panel could not conclude in favour of a single hypothesis. The panel concluded that it was unlikely that either crew wilfully disregarded the GPWS or were complacent given their earlier demonstrations of height awareness. The Panel concluded that ZE982's handling on the penultimate, right turn, directly positioned the ac in a position that compromised the ability to achieve the left turn after cresting the ridge into GLEN KINGLAS. Witness 1 Exhibit 5,6,63

57. **Final Turn.** At 12 secs to EOD, the Pilot reversed the turn. The ridge hindered an initial max performance turn from the start position, as the turn was relatively 2-dimensional, with only a slight upwards vector of ≈5° pitch up. The Pilot, aware of the terrain, was likely to be conscious that the turn was challenging. However, due to limitations in SA he did not recognise the Exhibit 5,6

[5] Cornering speed at which best rate and radius of turn can be sustained concurrently.

[redacted]

[redacted]

severity of the turn. Examination of the final part of the flight showed that the ac made a turn of almost 90°, over the last 9 seconds, giving approximately 1030m of turn radius. The Panel decided that the final turn commenced as the ac crested the ridge and pulled into the turn.

58. The ac was operating close to, or at, the manoeuvre capability of the wing sweep and wing configuration once the final turn manoeuvre had been commenced. 1GASO states that the use of reheat at low-level should be minimized. Modelling shows that there was no scope for further adjustment of the flight path in order to avoid the terrain without the use of reheat and flying towards NE limits. Exhibit 43,44

59. The average value of g from the RAIDS pod was 2.833g (beyond NO limits but within NE limits), somewhat greater than the sustained capability of the ac; thus accounting for the speed loss over this time - from 332 kCAS to 294 kCAS. Just prior to impact, 2.7g was recorded. It was not possible to model the changes in bank angle over this time, nor any transient effects. At the prevailing flight conditions, it was calculated that there would have been a potential increment in available normal acceleration of 0.15 - 0.3 g, had the ac been in 25 MVR, and the turn radius would have been approximately 70m less; this would not have prevented the accident but may have reduced the ac closure to the terrain with an increase in decision making time (measured in microseconds). Exhibit 6,43

60. **Final Turn Dynamics.** The Fast Jet Test Squadron Tornado Project Pilot considers that an earlier entry to the final turn may have affected the outcome. To achieve this earlier turn, the ac would have had to be manoeuvred more aggressively in a 3-dimensional manner, to crest the ridge at a higher point than actually flown. During the sortie brief, the Formation iaw F3 SOPs limited themselves to 90° of roll at low-level below 1000ft. The Panel concluded that the 90° limit was adequate to carry out the F3's operational task and that this allowance should have been factored into ac handling considerations. Exhibit 43 Witness 2

61. **AC AUW.** A number of different scenarios were modelled to understand the effects of AUW and different ac configurations: Annex C

a. With turning room of approximately 1030m and the same technique applied, the use of reheat at an early stage was the only way to successfully complete the final turn as flown.

b. An AUW of 23,500kgs limits the manoeuvrability and performance of the ac and its ability to both maintain airspeed and sustain g. Airspeed decreased considerably in the final 30 secs of flight. If the ac was flying at a lighter AUW and the same level of SA was assumed, airspeed may not have decreased as quickly and a more representative minimum speed of 350 kCAS would have been maintained in dry power; therefore maintaining a greater degree of performance. However, the Panel concluded that if the turn was made at ≥350 kCAS, using the greater performance of 3.5g at a lighter AUW, the turn radius would have been approximately 1100m. This turn radius would not have altered the final outcome.

62. **Rudder Input.** At 5.2 secs to EOD, the pilot applied a 16% left rudder input. This had the effect of dropping the nose into the turn with a resultant Exhibit 6

[redacted]

[redacted]

height loss of approximately 250ft; equating to a reduction of available turn room by approximately 75m. The use of rudder in the F3 at low-level was contrary to the Panel's expectations and is not a recognised technique for a swept wing ac. The Panel concluded that lowering the nose using the rudder input aggravated the situation by reducing the turn room available, but did not cause the accident.

63. **Pilot SA.** Prior to the penultimate turn at 16.5 secs to EOD, the Pilot retarded the throttles slightly as he crested the saddle at REST AND BE THANKFUL. As the airspeed was decreasing through 352 kCAS this retardation in throttle was considered unusual by the Panel. At low-level in a Tornado, 352 kCAS is considered slower than normal and a cruise speed in the region of 420 kCAS was expected. The throttle retardation could imply that the Pilot was approaching task saturation and that airspeed had fallen outside his usual cockpit scan, reducing his overall SA. If the Pilot was approaching task saturation, induced by the visual cues of the terrain and the rapid sequence of events created by flying at high speed, this would be at the expense of other sensory inputs. Although he acknowledged the Navigator's height prompt he may have actually stopped processing audible inputs at this point. The Pilot's change to a rapid "yes" or "yep" in response to the Navigator's height prompt may have indicated a need to cease the additional auditory load input from the Navigator and/or a reluctance to add to the auditory load from his own speech. The Pilot's lack of acknowledgement to the GPWS audio warning of 10 'pull-ups' even though he had previously acknowledged the 2 'pull-ups' prior to the turn, may have indicated a reluctance to add to the auditory load from his own speech. At the start of the final turn the Pilot perceived that there was sufficient room to complete the turn as planned. The terrain was challenging but within the capabilities of the ac and should have been within the capabilities of the Pilot. This suggested that the Pilot's SA at the start of the turn was incorrect. The Panel considered this was possibly a result of: Exhibit 5,6,63

a. **Audio Reaction.** There are 2 possible scenarios for the Pilots audio reaction: Exhibit 5

(1) The persistent nature of the RHWR up to this point may have contributed to the likelihood of the Pilot filtering out the auditory demands.

(2) The auditory demands were not filtered out but instead they contributed to the Pilot reaching his overall saturation threshold sooner.

b. **GPWS Masking.** If the Pilot had experienced auditory filtering or auditory saturation, this was likely to have influenced whether subsequent GPWS audio warnings were filtered out or masked. The Pilot of ZE982 did not acknowledge the GPWS audio warning of multiple 'pull-ups' during the last 2 turns, even though he had previously acknowledged the 2 'pull-ups' in the valley approaching REST AND BE THANKFUL. Exhibit 5

c. **Training/Experience.** The Pilot first flew the Tornado F3 on 7 Mar 08, at the start of his conversion to type. Prior to the accident he had accumulated 180 hrs on the F3 and, though not regarded as a supervisory concern as a dilutee, he would have been considered Annex A

[redacted]

[redacted]

inexperienced on type. Low flying in a fast jet carries an inherent degree of risk. As a dilutee, his previous fast jet training, supervision, and controlled exposure to the low-level environment should mitigate that risk. The Panel could not find any adverse safety comments on his performance when flying at low-level in the Hawk or F3. Conversely, the Panel could not find an assessment of the Pilot's low-level flying ability post OTE. A check of low-level competency is not a mandated requirement in a formal dual check within the extant regulations. Basic flying skills are trained to an automatic level so that a pilot does not have to use unnecessary processing capacity and become task saturated. To ensure these auto responses are instilled in a pilot, an adequate system of training, competency checking and supervision is required. Without this assurance process, inappropriate techniques may develop and incorrect mental models may subsequently be applied. Where incorrect techniques are not identified, there is potential for them to become auto responses. The Panel concluded that there was a plausible link between the amount of low-level F3 training, competency checking and the Pilot's light-ac flying experience that may have contributed to the accident.

d. **Visual Perception.** Exhibit 5

(1) **Salience Bias.** On entry to the final turn both crew of BLACKSMITH 2 mentioned looking at the end of the valley into LOCH FYNE. The end of the valley would have been a salient feature in the turn as it contained blue sky, blue water, a valley opening and was the destination point for exiting the tight series of valley turns. Further, neither crew would have had a 'long-focus' opportunity up to this point due to the density of the preceding turns. It is therefore very likely the Crew of ZE982 were also attracted to this feature. Witness 1,2

(2) **Confirmation Bias.** The Pilot was familiar with the western exit to the valley and it is possible he intentionally sought this out in the turn to confirm his location.

(3) **Expectation.** As the Pilot was familiar with the area, it is possible the hillside posed little threat to him and, as a result, he reduced its weighting in terms of it being a hazard.

(4) **Visual Illusion.** It is possible that the hillside was viewed directly at some point as the Navigator of ZE982 prompted "watch the high ground". The pilot may have scanned the hillside but afforded insufficient attention to it due to the previous points. Alternatively, it is possible the pilot afforded sufficient attention to it but the terrain features and environment presented cues that gave the pilot the impression it was shallower than it was. Additionally, the texture of the hillside was such that the high ground could have been masked by the features around it. The impact area had a slope of ≈45°. The Panel viewed the slope under varying light conditions from the approach direction of ZE982 and noted that the apparent severity of the slope changed due to both the definition of the ground and the run out of the north slope of the Glen towards the west.

[redacted]

[redacted]

e. **AUW.** A heavy ac will affect manoeuvrability and performance. More consideration, in pure ac handling terms, is required when flying such a heavy ac. Airspeed will reduce faster when manoeuvring and there are more restrictive ac handling limits and therefore more anticipation is required. If a pilot is already approaching task saturation, the handling demands of a heavy ac may limit pilot's spare mental capacity further reducing SA. Thereby, further diminishing the cues of an approaching hazardous situation. Exhibit 62

The potential salience bias, confirmation bias, expectation and visual illusion are very likely to have drawn the Pilot's attention away from the features of the hillside and towards the valley exit. Theses factors, combined with the increased workload of handling a heavy-weight ac in challenging terrain, may have compounded the Pilot's degradation in SA, allowing the Pilot to continue to think the turn was achievable.

f. **Low-Level Currency.** From the beginning of Jan 09 the Pilot had flown 90:30 hrs (68:45 hrs in the UK and 21:45 hrs in the FI). Unfortunately, the Panel were unable to ascertain how much of the flying in the FI was conducted at low-level. 2:43 hrs (4%) of the UK flying was conducted at low-level overland, with the last recorded occurrence in May 09 (1:33 hrs). It is unknown how much of this time was spent flying in Lima Fit at low-level. Due to the limited amount of time spent in the low-level overland environment, it is likely skill fade would have developed. Consequently, this would have aggravated all of the associated aspects listed previously and lowered the Pilot's competency to conduct low-level. Annex A,D

g. **Recognition of the Hazard.** As the last turns were executed, the Pilot did not recognise the developing hazardous situation. The points above wrt visual acuity/illusion are still pertinent as the final turn was being executed. In mitigation, with the ac belly-up to the facing slope, which may have appeared benign, the Pilot would be looking down the valley to the exit point and may have missed the cues that indicated the hazardous situation developing as the terrain approached. Until very late he is expecting to complete the turn as planned. The lack of challenge from the Navigator during the penultimate and final turn may have reassured the Pilot that the turn was achievable. In addition, the GPWS audio warning in the penultimate turn, with the ac not entering a hazardous situation, may have reinforced an incorrect mental model. As the Pilot pulls the ac round the final turn, airspeed reduces and ADD increases markedly which exacerbates the hazardous situation. Normally a pilot should have been expected to recognise these parameters. This provides further evidence that the Pilot had reached task saturation. It was only at 2.5 secs to EOD that the Pilot perceived the hazardous situation. This was possibly as a consequence of the Navigator's warning when he selected at least max reheat and applied a positive CC input to affect an escape from the terrain. This reaction, although appropriate, was too late to execute a successful recovery. Exhibit 5

The Panel concluded that there was sufficient evidence to determine that the Pilot's SA was degraded in the final portion of the flight.

[redacted]

[redacted]

64. **Navigator SA.** As ZE982 approached the saddle at REST AND BE THANKFUL the Navigator warned the pilot to watch the height. Additionally, the Navigator also warned the Pilot to watch the high ground concurrent with the GPWS audio warning at 7 secs to EOD. Although the Navigator did not challenge the Pilot directly wrt his ac handling including airspeed control, both these events suggest that the Navigator arousal level was reasonably high and that he was monitoring the Pilot. When the GPWS audio begins the Navigator talks over the warning, suggesting that either the GPWS audio volume is too low or, as the Panel believe, the Navigator is desensitized to the GPWS audio. The lack of a further challenge suggests that the Navigator's SA was degraded, as the turn progressed. In mitigation a navigator's forward view from the back seat of an F3 is limited. In the accident sequence, this was exacerbated by the dynamics of the turn and the fact that the ac was belly-up to the terrain, further reducing the possibility of awareness of the proximity to the terrain. If the Navigator was focused on the valley exit and also believed the valley was reasonably benign, he would expect to complete the turn as planned. Additionally, the Pilot's general cautiousness to aviation and his apparent familiarity with the route, possibly reassured the Navigator that the turn was achievable up until 2.5 secs to EOD when he warned the Pilot of the approaching terrain. Exhibit 5,63

65. **Pilot of BLACKSMITH 2.** The Pilot of BLACKSMITH 2 considered the choice of the final segment of the route challenging. He believed that the final turn was achievable. This suggests that the Pilot of BLACKSMITH 2's SA was also incorrect, probably for the same visual illusion issues mentioned previously. In addition, the cautious nature of the Pilot of ZE982 towards all aspects of his flying, reassured the Pilot of BLACKSMITH 2 that the final turn was achievable. Witness 1 Exhibit 5

66. **WSO of BLACKSMITH 2.** The WSO of BLACKSMITH 2 also considered the choice of the final segment of the route challenging. He also believed that the final turn was achievable; being further reassured by his Pilot who was one of the Sqn's senior pilots. He witnessed the fireball, though it was closer than he expected; suggesting that he too was focused further along track on the exit from the valley. Witness 2 Exhibit 5

67. **Escape Manoeuvre.** The Panel considered how the Crew may have escaped their predicament: Exhibit 43

a. Execution of a low-level abort consists of rolling the wings level, selection of maximum reheat and increasing the ac pitch attitude to 30° nose up at 3g. As the flaps were not in the MVR position, the manoeuvre capability of the ac was likely reduced from that expected; by the order of 0.3g. With the surrounding high terrain, the heading at which the abort manoeuvre would have been carried out would influence the proximity to the terrain during any abort manoeuvre.

b. At 12 secs to EOD, the ac was transitioned through wings level flight from a right to a left turn on a heading of 015° at 346 kCAS, at 518 ft radalt (1294 ft AMSL) at a pitch attitude ≈5° nose up. If an abort manoeuvre, using a wings level 3g[6] pull-up to a 30° nose up climb with reheat, had been initiated at this point, the ac would have achieved the desired climb angle in approximately 5 secs, with 2650 ft of horizontal

[6] Only 3g would be available due to the ac speed until reheat was established.

[redacted]

travel and an increase in height of 710 feet; achieving a pitch rate of ≈ 6.5°/sec. This profile would have been insufficient to avoid the terrain ahead of the ac; intersecting the terrain approximately 440 feet below the summit. These calculations assume g was applied instantaneously from level flight and that the ac speed remained constant throughout the manoeuvre. Therefore, the Panel concluded that the recognised low-level abort is unlikely to have been successful.

c. If the Crew had recognised their predicament, 2 options were available:

(1) The valley which runs in a north-easterly direction could have been used as an escape route.

(2) Reheat could have been selected and a tight climbing turn could have been initiated, similar to the recovery manoeuvre of BLACKSMITH 2.

68. **BLACKSMITH 2.** The flight path for BLACKSMITH 2 was very similar to that of ZE982 until just prior to final turn, indicative of number 2 following his leader in a narrow, steep sided valley. BLACKSMITH 2 crested the ridge as they turned into GLEN KINGLAS approximately 15m further west than ZE982. BLACKSMITH 2's flight path was then always inside that of ZE982 eventually displaced 100–110m further south. BLACKSMITH 2 was 30-40 kts slower than ZE982 when they crossed the ridge, although with a more positive pitch attitude. The ac height was similar to ZE982. The ridge was crested and the GPWS audio warning began. Reheat was selected following the recognition of the fireball from ZE982. The engines fully respond after approximately 2 secs. The maximum g during the recovery was approximately 3g which coincided with the g available at 280kts. The minimum radalt recorded during the recovery was 390ft. The lower speeds of BLACKSMITH 2, as it crested the ridge to turn left, resulted in a reduced turn radius using available g. The closure towards the high ground was further reduced by the vertical component of the recovery manoeuvre with an additional MSD increase being achieved by the vertical manoeuvre and the increased drop to the valley floor. BLACKSMITH 2's recovery was initiated due to the visual cue from the fireball created by ZE982. BLACKSMITH 2's focus was on the exit from the valley and, although the Pilot was aware that the turn would be challenging, he was not aware of his predicament at the time of the fireball. If BLACKSMITH 2 had delayed the start of their recovery manoeuvre by more than 1 sec and not selected reheat it is likely they would have crashed. Exhibit 43,44

69. **Conclusions.**

a. ZE982's handling in the penultimate turn directly positioned the ac in a location that prevented the aircraft from achieving the final turn after cresting the ridge, into GLEN KINGLAS.

b. In the final turn, the ac was operating at or close to maximum performance in dry power with little or no ability to change flight path.

c. The selection of wing sweep to approximately 27.9° and subsequent availability of manoeuvre slat only, although exacerbating, did not affect the outcome.

[redacted]

d. The final turn could only have been completed, as flown, if max reheat had been selected at the start of the turn and the ac flown towards NE limits.

e. An aggressive 3-dimensional manoeuvre into the westerly valley was likely to have affected the outcome.

f. The perceived credibility and cautiousness of the members of the formation gave a false reassurance of success.

g. It is considered very likely that RHWR played a role in the accident sequence by de-sensitising the crew to GPWS audio warnings.

h. It is unlikely either crew wilfully disregarded the GPWS or were complacent.

i. It was considered that ZE982 Crew's SA directly influenced the accident sequence.

j. If the crew had realised that there was not enough turning room available then they could have elected to use the valley to the north east as an escape route.

k. If the crew had selected max reheat and flown a tight climbing turn within the allowable reaction time of the GPWS audio warning sounding, it is likely that an escape manoeuvre could have been flown safely.

l. If BLACKSMITH 2 had delayed the start of their turn by more than 1 sec, after cresting the ridge, the aircraft is likely to have crashed.

m. The Panel concluded that it was unlikely that any on-the-day sortie preparation or briefing factors directly influenced the accident sequence. The Navigator spent approximately 1 hr in close proximity to the Pilot prior to authorising him; suggesting that he had no concerns over the fitness of the Pilot.

n. The Crews' behaviours and actions during the main part of the sortie did not indicate any intentional actions that directly influenced the accident sequence.

o. The Panel concluded that the Crew of ZE982 experienced Controlled Flight Into Terrain (CFIT). It should be noted that positive action was taken to recover the ac but insufficient time and performance were available.

p. The Panel concluded that BLACKSMITH 2 experienced a Controlled Flight Towards Terrain (CFTT). It should be noted that the reaction to the impact of ZE982 resulted in the successful recovery.

[redacted]

[redacted]

FACTORS AND OBSERVATIONS

70. **Cause.** The cause of the accident to ZE982 was CFIT, due to insufficient turning room being available within the valley to complete the turn as executed.

71. **Contributory Factor.** The Panel concluded the Crew had insufficient SA to successfully complete the selected route. Whilst not able to fully establish and quantify the reasons for a degradation in SA, the following sub-factors were found to have contributed:

a. Competency.

(1) Lack of a requirement for a low-level competency check.

(2) Lack of a requirement for low-level currency on the F3.

(3) Paucity of dual (General Handling) checks.

(4) Light-ac experience.

(5) Lack of Fast Jet refresher trg.

b. Distraction.

(1) The workload during the penultimate turn, including handling a heavy-weight ac in challenging terrain.

(2) The predetermined routing into GLEN KINGLAS as a consequence of the Pilot's familiarity with the area.

(3) The visual illusions perceived within GLEN KINGLAS by the Crew.

(4) The audio warnings in the cockpit.

(5) The NOTAM to the north of GLEN KINGLAS.

c. Wellbeing.

(1) The significant amount of change surrounding the draw-down of the F3 Fce and the associated short notice disbandment of the Sqn.

(2) The sudden change and insecurity in both immediate and long-term careers.

72. **Aggravating Factors.** The Panel considered that the following aggravating factors increased the severity of the accident:

a. A decision to eject not being made. However, the Panel judged that a crew could not reasonably be expected to have assessed and actioned a valid ejection decision in the limited time available (from awareness of predicament to impact).

[redacted]

[redacted]

b. The aircraft wing sweep and MVR configuration.

c. Lowering the nose during the final turn.

d. The AUW of the ac.

73. **Other Factors.** The Panel identified the following other factors, that may have an influence on future accidents:

a. The incorrect removal of a loose article entry from the ac Loose Article Register (F704LA) for ZE982 presented an unacceptable risk to airworthiness.

b. Gaps in aircrew currency were identified, presenting an undefined flight safety risk.

c. 1GASO wrt reheat is regularly misinterpreted. The Panel felt the GASO wording was correct with regard to reheat usage. However, rather than being 'minimized' it is regularly briefed as 'only for flight safety'. The Panel concluded that, although not a direct factor in this accident the GASO interpretation would be better served if crews used reheat to maintain an ac in a normal flight regime. Subsequently, they should question whether the activities being undertaken, that provoked the use of reheat, should be continued within the sortie profile.

d. A change in the procedure for informing the FI of deploying aircrew's flying authorisations, currency and competency resulted in the relevant OTS form becoming defunct. A replacement pre-deployment form may have prevented the Pilot's currency lapse being overlooked.

e. The F3 OTS enables sqn cdrs to award LCR at their discretion. The document contradicts itself by stating that *'ab-initio'* pilots are to have completed the whole of the AAR phase prior to being declared LCR.

f. The self auditing arrangements under the Fce HQ and Fce A7 process, led to the Sqn being directly responsible for checking itself. This resulted in anomalies in Sqn procedures not being highlighted.

g. An engine surge occurred on ZE982 the sortie prior to the accident. The ac was operating at 38000 ft and 250 Kts with the X-Drive Clutch in 'Auto'. Following an engine surge the X-Drive Clutch closed automatically as prescribed and the good engine was dragged down to sub-idle NH. The 'Auto' selection of the X-Drive Clutch contradicted the recommended advice given in the F3 RTS and Aircrew Manual. The Panel noted that the 2 reference documents gave conflicting recommendations of 25000 ft (RTS) or 15000ft (Aircrew Manual) for a maximum operating height with the X-Drive Clutch selected to 'Auto'.

74. **Observations.** The Panel observed:

a. BLACKSMITH 2 was fortunate to have recovered safely, in response to witnessing the fireball from ZE982.

[redacted]

b. Post recovery from the initial shock and a main radio failure, BLACKSMITH 2 carried out OSC to a high standard and this was positively commented on by the GR4 formation.

c. The PCM strategy and practice at RAF Leuchars enabled a rapid transition into PCM activities and enabled QRA to be maintained without compromise.

d. The turmoil of the Sqn closure and expeditious postings left some of the Sqn documentation requiring attention. However the Panel noted that a number of anomalies were generated prior to the disbandment decision being taken.

e. During the sortie brief, the Pilot briefed the maximum angle of bank (AOB) at low-level to be 90°. The TGRF briefs a maximum AOB of 150° at low-level to cross ridges and enable contour flying, and a maximum AOB of 90° for low-level evasion. This is implicit in the TGRF Authorisation Codes of LLUK and BEV (Briefed Evasion). Whilst investigating the circumstances of the accident, it became apparent that there was confusion among F3 aircrew as to the maximum allowable AOB at low-level when not evading. The F3 low-level Authorisation Code allows up to 90° AOB for all low-level flying.

f. The R-ADR panel markings did not meet DEF STAN requirements, thereby compromising the ability for this important item to be located.

g. The failure of the NAU has been a known issue across the fleet for a number of years that has yet to be addressed.

h. 1GASO steers the end-user in various directions to find information on the operation of the GPWS. The Panel felt that GASOs, as the higher level document, should either state how the GPWS was to be used or reference a single-source document.

i. The AIDU Low-Level Chart appeared to portray the north slope of GLEN KINGLAS to be shallower than it actually was. AIDU confirmed the scale of the chart was correct and that contours were as expected. It was noted that the spot height annotation on the north slope was present on the Central but not on the overlapping North Low-Level Chart. The placement of spot heights is adjusted by cartographers to ensure chart information is easily interpreted. The Panel observed that spot heights may emphasise more challenging terrain to users. AIDU are reviewing their guidance to ensure continuity across overlapping charts.

j. JSP 550 has differing rules and guidance from the Railway and Transport Safety Act 2003 wrt alcohol and flying. As these documents do not align, this has the potential to generate inconsistencies in any future inquiries to the detriment of the MOD, when viewed by an external body. Exhibit 29, 30

[redacted]

[redacted]

k. The lack of CAM HF advisors hampered the prompt progression of the inquiry.

l. There appeared to be some inconsistencies with the HQ 1 Gp Assurance Process; however, the Panel were unable to source the necessary documentation to pursue the matter any further, in the time available.

m. The lack of dedicated trained personnel and equipment able to transcribe digital media, hampered the prompt progression of the inquiry.

[redacted]